Perceptions of Comfort by Cyclists and Pedestrians on Unsegregated Shared-use Paths: Developing an Assessment Tool

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I, Pola Aleksandra Berent confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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ABSTRACT

This study investigates the perceptions of comfort on unsegregated shared-use paths between cyclists and pedestrians and attempts to develop a Level-of-Service assessment tool. A better understanding of user perceptions is crucial to promote active travel in the UK, especially in cities with limited space. Unsegregated shared-use paths could be a viable option: however, there is currently a limited number of guidelines on whether and how a path can be shared by pedestrians and cyclists and no assessment tools which consider perspective of both modes and are developed for UK context.

Data collection was in two stages, with samples of 919 and 899 respondents respectively: research method was online questionnaires, which included questions on perceptions of comfort in response to pictures and videos of unsegregated shared-use paths.

Stage 1 established the hierarchy of factors and path characteristics associated with comfort, as well as differences by user type, gender and age. After Stage 1 identified ‘path width’ and ‘volume of users’ as key contributors to perception of comfort, Stage 2 quantified their impact. I collected comfort scores, determining the effect of path width, volume of users, flow direction, type of passer-by, and the proportions of cyclists and pedestrians on perceptions of comfort.

Two approaches were considered for establishing whether unsegregated shared-use works and in what conditions: one assumed that cyclists and pedestrians should perceive their experience on the positive side of the comfortable spectrum. The second assumed that the facility works as long as cyclists and pedestrians are willing to use it.

This research contributed to practical understanding of comfort. It concluded that unsegregated shared-use paths can work but only in specific path width and volume of users circumstances. Where these cannot be met, it explored how it could be compensated through other interventions. The findings can assist transport professionals when designing new or re-designing existing unsegregated shared-use paths.

IMPACT STATEMENT

The expertise, knowledge, analysis and insight presented in this thesis bring benefits inside and outside academia.

In the context of understanding comfort in non-motorised transport, this study filled in the gap and addressed lack of consistency in available theory. It provided an insight into the factors and path characteristics and their importance for path users. It highlighted how views on comfort are affected by respondents' characteristics, including user type, gender and age. Further insight was gained on the effect of path width, volume of users, user type of the passer-by, flow direction and proportion of cyclists and pedestrians on perceptions of comfort.

This study developed an original assessment tool for unsegregated shared-use paths. It is the first Level-of-Service tool to focus on a UK-based sample and the first such tool for unsegregated shared-use paths which considers perceptions of both cyclists and pedestrians.

Moreover, this research has a significant methodological contribution: leading a way for user-led studies. Data collection relied on responses from path users: the characteristics chosen for Stage 2 were selected based on the responses by people, rather than assumed. By contrast, all other Level of Service tools had path characteristics pre-selected by the researchers.

Finally, this study contributed to the field of transport research, by trialling an original video-based survey. While video-based methods were used by researchers in the past, filming artificially designed scenarios which focused on particular path characteristics was an innovative approach, which proved efficient and effective.

In terms of impact outside academia, this research brings a significant contribution to the transport industry. There is currently insufficient knowledge available to industry professionals in the UK that could facilitate decision-making and validate the design of unsegregated spaces. This thesis is the first document to provide an insight into what facility users perceive as comfortable or not.

The main target audiences are transport professionals, policy-makers, advocacy organisations and cyclists and pedestrians. The findings will have impact on the development of guidelines, as well as contributing to improving existing facilities, to guide new investments and to optimize budgets. The knowledge obtained will allow practitioners to minimize the negative impacts of sharing on both cyclists and pedestrians.

Moreover, there is an on-going need within the industry, to understand the preferences of different ages and genders, especially with the drive to promote cycling among women.

The impact of the study will be maximized by effective dissemination of findings. I identified multiple organisations to facilitate the 'research to practice' knowledge transition, including Sustrans, Transport for London, and Living Streets, as well as professional organisations such as CIHT, TCPA. The Department for Transport and BDP (an architecture company) have also expressed interest in presenting the findings to the staff in-house.

My work in private transport consultancy gives me access to a variety of local authorities and architecture companies and also involves working on transport projects (masterplans, planning documents, transport strategies), where I can apply in practice the insight and experience gained from this study on a daily basis.

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CHAPTER 1: INTRODUCTION

1.0 Chapter Composition

The following chapter introduces this research. As the thesis title ‘Perceptions of comfort by cyclists and pedestrians on unsegregated shared-use paths: developing an assessment tool’ suggests, this study focuses on non-motorized transport modes and facility provision. Therefore, Chapter 1 provides an overall summary of background knowledge on cycling and walking.

This chapter begins with setting the context for this research and providing the rationale for this study in **Section 1.1**. **Section 1.2** gives an overview of cycling and walking policies in the UK. **Section 1.3** provides a definition of shared-use paths, including the distinction between unsegregated and segregated facilities. Finally, **Section 1.4** highlights the research aims and **1.5** describes briefly the thesis structure.

1.1 Context and Rationale

Due to increasing social awareness in regard to health and environmental sustainability, walking and cycling are being encouraged more and as attractive modes for transport and leisure, especially in urban areas such as London. In recent years, promotion of walking and cycling (‘active travel’) ‘*has moved up multiple policy agendas, including in relation to health, transport and climate change”* (Goodman, 2013). Providing adequate infrastructure for walking and cycling would be a key driver for their promotion. In the case of England, the shift was triggered by the White Paper on the future of transport in 1998, and the change has been on-going for over two decades. The Government recently published the Cycling and Walking Investment Strategy (CWIS; DfT, 2017a). It specifies walking and cycling targets and confirms that there is a strong will to make active travel (cycling and walking) a mode of choice for short journeys or stages (part of a longer journey) in urban and rural communities in England (DfT, 2017a).

Despite an increased focus on policies and targeted investment, walking keeps declining, while cycling remains a minority transport mode (levels vary year by year) (Department for Transport, 2016b). Currently, 25% of all trips are being walked and only 2% of all trips are cycled (Department for Transport, 2016b) (See Section 1.4). For cycling, there is an additional trend observed: as Delaney (2016) pointed out, there are prominent reductions in the number of cyclists cycling on road (from 46% of cyclists cycling on road in 2002 to 38% in 2012). Simultaneously, there is an increase in the number of people who cycle on cycle paths, off-road lanes and footways (from 25%

of people who cycle on cycle paths, off-road lanes and footways in 2002 to 30% in 2012) (DfT, 2012b).

Hence, with an on-going decline in walking stages in the UK, promoting pedestrian activity is crucial. Insufficient pedestrian activity can be regarded as a social problem, due to reduced social interaction resulting in reduced opportunities (Demerath and Levinger, 2003). Demerath and Levinger (2003) emphasized the importance of such interactions in creating a sense of community and overcoming increasing isolation. In fact, promoting short journeys by foot and cycle can contribute to the revival of local neighbourhoods, both on economic and social levels.

A key aspect of promoting active travel is provision of facilities. While there is an on-going drive to construct more infrastructure for cyclists and pedestrians (as reflected in DfT's CWIS or TfL's Healthy Streets for London agenda (Transport for London, 2017)), in reality there are constraints on the budget (combined with a tendency to prioritize large infrastructure projects such as Crossrail or M4 Reading-Heathrow motorway) as well as limited available space. Sharing space could be a viable solution, yet transport professionals consider it rarely even though it is an integral part of movement in the city: all types of users, including pedestrians, cyclists, public transport operators and drivers (despite their differences) coexist and interact in the urban setting (Patton, 2007).

From the perspective of cyclists, shared-use paths between cyclists and pedestrians could be an attractive option to promote cycling among the 'interested but concerned' (Dill and McNeil, 2013). Geller (2006) stated that riding a bicycle should not require bravery. One of the main safety concerns remains sharing the road with motorists, which in the UK is a common practice regulated by law (cyclists are not allowed to cycle on footways, except for designated shared spaces). From the perspective of pedestrians, promotion of shared-use paths could lead to creating more spaces for pedestrian use, reduced air pollution and an improved ability to switch freely between cycling and walking or enjoy multiple modes of transport when travelling in groups (for example, families travelling together where some members cycle and some walk).

Hence, sharing the same paths between cyclists and pedestrians could be seen as a beneficial scenario, and indeed, although there is no statistic available, some highway authorities create shared paths between cyclists and pedestrians or convert existing footways to shared paths (Kang and Fricker, 2016). One issue here is that there are only a limited number of guidelines on whether and how pedestrians and cyclists can share a path. DfT's Local Transport Note '*Shared-used routes for pedestrians and cyclists'* (2012a), which is one of a few guidelines, does not mention the conditions in which segregation/non-segregation is suitable, but only sets out some basic principles for shared paths between pedestrians and cyclists and insists that such a judgement be on a case-by-case basis. Simultaneously, it notes that potential conflict between pedestrians and cyclists are uncommon, with references to Countryside Agency (2003) and Atkins (2012).

More evidence is required which assists the decision-making of highway authorities; policymakers need to gain a better understanding of user perceptions and give this enough consideration in the decision-making process. Shared-use paths between cyclists and pedestrians in urban contexts are rarely studied from the perspective of pedestrians (see Section 3.6). However, it is even more unusual to study them from the perspective of pedestrians and cyclists: the majority of studies focus on the perspective of one user group. While this deepens the understanding of shared use paths and user interaction, it does not provide knowledge that can be applied in practice to deliver facilities that work for most people.

It should be noted that there are two types of shared paths: segregated paths and unsegregated paths. Segregated paths divide space into two parts - one for cyclists and the other for pedestrians - by installing barriers or kerbs on the boundary or by marking the surface e.g. with a line, whilst unsegregated shared-use paths have no method of segregation between modes, enabling the users to utilize the entire effective width (Sustrans, 2014a) (see Section 1.4). It is unsegregated paths that need careful decision-making as to whether cyclists and pedestrians can share the same space, because interaction and potential conflict or perceived risk of conflict between these two user types can be regarded as potentially high.

An assessment tool for unsegregated shared-use path will make delivery of such facilities more viable. The concept of Level of Service (LOS) has been used for evaluation of path qualities, and different approaches have been proposed for their measurement (see Chapter 3). At present, there are multiple PLOS (Pedestrian Level of Service) and BLOS (Bicycle Level of Service) tools (see Sections 3.4 and 3.5). A few Level of Service tools from the perspective of both cyclists and pedestrians have also been developed and a few from the perspective of cyclists or pedestrians on shared-use paths.

Yet, despite multiple Level of Service tools available, there are limitations on their applicability. Commonly used Highway Capacity Manual's Level of Service tool is limited. What makes the existing Level of Service tools even less applicable are the differences between the traffic laws and cultures both within the same country (e.g. United States) and across countries (Kang et al., 2013): since there is the possibility that pedestrians in some countries may care more about the visual comfort while pedestrians in others may think more about the functional comfort. Similar issues apply to cyclists and their perceptions.

1.2 Theoretical Contexts

With the purpose of addressing the key aim of this research (see Section 1.9), theory was drawn from two main literature sources: academic literature on comfort in cycling and walking, and existing assessment tools for walking and cycling facilities, with the focus on Level of Service tools. Both sources of theory were reviewed simultaneously and inspired the methodology adopted in this study (see Chapter 4).

Within the area of transport theory, 'comfort' has been previously identified as a variable affecting a demand for a transport mode within the theory of abstract modes. It states that an abstract mode is characterized by the values of the multiple variables that affect the desirability of its service to the public: these are speed, frequency of service, comfort and cost (Quandt and Baumol, 1966). While that theory was developed more in the context of airplanes, railroad, buses and private automobiles, its context also sits well with non-motorized transport modes.

Comfort can also be put in an additional, theoretical context, which draws on social psychology: the relation between social perception and social reality. It is the social constructivist perspective, which insists that perception creates social reality, equally, or more than it reflects it (Jussim, 1991). Based on that, this study assumed that perceptions of comfort are the key to individual's decision to use an unsegregated shared-use path.

Further review of the literature on comfort has identified the existing theory on comfort in the context of non-motorized travel modes. Exploring different definitions of comfort and factors and path characteristics associated with them was supposed to lead to establishing characteristics of interest for developing an assessment tool. However, despite the popularity of the term, lack of consistency in the available theory was revealed.

Reviewing the literature available on assessment tools for cycling and walking facilities, I identified a variety of methods, with objectives such as estimating health benefits, assessing national propensity to cycle, auditing cycling and walking routes, or route selection tool and level of service. Fitting with the aims of this research, my literature review then continued to focus on BLOS (Bicycle Level of Service), PLOS (Pedestrian Level of Service) and SUPLOS (Shared-Use Paths Level of Service). The focus on Level of Service tools showed a diversity of approaches: two main types of models were identified, a capacity-based and a characteristic-based approach. Some models appear to combine both (see Chapter 3).

1.3 Policy Contexts in the UK

In order to provide an insight into how the need for cycling and walking facilities has increased over the years in the UK, an overview of related transport policies was conducted. Understanding policy context is also instrumental to comprehend the interaction and attitude between different road users.

Until the 1990s, the primary focus in the UK was to cater for growing demand for motorized transport modes. The first sign of consistent change appeared in 1998, when the Government produced a White Paper 'A New Deal for Transport' (DfT, 1998), which reflected a strong turn towards sustainable modes of transport. At the beginning, the focus of policies was on cycling, and then the need to incorporate walking became more and more prominent.

In recent years, promotion of walking and cycling have moved up multiple policy agendas, mainly because of increasing environmental and health concerns. Active travel has a huge potential due to its low cost and contribution to healthy lifestyle. In a social context, it is a great option for individuals and families of different ages, income, gender and ethnicity.

The current Government, recognizing the benefits of active travel, is strongly committed to promoting cycling and walking as a part of the national agenda. The Department for Transport sees mainstreaming non-motorized travel as a cost-effective solution to reduce congestion and improve the quality of life (Department for Transport, 2013a). It perceives increased levels of non-motorized travel as the tool to stronger, better-linked communities, NHS savings, improved accessibility for disadvantaged groups, creation of more attractive public realm and a magnet for new businesses (Department for Transport, 2013a).

1.3.1 Cycling

According to Aldred and Golbuff (2011), the first indications of a shift to make cycling a viable transport option in the UK started in the late 1970s. In 1977, the Department for Transport conducted a study on the potential of cycling in the UK and the Labour Government published a White Paper, which offered local authorities funds for innovative cycling projects. However, they describe them as '*false starts'*: that is because despite multiple initiatives, by the end of the 1980s '*the great car economy'* took over.

The late 1990s brought another policy shift towards cycling. It was connected to growing environmental concerns and global warming awareness. This led to a partial institutionalization of cycling policy (Aldred and Golbuff, 2011). In 1996, the UK's first National Cycling Strategy was published with the aim of increasing cycling. It aimed to create a cultural change which promotes cycling among all age groups; introduces new policies and ensures good practice; and relies on innovative, practical solutions to making places more accessible by cycling (DoT, 1996).

In 2013, the Prime Minister stated that the Government wanted to '*kick-start a cycling revolution which would remove the barriers for a new generation of cyclists*' (British Cycling, 2014, online). Part of that plan was 'cycle proofing' the road network, ensuring that cycling was at the heart of future road developments and that the support for Bikeability (the nation-wide cycle training scheme) continued. There have also been prominent efforts in Wales, which published the Active Travel Act (Welsh Government, 2013).

In 2014, the Department for Transport published a Cycling Delivery Plan: a 10-year plan for England. It involved a commitment to double cycling by 2025 (the cycling activity was measured as the number of cycling stages, with a baseline of 0.8 billion stages in 2013). It also included a commitment to promoting walking: *'to increase the percentage of children aged 5 to 10 that usually walk to school from 48% in 2013 to 55%'.*

This was followed by the Conservative party publishing a manifesto in 2015 in which they committed to making *'motoring greener'* and promoting cycling: *'we want to double the number of journeys made by bicycle'.* A pledge was made to improve cycling safety by investing £200 million to *'reduce the number of cyclists and other road users killed or injured on our roads every year'* (Conservatives, 2015*).*

In 2017 the Department for Transport published a Cycling and Walking Investment Strategy, with the highlighted ambition of making *'cycling and walking the natural choices for shorter journeys, or as part of a longer journey'* (Department for Transport, 2017a, p1). The aim is to double cycling activity by 2025, make cycling safer for all and to reverse the decline in walking. In order to achieve that, over £1 billion was made available to local bodies to invest in cycling and walking over the next 5 years (DfT, 2017). This shows commitment and increasing interest to making active travel a viable option for people in England in the future, with the help of funding programmes such as Cycling Demonstration Towns (2005-2011), Cycling City and Towns, Cycle Ambition Cities, Bikeability and the Access Fund. Cycling safety also continues to remain on the agenda, with the most recent multimillion fund announced to make areas more bike friendly and improve road safety (Department for Transport, 2018a). Department for Transport has also issued *'Government Response to Call for Evidence, Cycling and Walking Investment Strategy: Safety Review'* (2018b), a supplementary document to CWIS (2017a) which summarised ways of making cycling (and walking) safer.

Commitment to promoting cycling also continues to be prominent in London: the most recent '*Mayor's Transport Strategy'* (Greater London Authority, 2018) puts cycling (along with walking and public transport) at the heart of the transport network. This is closely linked to the Healthy Streets

Agenda, which, as noted by Aldred and Croft (2019, p87) '*is the ambition to use street planning to radically increase mode share for sustainable and active modes'*. In fact, Bloyce and White (2018) emphasize the most recent trend of transport policy becoming more and more health related (in England).

1.3.2 Walking

When the policy shift to promote cycling happened in 1990s, walking still remained neglected. There was no National Strategy for walking: in fact, walking remained unacknowledged as a transport mode in transport policy (Delaney, 2016).

Even though organisations such as Living Streets (previously the Pedestrians' Association, founded in 1929) or the Ramblers (the largest walking charity) had been lobbying for the interests of pedestrians for years prior to that, the first official document which acknowledged walking enough to shift the policy focus was the 1998 White Paper *'A New Deal for Transport'* (Delaney, 2016).

In 2000, the Department of Environment, Transport and the Regions published *'Encouraging Walking: Advice to Local Authorities'.* It acknowledged walking as beneficial for people and communities and as a crucial part of the transport network. The document was a guide for transport professionals, looking at planning and partnerships, practical actions and ways of keeping the momentum.

Following this shift, walking became a part of the active travel agenda, along with cycling. *'Walking and Cycling: An Action Plan'* was published in 2004 (DfT, 2004a) and *'Active Travel Strategy'* in 2010 (DoH and DfT, 2010). Transport for London has also been continuously putting effort into improving the pedestrian environment, conducting research and publishing documents such as *'Improving walkability: Good practice guidance on improving pedestrian conditions as a part of development opportunities'* (2005), *'Attitudes Towards Walking'* (2011a, 2012 and 2014), *'Exploring the Market for Walking'* (2011b) and *'Walking- Exploratory Research'* (2009). Moreover, Scotland recognized the nationwide potential of walking and acknowledged it through publishing '*Let's get Scotland Walking: the national walking strategy'* in 2014 (Scottish Government, 2014). More recently, walking along with cycling, is being promoted as a part of active travel agenda as a part of the following initiatives: '*Cycling and Walking Investment Strategy'* (2017), '*Mayor's Transport Strategy*' (2018) and Transport for London's Healthy Streets Agenda (See Section 1.3.1).

While walking gets more and more recognition, multiple reasons make it more challenging to promote. These include walking levels are very high (compared with cycling and other modes of transport) and monitoring walking levels is more challenging (hence making it more difficult to report progress).

1.4 Sharing Space Between Cyclists and Pedestrians

1.4.1 Unsegregated versus Segregated Shared-use Paths

Shared-use paths can be classified as segregated and unsegregated:

1. Segregated shared-use paths *are 'a facility used by pedestrians and cyclists with some form of infrastructure or delineation in place designed to segregate these two modes'. (*Sustrans, 2014, p2)
2. Unsegregated shared-use paths are *'a facility used by pedestrians and cyclists without any measures of segregation between modes. It is designed to enable pedestrians and cyclists to make use of the entire available width of the path'* (Sustrans, 2014, p2).

There is an on-going debate about which type of facilities are better: safer, more comfortable and favoured by travellers. Unsegregated paths tend to generate strong opposition from cyclists who value speed. They are also sometimes disfavoured by some pedestrians and disabled people (Living Streets, 2016), in particular users with sensory impairments. They are believed to increase the risk of conflict and therefore are regarded as unsafe. On the other hand, the advantages of unsegregated shared-use paths include (Sustrans, 2014a):

1. More efficient use of space, greater effective width available
2. Cost-efficiency: Complete segregation can be expensive and difficult to maintain
3. Lack of segregation makes all users more alert and respectful of other users
4. Family groups might include people travelling by different modes (e.g. parents walking and children cycling).

There is also an additional advantage, which allows people with disabilities (also hidden disabilities) who use cycles as a mobility aid to use footways freely and avoid the dangers of cycling on road or even cycle paths (which might put pressure on cycling faster, so stopping or changing direction might be riskier). Hence, shared-use paths can be a solution to making the urban environment more accessible to all users.

The majority of official guidance documents represent advice that favours segregation. The priority of provision is visible in Table 1.1 from Department for Transport '*LTN 1/04 Policy, Planning and Design for Walking and Cycling'* (2004b). However, the factors that should be taken into consideration during decision-making (including pedestrian and cycle flow, cycle speed, cycle journey purpose, visibility along the path, presence of vulnerable users) in relation to the path characteristics are often ignored.

Table 1.1 DfT's Hierarchy of Provision from LTN 1/04 Policy, Planning and Design for Walking and Cycling guideline. (Department for Transport, 2004b, p11).

	Pedestrians	Cyclists
Consider first	Traffic reduction	Traffic reduction
	Speed reduction	Speed reduction
	Reallocation of road space to pedestrians	Junction treatment, hazard site treatment, traffic management
	Provision of direct at-grade crossings	Redistribution of the carriageway (bus lanes, widened nearside lanes etc)
	Improved pedestrian routes on existing desire lines	Cycle lanes, segregated cycle tracks constructed by reallocation of carriageway space, cycle tracks away from roads
Consider last	New pedestrian alignment or grade separation	Conversion of footways/footpaths to unsegregated shared-use cycle tracks alongside the carriageway

1.4.2 Shared-use Legislation

Currently there is very limited legislation to regulate the use of unsegregated shared-use paths in place. Delany (2016, p24) provides a summary of existing UK legislation regarding the behaviour of users on unsegregated shared-use paths. These include:

1. *'There is no law that says cyclists should give way to pedestrians (with the exception of zebra crossings, junctions, bridleways and in some individual cases based on Local Authority byelaws)'.*

2. *'If a person rides a cycle on a road without due care and attention, or without reasonable consideration for other persons using the road, he is guilty of an offence'*(the definition of a 'road' indicates that it includes shared-use paths: *'any highway and any other road to which the public has access...this includes footpaths, bridleways and cycle tracks'*) (Road Traffic Act, 1991).

3. Cyclists are advised to *'take care when passing pedestrians, especially children, older or disabled people, and allow them plenty of room...always be prepared to slow down and stop if necessary'* this however is not a legal requirement (DfT, 2015a).

4. By law when cyclists are using a shared-use segregated path they must *'keep to the side intended for cyclists as the pedestrian side remains a pavement or footpath'* (DfT, 2015a). However, pedestrians still have the legal right to use the cyclists' side of the path (DfT, 2004c).

Hence, while the legislation is limited, some organizations (Sustrans, Paths for All, Department for Transport, individual local authorities) have developed codes of conduct (Delaney, 2016): informal tools to provide more guidance and structure to users' behaviours. However, as Delaney (2016) points out, these documents mainly reinforce the common attitude in the shared-use literature: to either focus on one user group (in the case of codes of conduct it is generally cyclists) or introduce the division referring to 'us and them', blaming or shifting responsibility to each other. This does not promote the spirit of sharing.

1.4.3 Shared-Use in the UK

Shared-use paths were formally incorporated into the UK's walking and cycling infrastructure with the development of networks such as the Milton Keynes Redway System and Sustrans' National Cycle Network (NCN) in the 1970s (Delaney, 2016). These two large-scale projects caused a lot of controversy; unsegregated shared-use paths remain relatively unpopular among transport professionals.

McClintock (2002) highlighted some of the views on unsegregated shared-use in the UK in his book on planning for cycling. They are perceived as a simple solution to improve provision for cyclists, however, according to McClintock, in practice they can be controversial and increase the risks to vulnerable users. He suggested that surface and width improvements can *'attract more cyclists',* but simultaneously make them increase speed. However, he also emphasized that those concerns should not be the reason to completely reject shared-use paths: they can be a solution on less busy routes. Even though both user groups describe them as unpopular, they have potential to attract them due to the lower risk of conflict with motorised vehicle traffic.

McClintock also stated that new shared paths tend to be more acceptable than the converted ones (for example from solely pedestrian use). The variety of needs of pedestrians should also be considered when designing shared-use (McClintock, 2002). However, there is very limited knowledge on those needs. This could be a potential reason why unsegregated shared-use paths are currently at the bottom of the provision hierarchy.

1.4.4 Shared-use paths and tensions between walking and cycling

Mixing vulnerable user groups travelling at different speeds in an unregulated environment can give rise to tensions. As Ravenscroft (2004) stated, even though there is no observable evidence it is often claimed that shared-use trails generate interpersonal conflict between users. This can act as a constraint and discourage some people from using unsegregated shared-use paths.

To an extent these tensions can be caused by user behaviour. Cyclists and pedestrians are sharing space with no speed limit and no rules governing their behaviour. In fact, pedestrians and cyclists in the UK tend to behave similarly on shared-use paths to those in Australia. Their behaviour was described by Hatfield and Prabhakharan (2016) who pointed out that '*cyclists typically adhered to their responsibility of giving way to pedestrians, but often passed on the left, passed too close, passed without slowing, or passed without warning (e.g. with a bell). Use of mobile telephones and mp3 players is common, particularly amongst pedestrians*' (p35).

Ker et al (2006) listed a number of behavioural factors that may contribute to conflict on shared-use paths (p.37). The observations were also made in Australia, yet they apply to UK context. Table 1.1, taken directly from Austroads Research Report (2006) on '*Pedestrian-Cyclist Conflict Minimisation on Shared Paths and Footpaths*' summarizes them.

Table 1.2. User behaviours on unsegregated shared-use paths (p37).

Issue		**Brief description**
Footpath users	**Cycling on footpaths**	In some States/Territories, cyclists of all ages are permitted to ride on footpaths. Whilst this has caused concern for some, it appears that the perception of resulting pedestrian/bicycle conflict is greater than the actual number of incidents.
	Education issues	Different rules on roads and paths may send confusing messages to path users.
	Other legal users of paths	Wide range of legal users adds to the complexity of interactions and conflicts between pedestrians and cyclists.
	Unauthorised use of paths	Cyclists using walking paths and trails or riding illegally on footpaths. May include anything from in-line skates and motorised (2-wheel) scooters to horse riders and trail bikes. May include illegal parking of vehicles on paths.
	Non-movement uses in activity centres and other busy places	High level of competing, non-movement uses, with consequent pedestrian distraction, as well as high volumes of

		pedestrians and cyclists in a low-speed environment.
Persons with disabilities	**Range of abilities**	Persons with disabilities may have physical, sensory, cognitive or intellectual impairments, that are not always apparent to other path users.
Young and inexperienced users	**Child pedestrians and cyclists**	Younger people have little perception of left, right and give way and have immature peripheral vision. They have limited skills, control and co-ordination. Uncontrolled child pedestrians may exacerbate the conflict.
	Novice and returning adult cyclists	Inexperienced adult cyclists are likely to be most comfortable riding on paths, rather than on the road, as a way of gaining experience and developing confidence necessary for riding on the road. They may lack knowledge, competence and/or confidence.
User behaviour: awareness	**Lack of awareness**	Users may be unaware of the fact that the paths are to be shared with other users, and/or of the speed characteristics of the other users. Many pedestrians do not realise they cannot walk on a cycle only path.
	Lack of etiquette knowledge	Both cyclists and pedestrians may lack knowledge as to the rules/guidelines on shared path etiquette and laws.
	Lack of courtesy	Cyclists may not slow down when overtaking pedestrians, or pedestrians may not move over to let the cyclist pass. The conflict may be exacerbated by inattention by pedestrians using earphones and portable music players, hence unable to hear the cyclist.
	Lack of give way	Cyclists not giving way to pedestrians. Complicated by removal of requirement for pedestrians to keep left on paths.
	Poor conspicuity	Users wearing dark clothing, and cyclists not using proper lighting at night. [Note: Solutions may include improved lighting for paths, as well as user actions.].
User behaviour: operational	**Users not keeping left**	Pedestrian and cyclists not keeping left, even though they would do that if driving/riding on the road. Complicated by removal of requirement for pedestrians to keep left on paths, as advice to pedestrians walking on roads without

		footpaths is to face the oncoming traffic. As the bicycle is a quiet vehicle, pedestrians (especially those with a hearing impairment, for example) may feel more comfortable facing oncoming cyclists.
	Users travelling in groups	Users taking up the entire width of the path. Walking as a social activity with lack of focus on what is going on around. Walking as 'sightseeing' activity, with lack of focus on what is happening on the path. Cyclists in groups may be in 'social' mode or 'training' mode where the emphasis is on sustained effort.
	Unpredictable user behaviour	Some users such as dog-walkers, children, adults getting a fright may behave unpredictably.
	Lack of warning of presence	Cyclists may lack bells or fail to use them at all or with no sufficient warning, due to image problem, poor enforcement and general poor knowledge of the device. Pedestrians may also fail to give adequate warning of presence.
	Sudden entry onto path	Users entering the path at right angles to approaching users. Poor lateral sightlines especially at property boundaries and minor intersections. Lack of 'access control' (e.g. continuous accessibility from beaches or recreation areas). Can also occur at train and bus stations, where there may be large numbers of people moving across the path at times.
	Users with ancillary equipment	Pedestrians or cyclists carrying large loads occupy more space (e.g. on entering path with long item such as surfboard). Load itself may be 'unstable' – light but large items (e.g. surfboard) may blow across path inside breezes. Users may pay attention to managing the load rather than to other users of the path.
	Uncontrolled dogs	Dogs may run out under cyclists if owners are not keeping them on a leash or within arm's reach. Also, parents pushing prams (or people riding bikes) whilst walking the dog may be an issue. Some types of leash not readily visible. Extendable leashes do not necessarily prevent dog from rushing across path away from

		owner.
Speed	**Speed differential between cyclists and pedestrians**	Many cyclists wish to travel fast, which causes angst amongst slowly travelling pedestrians and less able cyclists. Many cyclists, even the 'less able' travel faster than pedestrians, or the cyclists themselves, realise. On the other hand, some pedestrians move more slowly than a cyclist might expect.
	Speed differences of different types of pedestrian or cyclist	Neither pedestrians nor cyclists are homogenous groups. Speed (and style of use) differences within each group will add complexity to interactions between the two groups.
	Speed of other users	Other users will travel at a variety of speeds and may be less predictable – either objectively, because their speed varies, or subjectively, because pedestrians and cyclists are less familiar with them.

The tensions are exaggerated even further through the politics of active travel. As described in Section 1.3, active travel remained neglected for many decades until the recent shift. Once the political interest started to pick up, lobbying started. As pointed out by McClintock (2001) there is less lobbying from pedestrian than cycling groups. This leads to limited awareness of the relevant knowledge and skills required for promoting walking. Cyclist lobbying, on the other hand, is regarded as more 'politically' aggressive. The image of cyclists, dressed in Lycra and travelling at speeds over 20mph, which is common in places like London and has been identified as an issue by Transport for London, does not help in managing those tensions: cyclists are often regarded as inconsiderate and threatening to pedestrians.

Moreover, cycling often overshadows walking: even under umbrella of 'active travel' schemes tend to focus on uptake of cycling and designated infrastructure. As a consequence, pedestrians can feel neglected or like the space is being re-allocated to cycling infrastructure at their cost.

1.4.5 Encouraging walking and cycling by implementing shared-use paths

As stated by Spotswood et al. (2015) even though there have been strong national and local efforts over the last decade to encourage uptake of cycling in the UK, levels of cycling (particularly utility cycling) stay relatively low at around 2% of journeys.

Shared-use paths have a potential to encourage cycling by providing a safer, more pleasant environment for more vulnerable cyclists. In some cities in the UK, sharing often highly congested roads with vehicles is perceived as dangerous. As Green et al. (2012, p282) pointed out '*cycling London safely, as it is currently constituted, requires knowledge, physical skills (balance, some strength and stamina) and the successful adoption of an 'assertive' style*'. Beginner cyclists rarely have such set of qualities: an alternative to share space with pedestrians could make it easier for them to gain confidence. Moreover, as stated by Aldred and Jungnickel (2014) currently '*some people may be willing to cycle alone on roads they perceive to be risky but unwilling to allow their children to do so'* (p86). More shared-use paths could give parents reassurance that children can cycle independently with lower associated safety risks and in longer-term it can create a cycling culture more accustomed to sharing and being considerate of other road users.

For walking, higher acceptance of shared-use paths could lead to more investment into infrastructure and higher quality public realm. That is because, currently the political focus is on delivering segregated cycling facilities and as highlighted by Aldred (2012) '*cycling infrastructure may have a variable effect on public space; cycling through parks, for example, is contested and in some cases may prove problematic to pedestrian interactions, closing rather than opening up space*' (online). Creating shared-use paths can provide a solution to that.

While there is always an associated risk of cycling acting as a deterrent to pedestrians, it is essential to consider the circumstances. For example, especially in dense urban setting, some paths could be used by commuter cyclists during morning and evening peak but remain predominantly pedestrian during the rest of the day. In other cases, the street where path is located could have more of a 'place' rather than 'link' characteristics: sharing between cyclists and pedestrians could contribute to the character.

1.5 Research Aims

As identified in the previous sections, despite on-going political efforts levels of cycling remain low and levels of walking are declining. Simultaneously, the amount of space available especially in cities is decreasing, while the amount of people keeps increasing. Unsegregated shared-use has potential to support promoting active travel: however, to achieve that a better understanding of user needs and path design is necessary to reduce the present tensions. This is a complex challenge that has not been sufficiently addressed yet and therefore a new perspective is needed.

The primary aim of this study is to propose an innovative, alternative approach to developing an assessment tool for the unsegregated shared-use paths in the UK, as inspired by the Level of Service tools developed in the United States (FHWA, 2006) and the Netherlands (Botma, 1995). The reasons why those tools are rarely used in the UK are described in Section 3.8.

The inventive methodological process reflects the attempt to shift the way assessment tools are developed towards more user led. The findings will be intended for use as a basis to improve existing paths and introduce new ones.

There are many factors to be considered when designing cycling and walking infrastructure; this research looks into path design, which is fully controlled by transport professionals. This study will seek to deliver a multimodal perspective and to improve transportation decision-making by looking at multiple transport modes (walking and cycling) through a single analytic framework.

This research assumes that user comfort is important to promote active travel: people are more likely to walk and cycle if they feel comfortable and less likely if they do not feel comfortable. Such attitude has been embraced more and more in the transport industry, with Transport for London and Greater London Authority leading the way with their Healthy Streets approach. It is in particular significant in circumstances that involve sharing, especially considering the tensions between walking and cycling due to user behaviour, as highlighted in Section 1.4.4.

Hence, in order to develop an assessment tool, the first phase of this research tries to understand better what ‘comfort’, a term often used freely by academics, planners and engineers, stands for. However, it does not attempt to define ‘comfort’ through on-going discussions on wellbeing or perceived safety (both in terms of interpersonal safety and user conflict/collisions). Instead, its purpose is to investigate the meaning of ‘comfort’ in a way that would enable transport professionals to directly impact it through their decision-making in the design process. Hence, this study investigates user comfort towards the conditions of unsegregated shared-use paths. It first explores the concepts of ‘comfort’ for cyclists and pedestrians, which may differ between them.

The second phase of this study attempts to develop an assessment tool for unsegregated shared-use paths in the UK context. It relies on comfort scores as the main variable and focuses on path characteristics identified in the first phase as the most important for user comfort. It represents an approach to Level of Service that has been used previously by researchers, which relies on using the users’ perceptions directly (Kang et al., 2013; Landis et al., 2011), but instead of repeating their methods, it proposes an alternative way of collecting data and looks into perceptions of both cyclists and pedestrians. Patton (2007) pointed out that street design, which accommodates several transport modes, is always based on establishing a balance of trade-offs and imperfect solutions. This study challenges the existing LOS, by giving the cyclists and pedestrians ‘greater standing’ in the decisions about the design of unsegregated shared-use paths, with the strongest argument being users’ comfort. Simultaneously, it proposes a new research methodology to capture users’ views in cost-efficient and generable way.

1.6 Thesis Structure

The thesis is divided into seven main chapters. **Chapters 2, 3 and 4** summarise the literature reviews conducted, pointing out the gaps identified in the existing studies. **Chapter 2** focuses on the literature on cyclists' and pedestrians' comfort. It also highlights issues related to shared-use paths. **Chapter 3** looks at available evaluation tools for cycling and walking infrastructure and explains the concept of Level of Service, as one of the assessment tools. It reviews the existing pedestrian Level of Service tools, bicycle Level of Service tools and Level of Service for shared-use. **Chapter 4** presents the technicalities of this research by introducing the chosen methodology and research methods.

Chapter 5 and **Chapter 6** provide the information, findings description and analysis of the Stage 1 of Data Collection on hierarchy of factors and path characteristics associated with comfort and Stage 2 of Data Collection focusing on the path width and volume of users, respectively. Each of these two chapters will include a discussion section, reflecting on the findings.

Chapter 7 concludes the study by summarizing the key findings and contributions and identifying the recommendations for future research.

It is also essential to emphasise that for the purpose of this thesis, the following terminology was adopted (Schepers et al., 2015):

- Cycle or pedestrian path: a path specially provided for cycles or pedestrians, can be unsegregated shared-use (See Section 1.4.1)
- Cycle or pedestrian route: a route for cyclists or pedestrians defined by an authority (for example local council), can be a mix of different facilities
- Cycle lane: a lane reserved for cyclists on a carriageway, can be segregated or not segregated from motor vehicle traffic.

CHAPTER 2: LITERATURE REVIEW ON PERCEPTIONS OF COMFORT

2.0 Chapter Composition

The following chapter explores the concept of 'comfort'. As comfort was chosen as the primary measure for developing the assessment tool, it was essential to review the existing literature in order to establish the path characteristics of primary interest. The literature review revolves around active travel, travel behaviour and urban mobility, with the focus on cycling and walking.

The research questions included:

1. What does 'comfort' mean in the context of cyclists and pedestrians using the facilities?
2. What factors affect cyclists' and pedestrians' perception of comfort?
3. What path characteristics affect cyclists' and pedestrians' perception of comfort when using a facility?
4. Are 'comfort' and related terms (such as comfortable, discomfort, uncomfortable) used in design guidelines? How are they defined?
5. Does path width affect cyclists' and/or pedestrians' perceptions of comfort?
6. Does volume of users affect cyclists' and/or pedestrians' perceptions of comfort?

The chapter first reviews the attempts to define 'comfort' and its importance to sustainable modes of transport in **Section 2.1**. This is followed by **Sections 2.2 and 2.3**, which summarize the existing research on factors and path characteristics associated with comfort of cyclists and pedestrians. The facilities of interest in this study – the unsegregated shared-use paths - accommodate a mixture of non-motorized users. Yet, the majority of existing literature focuses on specific user types. Hence, these subsections review the comfort of cyclists and pedestrians separately and consider the type of traveller, rather than whether the facility is segregated or not. This is followed by **Section 2.4**, which elaborates on impact of user behaviour on comfort and **Section 2.5** includes a review of design guidelines, with particular focus on the documents for designing shared-use paths. This leads to gaps in the literature being defined in **Section 2.6**.

2.1 Understanding Comfort

The most consistent attempt to define 'comfort' was presented by Li et al., who described it as a generic term reflecting the level of satisfaction a cyclist gets from using a facility (Li et al., 2012). Slater's 1985 definition of comfort as *'a pleasant state of physiological, psychological and physical harmony between a human being and the environment'* is commonly accepted, yet very general (Ahmadpour et al., 2014, p1). Arens and Ballanti state similarly that *'human comfort is determined* *by many factors, both psychological and physiological'* (Arens and Ballanti, 1977, p.115) and emphasise the importance of considering them in facility design. While there may be many factors contributing to comfort, it is also assumed that such factors may vary between different users, as well as different types of facilities.

Overall, there has been a lot of discussion revolving around 'comfort' in academia, but in most cases the term is used as an umbrella concept and lacks definition. Yet it is repeatedly used in design guidelines without sufficient explanation and understanding of its importance and ways the users perceive it (see Section 2.5). Hence, comfort is acknowledged as a key aspect to encourage cycling and walking by academics and transport professionals, but with little attempt to define it in the context of provision of specific facilities and user perceptions.

Patterson et al. (2013) have recognised the importance of routes that are comfortable for everyone in order to make cycling appealing 'to a wider audience'. This view has been supported by Holzel et al. (2012), who also insisted that prioritising comfort when designing cycling paths can encourage more people to cycle, especially the elderly. Litman (2007) pointed out that travellers value factors such as convenience, comfort, security and prestige highly. He stated that this is connected to the fact that improvements in convenience and comfort tend to decrease the unit travel time costs and hence are 'equivalent in value to increased travel speed'. He also observed that the current focus of conventional transport planning practices remains on quantitative impacts and not so much attention is paid to qualitative impacts.

Hence, the importance of understanding 'What is comfort?' and how it is achieved by path design is clear. If approached correctly, cycling and walking can provide all of those (convenience, comfort, security and prestige), being an attractive alternative to motorized traffic especially in the urban environment of the UK's cities. Moreover, as stated by Helbing et al. (2001) commonly used paths are regarded as more comfortable and therefore more attractive than ones that are not so popular: that the popularity makes them more attractive until saturation is reached.

As Litman (2007) pointed out, there is a prominent shift in approach in transport planning, which applies '*a marketing paradigm'*, where path users are perceived not as objects, but as customers, with their own, diverse preferences and needs. It relies on knowledge acquired from the travellers in order to deliver services that meet their expectations (Litman, 2007). The knowledge about these expectations can be collected through stated preference studies and revealed preference studies (Forkenbrock and Weisbrod, 2001). The aim is to incorporate travellers' convenience and comfort into planning and project evaluation (Litman, 2007). This suggests that facility designers consider more 'what factors are associated with user comfort?' and 'which users appreciate what factor?'.

2.2 Factors and Path Characteristics Associated with Cyclists' Perceptions of Comfort

Patterson et al. (2013) argued that the comfort offered by cycle paths plays a significant role in increasing bicycle use, especially among potential users: those who have interest but are concerned. They associated comfort with a smooth pavement, minimised delays, large visibility triangles at major road crossings, as well as clear indications of where to stop and wait if the traffic light turns red. Li et al. (2012) identified the variety in cyclists' comfort on different types of path, claiming that on separated lanes it is mainly influenced by the path geometry and surrounding conditions, while on on-street paths it is associated more with the effective width and traffic. Harkey et al. (1998) also identified that the presence of a wide cycling path or paved shoulder and the presence of on-street parking, with vehicles pulling in and out, decreased the perceived comfort of cyclists. Holzel at al. (2012) made a more general statement that comfortable cycling requires smooth rolling at the lowest possible energy input. In addition, it has been found that greater motor traffic volume and speed decreased the level of comfort (Pikora et al., 2003).

Comfort is regarded as one of the priorities when designing for cycling. The London Cycling Design Standards (LCDS) point out five core design principles: coherence, directness, safety, comfort and attractiveness (Transport for London, 2014a and 2016). LCDS's Cycling Level of Service assessment matrix associates comfort with six elements: surface quality, surface material, effective width without conflict, gradient, deflections and undulations. Similarly, the Sustrans Design Manual Handbook for cycle-friendly design (Sustrans, 2014b, p6) states that comfortable cycle paths should '*be smooth, non-slip, well maintained, drained and free of debris'*, '*have sufficient width for the level of use*', '*have easy gradients'*, '*be designed to avoid complicated manoeuvres*', 'enable cyclists to maintain momentum' and '*minimise impacts of noise, spray and headlight dazzle from other traffic'*. This suggests that these guidelines build the view of comfort through acknowledging the bicycle as a vehicle and its technical requirements, rather than the perceptions of cyclists.

2.3 Factors and Path Characteristics Associated with Pedestrians' Perceptions of Comfort

Comfort is also important for pedestrians and was introduced as a right by the first section of the European Charter of Pedestrians' Rights (adopted by the European Parliament in 1988), which states (8, p. 16): *'the pedestrian has the right to live in a healthy environment and to freely enjoy the amenities offered by public areas under conditions that adequately safeguard his physical and psychological well-being'* (Sarkar, 2003). According to Ovstedal and Ryeng, comfort is a positive emotional reaction to surroundings (the walking environment) in various contexts, such as physiological, physical, social and psychological. (Ovstedal and Ryeng, 2002).

From the perspective of pedestrians, the design of facilities can play a significant role in their travel behaviour and if it meets their needs and preferences, encourage walking. This is without a compromising effect on factors like safety and convenience (Handy, 2005; Shriver, 1997).

Hawthorne (1989) [2] emphasised the importance of green, clean and safe walking environments for pedestrians' comfort. He also claimed that comfort can be negatively affected by environmental qualities such as air pollution; litter and garbage; dangerous street crossings; traffic noise; poor maintenance; as well as other users, particularly the presence of skateboarders and cyclists. Pikora and his colleagues summarized it by stating that the features, which appear repeatedly in the literature as important, include aesthetics (greenery), safety (lighting, risks associated with traffic) and convenience/proximity of services (shops, schools) (Pikora et al., 2003). The importance of path width for pedestrians was mentioned by Demerath and Levinger (2003), who stated that wider footways ensure better mobility by allowing people to 'weave' without changing their pace.

Cyclist speed has been also identified as a factor that affects pedestrians' perceived level of service: Kang et al. (2013) indicated that higher speeds lead to lower perceived comfort. Additionally, Kang et al. (2013) identified the impact of improved visibility, which was then translated into the potential role of lighting in improving pedestrians' perceived LOS.

Christopolou et al. (2012) pointed out that the fact that motor vehicle volume affects pedestrians' perception of safety and comfort is proved by being included in the majority of methodologies. They also stated that pedestrian volume is considered a key factor.

*'Pedestrian Comfort Guidance for London' (*Transport for London, 2010a) focuses purely on pedestrian comfort. The entire document covers creating excellent pedestrian environments, through undertaking comfort assessments for existing sites and schemes in development (with the emphasis on operation during peak hours). It focuses on a variety of pedestrian routes and crossings (TfL, 2010a). While TfL (2010a) approaches comfort through engineering and planning knowledge combined with user perceptions (collected through surveys), it fails to specify pedestrians' needs and hence does not provide design solutions to meet them. Its emphasis is on pedestrian flow and street furniture in relation to path capacity rather than users' views. However, it goes further than Fruin's original Level of Service tool, which was primarily a crowding assessment: the TfL guidance does consider user comfort, through taking into account user perceptions and observed behaviours.

Another document, DfT's '*Traffic Advisory Leaflet on Bollards and Pedestrian Movement'*, also identified comfort as an interrelated issue affecting pedestrian movement. Yet, apart from a brief mention, the concept remains marginalized and pedestrians' comfort and how to achieve it are not clearly explained (DfT, 2013b). DfT's guidance for shared-use routes considers pedestrian comfort on shared use paths by pointing out that *'comfort will be influenced by a range of factors, such as the ratio of pedestrians to cyclists, the type of journeys being made and the extent to which people walk in groups'.* (DfT, 2012a, p44)

2.4 Impact of user behaviour on perceptions of comfort

Section 1.4.4 in Chapter 1 highlighted a number of cyclist and pedestrian behaviours that may contribute to conflict and ignite the tensions between both user groups. As a consequence, these user behaviours can positively or negatively influence perceptions of comfort, enhancing the impact of path characteristics listed in sections 2.2 and 2.3. For example, no matter how wide the path is if users are unpredictable and inconsiderate it is likely that other users' comfort will be affected. Simultaneously, the path can be narrow and poorly maintained, but if users are considerate and respectful of each other their perception of comfort will remain high.

While this research focuses on unsegregated shared-use path design, it acknowledges the importance of user behaviour for their operation. There is potential to enhance the regulatory framework, which currently remains unclear and lacks detail, through the introduction of codes of conduct. As pointed out by Delaney et al. (2017) there are currently two codes of conduct in the UK, on by Department for Transport and one by Sustrans. However, they focus on regulating cyclist behaviour, which put the responsibility for interaction only on one user group, questioning the idea of 'shared-use'. Delaney at al. (2017) also identified a few local codes of conduct that refer to cyclists and pedestrians, including for the Two Tunnels route near Bath and for Hailey Park, Cardiff. Yet, these documents address both user groups separately rather than promote shared use (Delaney et al., 2017).

2.5 Design Guidelines

Table 2.1 shows the main guidelines used for the design of shared-use, walking and cycling facilities. In green are highlighted the ones that mention comfort/comfortable/discomfort/uncomfortable at least once.

Table 2.1. UK design guidelines for shared-use facilities, cycling facilities and walking facilities.

UK Design Guidelines		
Shared-Use Facilities	**Walking Facilities**	**Cycling Facilities**

Local Transport Note 1/12 Shared Use Routes for Pedestrians and Cyclists, Department for Transport, 2012a Segregation of Shared Use Routes: Technical Information Note No.19, Sustrans, 2014a Shared Use Path in Scotland, Paths for All, 2011 Shared use cycle paths feasibility study, Atkins for Royal Parks, 2016 LTN 2/04- Adjacent and Shared Use Facilities for Pedestrians and Cyclists, Department for Transport, 2004c	Pedestrian Comfort Guidance for London, Transport for London, 2010a Design Manual for Roads and Bridges, TA 91/05, Provision for non-motorised users, Standards for Highways, 2005a Design Manual for Roads and Bridges, TA90/05, The Geometric Design of Pedestrian Cycle and Equestrian Routes, Standards for Highways, 2005c London Pedestrian Design Guidance, Transport for London Oxfordshire Walking Design Standards, Connecting Oxfordshire, 2017a Guidelines for Providing for Journeys on Foot, The Institute of Highways and Transportation, 2000 Designing for Walking, CIHT, 2015a Planning for Walking, CIHT, 2015b **Living Streets Street Review Guidance, Living Streets**	Handbook for cycle-friendly design, Sustrans, April 2014b London Cycling Design Standards, Transport for London, 2014a Local Transport Note 2/08, Cycle Infrastructure Design, Department for Transport, 2008 Cycling by Design, Transport Scotland, 2011 Interim Advice Note 195/16: Cycle Traffic and the Strategic Network, Standards for Highways, 2016 Greater Manchester Cycling Design Guidance and Standards Version 2.0, Transport for Greater Manchester, 2014 **Oxfordshire Cycling Design Standards: A guide for Developers, Planners and Engineers, Connecting Oxfordshire, 2017b** Birmingham Cycling Design Guidance, Birmingham City Council, 2014 A guide to inclusive cycling, Wheels for Wellbeing, 2017 International Cycling Infrastructure Best Practice Study, Report for Transport for London, 2014b Design Manual for Roads and Bridges, TA90/05, The Geometric Design of Pedestrian Cycle and Equestrian Routes, Standards for Highways, 2005b Planning for Cycling, CIHT, 2014 Design Manual for Roads and Bridges, TA 91/05, Provision

		for non-motorised users, Standards for Highways, 2005a

The fact that out of 26 published documents, only two (Living Streets Street Review Guidance and Oxfordshire Cycling Design Standards: A Guide for Developers, Planners and Engineers) do not include 'comfort'-related terms proves that the term is used commonly by transport professionals in a variety of situations. This Table also shows how much more attention is currently paid to cycling facilities: 12 out of 26 documents focus on cycling, nine on walking and only five on shared-use.

The focus of this study is on unsegregated shared-use paths between cyclists and pedestrians, hence the guidelines for shared-use were analysed in more detail. Table 2.2 includes more detailed background information on the context in which 'comfort' is related to in each of the documents. However, it needs to be emphasized that the majority of guidelines for shared-use facilities pay more attention to segregated rather than unsegregated shared-use.

Table 2.2. UK design guidelines for unsegregated shared-use facilities.

Guideline	**Context of Referring to Comfort**
Local Transport Note 1/12 Shared Use Routes for Pedestrians and Cyclists, DfT, 2012a	- States that poorly designed schemes, and schemes where the available width is insufficient to comfortably accommodate the expected flows of pedestrians and cyclists, are likely to reduce the amenity value of the route (p6). - Points out core design principles, including comfort (p12). - Associates comfort with gradients (p18). - Suggests that due to lack of segregation on unsegregated shared-use path some pedestrians might be uncomfortable with new arrangement and decide to divert to another route, increasing their journey time (p22). - Lists perception of reduced safety as a factor affecting user comfort, especially for older people and disabled people (p23). - Points out the importance of path width as a key factor influencing the quality of shared use routes: with insufficient widths reducing user comfort (p40). - Highlights the issue of path capacity and suggests that a shared use route will tend to become uncomfortable to use before full capacity is reached (p46). - Identifies the following factors that influence user comfort: the ratio of pedestrians to cyclists, the type of journeys being made and the extent to which people walk in groups (p46). - Suggests that practitioners can determine the comfortable level of use of a potential scheme by observing existing shared use routes carrying flows similar

	to those expected (p46). - Considers comfort in relation to user flows, suggesting that on wider routes, flows considerably in excess of 180 users per hour per metre width might be comfortably accommodated (p47). - Considers ways of improving comfort for shared-use paths located near high speed roads (by creating a buffer zone) (p49).
Segregation of Shared Use Routes: Technical Information Note No.19, Sustrans, 2014a	- Suggests comfortable path widths for unsegregated and segregated shared-use and passing. - Specifies a suggested preferred minimum for a segregated shared use path (without side constraints) as 7m (3.5m for cyclists and 3.5m for pedestrians). Such width allows two cyclists riding side by side to pass another cyclist and four pedestrians to pass 'comfortably', whilst conforming with segregation (p3). - Specifies an acceptable minimum for a segregated shared use path (without side constraints) is 4.5m (2.5m for cyclists and 2m for pedestrians). Such width allows two cyclists to pass and two pedestrians or wheelchairs to pass 'comfortably' whilst conforming with segregation' (p4).
Shared Use Path in Scotland, Paths for All, 2011	- Lists perceived comfort among path users' likes (in one category with personal safety, in relation to concerns about potential collisions, feelings of intimidation, unpredictable movements of other users). - Suggests adequate widths (to cater for a range of users and enable them to travel and pass in safety and comfort). - Mentions discomfort in context of path maintenance. - Suggests 'softer' surfaces provide comfort, larger stones make users uncomfortable. - Implies segregated paths can enhance the safety and comfort of more vulnerable path users.
Shared use cycle paths feasibility study, Atkins for Royal Parks, 2016	- Uses 'comfort' repetitively to describe cyclists experiences, for example '*route does not currently cater for less confident cyclists who are uncomfortable cycling in busy motor traffic*' (p16), '*those cyclists that are less comfortable to cycle on the busy adjacent roads*' (p17). - Mentions Mayor's Vision for Cycling with one of the main objectives being '*normalizing cycling, making it something that anyone feels comfortable doing'* (p17). - Associates discomfort of cyclists and pedestrians and cyclists on unsegregated shared-use with high risk of conflict and congestion. - Suggests that presence of cyclists on unsegregated shared-use in parks could cause discomfort to leisure users. - Suggests higher volume of pedestrians might make the route uncomfortable for cyclists (Green Park case study).

	- Suggests that routes with steep gradients might be uncomfortable for cyclists and that to increase comfort localized increases in width can contribute. - Insists that for shared-use route assessment it is critical to assess the level of pedestrian comfort, '*given that cyclists will occupy a proportion of the footway, reducing the effective width for pedestrians*' (p62). - In addition to conflict and safety issues, The Royal Parks Criteria for Success for Proposed Shared-Use Pedestrian Cycle Routes (2011) states that user perceptions are key and that: (among others) '*over 75% of people should be 'satisfied, comfortable or very comfortable*' (p103) with cycling on the route.
LTN 2/04- Adjacent and Shared Use Facilities for Pedestrians and Cyclists, Department for Transport, 2004c	- States that it should be demonstrated in the case for an adjacent or shared use solution that it will be attractive to new and existing cyclists using the path and simultaneously address the needs and concerns of non-cyclists. It needs to be shown that the proposed solution will: *'(…) be well designed, attractive, comfortable to use, and have a good riding surface'* (p6). - Suggests that in most cases, journey times for pedestrians will remain unaffected, as well as comfort and safety if a path has sufficient width (p13). - Suggests that the main benefits of adjacent or shared use facilities for cyclists should be reflected in safety, journey time (including convenience of route) and environment (including attractiveness and comfort) (p14)'. - Recommends the width for urban footways on local roads being **2m**, stating that it is sufficient to allow a pedestrian walking along a pushchair to pass another pram or wheelchair user comfortably (p21).

As highlighted in Table 2.2 (the term 'comfort' is underlined), the guidelines for shared-use paths use 'comfort' and related terms primarily in the context of path width and users passing each other. The suggested minimum path widths are based on the assumption of users 'comfortably' passing each other. However, this applies primarily to segregated shared-use paths. Multiple documents (DfT, 2012a; Paths for All, 2011; Atkins for Royal Parks, 2016; DfT, 2004c) also emphasize the importance of comfort as one of the main objectives for shared-use design. It is sometimes put in the same bracket as attractiveness or safety.

2.6 Gaps in the Literature

The literature review revealed that there is minimal understanding on what 'comfort' means/is associated with, yet the term is commonly used in official documents (design guidelines) and academic research (studies on cycling and walking, level of service tools).

While some studies exist on the separate comfort of cyclists (Patterson et al., 2013; Li et al., 2012; Harkey et al., 1998; Holzel et al., 2012; Pikora et al., 2003) and pedestrians (Ovstedal and Olaussen, 2002; Hawthorne, 1989; Pikora et al., 2003; Kang et al., 2013), the literature review pointed out the inconsistencies in the available studies in terms of findings, evidence and methods. This means that, for example, the importance of effective width for cyclist's comfort mentioned by Li et al. (2012), Harkey et al. (1998) or Transport for London (2014) might mean something different in each case. Furthermore, due to differences in research design, these factors cannot be put in the context of each other: hence, transport professionals are unable to state which of them contributes more or less to user comfort. The existing knowledge is not universal enough to be applied in practice.

The existing research appears to put a strong emphasis on path characteristics, both for pedestrians and cyclists. For cyclists, these path characteristics include smooth pavements (Patterson et al., 2013) or smooth rolling (Hozel et al., 2012), signage (Patterson et al., 2013), path width (Li et al., 2012; Harkey et al., 1998) and on-street parking (Harkey et al., 1998). For pedestrians, these are green, clean and safe walking environment (Hawthorne, 1989) which can be achieved through trees, lighting and traffic related measures (Pikora et al., 2003). Cyclist speed and visibility affect comfort on unsegregated shared-use paths (Kang et al, 2013). However, while the studies on cyclists' comfort focuses more on the practical aspects of route design related to the ease of cycling, pedestrians' needs have been researched in consideration of multiple dimensions of the overall travelling experience.

Putting it in the context of unsegregated shared-use paths, there is currently no academic literature that investigates the meaning of comfort when using an unsegregated-shared use path. Yet, expressions such as 'comfort', 'discomfort' 'comfortable' and 'uncomfortable' are repeatedly used in the guidelines for their design (see Section 2.5). The term 'comfort' has also been used in studies on developing Level of Service tools as a primarily measure to assess the quality of facilities (See Chapter 3). Only one study (Delaney, 2016) has compared the perceptions of cyclists and pedestrians. Yet, in the urban context, both user types often fall into the category of active travel/sustainable travel modes and are sometimes approached together as one. While it is not a common occurrence yet, in some cases sharing space between them might be a viable option with multiple benefits (See Section 1.4). Hence, it would be useful to compare the needs of the two types of users to ensure that the facilities cater for both, rather than prioritise one user group.

Furthermore, while the existing studies have suggested some characteristics, which contribute to comfort for cyclists and for pedestrians, little has been done to rank the extent to which each of them affects comfort. There is a significant gap in establishing the hierarchy of importance and the sensitivity of the characteristics - to what extent the improvements would improve the users' comfort. The understanding of such a hierarchy is crucial, as it would be the first step to establish which path characteristics should be researched further with the most benefit for the transport practitioners and users. The additional advantage would be establishing this hierarchy through a user-led process.

Currently, there is insufficient research evidence on what 'comfort' means to different user groups, as well as lack of credible conclusions on how it is applicable on unsegregated shared-use routes. Thus overall, advocating this type of facility remains a challenge. Hence, better understanding of users' perceptions of comfort is essential in order to deliver a high-quality, innovative assessment method. It will also complement the successful and efficient promotion of active travel through delivering facilities cyclists and pedestrians are willing to use and facilitate the evaluation of existing paths, leading to better planning decisions. The need is thus transparent for future research to focus on the users' perceptions of comfort and elements of design that are associated with it.

CHAPTER 3: LITERATURE REVIEW ON CYCLING AND WALKING ASSESSMENT TOOLS

3.0 Chapter Composition

This chapter first reviews existing assessment tools for cycling and pedestrian facilities in **Section 3.1**. Based on that, Level of Service (LOS) is chosen for the assessment tool to be developed as a part of this research. It then defines Level of Service in **Section 3.2** and summarizes the general approach towards developing LOS for cycling and walking facilities in **Section 3.3**. This is followed by a brief summary of Pedestrian Level of Service (PLOS) in **Section 3.4**, Bicycle Level of Service (BLOS) in **Section 3.5** and Shared-Use Path Level of Service (SUPLOS) tools in **Section 3.6**, identifying how they differ depending on approach, facility type, location and other factors. Existing PLOS, BLOS and SUPLOS tools are reviewed in order to gain a better understanding of the development, applicability, and strengths and weaknesses of existing tools.

This study attempts to develop an alternative SUPLOS, however there are currently only two of those available (Botma, 1995; FHWA, 2006). The facilities of interest in this study – the unsegregated shared-use paths - accommodate a mixture of non-motorized users. Yet, the existing LOS tools are developed focusing on cyclists or pedestrians separately (dismissing the other user group). **Section 3.7** includes a review of how comfort is utilized as a measure in the majority of LOS tools. This leads to gaps in the literature being defined in **Section 3.8**.

3.1 Assessment Tools for Cycling and Pedestrian Facilities

With the recent policy shift to promoting non-motorised transport modes (see Section 1.3), increasing attention has been paid to improving existing cycling and walking facilities and ensuring that new facilities are of high quality. In order to deliver that, multiple assessment tools were developed to facilitate the process. The main disciplines involved in this process are transport planning, public health and engineering.

For example, the Health Economic Assessment Tool (HEAT) for walking and cycling (WHO, 2014) was designed to estimate maximum and average benefits of cycling and walking per year, using the measure of reduced mortality. The tool looks at walking and cycling from the economic perspective and can facilitate acquiring investment or to show benefits of active travel in the context of reduced mortality. Methods such as the National Propensity to Cycle Tool (NPCT) (DfT, 2016a) are currently prototyped to assess the potential for cycling in specific areas. This type of tool is more applicable on the network scale.

There are also multiple tools that focus on particular road segments: The Level of Traffic Stress (LTS) model assesses the traffic stress that road segments or crossings impose on cyclists. The Cycle Route Audit Tool (CRAT) (Welsh Government, 2014b) and Walking Route Audit Tool (WRAT) (Welsh Government, 2014a) are spreadsheet-based tools: the person conducting the assessment rates the route on its attractiveness, comfort, directness, safety, and coherence. The Route Selection Tool (RST) (DfT, 2017b), on the other hand, was developed with the future in mind: while it can be used to assess the suitability of the path in the current condition it also allows practitioners to run a comparison on how it will score depending on the improvements made. The scores are for directness, gradient, safety connectivity and comfort. The tool also considers junctions.

As Kang et al. (2013, p10) pointed out '*engineers have used traditional measurement techniques in an attempt to establish some quantitative assessment of what might constitute a pedestrian-friendly walking environment in terms of pedestrian comfort and measures of congestion'*. The same applies to cycling. The primary tool used for quantitative assessment is Level of Service. The LOS assessment method is reviewed further in the section below.

3.2 What is a Level of Service Tool?

'Level of Service' was initially created as a measure for highways to assess the quality of traffic service. The Highway Capacity Manual defines levels of service (LOS) as a qualitative tool that categorizes operational conditions within a traffic stream and their perception by motorists and passengers. The terms used in describing each LOS (designated as A through F, with LOS A being the most desirable) include speed and travel time, freedom to manoeuvre, traffic interruptions, and comfort and convenience (The Highway Capacity Manual, 1985).

The key aspect of Level of Service assessment tools is that the traffic conditions are assessed based on the perspective of the user, rather than transport professional or road authority (Botma, 1995). Yet, the concept of LOS was first introduced to qualify the operational characteristics associated with various levels of vehicles or people passing a given point during a specified time period. For this reason, LOS has, in reality, been a qualifier of conditions related to vehicle or person throughput rather than a qualifier of conditions related to individual comfort level.

Due to the recent increasing popularity of active travel, cycling and walking facilities are becoming more prominent parts of transport networks in cities around the world. Sections 3.4 and 3.5 below provide a review of available Pedestrian and Bicycle Level of Service tools.

3.3 Level of Service Tools for Cycling and Walking

'Since its inception in 1965, the Level-of-Service (LOS) has proved to be an important and practical 'quality of service' indicator for transportation facilities around the world, widely used in the transportation and planning fields' (Almonte-Valdiva, 2009, Abstract). The original one was based on the relationships between vehicle speed (e.g. km/hour), density (e.g. cars/km) and flow volume (e.g. cars/hour), and Level of Service was determined by segmenting the observed approximation curve on the relationship between density and flow volume. The concept was applied to pedestrian traffic on busy footways in North America by Fruin (1971) and later to other places as well as to cycle traffic by many researchers and authorities (see Sections 3.5 and 3.6) in order to set a common standard for the performance of cycling and walking infrastructure for routes and schemes.

However, as cycling and walking differ significantly from motor vehicles as transport modes, the approach towards developing Level of Service therefore had to differ too. The main differences I identified include:

- There is usually a lack of a specified trail: pedestrians and cyclists can use the whole available width; in contrast the cars have to stick to lanes.
- There is limited traffic law identifying who has the right of way, when and where to stop, etc.: hence, the entire environment becomes less predictable and the potential for conflict increases.
- Walking and cycling for leisure is significantly different to walking and cycling for transport (this level of diversity does not exist among vehicles; the only similar, yet not too prominent phenomenon is described as 'Sunday drivers' who either travel slowly to reach their destination or drive for leisure).
- Pedestrians' and cyclists' activity face more barriers (require certain level of physical fitness or function; can be affected by weather conditions; is limited by distance etc).
- The presence of reverse flows within one lane on shared space.

The differences have made it challenging for researchers and engineers to develop a universal Level of Service tools for cyclists and pedestrians. Hence, multiple assessment methods have been established over the years. In fact, Fruin (1971) identified that capacity ratings are not sufficient to represent the human environment within the pedestrian traffic. He states that designing pedestrian facilities is a combination of traffic engineering principles and considering user convenience and the design environment.

In 1995, Botma claimed that users' perceptions should be the key criteria for assessing the quality of traffic operation. Even though the issues were identified, not much has changed. Decades later, Sisiopiku et al. (2007) pointed out that some of the existing Level of Service tools use the principles of vehicular traffic to evaluate pedestrian traffic operation and that others focus more on the facility design and walking environments. He referred to the critics who claimed that current pedestrian LOS determination methods still remain modelled too closely on vehicular LOS determination methods. The risk of that approach was primarily centred around the outcomes of assessments: the possibility that unacceptable (inhospitable) walking environments could end up with good LOS ratings (Sisiopiku et al., 2007). For example, even though the Highway Capacity Manual (HCM) has been updated since 1985, there were still concerns whether HCM 2000 really addressed pedestrian quality of service, based on the user's perspective. The research confirmed that HCM 2000 method tends to overestimate footway LOS, primarily because its design dismissed factors associated with user preferences and perceptions (Sisiopiku, 2007).

Hence, in line with Sisiopiku (2007, p117)'s view that '*an effective pedestrian LOS determination method should consider both the operating conditions of a system and how the users perceive such conditions*', Christopoulou et al. (2012) also emphasized the importance of perceptions, setting is as the ultimate research goal to develop a pedestrian level of service tool which integrated users' perceptions.

In fact, in recent years, the original approach has been modified with more focus on the perceptions of path quality through measurable parameters, such as user flow, modal split or path width. '*This approach is considered to have merit in that it provides a logical and auditable methodology for predicting users' opinions of conditions on a particular path*' (Phil Jones Associates for Sustrans, 2011, p8). It has been inspired by the work of Harkey, et al., (1998) and Landis, et al., (1997) who both developed LOS criteria for cycling paths, which were validated against user perceptions. Their studies proved that combining quantitative methods with user perceptions results in better approval from all stakeholders (technical staff, elected officials, facility users, and the general public).

In regard to practical application for these non-motorized transport modes, transport professionals often apply such a tool during the decision process for introducing new facilities. Depending on the variables, the tool provides a scale that guides the potential quality of the infrastructure. FHWA (2006) elaborates this process on the example of path width on unsegregated shared-use paths. The document explains that a question on how wide the path should be always coming up during the design process. The question is usually followed by further enquiry: '*What types of users can we reasonably expect? When will we need to widen the path? Do we need to separate different types of users from each other?*'. Answering these questions as accurately as possible is crucial: mistakes can lead to wasting money (if the path is wider than predicted future use justifies) or affect user safety and comfort (if the path is too narrow, leading to conflicts and unhappiness among users).

Level of Service tools are also utilized for assessment of existing paths, as has already been done for some of the London routes, though mostly for pedestrians. Another potential application (emerging, not commonly used yet) is determining whether to introduce separation between modes or directions of travel (FHWA, 2006).

Even though LOS methods have multiple applications with wide benefits (facilitating designers' work and improving facilities through catering to user views), to make the tools more practical, the quality of the method itself remains key. FHWA (2016) identified three factors crucial to ensuring the LOS methodology is used more commonly. These include: the ease of use; its applicability to path design scenarios; and access to necessary data needed to use the model. Determining whether to separate modes or directions of travel is also emerging as a key application (FHWA, 2006).

3.4 Pedestrian Level of Service (PLOS)

3.4.1 Capacity-based and Characteristic-based Approach

There are multiple Pedestrian Level of Service tools available. As Asadi-Shekari et al. (2013) stated in their review of pedestrian level of service tools, there are two common approaches for evaluating PLOS: one is a capacity-based model and the second is a roadway characteristic-based model (based on pedestrian facilities and environmental factors). My literature review has identified eight PLOS tools, among which seven are roadway characteristic based models (Highway Capacity Manual, 2010; Landis et al., 2001; Jensen, 2007; Christopoulou et al., 2012; Dixon, 1996; Gallin, 2001; Sarkar, 1993; Kang et al., 2013).

The tool by Mori et al. (1987) stands out as it explores two approaches: one method is based on pedestrian behaviour and the other one on pedestrian opinion. The recommendation is to use the behaviour-based tool for all footways (especially more congested ones) and opinion-based for footways with lighter pedestrian traffic.

3.4.2 PLOS Assessment Criteria

In terms of the main criteria used for PLOS assessments, there is a wide diversity, which might be due to the approach, the location or type of facility of interest. Hence, while a significant number of tools measure comfort and/or safety, the actual measures vary.

For example, Landis et al. (2001) studied the roadside walking environment and highlighted that the model developed is applicable at facility corridor and network levels. While this model might appear universal, it has in fact a very specific focus; it measures sense of safety and comfort, but mainly in relation to the presence of motor traffic. This is prominent in the choice of environmental characteristics used for the tool, such as presence of a footway; lateral separation from motor vehicle traffic; barriers and buffers between pedestrians and motor vehicle traffic; motor vehicle volume and composition; effects of motor vehicle traffic speed; and driveway frequency and access volume.

The commonly used Highway Capacity Manual (2010) bases the criteria for PLOS on scores rated by people travelling, which indicate the perception of '*service quality'* (p. 16-7). Those are combined with average pedestrian space on the footway and can be used to assess path segments or intersections. However, HCM PLOS did not associate perception of service quality with specific characteristics: instead, pedestrians were asked to rate from A (best) to F (worst) based on their individual experience. Other data elements included in the method include segment length, presence of footway and pedestrian travel speed.

Jensen (2007) developed a tool to assess the roadway segments. Hence, the criteria, based on their significance (established by cumulative logit regression), are less particular and reflect the diversity of road environment. They include '*motorized traffic volume and speed; urban land uses; rural landscapes; the types and widths of pedestrian and bicycle facilities; the numbers and widths of the drive lanes; the volumes of pedestrians, bicyclists, and parked cars; and the presence of median, trees, and bus stops'* (p43). The study also established a hierarchy of those characteristics and concluded that the width of facilities is the most important variable.

Dixon (1996) developed PLOS as a part of Gainesville Mobility Plan Prototype. In this case, the purpose (being a part of a city mobility plan) determined the characteristics: the main measures were the provision of basic facilities, conflicts, amenities, motor vehicle LOS, maintenance, provision of transportation demand management programs and multimodal provisions.

Gallin's (2001) PLOS aims to be used to evaluate pedestrian facilities through the prism of pedestrian 'friendliness' and assessing level of comfort. Factors affecting level of service were identified through consultations with key stakeholders. They include design factors (physical characteristics) such as path width, surface quality obstructions, crossing opportunities, and support facilities; location factors such as connectivity, surroundings, and potential for vehicle conflict; and user factors such as pedestrian volume, mix of path users and personal security.

The facility type also dictates the criteria. Kang et al. (2013) developed PLOS, however, in contrast to other methods, the facility of interest was footways shared with bicycles (based in China). The main measure was perception of comfort, which as identified, is affected by footway width (highly significant), pedestrian and bicycle flow, bicycle speed, presence of businesses, physical separation from motor-vehicle traffic, presence of parking and environmental factors. Kang et al. (2013) quantified the magnitude of their impact and investigated how it may vary across the pedestrian population.

Furthermore, as mentioned, the specific location can also play a role when choosing the criteria. Christopoulou et al. (2012) took into consideration the fact that the footways for assessment were based in Greek urban areas. The study included a review of eleven PLOS, followed by the selection of the most appropriate factors for Greek conditions. Compared with other LOS tools, Christopoulou considered very detailed characteristics as measures: traffic factors (distance from traffic, outside traffic lane speed, separation from traffic, traffic noise, traffic volume, lateral streets); geometry/environmental footway factors (total footway width, free height, guide for the blind, pavement condition of footway, ramps, trees and plants); and pedestrian movement factors (pedestrian volume, sense of safety, manoeuvres in order to void obstacles, manoeuvres in order to avoid vertical movements towards entrances, formation of a queue at bus stops/intersections).

Finally, the tools developed by Mori et al. (1987) show how the choice of measures is affected by the researchers' approach. The tool based on pedestrian behaviour focuses on speed, density, flow and overtaking. It resulted in a four-level tool for designing new facilities: level A is for residential areas; level B for general conditions in central business districts or other busy areas; level C for local and temporary circumstances; and there should be no design when level D occurs. The pedestrian opinion tool focused on the physical characteristics of the footway (total road width, total footway width, effective footway width, footway type, obstacle ratio, green ratio, traffic flow, pedestrian flow, and number of parked vehicles on the street).

Overall, as Sisiopiku et al. (2007) pointed out (based on methods applied in their study), each of the LOS tools available evaluates the footway based on different criteria. The same conclusion is reached based on this literature review. Some of the factors are similar (for example footway width occurs in multiple studies), others are original for individual tools. As a result, the same facility can obtain a different score depending on the method used.

3.4.3 Qualitative Versus Quantitative PLOS

Another point worth mentioning is the process of developing LOS tools. PLOS tools, in general, are developed relying on quantitative data. Sarkar (1993) approached level of service from a more qualitative perspective, stating *that 'qualitative evaluation of pedestrian precincts is important for providing adequate facilities for the elderly, the physically challenged, and children, who are most inclined to use this mode of travel'* (p35). The level of service was inspired by the works of Fruin and

Vuchic, and relied on the following criteria: safety, security, convenience and comfort, continuity, system coherence and the visual and psychological attractiveness of the environs. Different levels (A-F) were showcased using case studies from European cities. However, this qualitative approach risks being more subjective: for example, for Service Level A, Sarkar (1993) used expressions such as *'the security of the pedestrian environment is ensured by the presence of people and police cars'* (p37), without any proof that crime levels were low. Furthermore, the qualitative assessment did not identify clear boundaries between different levels, meaning that depending on who is applying the tool, the levels assigned to footways might vary.

3.4.4 Inclusive PLOS

The majority of PLOS tools consider pedestrians as a whole: however, they do not attempt to gain a better understanding of specific user groups among pedestrians. For example, the Highway Capacity Manual (2010) states that the focus of the methodology is on a '*typical pedestrian'* (p. 16-14) and not any pedestrian sub-group, '*such as pedestrians with disabilities'*.

Christopolou et al. (2012) is the only Level of Service tool which puts emphasis on ensuring inclusivity by incorporating regulations for people with special needs (based on the Ministry of Transport's Handbook '*Designing for All*'). Sarkar (1993) also referred to '*physically-challenged'*, who along with the elderly and children were seen as potential beneficiaries of the qualitative evaluation tool.

3.5 Bicycle Level of Service (BLOS)

Similarly to PLOS, there are a number of Bicycle Level of Service tools available. Again, the primary measures are comfort and safety. Also alike, the criteria depend on the location, the purpose of the tool and the type of facility of interest. However, there is significantly more diversity in terms of approaches taken: the capacity-based and roadway characteristic-based models or combinations of both.

Botma's (1995) tool relied on the relationship established between volume, composition, path width, direction of traffic (one or two-way) and perceived hindrance of users and focuses on establishing the boundary values for LOS levels. The main criterion was '*the frequency (meetings or passings) of events with respect to time*' (p40). Due to this, Botma differentiated between one-lane (where only passings are considered) and two-lane paths.

Landis et al. (1997), who developed a BLOS tool with the measure of sense of safety and comfort, attempted a similar approach. The variables chosen were directly related to the bicycle as a vehicle.

They include per lane traffic volume, traffic speed, traffic mix, cross-traffic generation (traffic flow turbulence), pavement surface condition and available roadway width.

Harkey et al.'s (1998) BLOS approach was about developing the bicycle compatibility index, meaning a tool for assessing how compatible a roadway is for allowing efficient operation of both bicycles and motor vehicles. It focused on urban and sub-urban roadway segments. The main variables of interest included path characteristics associated with '*bicycle friendliness*' such as width, traffic volume and vehicle speeds.

Jensen's (2007) bicycle level of service tool follows similar principles as Jensen's PLOS (see Section 3.4). The criteria of interest are motorized traffic volume and speed; urban land uses; rural landscapes; the types and widths of pedestrian and bicycle facilities; the numbers and widths of the drive lanes; the volumes of pedestrians, bicyclists, and parked cars; and the presence of median, trees, and bus stops.

The criteria that appear repeatedly in each of the BLOS tools above are path width and volume of cyclists. This could suggest that those BLOS models are capacity-based. This is different to Pedestrian Level of Service, which was predominantly characteristic-based approach: while the original - Fruin's LOS concept - was based on capacities, it has evolved, and the majority of versions consider path characteristics. Such an approach also simplifies the tool and eliminates the element of user-perception.

Dixon (1996) took a different outlook in the Gainesville Mobility Plan, which (in addition to PLOS) also included BLOS. Again, it is a good example of how the purpose of the tool (part of the city plan) determined the criteria. The main measures were the provision of basic facilities, conflicts, speed differential, motor vehicle LOS, maintenance, provision of transportation demand management programs and multimodal links to transit.

The Highway Capacity Manual (2010) Bicycle Level of Service (similarly to HCM's PLOS), which is a part of MMLOS (Multimodal Level of Service Methodology) looks at the multiple units of facility: intersections, links, segments and facility overall. It considers bicycle travel speed, segment length and bicycle LOS score for the segment. Lowry et al. (2012) takes this approach and applies it on a network level. It focuses the level of service tool on communitywide bikeability: the measures are comfort and convenience of travelling by bicycle. The tool uses the existing method; it relies on HCM's BLOS to assess bicycle suitability.

3.5.1 Inclusive BLOS

The majority of BLOS listed above do not investigate characteristics of users. Landis et al.'s (1997) model stands out as it investigated the differences between genders and bicycle experience levels. None of the BLOS tools considers adapted cycles used by people with disabilities (which might have different facility requirements).

3.6 Level of Service for Shared-Use Paths

More recently, some research has been done to establish methodologies to objectively assess LOS on shared-use routes with mixed traffic. The most commonly used Level of Service tool for shared-use paths was developed by the Federal Highway Administration (2006) in the USA. The method utilizes traffic-flow concepts, data collected on-site and user perceptions. It is done from the perspective of a cyclist, with the primary measure being the number of times a cyclist meets or passes another path user; the number of passings that are delayed; the path width; and whether the facility has a centre line. SUPLOS (Shared Use Path LOS) (FHWA, 2006) considers 'passive passings' (an occasion when the bicyclist is passed by a faster path user) and 'delayed passings' (times when the test bicyclist would arrive behind a slower path user and not be able to pass because of the lack of an adequate-sized gap in the next lane to the left (oncoming or same direction)). Yet there has not been any research to confirm that 'meetings' or 'passings' in that scenario affect user perceptions of the facility and to what extent.

Botma (1995) developed two Level of Service tools (for BLOS see Section 3.5), the second being for pedestrian-bicycle paths. The method was developed on two-lane paths, with widths of 1.5m-2m. The principle was similar to (and inspired the development of) SUPLOS (FHWA, 2006). The main measure was hindrance, assessed through 'passings' and 'meetings' and their total frequency. Botma (1995) also identified the challenges involved in developing Level of Service for two types of users simultaneously. He pointed out that the types of hindrance show that the LOS in a particular scenario can differ for pedestrians and bicyclists and suggested that this is a result of the user-driven assessment method. He also advised that LOS for a specific user group should be assessed in the context of provision of facilities for each group. However, there is also an acknowledgement that it might be useful to develop one LOS for traffic situations involving both cyclists and pedestrians, by combining tools for each of them into one. This can be done by taking the average frequency of events and deriving from them the overall LOS.

Among other PLOS and BLOS tools (see Sections 3.4 and 3.5), shared-use facilities are occasionally considered. In the Gainesville Mobility Plan, Dixon (1996) addressed the issue of shared space between cyclists and pedestrians, stating that in cases when a path is determined to be primarily multiuse a higher pedestrian LOS might be useful to cater for a safer interaction, or a higher bicycle LOS may be beneficial to attract bicyclists from the roadway to the off-street route. Moreover, Kang et al. (2013) developed PLOS for footways shared with cyclists (which is a common occurrence in China) (see Section 3.4).

3.7 Comfort in Level of Service

User comfort is a concept widely utilized among the Level of Service methodologies for cyclists and pedestrians. Some (Sarkar, 1993; Kang, 2013; HCM BLOS, 2010; Gallin, 2001; Landis et al., 1997; Landis et al., 2001; Mori et al., 1987; Lowry et al., 2012; Botma, 1995) used it as the primary measure/variable for developing the tool and then drew the criteria/specific characteristics that affect it. However, there has been little attempt to define what 'comfort' means and also very limited rationale on why particular criteria are chosen. For example, Kang et al. (2013) rely on perception of comfort as the primary measure for LOS, yet do not define what 'comfort' means and assume that the perceptions of comfort levels would vary considerably among respondents.

Harkey et al. (1998) also based their data collection on the concept of comfort: the survey participants were asked to rate each roadway based on how comfortable they would be riding there. In the pilot study of Harkey et al.'s research, comfort was defined by '*the level of risk you would feel as a bicyclist'* (Appendix C). In the full-scale data collection, 'comfort' was also used repeatedly: the reliance on the term 'comfort level' was due to the belief that it would allow the best chance of achieving a level of understanding and consistent interpretation.

Mori et al. (1987) referred to comfort too, using the term 'comfortable walking', however without defining what it stood for.

3.8 Gaps in the Literature

This literature review identified primary areas of knowledge that are currently missing.

First of all, there is currently very little understanding of what 'comfortable' means. Comfort has been treated as an umbrella concept but without definitions (see Chapter 2). Even though it is repeatedly used as one of the main LOS measures (see Section 3.7), there is no background information on the factors and path characteristics it is associated with in the context of cycling and walking facilities.

As a consequence, when it comes to the meaning of comfort, studies lack consistency. Christipolou et al. (2012) in their Pedestrian Level of Service tool, which included a review of alternative LOSs, stated that each method varies in the way it approaches pedestrian safety and comfort. Kang et al. (2013), despite relying on perception of comfort as principal measure, emphasized that in their study the concept of pedestrian comfort remained undefined. Harkey et al. (1998) defined comfort in the pilot study but did not follow through in actual data collection.

In fact, the understanding of ‘comfort’ might vary significantly between and among the academics developing LOS, transport professionals utilizing it and the users themselves. The risk is especially prominent for studies like Sarkar (1993), which are based on qualitative measures.

Moreover, this is also directly related to the trend of developing LOS tools based on user-perceptions. While there has been a shift towards more perception-oriented Level of Service methods, the majority of tools (in particular capacity-based BLOS models, see Section 3.5) are still inspired by the original ones designed for vehicular traffic. This has been widely criticized and an emphasis on importance of user perceptions in future studies was repeatedly stated (Botma, 1995; Sisiopiku, 2007; Christopoulou et al.; 2012). In order to attempt this successfully, with consideration that comfort remains the primary measure, a better understanding of what users find comfortable is crucial.

Moreover, there is a need for gaining a better understanding of how different user characteristics affect the perceptions of comfort and LOS ratings. The existing PLOS, BLOS and SUPLOS tools differentiate only between the user types, without considering socio-demographic characteristics. Asadi-Shekari et al. (2013) criticize the lack of pedestrian assessment tools that consider elderly and young pedestrians and people with disabilities.

Secondly, I identified that the LOS criteria vary depending on the type of facility of interest. Existing PLOS tools cover facilities such as the roadside walking environment (Landis et al., 2001); the roadway segments (Jensen, 2007); pedestrian facilities (Gallin, 2001); and footways (Christopoulou et al., 2012) (Mori et al., 1987) (Sarkar, 1993). BLOS tools cover cycle paths (Botma, 1995) and the roadway (Harkey et al., 1998).

Since shared-use paths are becoming increasingly attractive options, transport professionals are challenged by the lack of information on when and how to decide what is a suitable design for the facility. Currently, there is very little research and guidance available to aid them in those decisions: there are two main tools for shared-use paths, SUPLOS (FHWA, 2006) and Botma’s (1995) model. Each of them measures Level of Service through hindrance, with an assumption that it is the number and type of ‘meetings’ and ‘passings’ of other users that affect the quality of the facility. Neither of them is purely user-perception based. Kang et al.’s (2013) model is also applicable for shared-use paths; however, it only considers the views of pedestrians.

None of the available LOS models looks into and compares the perceptions of both cyclists and pedestrians on unsegregated shared-use paths: they tend to focus on one user type rather than both and on shared-use facilities, not specifying unsegregated. This is unacceptable if the facility is unsegregated and aims to cater for multiple user types. In the final report 'Evaluation of Safety, Design and Operation of shared-use paths' (FHWA, 2006), the Federal Highway Administration pointed out the need for research to estimate level of service from the perspective of other users (pedestrians, skaters, etc).

Moreover, Kang et al. (2013) identify the need for further research in the following areas: for when the volume of users on shared-use path is higher (flow rates exceeding 8.3 ped/min/m); in more countries; and with more diverse samples (Kang and colleagues' sample included 114 Chinese respondents).

Another limitation identified through this literature review is that the significant majority of Level of Service tools were developed in the United States. In fact, none of the studies shown in this literature review were conducted in the UK context. One might argue that USA research can be used as a case study in the UK. However, that does not take into consideration differences in facility provision, traffic law and culture. Some of the differences include the fact that in the USA, cyclists are the most common users of shared-use paths (FHWA, 2006) and USA paths are usually wider than in the UK. Allen et al. (1998) also emphasized the differences between the United States and Europe. In their literature review of methods, which led to developing an operational analysis method for uninterrupted cycle facilities, the authors recommended the Dutch approach to be used in the future versions of HCM. However, they emphasised the need for the procedures to be '*widely validated due to differences in cyclist behaviours, levels of experience, cycle path widths and cycles themselves' (p36)*.

It needs to be pointed out that US researchers occasionally draw knowledge from European research. When developing SUPLOS, FHWA was inspired by Botma's Level of Service. However, the document pointed out that '*the procedure needs to be calibrated and validated for US conditions' (p3)*.

The main differences between the Netherlands and the US (limitations) identified included:

- US paths tend to be wider and the cyclists tend to be less experienced.
- US cyclists cycle more for leisure than commuting.
- US bicycle design is different.
- Botma's work did not consider 'passive passings' (when the cyclist is passed by a faster path user).

- Botma's work assumed that path users do not affect each other's movements (there is enough space for sharing without interaction) (p3).

It was impossible to establish the numerical differences, as at the time of writing the FHWA Report (2006) there was no database in North America with statistically valid data which would allow direct comparisons.

Similarly, while Level of Service tools developed abroad can be treated as a guidance documents, in order for LOS to work efficiently in the UK, it needs to consider local conditions. Jensen (2007) pointed out the need to consider the Danish context, especially when the basis for the tool are American studies. In the LOS developed, Danish conditions were taken into consideration and the differences were pointed out (higher levels of walking and cycling in Denmark, more pedestrian and bicycle facilities, and the different designs of some of these facilities).

Therefore, the Level of Service tool I will seek to develop will aim to reflect more accurately the level of service of UK unsegregated shared-use path than the available methods, and inform the need to consider differences in traffic law, culture and other relevant factors when a LOS system is applied to other countries.

CHAPTER 4. METHODOLOGY

4.0 Chapter Composition

This chapter elaborates the choice of methods for this research. The data for this research was collected in two stages. Both Stage 1 and Stage 2 of data collection involved an online survey: both relied on quantitative data.

Section 4.1 explores the theoretical paradigm (positivist approach) which led this research and discusses the methodological strategy in the context of that paradigm. It also reflects on other theoretical approaches and how they could have had impacted on research's viability. It then proceeds to **Section 4.2,** summarising the methodological strategy adopted in this study. It is approached through the prism of Firestone's (1987) criteria for quantitative research. **Section 4.3** lists the research questions and describes the research methods, pointing out the advantages and disadvantages of quantitative surveys and of distributing them online. **Section 4.4** gives an overview of research methods used to develop other Levels of Service tools and their critical appraisal. Finally, **Section 4.5** summarises the sampling strategy, including pointing out the risks of relying on non-probability self-selection sampling.

4.1 Theoretical Paradigms

4.1.1 Positivist Paradigm

This research adopted a theoretical approach, which led the way the knowledge was studied and interpreted. The term paradigm originates from Thomas Kuhn (1962), who defined it as *'an integrated cluster of substantive concepts, variables and problems attached with corresponding methodological approaches and tools'* (cited by Hussain et al., 2013).

The positivist approach was identified as the framework of the study. Referring to Kaboub (2008, p343) *'the positivist paradigm asserts that real events can be observed empirically and explained with logical analysis'.* Positivist research methodology (methodological individualism) emphasizes micro-level experimentation in a lab-like environment that eliminates the complexity of the external world'. Bryman (1984, p77) noted that *'the paraphernalia of positivism are characterized typically in the methodological literature as exhibiting a preoccupation with operational definitions, objectivity, replicability, causality, and the like'.*

The choice of theoretical approach dictates the research methods. A positivist paradigm is often associated with quantitative methods of data collection. As Bryman (1984, p77) stated: *'the terms* *'positivist' and 'empiricist' often denote the same fundamental approach as 'quantitative'.* Also, Bryman (1984) suggested that the social survey is regarded as a preferred instrument of research within this tradition.

Social surveys are designed to collect information in a structured way from large samples that are representative of the population of interest to the researcher. Such surveys allow the concepts to be operationalized. The research remains objective through establishing the distance between the researcher ('observer') and participants ('the observed'). There is also the prospect of externally checking a participant's questionnaire and the possibility of replication of the same research method in a different context (Bryman, 1984, p77). Because of the ability to reach a wide and diverse pool of respondents, a survey, with the benefits of objectivity and replicability, became a research method of choice for this study.

4.1.2 Other Paradigms

Whilst originally the decision was made to firmly ground this project in the positivist paradigm, some consideration was also given to other theoretical approaches. The potential role of alternative paradigms in guiding this research became more prominent in the process: as Stage 1 and Stage 2 of data collection progressed, it was clear that additional validation could have been achieved by alternating the methodology.

Social constructionism sets a framework, which sees the concept of 'truth' as varying, socially constructed, and ever-changing. It assumes that reality is created by a collective and framed by social context and interactions (Blackstone, 2012). Such approach reflects well on the research based on user perceptions.

Hence, upon reflection, while positivist paradigm inspired quantitative analysis, which resulted in descriptive understanding and meanings inferred from statistical analyses, alternative theoretical approach could have added more depth by encouraging applying qualitative research methods. This would have minimised bias and the risk of respondents not reflecting their perceptions accurately in a quantitative way. Such mixed method approach could have been used to validate the findings of Stage 1 and Stage 2 of data collection.

4.2 Methodological Strategy

Following the direction dictated by the positivist paradigm, this research adopted a quantitative approach. The decision was supported further by the literature review, which identified the methods used to produce Level of Service tools in the past.

Table 4.1 shows four main criteria defining quantitative research, as specified by Firestone (1987). The following points provided guidance and theoretical structure for the research.

However, in the process of designing the research, consideration was given to the fact that the focus on quantitative research in transport studies has been criticized before (Banister, 2016). Banister (2016) pointed out the weaknesses of such an approach stating that the *'traditional positivist approach based on the 'scientific' method and the belief that through careful quantitative analysis one could understand the complexity of cities and evaluate a range of alternative strategies to meet expected levels of traffic demand'* is no longer sufficient. He elaborated that there is an increasing awareness in transport planning that the quantitative approach has its limitations and that the political nature of decision-making in transport calls for a wider range of quantitative and qualitative analysis (Banister, 2016).

Yet, the literature review identified that including user perceptions in quantitative measures can result in better recognition from stakeholders at all levels – technical staff, elected officials, facility users, and the general public (US Department of Transportation, 2006a and 2006b). Therefore, I ensured that all information used to develop a tool for assessment of shared-use paths originated from or was verified by potential and existing shared-use path users. That approach provided the direction for the choice of the research methods, which was also supported by the literature review (Chapter 2 and Chapter 3). The approach relied on quantitative methods, with the focus on user perceptions.

Moreover, I decided that the data for this research would be collected in two phases. This structure was drawn from the review of cycling and walking in the UK (Chapter 1) and the literature reviews on comfort (Chapter 2) and assessment tools for walking and cycling facilities (Chapter 3).

Table 4.1. Criteria for quantitative research

Criterion	Firestone's Definitions	Research
Assumptions about the world	'*Based on positivist philosophy'* (Firestone, 1987, p5), social facts and objective reality exist, less emphasis is put on the subjective reality constructed by individuals view of the situation (Taylor and Bogdan, 1984).	For the purpose of producing a Level of Service Tool and supporting guidance for providing high quality unsegregated shared-use paths, adapting the concept of '*objective reality*' was necessary. This meant that the findings would be 'universal and applicable in a variety of contexts However, this study did embrace the importance of subjective reality, by focusing on user perceptions and acknowledging that's individuals experience is a valid argument within the social fact.
Purpose	'*Seeks to explain the causes of changes in social facts, primarily through objective measurement and quantitative analysis'* (Firestone, 1987, p5); Less emphasis is put on understanding.	
Approach	Relying on experimental or correlational designs to reduce error, bias (Cronbach, 1975). Ethnographical approach is not adopted.	This research adapted both correlational and experimental designs.
Researcher role	Detached from the research to reduce bias (Firestone, 1987, p5).	The researcher had very limited past experiences of using unsegregated-shared-use paths. There was also no history of pro-cycling or pro-walking lobbying, which could have resulted in favouring one of those transport modes. This meant that the research design and data analysis (the only aspects where researcher was fully in control) was not affected by researcher bias. Survey, as the data collection method of choice, has detached the researcher even further.

The decision to conduct research in two stages was inspired by the knowledge gaps identified by those literature reviews: when reviewing factors affecting comfort of cyclists and pedestrians and available PLOS, BLOS and SUPLOS tools, the inconsistencies were prominent. Hence, the best way of choosing the criteria for a new LOS tool was to collect data on comfort and ask potential users (cyclists and pedestrians) for their views.

As the literature review on comfort identified (See Chapter 2), there is currently no academic literature that investigates the meaning of comfort when using an unsegregated-shared use path.

However, a diversity of factors and path characteristics have been proved to have impact on perception of comfort by cyclists and pedestrians independently (in a non-sharing context). Hence, the initial set of characteristics of interest for the Stage 1 study was determined on the basis of the literature review and consultation with transport professionals (Sustrans).

While both data collection stages aimed to collect quantitative data, their objectives were different:

1. Stage 1 of data collection was designed primarily as exploratory research. Its main objective was to take an umbrella concept of 'comfort' and put it in the context of user perceptions of unsegregated shared-use paths. It aimed to establish the hierarchy of factors and characteristics of cyclist-pedestrian shared-use paths associated with the comfort of users.

2. Stage 2 of data collection, on the other hand, was designed as confirmatory research. Its purpose was to look more closely into the path characteristics identified during the Stage 1 of data collection. These characteristics were to be explored further to develop an assessment tool.

4.3 Research Questions and Associated Methods

This quantitative research relied on collecting data through two questionnaires. Questionnaires have been previously successfully used as the method of data collection in research related to walking and cycling.

Warwick and Lininger (1975) insisted that for the sample survey to be an appropriate and useful data collection method, it needs to meet the following conditions:

- The goal of the research should call for quantitative data
- The information of interest should be 'reasonably specific' and 'familiar' to survey participants
- The researcher has to have a certain amount of background knowledge on the topic of interest and the variety of potential responses.

Based on these criteria, it was confirmed that a survey was a suitable form of data collection for this study.

The main advantage of using questionnaires was wide geographic coverage, lack of interviewer bias and low cost. The challenges to be faced included questionnaire design, response rate and lack of control of who completes it.

Table 4.2 shows the advantages and disadvantages, as identified by the researcher, of relying on surveys as primary data collection method.

Moreover, developing the Level of Service tool, which was identified as the objective of Stage 2 of data collection, with consideration of user perceptions required gathering numerical data. In the past, surveys have proved to be an efficient way of collecting data and were widely used by fellow researchers (Jensen, 2007; Mori et al., 1987; Dowling et al. 2008; Harkey et al., 1998; Kang et al., 2013).

The decision was made to distribute the surveys online. The concern about online distribution was that the data collected that way might appear more systematic and scientific in one way, but less in another: this is because the data obtained report only what people say they do and feel, and not what a researcher has witnessed them say, do and feel. Also, the issue connected with online distribution is lack of random sample and hence, the concern over the representativeness of the data (for more limitations see Table 4.3).

Table 4.2. Advantages and disadvantages of a survey as a data collection method.

Advantages	**Disadvantages**
1. Ability to collect data from a larger sample of respondents 2. Convenient methods of gathering data 3. Precision in measuring the data gathered 4. Structure allowing comparison of responses 5. Flexibility in data analysis	1. Data errors due to non-responses, creating bias 2. Participants' fear of putting themselves in an unfavourable light (social desirability bias, which can be reduced by making the survey anonymous) 3. Subjective way of interpreting the answers (e.g. 'very comfortable' might mean something different to individual participants) 4. Inflexible design, with limited ability to apply changes throughout the data collection process 5. Lack of control over accuracy and honesty of the answers

Table 4.3 shows the advantages and disadvantages of distributing the surveys online.

Taking into the consideration the complex nature of the research process, when defining a methodological framework and choosing research methods, several research questions and sub-questions were defined. They are listed in Table 4.4, with an indication of which stage of data collection was designed to provide answers. Research questions for Stage 2 of Data Collection were specified, after Stage 1 of Data Collection was completed (See Chapter 5).

Table 4.3. Advantages and disadvantages of distributing surveys online.

Advantages	**Disadvantages**
1. Cost-efficient way of collecting responses: considering a limited budget, an online survey allowed us to organize a prize draw as an incentive to participate instead of paying the participants for their attendance. 2. Researcher was able to save time: once the survey was designed, it required minimum time to administer and collect the results. 3. Considering that the online survey is completely anonymous, respondents might have felt more comfortable filling it in. 4. Accessibility: the survey could have been filled in using multiple devices such as computer, tablet or phone.	1. Limited control over the sample 2. No guarantee that a sufficient number of respondents would complete the survey 3. Exclusion of participants without access to the Internet 4. The absence of the interviewer to ensure that the answers given are of adequate quality and not filled in purely with the aim of getting an incentive. 5. Non-random sample

Table 4.4. Research questions.

Research Question	**Stage 1**	**Stage 2**
	Survey	**Survey**
How can comfort on unsegregated shared-use path be defined?	X	
What is the hierarchy of factors associated with perceptions of comfort on unsegregated shared-use paths?	X	
What is the hierarchy of path characteristics associated with perceptions of comfort on unsegregated shared-use paths?	X	
Do the users' individual characteristics affect the perceptions of comfort on unsegregated shared use paths, and if so, to what extent? - User Type - Gender - Age	X	

How willing are people to use unsegregated shared-use paths, assuming the route is fastest and most direct? What level of comfort/discomfort do users have to achieve to re-consider using unsegregated shared-se path? · When the unsegregated shared-use path covers a major part of the journey? · When the unsegregated shared-use path covers a minor part of the journey?		X
How do specific characteristics (identified in Stage 1 of data collection) affect perceptions of comfort?		X
Do the users' individual characteristics affect the perception of comfort, in the context of those path characteristics? - User Type - Gender		X

4.4 Developing a Level of Service Tool

As the outcome of this study was set on developing a Level of Service Tool, a review of numerous possible methodological approaches was conducted. It included identifying the type of facility, geographical origin, mode of transport whose perspective was considered, applied research method and chosen measure or variable of interest. Table 4.5 summarises research methods applied to the LOS tools reviewed in Chapter 3.

Table 4.5. Level of Service tools and applied research methods.

Level of Service	Facility Location	Mode of Transport	Research Method	Measure
Federal Highway Administration, FHWA Evaluation of Safety, Design and Operation of Shared-Use Paths: Final Report, 2006	United States Unsegregated Shared-Use Paths (also referred to as trails)	Cyclist	The researchers assembled the new method using new theoretical traffic-flow concepts, a large set of operational data from 15 paths in 10 cities across the United States, and the perceptions of more than 100 path users. They relied on the moving-bicycle method (collected meetings and passings from the	The number of times a typical bicyclist meets or passes another path user; the number of those passings that are delayed; the path width; and whether the path has a centreline

			perspective of a test bicyclist using a camera mounted on the bicyclist's helmet).	
Flannery et al., Customer-Based Measures of Level of Service, 2006	United States (Florida and Maryland)	Drivers, (also mentions LOS for Cyclists, Pedestrians)	Literature Review	N/A
Sisiopiku et al., Application of Level-of-Service Methods for Evaluation of Operations at Pedestrian Facilities, 2007	United States, Study sites located in Birmingham, Alabama Pedestrian footways in urban settings (middle-sized city)	Pedestrian	Comparison of common and widely accepted methods for determination of the pedestrian LOS at footways (the *Highway Capacity Manual* 2000 method, the Australian method, the Trip Quality method, the Landis model, and the conjoint analysis approach). Evaluation of 13 footways at two study sites.	The measures of existing LOS tools (the *Highway Capacity Manual* 2000 method, the Australian method, the Trip Quality method, the Landis model, and the conjoint analysis approach).
Asadi-Shekari et al., Non-motorised Level of Service: Addressing Challenges in Pedestrian and Bicycle Level of Service, 2013	Overview of multiple countries (all-over the world)	Pedestrian Cyclist	Literature Review The aim was to identify effective indicators for non-motorised trips, highlight current street evaluation methods (focus on cyclists and pedestrians) and identify their strengths and weaknesses.	N/A
Sarkar, Determination of Service Levels for Pedestrians, with European Examples, 1993	United States Examples of Munich, Germany Rome, Italy	Pedestrian (focus on the elderly, the physically challenged and children)	The LOS levels (LOS A-F) were demonstrated through illustrations, using examples from different types of walkways that are operational in Munich, Germany, and Rome, Italy. Detailed descriptions for each of the measures was	Safety, security, comfort and convenience, continuity, system and attractiveness.

			provided.	
Jensen, Pedestrian and Bicyclist Level of Service on Roadway Segments, 2007	Denmark Road sections between intersections	Pedestrian Cyclist	407 randomly selected Danes were shown video clips from 56 roadway segments filmed by a pedestrian walking and a bicyclist riding along the road. Respondents rated the roadway segments on a six-point scale ranging from very dissatisfied to very satisfied. The videos were shown in local ballrooms by using professional video projectors on screens 2.7 by 2.0 m and sets of stereo loudspeakers. The sound was set so that it matched the sound in real traffic. Between 20 and 43 respondents participated in the individual video shows. Each video clip was shown in four video shows and was rated by 113 to 161 respondents. A respondent attended a 56-min video show that included a welcome, presentation of the questionnaire, the provision of answers to eight background questions (age, sex, rural or urban residence, type of residence, number of kilometres walked weekly, number of kilo-meters bicycled weekly, the aids used for	Levels of satisfaction To remain consistent with the *Highway Capacity Manual* (*10*), six LOS designations (LOSs A through F) were defined as follows. A 'democratic' definition of LOS was used (LOS is designated A if 50% or more of the respondents are very satisfied, LOS is designated B if 50% or more are very or moderately satisfied and less than 50% are very satisfied, and so forth, ending up with an LOS of F if 50% or more are very dissatisfied).

			walking, and whether the respondent was able to bicycle without problems), two learner video clips, a time for questions and answers, the first rating session with 21 video clips, a 10-min break with refreshing soft drinks, a second rating session with 21 video clips, and a closure. If the learner clips and the first rating session included the pedestrian video clips, then the second session was the bicycle video clips, and vice versa. Half of the video shows were with pedestrian video clips in the first rating session. Roadway segments and video clips were described by 150 variables. Pedestrian and bicyclist satisfaction models were developed by cumulative logit regression of the ratings and the variables. The models included variables that related significantly to the satisfaction ratings.	
Gallin, Quantifying Pedestrian friendliness: guidelines for assessing pedestrian level of comfort, 2001	Western Australia Pedestrian facilities	N/A	Factors affecting LOS were defined in consultation with key stakeholders. A model for assessing LOS was developed based on the measurement of factors influencing LOS and the LOS scale (A-F). Weightings were developed through consultation with key	Pedestrian Friendliness Factors affecting LOS Design factors (Physical Characteristics): Path width, Surface quality, Obstructions, Crossing Opportunities, Support Facilities Location factors: Connectivity, Path

			stakeholders.	Environment (Surroundings), Potential for Vehicle Conflict User factors: Pedestrian Volume, Mix of Path Users, Personal Security
Landis et al., Real-Time Human Perceptions Toward a Bicycle Level of Service, 1997	United States Shared roadway environment	Cyclist	This study placed its participants in urban traffic and roadway conditions to obtain feedback on real-time perceptions. Real-time data collection activity: Fun Ride for Science (run during single time-block to ensure the experiences were as similar as possible;150 bicyclists; 27km course, consisting of 30 road segments) The participants evaluated on a 6-point (A to F) scale how safe and comfortable they felt as they travelled each segment. (A: most safe and comfortable F: least safe and comfortable)	Sense of safety and comfort Relevant variables were selected for consideration in the second step of the model-development process: per-lane traffic volume, traffic speed, traffic mix, cross-traffic generation (traffic flow turbulence), pavement surface condition, and available roadway width for bicycling.
Landis et al., Modelling the Roadside Walking Environment Pedestrian Level of Service, 2001	United States Roadside walking environment	Pedestrian	Trial: 75 participants; 8km; 24 segments with near equal lengths but with varying traffic and roadway conditions. Participants were placed in actual traffic and roadway conditions. 'FunWalk for Science': participants provided demographic info and evaluated on a 6-point (A to F) scale how safe and comfortable they	Sense of safety and comfort (Presence of a footway, lateral separation from motor vehicle traffic, barriers and buffers between pedestrians and motor vehicle traffic, motor vehicle volume and composition, effects of motor vehicle traffic speed, and driveway frequency and access volume.)

			felt as they travelled each segment. (A: most safe and comfortable F: least safe and comfortable) Total of 1,250 real-time observations was recorded. The list of independent variables was generated based on: the results of the Pearson Correlation analyses, variables (and model terms) identified by group consensus and confirmed during the development of the earlier Roadside Pedestrian Conditions Model (developed for the Tampa metro area's Hillsborough County Metropolitan Planning Organization Pedestrian Plan); and extensive iterative testing of segment groupings with common levels of independent variables (wherein additional variables were identified that potentially could further explain the variation of the dependent variable—the pedestrians' ratings of safety and comfort).	
Dixon, Bicycle and Pedestrian Level-of-Service Performance Measures and Standards for Congestion Management Systems, 1996	Gainesville Mobility Plan Prototype (the Plan) Florida, the US	Bicycle, Pedestrian (separate LOS)	N/A	Bicycle LOS: provision of basic facilities, conflicts, speed differential, motor vehicle LOS, maintenance, and provision of transportation demand

				management (TDM) programs or multimodal links to transit Pedestrian LOS: the provision of basic facilities, conflicts, amenities, motor vehicle LOS, maintenance, and TDM and multimodal provisions
Mori et al., A New Method for Evaluation of Level of Service in Pedestrian Facilities, 1987	Ordinary footways in urban areas Japan	Pedestrian	Time-lapse photographs of uni-directional flows of commuters (bird's eye view camera in the CBD of Osaka City) were taken. Footway sections: 2.2m to 4.5m in width and 20m in length ------------- During the pilot study specific factors were isolated which gave consistent user response between on-site evaluation and VTR. 9 male Osaka University students run the pilot. The selected factors were presented at various levels to a large sample of subjects and their evaluations were correlated with physical characteristics of photographed sites. 129 footway locations 9 factors chosen: footway width, anxiety from vehicular traffic,	2 approaches: Indices of pedestrian density and footway width Behaviour and awareness of pedestrians (pedestrian opinion)

			green volume, pressure from building, sanitary condition, signboards, obstacles, easiness to walking, footway overall evaluation. For each factor 13 pictures with varying conditions were chosen. Based on the pilot study 6 reliable factors were selected. Respondents: 8 students and 27 residents of Senboku-Newton in Osaka.	
Dowling et al., Multimodal Level of Service for Urban Streets, 2008	Urban street, United States	Auto-driver, Transit-passenger, bicycle rider, pedestrian	This study utilized a video lab survey method. 90 video clips (from auto driver, bicyclist or pedestrian point of view) were shot across the US (30 clips per mode of transport). 30s-8min long videos were recorded (depending on a time needed to travel 0.5 mile distance). Video clips were combined into 4 randomly sequenced movies (one movie per video lab in one city). 145 participants participated (35-40 people per city). Rating scale A (best) – F (worst). Each participant was asked to decide for himself or herself what constituted LOS A and what	User satisfaction

			constituted LOS F. The FQLOS bicycle and pedestrian segment and intersection models were used as the building blocks for the urban street models of bicycle and pedestrian LOS. The key variables for these two models (bicycle and pedestrian) were derived from Florida DOT research. Regression was used to determine the weights for combining the segment and intersection components of the overall street model for each mode. The uniformity of the reported transit LOS results precluded a statistics-based approach to the transit model development. A patronage elasticity approach was used to determine the factors most affecting transit patronage (and therefore indirectly the perceived level of service). The weight for each factor was determined based on published data on the elasticity of transit ridership as a function of the factor, as compared with a base level for that factor.	

Allen et al., Operational Analysis of Uninterrupted Bicycle Facilities, 1998	North America Uninterrupte d bicycle facilities: exclusive off-street bicycle paths, shared off-street paths, on-street bicycle facilities	Bicycle	Literature Review	N/A
Lowry et al., Assessment of Communitywide Bikeability with Bicycle Level of Service, 2012	Bike lanes, Shared-use pathways (network bikeability) United States	Bicycle	Calculated BLOS for all bikeways across the community (a bikeway is any roadway where bicycle travel is permitted regardless of the presence of a bike lane) Once suitability was determined for an entire bikeway network and important destinations were identified, the bikeability was calculated.	Comfort and convenience of travelling by bicycle (taking into the consideration suitability of the bikeways)
Botma H., Method to Determine Level of Service for Bicycle Paths and Pedestrian-Bicycle Paths, 1995	Netherlands Cycle path, Shared-use path	Cyclist Pedestrian	The existing Dutch guideline for the required width of a separate bicycle path was reviewed and levels of service (LOSs) were determined. The same method was used to define LOSs for paths used by pedestrians and bicyclists. The main emphasis of the study was on methods (rather than	The frequency of the manoeuvres (a proxy for hindrance experienced by the users) Comfort and convenience

			results). The results in the article were based on first guesses of some parameters (just for an illustration of how the method works).	
Harkey et al., Development of the Bicycle Compatibility Index: A Level of Service Concept: Final Report, 1998	United States Urban and sub-urban roadway segments (both bicycles and motor vehicles) Intersections	Cyclist	The participants viewed a number of roadway segments on video (approximately 40s) and rated them depending on how comfortable they would be riding there under the conditions shown.	Variables which bicyclists typically use to assess the ‘bicycle friendliness’ of a roadway (e.g., width, traffic volume, and vehicle speeds) The study also consistently refers to ‘comfort ratings’. In the instruction to the survey the participants were requested ‘to rate each roadway with respect to how comfortable you would be riding there’. Comfort was defined by ‘the level of risk you would feel as a bicyclist’ (for pilot study). For the full-scale data collection effort, a 1-6 scale incorporating ‘comfort level’ was developed and used. The simplicity of the term ‘comfort level’ was believed to have the best chance of achieving this level of understanding and uniform interpretation.
Kang et al., Statistical analysis of pedestrian perceptions of footway level of service in the presence of bicycles, 2013	Footways shared with bicycles (in China)	Pedestrian	114 Chinese respondents participated. The participant rated 15 60s video clips, assessing the pedestrian level of	Perception of comfort

			service in the video on a scale from LOS A (the most comfortable pedestrian environment) to LOS F (the least comfortable pedestrian environment) on the scale 1-6. It was emphasized that videos might miss out on real-life experiences: the perceptions of comfort might vary. To allow for both the discrete and ordered nature of the data, an ordered probability approach is an appropriate modelling choice (see Washington et al., 2011).	
Highway Capacity Manual BLOS, 2010		Cyclist		Perception of 'comfort and safety' 1) width of outside lane, 2) width of bike lane, 3) width of shoulder, 4) proportion of occupied on-street parking, 5) vehicle traffic volume, 6) vehicle speeds, 7) percent heavy vehicles, 8) pavement condition, 9) presence of curb, and 10) number of through lanes
Christopoulou et al., Development of a model for the estimation of pedestrian level of service in Greek urban areas, 2012	Greece Thessaloniki, Footway	Pedestrian	A review of eleven available pedestrian level of service tools, followed by the selection of most appropriate factors for Greek conditions. The developed model	Traffic factors: distance from traffic, outside traffic lane speed, separation from traffic, traffic noise, traffic volume, lateral streets (discontinuities) Geometry/

			and five other methodologies were then applied along a footway in Thessaloniki. Extensive survey was implemented along the footway.	environmental/ footway factors: total footway width, free height (without obstacles e.g. tents, signs), guide for the blind, pavement condition of footway, ramps, tree and plants Pedestrian movement factors: pedestrian volume, sense of safety (e.g. adequate lighting, other pedestrians), manoeuvres in order to avoid obstacles, manoeuvres in order to avoid vertical movements towards entrances, formation of a queue in bus stops/intersections, reinforce multimodal transport

Each of the methods, listed in the Table 4.5 had its advantages. Data collection methods used by Jensen (2007) and Kang et al. (2013) particularly stood out due to the use of video footage and surveys that involved rating experience by users. However, neither of the Level of Service tools listed above is currently applied in the transport industry in UK in a mainstream way: there is not enough resource available to translate the findings into UK context, especially when unsegregated shared-use remains and unpopular choice. In fact, most of them are not accessible to transport professionals and have never been endorsed by public or private sector. That is due to their impracticality or outdated approach towards cycling and walking infrastructure (based on original, vehicle-focused Level of Service tool).

The method chosen for pursuing the development of Level of Service in this case was carefully thought through and established to fill in the weaknesses of past assessment methods, which were identified in Section 3.8. After reviewing other tools , it was concluded that the ones developed by Harkey et al. (1998), Dowling et al. (2008), Mori et al. (1987), Jensen (2007) and Kang et al. (2013) were most aligned with user-led perspective: however they lacked generalisable outcomes that could be applied to guide the design of unsegregated shared-use paths. Therefore, an approach that prioritised sample size and applicability and simplicity of findings was developed.

As for the data collection methods, Section 4.3 further summarises the advantages and disadvantages of relying on survey as data collection method and distributing it online. The rationale and advantages and disadvantages of relying on artificially designed scenarios are described further in Section 6.3.

4.5 Sampling Strategy

There are multiple (non-motorized) user type, who can use unsegregated shared-use paths. This study focused on the population of adult pedestrians and cyclists. The other users who are seen on unsegregated shared-use paths occasionally include roller skaters, skateboarders, and people using scooters, wheelchairs or adapted cycles. However, they were excluded from this research because of difficulties with recruiting a sufficient sample, with the potential to be included in the future.

The decision of was made to exclude cyclists and pedestrians under 18. This was done due to practical constraints (recruiting respondents) and because the travel decisions of people under 18 are often made by adults. Moreover, since the survey was distributed online or through leafleting but with the requirement of following the World Wide Web link to fill in the responses, this survey only covered individuals with access to the internet. The consequence of online distribution was digital exclusion of specific user types: this particularly affected those without digital literacy, with the main determinants being age, disability, learning difficulties and poverty.

This study adapted a non-probability sampling technique based on self-selection sampling. Self-selection sampling takes places when respondents ‘volunteer’ themselves to participate in research (Bradley, 1999). The need for participants was publicised through a variety of means (see Section 5.4 and Section 6.8): the requirements for user type (cyclist and pedestrian) were specified in the advertisement.

The choice of this sampling technique was based on the fact that this study was looking to obtain a high number of responses in a limited time. What needs to be emphasised is that the research was designed to involve two stages of data collection, with the objective to gain a minimum of 600 respondents (300 pedestrians and 300 cyclists) for each. The sample size needs were determined using Survey Monkey Sample Size calculator tool and then adjusted with the consideration for time and cost restrictions. In particular, cyclists are relatively rare and therefore difficult to locate to participate (especially when the focus is not a specific type of cyclist, for example racing cyclists).

Non-probability self-selection sampling carries a major risk of self-selection bias. In order to avoid people participating in the survey purely because of personal interest in shared space between cyclists and pedestrians (and hence being at risk of having strong preconditioned views), the survey advertisement included a mention of a prize draw. This was designed as the main incentive to encourage people to participate.

4.6 Next Steps

In conclusion, the theoretical approach for this research was established early on to ensure consistency throughout the process. The positivist paradigm was identified as the framework of the study, which was then reflected in the research questions, research methods and sampling strategy. Research methodologies applied to development of other Level of Service tools were reviewed, in order to extract their strengths and weaknesses. The following Chapters 5 and 6 show how the framework and the objectives have been applied in practice during Stage 1 and Stage 2 of data collection.

CHAPTER 5. UNDERSTANDING COMFORT ON INSEGREGATED SHARED-USE PATHS: PERCEPTIONS OF CYCLISTS AND PEDESTRIANS

5.0 Chapter Composition

Following the findings of the literature review (Chapter 2 and Chapter 3) and after establishing the research methodology and methods (Chapter 4), the study proceeded. This chapter focuses on Stage 1 of data collection: the research method, its design and execution, the process of collecting data, analysis and results.

In line with the research questions identified in Chapter 4, **Section 5.1** specifies the objectives of Stage 1 of data collection and **Section 5.2** provides a rationale for it. **Section 5.3** focuses on the research method - an online survey - and describes the process of choosing factors and path characteristics of interest and survey design, including the breakdown on questions. This is followed by **Section 5.4**, which highlights the different ways I promoted the survey and collected the data. **Section 5.5** specifies the types of analysis applied to the data collected and **Section 5.6** presents and discusses the results, also putting them in the context of literature review. The discussion of results details the sample characteristics, the ranking of factors and path characteristics associated with comfort from highest to lowest importance, a comparison of responses between user types (cyclists and pedestrians) and genders (males and females), analysis of underlying factors and cluster analysis. Finally, **Section 5.7** highlights the conclusions and describes the implications and applications of findings.

5.1 Aim and Objectives

With the primary aim of establishing path characteristics to be explored further in the Stage 2 study, the objectives for the Stage 1 study were:

1) to understand which factors people instinctively associate with their comfort;
2) to understand how different users (considering both the user type and users' personal characteristics) perceive their comfort when using unsegregated shared-use paths;
3) to establish a hierarchy of path characteristics which contribute to comfort of users when using unsegregated shared-use paths; and
4) to explore the perceptions of comfort on unsegregated shared-use paths among the users based in the UK, where cyclists mostly share road space with cars (as majority of existing research is not UK-specific).

This study could be seen as investigating levers to promote behavioural change of transport users with diverse preferences and needs. It relies on the knowledge acquired from the users in order to deliver services that meet their expectations (Litman, 2007), which can be collected through stated preference studies (Forkenbrock and Weisbrod, 2001). This first phase of this study was the background research for the further research aiming to produce perceived Level of Service tool for unsegregated shared-use paths in the UK.

5.2 Rationale

The rationale for the Stage 1 study was drawn from the literature review (See Chapters 2 and 3), which proved that there is not enough existing research to select path characteristics to develop LOS for unsegregated shared-use paths based on the information available. It was also impossible to establish which path characteristics are of the highest significance to both cyclists and pedestrians, considering that the majority of research considers them separately. Hence, the decision was made to develop Stage 1 of data collection in order to source the hierarchy of path characteristics from cyclists and pedestrians themselves.

The Stage 1 data collection was designed with a specific interest in respondents' socio-demographic profiles. Considering that cyclists in the UK are typically white, male, between 25 to 44, and with a higher than average income (Transport for London, 2010b), it appears that some groups remain excluded. Interestingly, in other countries with high levels of cycling, like the Netherlands and Japan, women, children and the elderly make a high proportion of people who cycle.

The need for better understanding of the differences between genders in regard to mobility has been emphasized (Spinney, 2009). Law (1999) argued that existing research has neglected the experiences of mobility informed by gender. Borrell (2015) reflected further on people of disadvantaged socioeconomic position (which includes women) and how the transport system should benefit the population equally. Kang and Fricker (2014) emphasized the importance of personal characteristics for pedestrians, stating that in their study *'personal characteristics of pedestrians were found to play a critical role in determining attitudes or perceptions when it comes to sharing space with bicyclists'* and *that 'the personal characteristics of pedestrians should not be ignored'.* Among the characteristics were gender and age, which this study explores further.

5.3 Research Method

The research method of choice was an online survey. The questionnaire was web-based and designed to be self-completed by the respondents.

The choice of quantitative research methodology was driven by the desire to reach as many respondents as possible. Moreover, the aim was to reach as diverse sample as possible, which included not being limited to specific locations. Section 4.3 highlighted the advantages and disadvantages of relying on surveys (Table 4.2) and of distributing the surveys online (Table 4.3).

5.3.1 The Choice of Factors and Path Characteristics Associated with Comfort

The set of factors related to comfort in general and the characteristics of mixed-use paths were both chosen through the literature review. Safety, speed, other users, space and surroundings were drawn from the review of available literature (see Sections 2.2 and 2.3) and the existing guidelines (See Section 2.3). ‘Space’ and ‘other users’ were used as terms that generalize path width and volume of users (traffic, number of users) and have less ‘numerical’ or ‘technical’ association. Path length was introduced as a ‘dummy’ variable. While one could argue that some of the factors are not mutually exclusive (for example safety and speed), the purpose was to provide a hierarchy of factors that the users instinctively associate with comfort in their own mind, rather than in-depth understanding and definition of each of them.

The literature review on comfort (See Chapter 2) and Level of Service (See Chapter 3) identified multiple path characteristics of interest. These included: density, flow volume, vehicle speed, presence of motor traffic, urban land uses, volumes of pedestrians, volumes of cyclists, volumes of parked cars, provision of facilities, maintenance, path width, presence of obstructions, connectivity, surroundings, etc. However, lack of consistency was prominent: the path characteristics associated with comfort as well as the ones used as measures for existing LOS tools were chosen by the researchers in different contexts, for different users and for a variety of facilities.

Some of the factors identified in the literature review, such as path surface or gradient, were not considered: this was a decision made due to practical reasons, as it was established that these factors did not fit with the method adopted. The way they affect comfort is more related to physical fitness, ease of movement and bicycle wheel-rolling, and their impact can be measured in more efficient ways. This was also supported by the literature review of Level of Service tools.

Pikora et al. (2003) suggested a list of physical environmental factors that might influence walking and cycling in a local neighbourhood (Figure 5.1). He divided them into four main groups: functional, aesthetics, safety and destination.

Figure 5.1, which includes the list of path characteristics, was the basis for the discussion with transport (active travel) professionals at Sustrans. Considering that the original list focused on walking and cycling in general, it was regarded as an overview and was too general for the purpose of this research, which is why additional input was necessary to make a selection. The aim was to identify the characteristics of potential interest for the design of unsegregated shared-use paths. Of particular importance for this study were functional, safety and aesthetic factors. The main criteria used in the selection were: industry need; gaps in available guidelines; and, from perspective of this research, the characteristics which, after analysis, can be utilised as a part of the developed tool.

First of all, it was established that functional physical environmental factors were of most interest, primarily because they relate most directly to path design. Those were reviewed in relation to unsegregated shared-use paths. After the initial discussions, the following path characteristics were chosen to be explored further: path width, path maintenance, volume of pedestrians, volume of cyclists, user speed, lighting, street furniture, verge width and surrounding.

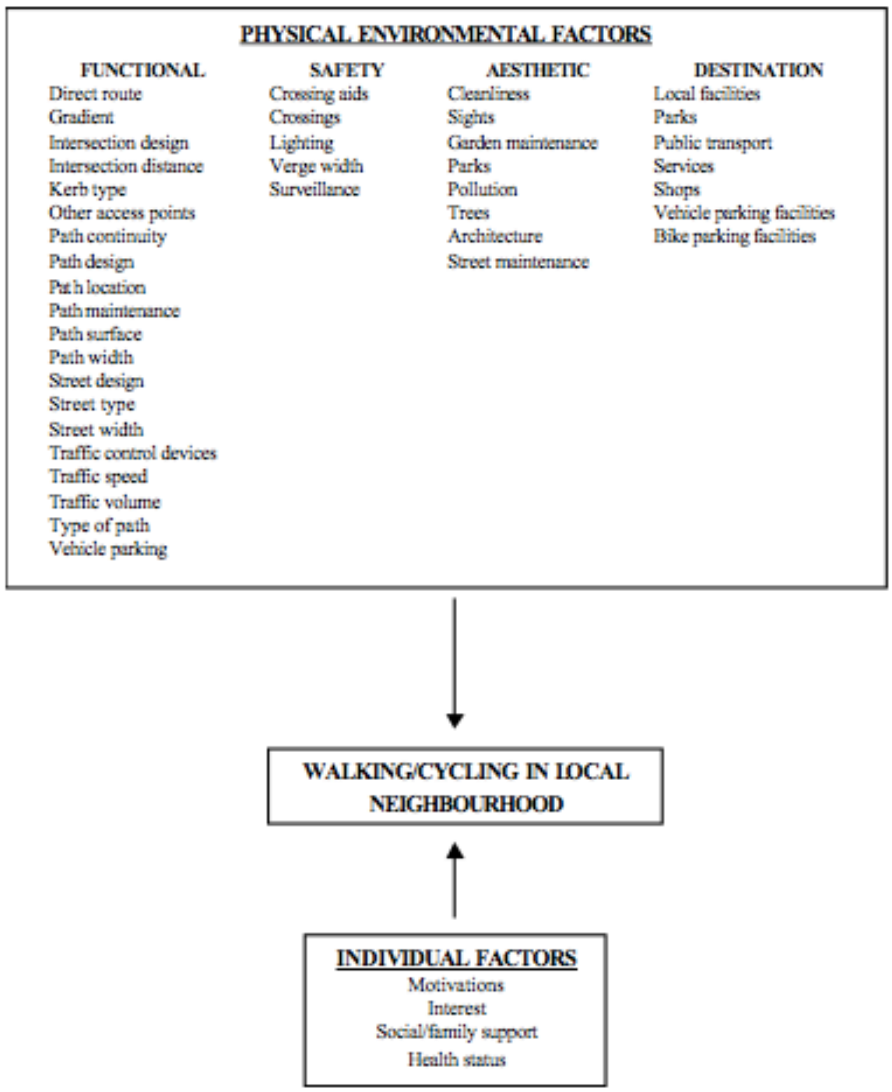


Figure 5.1. Schema of the physical environmental factors that may influence walking/cycling in the local neighbourhood (Pikora, 2003).

5.3.2 Survey Design

The survey was divided into sections which consisted questions designed to provide information on:

- **Respondents' cycling and walking behaviours:** as an opening, the participants had to identify themselves as regular cyclist or regular pedestrian. It was not possible for them to choose both. Those who chose 'regular cyclist' were classified as cyclists in the later analyses, with respondents who chose 'regular pedestrian' as pedestrians. The questions that followed investigated the frequency and reasons for the activities. These questions were the key to analysing further the relationship between different cycling and walking behaviours and perceptions of comfort on shared-use paths.

- **Shared-use paths and comfort:** the main focus of the questionnaire was to explore the perceptions of comfort on shared-use paths by current and potential users. The questions looked into different factors and characteristics and their importance for comfort and barriers to using shared-use paths. More detail was acquired through specifically designed questions that relied on a set of photo-shopped pictures reflecting different levels of the design characteristics: path width, street furniture, path maintenance and volume of path users. The purpose was to establish the hierarchy of characteristics to be further explored in Stage 2 of the data collection.

- **Respondents' characteristics:** it was of particular interest to gain information on who the respondents were, especially as the sample was not selected randomly in the first place. Therefore, questions asked about the participants' gender, age group, ethnicity, address and information on disability.

The questionnaire consisted of 24 questions and included the following three sections:

1. **Rating factors important for comfort on shared-use path:** the aim of this general question was to establish the hierarchy of factors commonly associated with comfort, based on perception of the users. The question was phrased: *'For each of the factors below (i.e. space, safety, speed, path length, other users, and surroundings), please rate its importance for your comfort on a mixed use path using a scale of 1 (very important) – 6 (not important at all)'*. The scale used an adapted Likert scale (Allen and Seaman, 2007).

2. **Rating path characteristics and their importance when the respondent uses mixed-use paths:** the purpose was to investigate path characteristics to inform the design guidelines on users' preferences. The path characteristics investigated were 'path width', 'verge width', 'lighting', 'user speed', 'volume of pedestrians', 'volume of cyclists', 'street furniture', 'path

maintenance', and 'surroundings'. For each of the characteristics, the respondents were asked *'On a scale 1 (very important) – 6 (not important at all), rate how important is the following characteristic for your comfort while using a mixed-use path?'*.

3. **Rating pictures with different levels of path width, path maintenance and street furniture:** the aim was to gain understanding of the chosen characteristics in more detail and establish to what extent different levels affect the perception of comfort. However, the focus was more on the concept rather than detailed differences. While this method has not been commonly used before in similar studies, this research has identified value in such an approach. What is important is that the design guidelines rarely (or never) specify the exact level of provision, often using general terms such as 'poor path maintenance' or 'high volume of users'. Similarly, the purpose of these questions was to 'guide' rather than establish comfort thresholds. Moreover, they provided a good foundation for the design of Stage 2 of the data collection, which was based around similar ideas of presenting participants with specific characteristics at different levels but using a different visual means (video).

   In the questionnaire, participants were shown three pictures at broadly different levels for each characteristic (e.g. different widths: narrow, medium, wide), and were asked, for each picture, to *'On a scale of 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking [/ cycling] on the path pictured on the following photograph'*. The pictures were put in random order to ensure that order-of presentation bias was reduced. The same approach was then applied to vide-based questions in Stage 2 of data collection.

   Width, volume of users, path maintenance and street furniture were examined with the use of specially designed photographs, which were adjusted using Adobe Photoshop Elements (Version 13) to represent different scenarios:

   - **Width:** the pictures represented three significantly different widths: 'narrow', 'medium' and 'wide'.

   - **Volume of users**: the pictures portrayed three scenarios with different number of users: 'low', 'medium' and 'high' user flow.

   - **Path Maintenance:** the pictures represented three different levels of path maintenance on shared-use paths. One was 'well-maintained' (clean, with a consistent surface), the second one was 'fairly maintained' (concrete, uneven surface, with some grass growing through), and the third picture was 'poorly maintained' (uneven surface with holes, waste).

- **Street Furniture:** the pictures showed three levels of street furniture provision. These were 'no street furniture', 'basic presence of street furniture' and 'street clutter'.

The pictures represented very simplified situations and, therefore, cannot be regarded as completely reliable sources of detailed information. They showcase only three basic scenarios, which is not satisfactory to draw final conclusions. They were designed and utilised in this way to provide general information and guidance on characteristics associated with perceived comfort with the purpose of being analysed further in Stage 2 of data collection.

Figure 5.2 shows a group of pictures used for the path width. The pictures used were the same for cyclists and for pedestrians.

Figure 5.2. The set of photo-shopped pictures used to represent different widths: 'narrow', 'medium' and 'wide'. The respondents were shown, and asked to rate, one picture at a time.

The questionnaire was designed using Opinio software, which is a complete survey software application. It was distributed online through social media and various mailing lists to which I had access. The respondents were based in the UK.

The choice of a 6-point Likert scale for rating was intentional, with an assumption that the neutral 'neither comfortable, nor uncomfortable' option is not a valid choice for rating comfort. *'Since they have no neutral point, even-numbered Likert scales force the respondent to commit to a certain position (Brown, 2000) even if the respondent may not have a definite opinion'* (Croasmun and Ostrom, 2011, p20). Additionally, considering that this research is a background study for the further data collection which will attempt to establish a Level of Service tool, the choice was made to stick to a 1-6 scale to capture comfort levels to avoid inconsistencies between stage 1 and stage

2 of data collection. Jensen (2007) used a similar methodology by presenting video clips which were then rated from 1-6.

It is also worth pointing out that for the purpose of this survey, the term ‘mixed-use’ was used in the questions rather than ‘shared-use’. This was decided after the pilot, where some of the respondents were confused by ‘shared-use path’ terminology. However, since the term ‘shared-use’ is commonly used in academic literature and design guidelines, I have used it when describing the further analyses.

5.4 Data Collection

The participants were recruited through three routes:

- Data **Collection 1.** *Uncontrolled sample:* Initially, the link was sent out to the private mailing lists and to academic and professional contacts with the purpose of reaching out to as many potential respondents as possible.
- **Data Collection 2.** *Sustrans’ mailing list:* this mailing list was used in order to increase the number and diversity of respondents. Sustrans utilized their social media presence, including Facebook and Twitter platforms, to promote the survey among their followers.
- **Data Collection 3.** *UCL’s mailing list:* the purpose of promoting the questionnaire by sending it out through UCL’s Department of Civil, Environmental and Geomatic Engineering and Department of Epidemiology and Public Health mailing lists was to reach out to potential respondents representing younger age groups.

5.5 Analysis

The initial analysis was conducted using average scores, in order to establish the hierarchies of importance. A t-test for independent samples was performed for each factor and path characteristic to establish the significant differences between cyclists and pedestrians and males and females. Additionally, to compare the effects of the user type and the gender, an ordinal regression analysis was performed for each factor and path characteristic.

Further analysis was conducted to gain better understanding of perceptions of path characteristics. It was assumed that there may be underlying factors behind them. For example, behind ‘users’ speed’ and ‘volume of cyclists’, there may be an underlying factor concerning the risk of potential conflict.

Hence, a factor analysis was performed for cyclists and for pedestrians. The aim of the factor analysis was to reduce the correlated observed variables to a smaller set of important independent composite variables. For this study, understanding the structure of factors associated with path characteristics was the basis for informing Stage 2 of data collection. It also was chosen with the purpose of helping planners/designers: the conclusions informed which factors should be treated together or differently from others.

Factor analysis was performed against responses for questions in Section 2 using Principal Factor Axis with the direct oblimin method. Among computed factors, those with eigenvalues greater than 1 were chosen in analysis. The analysis was performed using SPSS v22. The responses for other two questionnaire sections (i.e. Section 1 or 3, see Section 5.3.2 above) were excluded from this analysis.

Once the factors were extracted, in order to understand the characteristics of users and their relation to how they evaluate the environmental characteristics, cluster analyses were performed using the factor scores for the extracted factors. Clustering is a method of detecting natural groupings in data. While this could be perceived as risking the loss of information (clustering based on extracted factors), for the purpose of this research it was regarded as a simplification. Clustering leads to classification of users and their responses to the questions. Such classification is important as it can make users visible to planners and designers. Practitioners, who often have profiles of potential users based on the location and surrounding environments of a planned path, can then link the results of this paper to such profiles. Such an approach is called factor-cluster segmentation and is often deployed in marketing (Kibicho, 2008).

The analyses were conducted for pedestrians and cyclists separately. The clustering method was between-linkage measured by chi-square distance (the type of distance metric to use between objects). For the cyclists, the number of clusters was originally set as 15 according to the factor analysis elbow method, which considers the percentage of variance, which can be explained as a function of the number of clusters (Ketchen and Shook, 1996).

Clusters which included only 5% or fewer samples of the whole cyclist sample were removed from later analyses because of the small sample size. After the removal, three clusters were identified and named as CA, CB, and CC. For the pedestrians, the number of clusters was originally set as 11 according to the Elbow method, but after removal of clusters which include only 5% or fewer samples, four clusters were extracted and named as PA, PB, PC and PD (these are further described in Section 4.6 Cluster analysis).

Finally, a paired t-test was performed for each pair of scenarios. These included average scores between Scenario A1 (Wide path) and Scenario A2 (Medium path); scores between Scenario A2 and Scenario A3 (Narrow path); average scores between Scenario B1 (Clean, well-maintained path) and B2 (Medium clean path) and between B2 and B3 (Badly maintained path); and average scores between C1 (Low volume of users) and C2 (Medium volume of users) and C2 and C3 (High volume of users). Each of these pairs were considered within each cluster. In addition, an ANOVA was performed to examine whether there was a significant difference between clusters within the same user type (i.e. cyclist or pedestrian) for each question.

5.6 Results and Discussion

5.6.1 Sample

In total, 945 respondents participated in the questionnaire, classifying themselves as a 'regular cyclist' (579, 61%) or 'regular pedestrian' (340, 36%). There were a small number of respondents (26) who were regular wheelchair or mobility scooter users, but these people were excluded from the analyses below because this paper primarily aims to understand the structure of the factors associated with the comfort of ordinary cyclists and pedestrians; the results of those wheelchair/scooter users will be analysed elsewhere. This resulted in 919 responses available for analysis. Note that 86% of respondents were of white ethnic origin, 10% represented 'other ethnic group' and 4% either preferred not to say or did not answer the question on ethnic background. Table 5.1 shows the exact composition of genders, age groups and frequency of cycling/walking by cyclists and pedestrians within the sample. All the respondents were based in the UK.

Table 5.1. The characteristics of the cyclists and pedestrians participating in the study

	Cyclists		Pedestrians		Total	
	N	%	N	%	N	%
Total	579	63%	340	37%	919	100%
Gender						
Male	411	71%	121	36%	532	58%
Female	168	29%	219	64%	387	42%
Age-group						
18-24	17	3%	82	24%	99	10%
25-34	133	23%	84	25%	217	23%
35-44	142	25%	46	14%	188	20%
45-54	141	24%	57	17%	198	21%
55-64	103	18%	55	16%	158	18%

65+	43	7%	16	5%	59	7%
Frequency of cycling / walking						
Daily or x6 pw	335	58%	280	82%	615	67%
X2-5 pw	216	37%	49	14%	265	29%
Weekly	22	4%	7	2%	29	3%
Fortnightly	5	1%	3	1%	8	1%
Monthly	1	0%	1	0%	2	0%

5.6.2 Overall (ranking most to least important)

As shown in Table 5.2, overall (regular cyclists and pedestrians combined) the mean score ranged between 1.5 and 3.1, which indicates that all factors were regarded as between ‘high’ and ‘medium’ importance. The factors of highest importance to the users were ‘safety’ and ‘space’, with mean scores of 1.5 and 1.6 respectively. The factors of lowest significance were ‘path length’ and ‘surroundings’ (both mean 3.1). Table 5.3 includes the hierarchy of path characteristics and their importance for comfort. Path width was considered to be the most important factor.

Table 5.2. Overall ranking of factors associated with comfort on mixed-use paths and average scores.

Factors associated with comfort	Ranking	Mean
Safety	1	1.5
Space	2	1.6
Other Users	3	2.5
Speed	4	2.5
Path Length	5	3.1
Surroundings	6	3.1

Table 5.3. Overall ranking of path characteristics associated with comfort on the mixed-use paths and average scores.

	Ranking of path characteristics and their importance for comfort on mixed-use paths	Mean
Path width	1	1.5
Path maintenance	2	1.8

Volume of pedestrians	3	2.1
Volume of cyclists	4	2.1
User Speed	5	2.3
Lighting	6	2.5
Street furniture	7	2.9
Verge width	8	3.1
Surroundings	9	3.3

Considering that the sample was unevenly distributed between cyclists and pedestrians and females and males, it was necessary to identify the associations between the ratings and user type and gender independently (the impact of user type on ratings and the impact of gender on ratings) and interdependently (the impact of the gender within the user type, for example female cyclists or male pedestrians). This means that the analysis looked into the relationships between the gender and user type and user attitudes (males, females, cyclists and pedestrians independently) and into the relationship between gender and user attitudes within user type (for example female cyclists or male pedestrians). Table 5.4 summarises the findings, highlighting the probability values (p-value). The significant associations are highlighted in grey.

I established that the user type of the respondent had a statistically significant effect on ratings for all of the factors and all of the path characteristics. The respondents' user type was statistically significant for 'safety', 'speed' and 'surroundings', and for all path characteristics apart from 'path width' and 'volume of pedestrians'. Gender within the user type had a statistically significant effect on scores only for 'path width'.

Table 5.4. The significant associations between factors associated with comfort and path characteristics important for comfort and user type and gender (independently and interdependently).

Factor associated with comfort	**User Type**	**Gender**	**User Type* Gender**
Space	**0.002**	0.388	0.453
Safety	**<0.001**	**<0.001**	0.118
Speed	**0.038**	**0.043**	0.331
Path Length	**<0.001**	0.099	**0.027**
Other Users	**<0.001**	0.052	0.591

Surroundings	**0.001**	**<0.001**	0.593
Path characteristics important for comfort			
Path Width	**0.001**	0.138	0.787
Verge Width	**<0.001**	**<0.001**	0.135
Lighting	**<0.001**	**<0.001**	0.605
Users Speed	**<0.001**	**<0.001**	0.411
Volume of Pedestrians	**<0.001**	0.645	0.979
Volume of Cyclists	**<0.001**	**<0.001**	0.180
Path Maintenance	**<0.001**	**0.013**	0.483
Street Furniture	**<0.001**	**0.018**	0.311
Surroundings	**<0.001**	**<0.001**	0.261

Overall, the analysis of the averages of questionnaire responses shows that the factors of most importance when using a shared-use path were ‘safety’ and ‘space’ (overall, and separately for both cyclists and pedestrians) and ‘path length’ and ‘surroundings’ were of least importance (Table 5.1 and Figure 5.2). This is crucial to understanding the dynamics of choice making using a shared-use path. The literature review has found that comfort is often considered to be ‘individual’ experience, and hence too subjective to be influenced by ‘third person’ interventions. However, my research has suggested that factors associated with comfort can be within the control of the professionals. Considering that the conflict between different users is a rare occurrence (Sustrans, 2012), safety may be a perception issue and can be engineered by street and route designs. The availability of space (both physical and personal) could be based on the path width assessed against the user traffic and be a determinant criterion in the decision-making process.

In regard to the mixed-use path design, the characteristics of most importance for comfort, based on average scores, were ‘path width’, ‘path maintenance’, ‘volume of pedestrians’ and ‘volume of cyclists’ (Table 5.2). However, there were some differences between the views of cyclists and pedestrians. While ‘path width’ was the most important for both, pedestrians put significantly more emphasis on ‘user speed’ and ‘volume of cyclists’. Cyclists, on the other hand, put more emphasis on ‘volume of pedestrians’ and ‘path maintenance’. Hence, it does appear that the presence of the other user group (cyclists in the case of pedestrians and pedestrians in the case of cyclists) can play a role in affecting the perception of comfort. This is strongly related to traffic and path capacity and would vary for every individual case.

5.6.3 Comparing responses from cyclists and pedestrians and gender differences

Figure 5.2 shows the means of the responses about factors which respondents think are important for comfort. Some significant differences were observed in the ranking of the factors by travel mode. ‘Space’, ‘path length’ and ‘other users’ were rated as more important by the cyclists and ‘safety’, ‘speed’ and ‘surroundings’ by pedestrians.

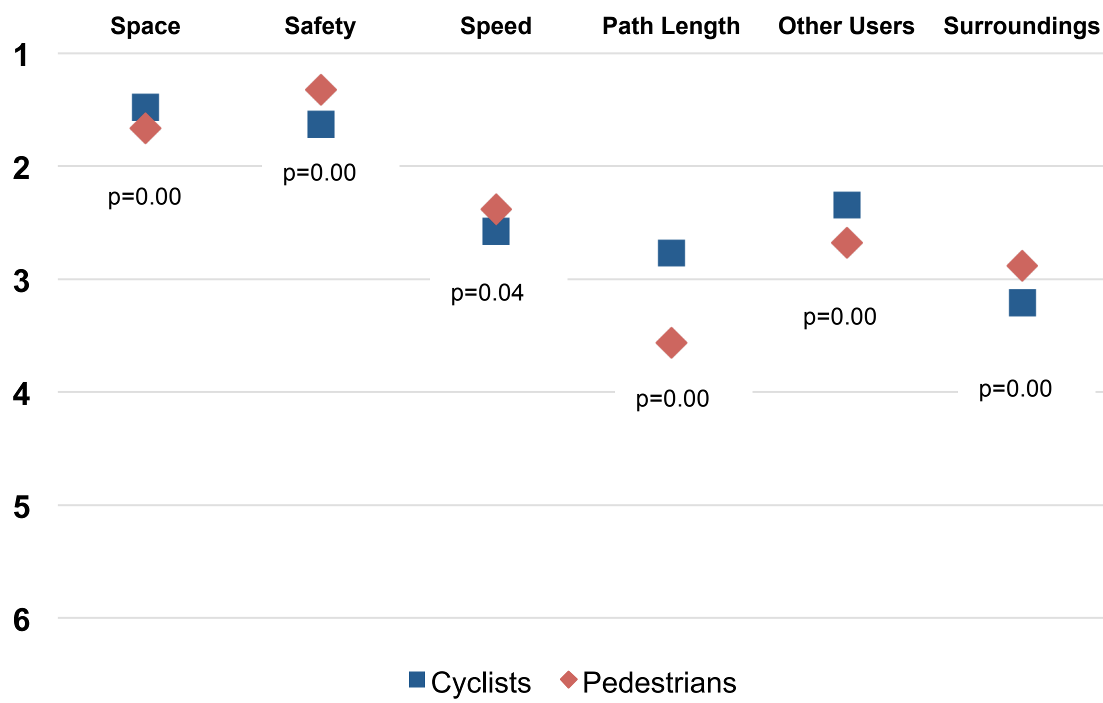


Figure 5.3. Factors which respondents think are important for comfort. The scale was from 1 (very important) to 6 (not important at all).

Figure 5.3 shows the means of the responses about path characteristics, which respondents think are important for comfort. For each factor, there was a statistically significant difference for all the factors (p=0.00) between the rankings by cyclists and pedestrians. ‘Path width’, ‘volume of pedestrians’, ‘path maintenance’ and ‘street furniture’ were scored lower (more important) by cyclists and ‘verge width’, ‘lighting’, ‘user speed’, ‘volume of cyclists’ and ‘surroundings’ by pedestrians.

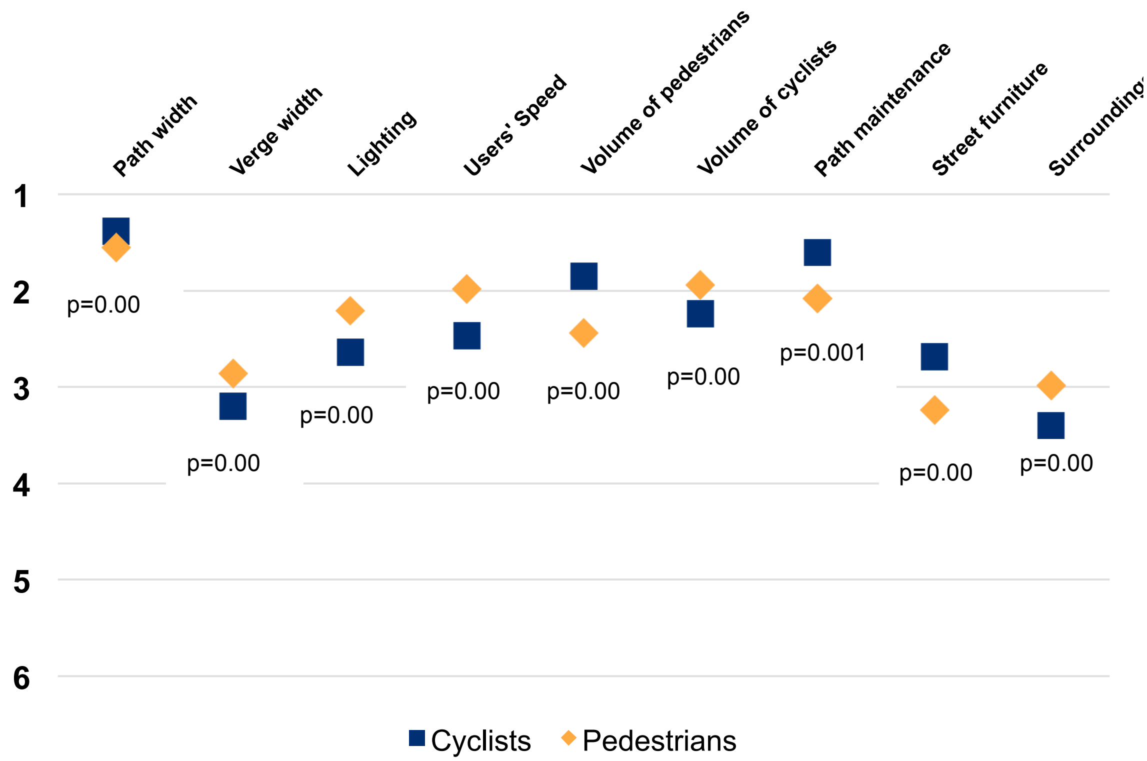


Figure 5.4. Paths characteristics which respondents think are important for comfort. Comparison between cyclists and pedestrians. The scale was from 1 (very important) to 6 (not important at all).

In general, the majority of the listed factors (apart from 'path length') were scored lower by women than men. T-tests for independent samples reveal that 'safety', 'speed' and 'surroundings' had a significant difference by gender. Table 5.5 summarises the results.

As shown in Table 5.5, the path characteristics show significantly stronger association with gender than the general factors associated with comfort do, with only 'path maintenance' and 'street furniture' with significance p>0.05. Overall, 'path width', 'verge width', 'lighting', 'user speed', 'volume of pedestrians', 'volume of cyclists' and 'surroundings' were rated as more important on average by females and 'path maintenance' and 'street furniture' by males. The differences between average scores between males and females varied between 0.64 ('lighting') and 0.53 ('verge width') and 0.03 ('volume of pedestrians') and 0.08 ('path width').

Table 5.5 Comparison of averages scores between men and women in Factors associated with comfort and Path Characteristics associated with comfort. The scale was from 1 (very important) to 6 (not important at all).

Factors associated with comfort					**Path characteristics associated with comfort on mixed-use paths**				
Factors	**Male**		**Female**	**p**	**Characteristics**	**Male**		**Female**	**p**
Space	1.57		1.52	0.38	Path width	1.48		1.40	0.14
Safety	1.62	>	1.37	**0.00**	Verge width	3.30	>	2.77	**0.00**
Speed	2.58	>	2.40	**0.04**	Lighting	2.75	>	2.11	**0.00**
Path Length	2.98		3.17	0.10	User Speed	2.44	>	2.08	**0.00**
Other Users	2.54		2.37	0.05	Volume of pedestrians	2.08		2.05	0.65
Surroundings	3.26	>	2.86	**0.00**	Volume of cyclists	2.28	>	1.93	**0.00**
					Street furniture	1.71	<	1.87	**0.02**
					Path maintenance	2.79	<	3.02	**0.01**
					Surroundings	3.40	>	3.04	**0.00**

In order to compare the effects of the user type and the gender, an ordinal regression analysis was performed for each factor and path characteristic. In each analysis, the dependent variable was each factor or path characteristic (e.g. score of the factor 'Space') while the independent variables are the user type (cyclist:1, pedestrian:0) and the gender (male:1, female:0).

Table 5.6 shows a summary of the computed coefficients and p-values. To compare the coefficients of the independent variables, one with the higher value (after they are converted to absolute numbers) is highlighted with grey. Note that a correlation analysis between the responses for the Gender and User type questions was also performed and a coefficient of 0.346 was obtained, suggesting that there is no statistically significant relationship between the variables.

Table 5.6. Correlations between Gender and User Type and Factors and Path Characteristics associated with comfort.

Factor	User Characteristic	Coefficient	Sig	Path Characteristic	User Characteristic	Coefficient	Sig
Space (Pseudo R^2: 0.017)	User type	-0.58	0.00	**Path Width** (Pseudo R^2: 0.021)	User type	-0.66	0.00
	Gender	0.26	0.07		Gender	0.31	0.04
Safety (Pseudo R^2: 0.039)	User type	0.61	0.00	**Verge Width** (Pseudo R^2: 0.037)	User type	0.26	0.04
	Gender	0.46	0.00		Gender	0.57	0.00
Speed (Pseudo R^2: 0.009)	User type	0.28	0.03	**Lighting** (Pseudo R^2: 0.074)	User type	0.38	0.00
	Gender	0.13	0.32		Gender	0.84	0.00
Path Length (Pseudo R^2: 0.057)	User type	-0.92	0.00	**Users Speed** (Pseudo R^2: 0.058)	User type	0.72	0.00
	Gender	0.08	0.52		Gender	0.40	0.00
Other Users (Pseudo R^2: 0.029)	User type	-0.64	0.00	**Volume of Pedestrians** (Pseudo R^2: 0.071)	User type	-1.12	0.00
	Gender	0.45	0.00		Gender	0.48	0.00
Surroundings (Pseudo R^2: 0.023)	User type	0.30	0.02	**Volume of Cyclists** (Pseudo R^2: 0.030)	User type	0.33	0.01
	Gender	0.38	0.00		Gender	0.46	0.00
				Path Maintenance (Pseudo R^2: 0.055)	User type	-0.95	0.00
					Gender	0.05	0.73
				Street Furniture (Pseudo R^2: 0.036)	User type	-0.66	0.00
					Gender	-0.10	0.43
				Surroundings (Pseudo R^2: 0.0028)	User type	0.46	0.00
					Gender	0.29	0.02

While generally pseudo R square values are low, which means that only a small percentage of variance is explained by the independent variables, the user type has a higher coefficient (in absolute numbers) in many cases.

To conclude, pedestrians and women tend to score the majority of factors and path characteristics lower (more important for comfort). The sample included more women in the user type category of ‘pedestrians’ with more males in ‘cyclists’ (see section 4.1). Garrard et al. (2008) suggested that women have been shown previously to have higher expectations of the path design and the quality of their experience affecting their modal and route choice, and these results correspond to this. Note that the attempt to differentiate the effects of the user type from that of the gender (in Section 4.5) did not obtain any conclusive findings due to low pseudo R square values of the models. Interestingly, the biggest difference in averages was observed for ‘lighting’, a characteristic strongly connected with safety, which proved a more important design feature to women than men. This is in line with existing research into cycling and walking infrastructure that tends to portray women as more vulnerable users, who put more emphasis on safety (Steinbach et al., 2011; Garrard, 2003; Twaddle et al., 2010; Heesch et al., 2012; Garrard et al, 2008; Dickinson et al., 2003; Clifton et al., 2005; Foster et al., 2004). There was no rating difference for volume of pedestrians or path width and the association with gender was not identified. Based on Table 5.5, ‘street furniture’ and ‘path maintenance’ seemed more important to men than women.

5.6.4 Analysing underlying factors

Table 5.7 shows the results of Factor Analysis for path characteristics for cyclists. Table 5.8 shows the results for path characteristics for pedestrians.

Table 5.7. Rotated factor loadings for shared-use path characteristics for cyclists. Highlighted are values greater than 0.4 or smaller than -0.4.

Characteristics	Factor		
	1	2	3
Path width	0.329	-0.293	-0.631
Verge width	0.463	-0.245	-0.120
Lighting	0.588	-0.317	-0.147
Users' Speed	0.319	-0.479	-0.110
Volume of pedestrians	0.177	-0.776	-0.288
Volume of cyclists	0.399	-0.812	-0.037
Path maintenance	0.483	-0.152	-0.214
Street furniture	0.337	-0.208	-0.111
Surroundings	0.442	-0.125	0.207

Table 5.8. Rotated factor loadings for shared-use path characteristics for pedestrians. Highlighted are values greater than 0.4 or smaller than -0.4.

Characteristics	Factor[a]		
	1	2	3
Path width	-.063	-.141	.400
Verge width	.085	.053	.704
Lighting	.349	.040	.236
Users' Speed	.090	-.426	.052
Volume of pedestrians	.083	-.583	.058
Volume of cyclists	-.081	-1.021	-.048
Path maintenance	.666	-.114	-.122
Street furniture	.742	.014	.086
Surroundings	.504	-.028	-.026

As a result of factor analysis for each of the two sample groups (i.e. cyclists and pedestrians), three factors were extracted. The first factor has greater factor loadings for 'surroundings', 'path maintenance', and 'lighting' than others. Thus the first factor can be considered to represent static environmental characteristics. The second factor has greater factor loadings for 'user speeds', 'volume of pedestrians', and 'volume of cyclists'. The second factor can therefore be considered to represent other users. The third factor has greater factor loadings particularly for 'path width' and 'verge width'. The third factor can be considered to represent the available space. The factor analysis was a basis for conducting further factor analysis.

For cyclists and pedestrians, three underlying factors were extracted, representing the static environmental characteristics, other users and available space (Section 4.5). These were a basis for further analysis, which categorised respondents into several clusters and analysed the profiles and tendencies of the clusters (Table 5.7, Table 5.8).

5.6.5 Cluster analysis

The clusters' shares are shown in Figures 5.5 and 5.6, while their gender, age and usage profile are shown in Figures 5.7, 5.8 and 5.9.

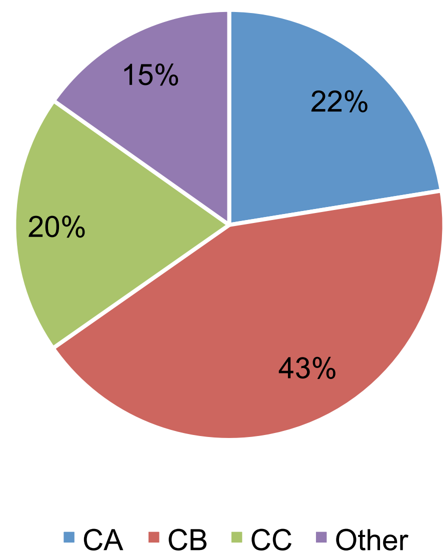


Figure 5.5. Share of each cluster by sample size. The clusters with a sample size of 3% or smaller of the total cyclist sample size were combined to Cluster Other.

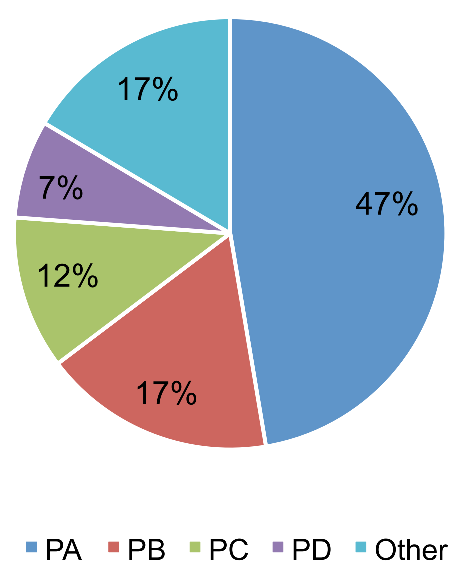


Figure 5.6. Share of each cluster by sample size. The clusters with a sample size of 3% or smaller of the total pedestrian sample size were combined to Cluster Other.

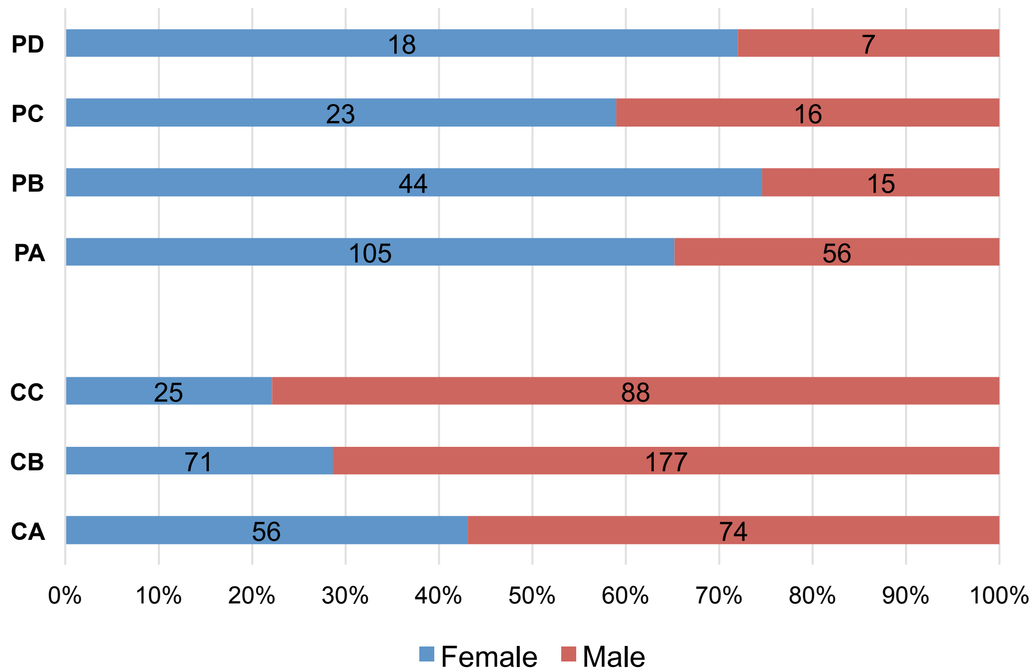


Figure 5.7. Gender composition of each cluster.

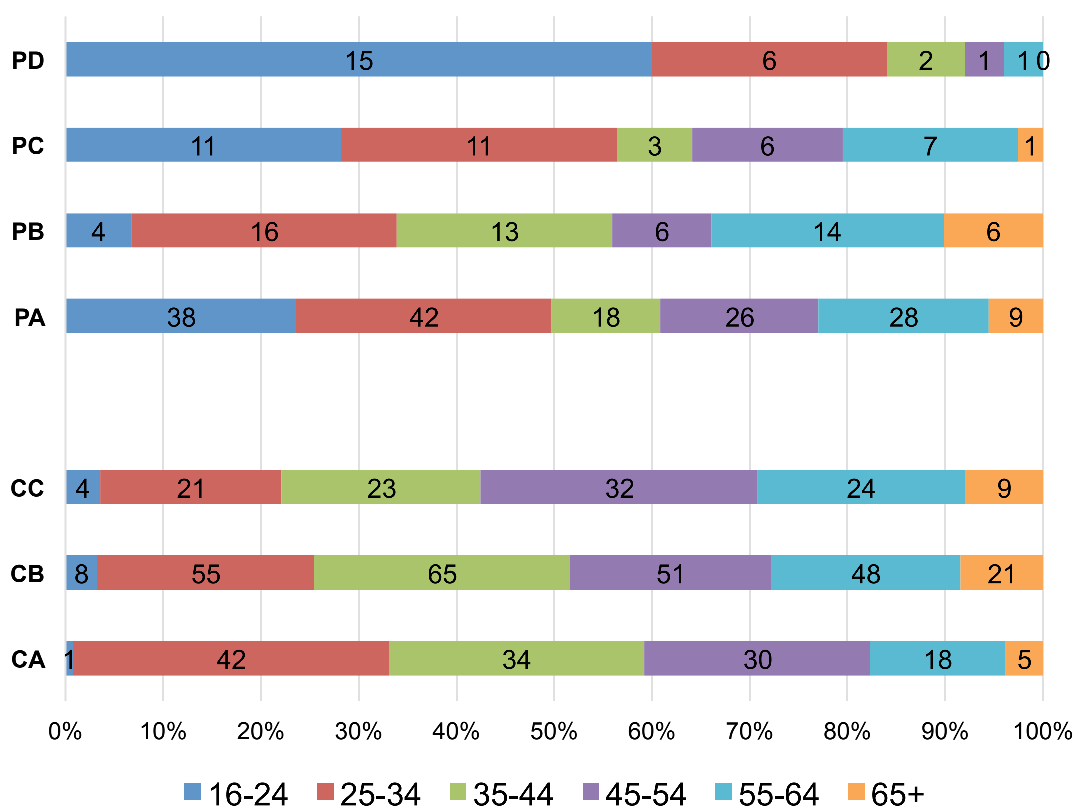


Figure 5.8. Age composition of each cluster.

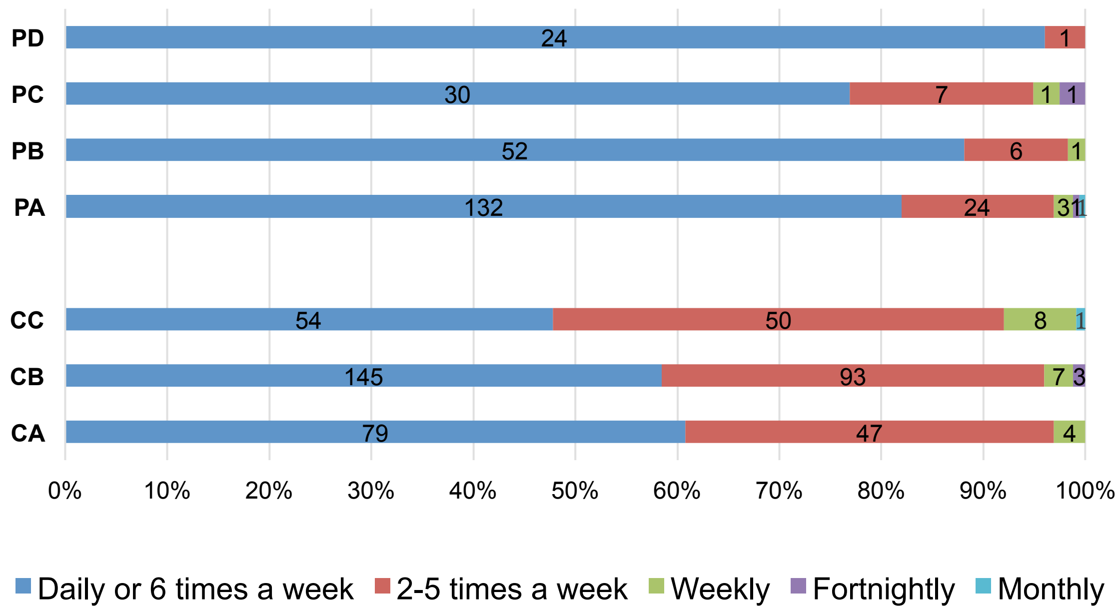


Figure 5.9. Cycling/walking frequency profile of each cluster.

The answers of the samples of each cluster to the questions about the importance of the path characteristics, namely 'path maintenance', 'volume of pedestrians', 'path width', and 'volume of cyclists' are shown in Figures 5.10, 5.11, 5.12 and 5.13. These characteristics are chosen as representatives for the factors extracted.

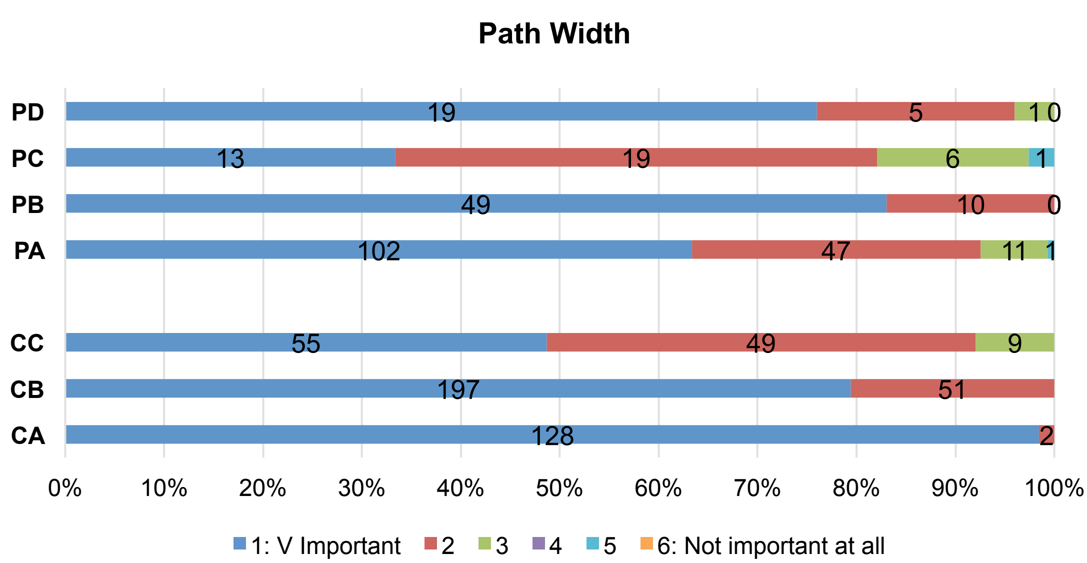


Figure 5.10 Path width score composition of each cluster.

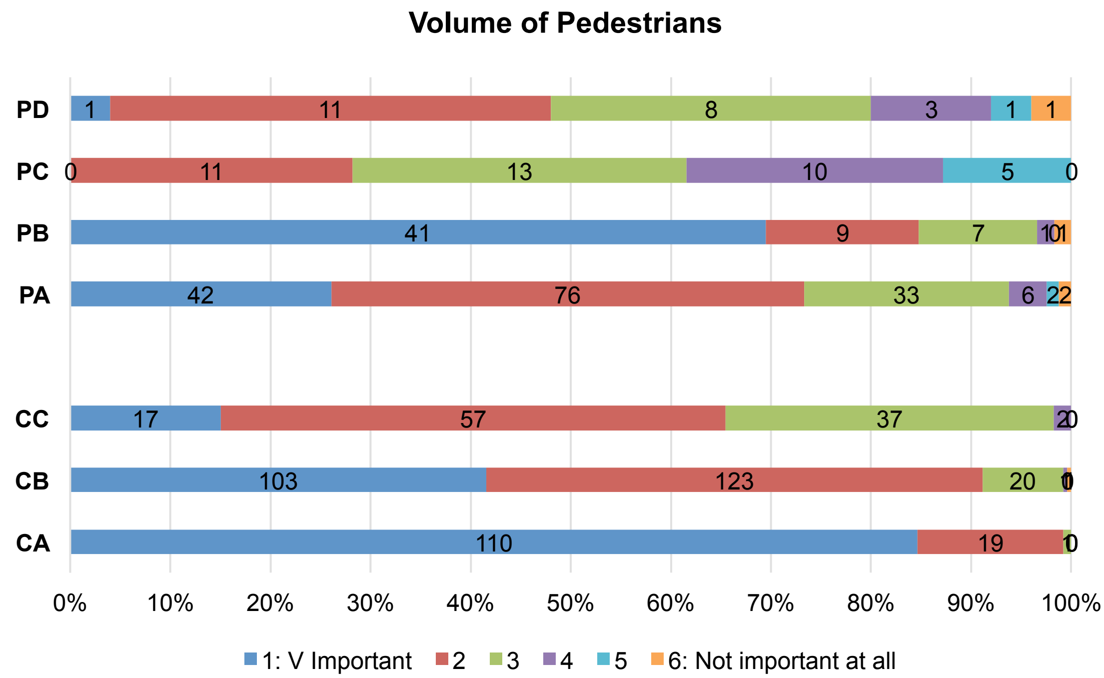


Figure 5.11 Volume of Pedestrians score composition of each cluster.

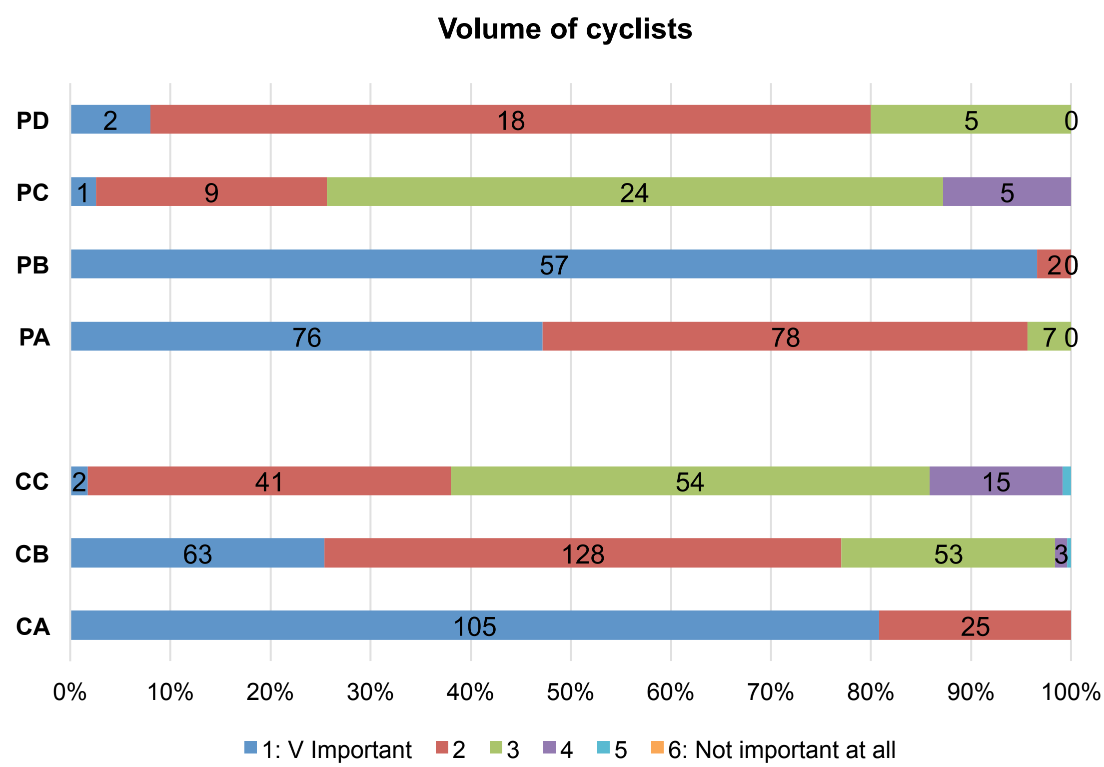


Figure 5.12 Volume of Cyclists score composition of each cluster.

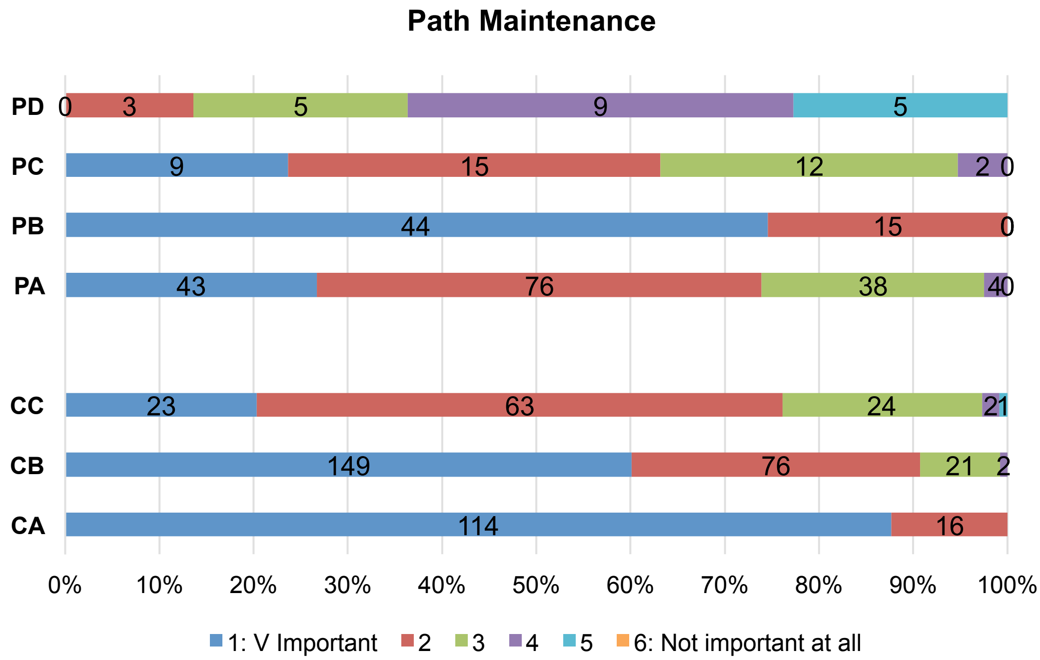


Figure 5.13 Path maintenance score composition of each cluster.

Tables 5.9 and 5.10 provide a summary of findings: the representative user characteristics of each cluster (based on Figures 5.7, 5.8 and 5.9) and its responses to the above questions about those characteristics.

Table 5.9. Summary of key representative cyclists' characteristics and their evaluation of importance of path characteristics.

Group	Share (%)	Representative user characteristics	Perceptions of importance of the environmental characteristics
CA	22	• More females and more young people.	• All the path characteristics examined are very important
CB	43	• Mainly male.	• Path width, Path maintenance are important. • Diverse response to Volume of cyclists.
CC	20	• Predominantly male. • More middle-aged and older. • Least cyclists who cycle daily or 6 times/ week.	• Path width not as important as CA or CB • Diverse responses to Path maintenance. • Volume of cyclist not so important, and is considered to be less important than Volume of pedestrians

Table 5.10. Summary of representative pedestrians' characteristics and their evaluation of importance of path characteristic.

Group	Share (%)	Representative user Characteristics	Perceptions of importance of the environmental characteristics
PA	47	• Similar to the profile of pedestrians in total (mainly female with fairly even age distribution)	• All the characteristics very important, but the percentage of respondents who chose 'very important' is lower than PB for each characteristic. • Path width received the highest number of 'very important' scores and path maintenance the lowest.
PB	17	• Highest proportion of females, lowest representation of pedestrians aged 16-24 and the highest representation aged 55-64 and 65+.	• All the characteristics very important. • Volume of cyclists rated as most important with over 95% of 'very important' scores.
PC	12	• Similar to the profile of pedestrians in total (mainly female with fairly even age distribution), but the percentage of males is the	• Path width not as important as other clusters. • Volume of cyclists had the least importance.

		highest among the clusters.	
PD	7	• High numbers of pedestrians aged between 16-24 and 25-34. • Mainly female	• Path width was the most important among the path characteristics • Path maintenance received the lowest rating.

For cyclists, for each path characteristic, the percentages of respondents who consider the characteristic to be 'very important' were in the order of CA (more females, more young people), CB (mainly male) and CC (predominantly male, middle-aged and older, least cyclists who cycle 6-7 times a week) (with the CA highest). This corresponds with the order of the averages of the scores for the picture questions. Comparison of the differences of the percentages of respondents who consider the characteristic to be very important between CA and CC for different path characteristics lead to notice that the difference for 'path width' was the largest with 'volume of cyclists' the smallest. This corresponds with the results of Figure 5.4, which shows the order of the averages of cyclists' responses regarding the importance of each path characteristics. This suggests that while the most important path characteristic (path width) has small variation in terms of respondents' view on its importance, the least important characteristics (path maintenance, and volume of cyclists) have the larger variations.

For pedestrians, the cluster with the highest representation of people aged 55-64 and 65+ (PB), had the highest number of 'very important' ratings for all three characteristics. Hence, this suggests that the older users have higher requirements to feel comfortable.

Overall, it has been found that the structure of path characteristics contributing to comfort for cyclists is simple: while path width is considered to be very important across the clusters of this mode, clusters with more male and more middle-aged or older (65+) cyclists consider other path characteristics to be less important. On the other hand, the structure for pedestrians seems complex. The cluster PB with a high proportion of females and a low representation of young adults consider all the path characteristics examined (in particular volume of cyclists) to be very important; other clusters' views on other path characteristics vary, and, perhaps more importantly, the requirements for each characteristic in order for the respondent to feel comfort can also vary.

Further research is required to deepen the understanding of how pedestrians feel comfort from environmental characteristics. It should be noted all the clusters identified (both among the cyclists and pedestrians) had a majority of respondents that cycle or walk between twice a week and daily. Hence, further research is essential to look into the perceptions of more occasional users or people who do not currently cycle or walk at all.

5.6.6 Further analysis on the user types and their views on path width, volume of users and path maintenance.

The previous section classified cyclists and pedestrians into several clusters and the characteristics of each cluster were analysed. To further examine the clusters, this section looks into how they evaluated, in terms of their comfort, different levels of path width (narrow, medium, wide), path maintenance (poorly maintained, medium, well-maintained) and volume of other users (low density, medium, crowded). Used here are respondents' answers to photo questions (see Section 3). By comparing answers between clusters, it is possible to see how sensitive the respondents are to the different levels of the aforementioned path characteristics and hence help to further understand each cluster.

Figure 5.14 shows the average scores in answers to pictures of paths with different widths by cluster. Because the questions asked to rate pictures using a Likert scale (1-very comfortable to 6-very uncomfortable), the smaller the score, the better. A statistically significant difference was found in all the cases ($p<0.05$). Cluster CC rated the photos most favourably while PB gave the worst scores.

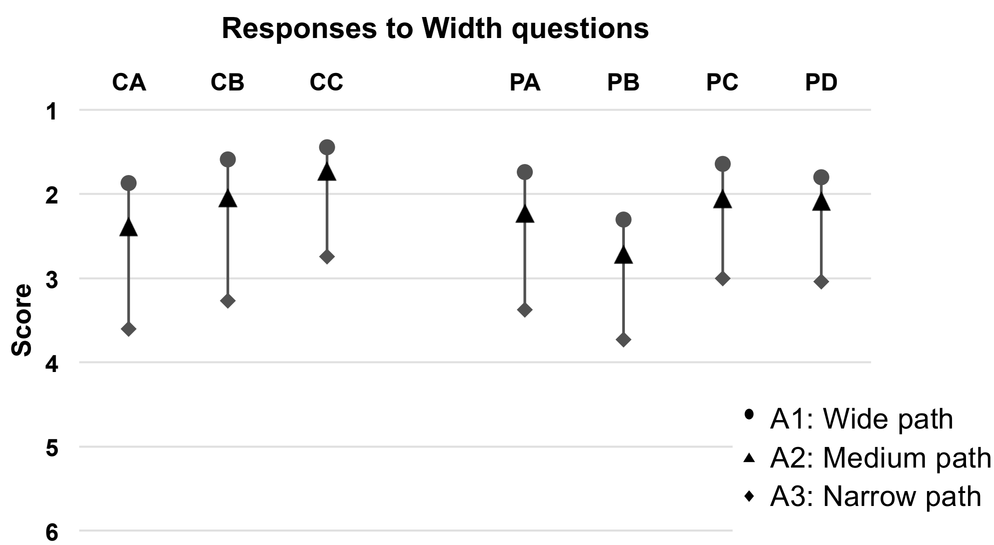


Figure 5.14. Average scores in answers to pictures of paths with different widths by cluster. The scale used was from 1: Very comfortable to 6: Very uncomfortable.

Figure 5.15 shows the average scores in answers to pictures of paths with different surface maintenance by cluster. In all the cases, a statistically significant difference was observed ($p<0.05$). A statistically significant difference was found in all the cases ($p<0.05$) except for answers between the clusters of pedestrians for Question 30. Cluster CC rated the photos most favourably while PB gave the worst scores. The way clusters answered (e.g. the averages of CA being more than CB) was similar to that for path width, although the average scores for surface maintenance were lower than for path width and the ranges (e.g. score difference between B1 and B3) were larger.

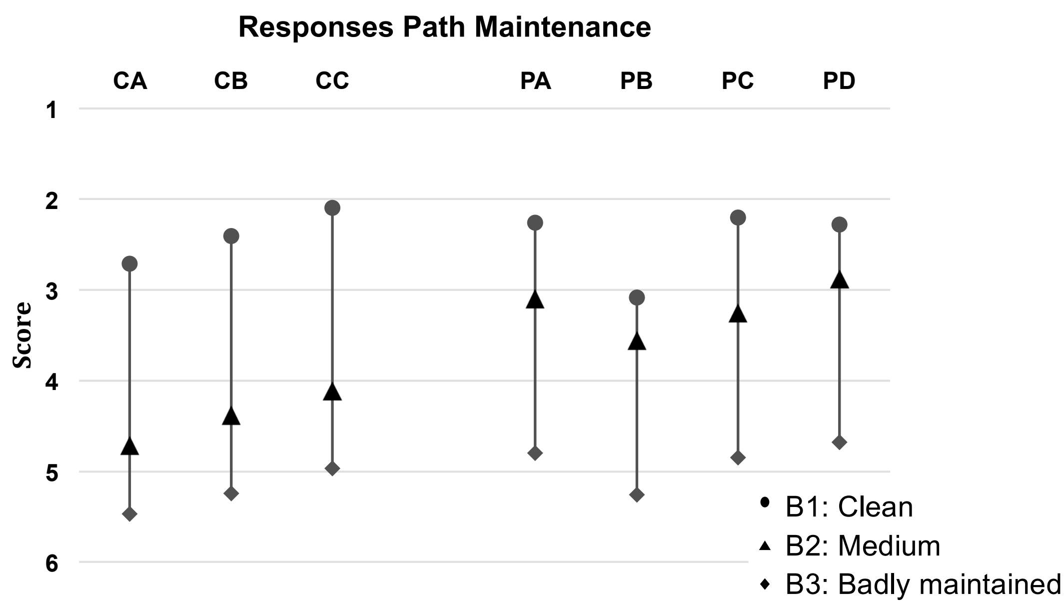


Figure 5.15. Average scores in answers to pictures of paths with different path maintenance by cluster. The scale used was from 1: Very comfortable to 6: very uncomfortable.

Figure 5.16 shows the average scores in answers to pictures of paths with different volumes of users by cluster. A statistically significant difference was found in all the cases (a<0.05) except for answers between the clusters of pedestrians for Scenario C3. It can be seen that for the same photo questions, pedestrians responded more favourably than cyclists. There was not much difference between the perceptions of the path with high and medium traffic volume. While PA and PD showed a similar tendency, PB was affected significantly more by the change between low and medium traffic. PC's range of averages between C1 and C3 was the smallest among all the pedestrian clusters.

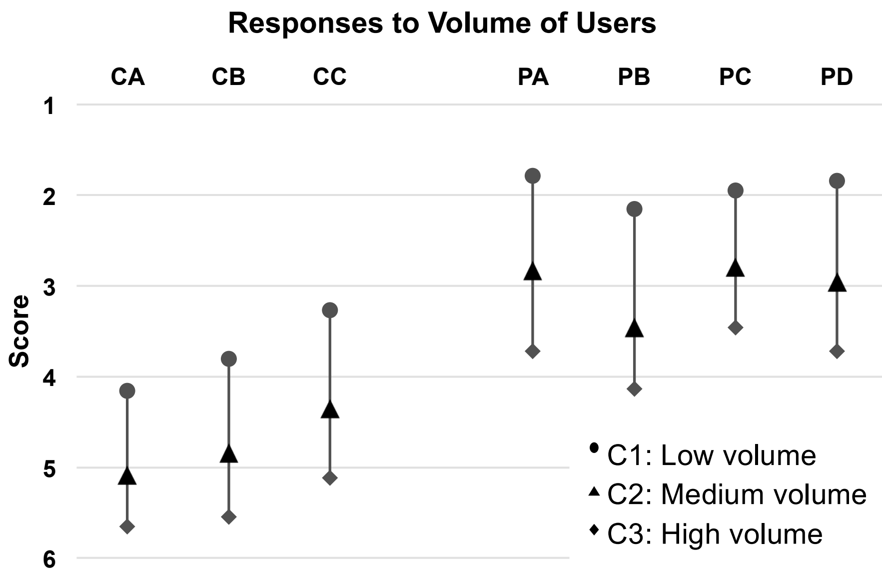


Figure 5.16. Average scores in answers to pictures of paths with different volumes of users by cluster. The scale used was from 1: Very comfortable to 6: very uncomfortable.

Overall, for the pictures showing different volumes of users (Figure 5.16), the cyclists felt less comfortable than the pedestrians. This could be due to the fact that the picture representing high volume of users showed a high number of pedestrians, which can be further linked to the previous findings that ‘volume of pedestrians’ is more important to cyclists than pedestrians.

In contrast, for ‘path width’, which is considered to be most important for comfort by both user types, there was not such a clear distinction (Figure 5.14). This suggests that to feel comfortable, cyclists and pedestrians have different requirements for the longitudinal distance from another path user in front. On the other hand, the requirements for the lateral distance from another user may be similar. This can be explained by the fact that cyclists need a longer braking distance than pedestrians. Interestingly, many existing guidelines for paths use the index of ‘density’, which takes account of both longitudinal and lateral distances. Further research can be conducted to decompose ‘density’ to further deepen our understanding of its contribution to user comfort.

For ‘path maintenance’ (Figure 5.15), comfort ratings were similar for clusters of cyclists and pedestrians. However, a difference was observed in the way the differences between scores were distributed: for cyclists, the biggest drop in comfort level was noticeable between ‘well-maintained’ and ‘fairly-maintained’ scenario. For pedestrians, on the other hand, it occurred between ‘fairly-maintained’ and ‘poorly-maintained’ scenarios.

5.7 Conclusions and Research Implications

Chapter 5 concluded that cyclists and pedestrians differ in their perception of comfort on unsegregated shared-use paths. 'Space', 'path length' and 'other users' were rated as more important by the cyclists and 'safety', 'speed' and 'surroundings' by pedestrians. 'Path width', 'volume of pedestrians', 'path maintenance' and 'street furniture' were scored lower (more important) by cyclists and 'verge width', 'lighting', 'user speed', 'volume of cyclists' and 'surroundings' by pedestrians.

Demographic factors (age, gender) affected how important pedestrians considered various path characteristics. Women over 25 years old were especially affected by the volume of cyclists, hence when a facility is especially popular among cyclists, segregation might be a preferable solution.

It has been found that the structure of path characteristics contributing to comfort for cyclists is simple, while the structure for pedestrians seems complex. Hence, further research is required to deepen the understanding of how pedestrians feel comfort from environmental characteristics. Further research is also needed to look into the perceptions of more occasional users or people who do not currently cycle or walk at all.

In the context of design guidelines, this research brings a more in-depth understanding of views represented by different user groups. Considering that the previous focus was primarily on the preferences of cyclists and the needs of different users were considered separately, this is a crucial step to making integration a more successful option. The Department for Transport 'Shared-use routes for pedestrians and cyclists' guidance report (DfT, 2012a) gives very limited guidelines regarding unsegregated shared-use paths. The questionnaire has identified the path characteristics of highest importance for users and should be followed up by further investigation into each of them, in order to deliver comprehensive guidelines, letting professionals make more informed choices and, hopefully, leading to making unsegregated shared-use space a more viable option and a good way of promoting active travel in the UK.

The results of the cluster analysis provide a more consistent understanding of the needs of users with particular characteristics. This knowledge is particularly important for the process of planning and designing new routes. Each cyclist-pedestrian shared path scheme designer may know the expected profile of its potential users, for example, through the analysis of surrounding services. Hence, knowing the preferences of different users and their weight for comfort, depending on age, gender and mode of transport, will allow the professionals to adjust designs to suit the expected users. The further analysis (Section 5.6.6) of path width, volume of traffic and path maintenance provides a quantitative way of measuring how different interventions can benefit the comfort of specific user groups, which can be applied to both existing and new routes.

For example, based on this study, it appears that the paths used by a higher proportion of females and young people who cycle (e.g. located next to schools) should put more emphasis on every single characteristic (path width, path maintenance and volume of cyclists). In contrast, routes which are used predominantly by male cyclists with a higher proportion of middle-aged and elderly people might not require as much emphasis put on the facilities, considering that compared with other clusters they do not put as much significance on path width, have a variety of views on path maintenance, and consider volume of cyclists to be less important. For pedestrians, the most prominent preferences were identified, suggesting that the cluster with highest representation of females over 25 years old are especially affected by the volume of cyclists, hence the design of the routes used by people matching that user profile should ensure that is taken into consideration: in some cases, when the facility is especially popular among cyclists, segregation might be a preferable solution.

The findings of this research have the potential to improve practical aspects of shared-use path design and implementation and make them a more viable option in cities with limited road space. The existing studies tend to focus on the differences between different users defining them by each individual characteristic separately, e.g. looking into differences between genders or age groups. Yet, in practice, the users cannot be classified in such one-dimensional way: depending on the land use in the neighbourhood, cyclists and pedestrians need to be classified through a variety of socio-demographic characteristics. Hence, user-profiling looking into gender, age and cycling/walking frequency has been conducted in this study.

The findings of Chapter 5 created a basis for the design and analysis of Stage 2 of the data collection, which is summarised in Chapter 6. ‘Path width’ and ‘volume of users’ (with the distinction for volume of cyclists and pedestrians) were chosen for further exploration due to their importance to users and quantifiable nature.

CHAPTER 6. DEVELOPING LEVEL OF SERVICE TOOL FOR UNSEGREGATED SHARED-USE PATHS

6.0 Chapter Composition

This chapter focuses on Stage 2 of the data collection: the research method, its design, and execution, process of collecting data, analysis and results.

Section 6.1 describes the aims and objectives of the study. **Section 6.2** highlights the path characteristics of interest: path width, volume of users and the direction of flow. **Section 6.3** rationalizes the choice of survey as research method and points out the advantages and disadvantages of relying on video technique. This is followed by **Section 6.4**, which is committed to describing the process of scenario design. It includes a detailed explanation of how individual scenarios were designed in the context of user flow direction and passer-by user type. It also explains the process of calculating the volume of users and proportions of cyclists for the recordings of scenarios focused on volumes of users. **Section 6.5** focuses on the practical aspects of video recordings, such as the equipment used, editing of the footage and detailed description of what happened on site on the day of recording.

The survey questions are quoted and described in **Section 6.6**. This is followed by the description of the pilot study in **Section 6.7**, which was run to ensure that that survey design and process was clear. **Section 6.8** describes the process of survey distribution and **Section 6.9** focuses on ways of analysing the collected data and the development of Level of Service Tool, followed by discussion, conclusions and implications summarized in **Section 6.10.**

6.1 Aim and Objectives

The purpose of Stage 2 of Data Collection was to explore further the shared-use paths characteristics that were identified by the participants in the Stage 1 of Data Collection as the most important to their comfort. The focus was on path width and volume of users. The analysis was conducted to investigate how the variables (path width, total volume of users) and sub-variables (volume of cyclists, volume of pedestrians, direction of traffic flow, user type of the passer-by) affected the level of service comfort scores.

The objective of the research was to investigate what range of widths are regarded as most comfortable; what range of widths are seen as comfortable/acceptable; and what range of widths are regarded as uncomfortable (to the extent the users would still use the path, and at what point they would stop using the path). It also aimed to establish the levels of users' volume (total number of users within a set area) and classify them in relation to users' comfort in order to find out what is the maximum user density (at a specific path width) before different user groups reach the point when they are no longer comfortable using the facility.

The data collected allowed me to establish how different path widths and volumes of users affect the perception of comfort among cyclists and pedestrians; and what users' comfort/discomfort threshold is for using unsegregated shared-use paths. It was then a basis for creating a framework for developing the innovative Level of Service tool. Further analysis was conducted in order to gain a better understanding into perception differences by gender and age.

6.2 Path Characteristics

The second stage of data collection focused on unsegregated shared-use paths, as an uninterrupted-flow facility, meaning that there are no fixed elements of path design that are external to the traffic stream and might interrupt the traffic flow. This resulted in traffic flow conditions being affected purely by interactions among the users and between users and geometric and environmental characteristics of the path. Hence this was not a realistic scenario for an entire path: attention was paid to short segments.

The Stage 1 study identified three elements of highest importance to comfort on unsegregated shared-use paths: path width, volume of users and environmental characteristics. The environmental characteristics were not considered as an index in Stage 2 study because quantifying environmental characteristics is less straightforward: in this case, it was decided that the amount of detail on path maintenance and street furniture obtained in the Stage 1 of Data Collection and their importance to users (by age, gender and user-type) was sufficient to help transport professionals assess their impact and make more informed decisions. Also, when it comes to delivery of unsegregated shared-use paths, the environmental characteristics might be in the hands of other professionals (for example a Public Realm team). Hence, further investigation into their impact might have been less applicable.

Thus, the two path characteristics of focus in the Stage 2 study were path width and volume of users, as identified by Stage 1 of data collection, the literature review, and discussions with professionals.

6.2.1 Path Width

In the urban environment, the space available is often limited by the existing built environment or planned future developments: in most cases, flexibility in terms of the effective path width is very restricted. Therefore, the approach towards cycling and walking infrastructure needs to be efficient, meaning that in the limited space available, users' comfort needs to be maximized by ensuring the facilities are of high quality and as user-friendly as possible. In order to deliver the facilities 'efficiently' (to achieve the maximum productivity with minimum waste of resources), more in-depth knowledge into user perceptions is necessary. This is to ensure that 'efficiency' does not lead to people refusing to use the facilities.

In fact, in some cases, introducing an unsegregated shared-use path for pedestrians and cyclists might be a better solution than segregation, which in a restricted environment can mean two narrow, uncomfortable paths (one for cyclists, one for pedestrians). Furthermore, unsegregated shared-use paths can be an attractive solution for urban spaces to be enjoyed by a mixture (for example by families, where different members want to walk or cycle) and by those disabled people who use cycles as mobility aids.

Hence, for the unsegregated shared-use to become a 'potentially' feasible option, considered more often by transport professionals, it is essential to gain a better understanding of how differences in path width can affect user comfort and the decision to use an unsegregated shared-use path.

The existing Department for Transport guideline claims that '*a width of 3 metres should generally be regarded as the preferred minimum on an unsegregated route, although in areas with few cyclists or pedestrians a narrower route might suffice. Where a significant amount of two-way cycling is expected, additional width could be required. However, the need here for additional width is not clear cut, because the absence of segregation gives cyclists greater freedom to pass other cyclists. It might therefore depend on user flow*s' (DfT Shared Use Routes for Pedestrians and Cyclists, 2012a, p41).

However, the guideline does not provide the information behind the suggested effective width of 3m and does not consider how the change of width might affect users' perceptions. The document, '*Local Transport Note 1/12 Shared Use Routes for Pedestrians and Cyclists*' (Department for Transport, 2012a) gives no reference to the source of this recommendation. This increases the risk that, where implemented, shared-use might not work in an urban context, leading to general negativity among both the public and transport professionals.

Other documents that provide guidelines on shared-use paths (see Table 2.2) tend to suggest path widths only for segregated shared-use paths.

6.2.2 Volume of Users

When delivering facilities, full control is possible neither over how many users will use it nor the proportion of different user groups. Furthermore, there is a high likelihood that the volume of users in general or from particular user groups will fluctuate over time. This can be caused by a new development, new destination, new facilities (for example cycle parking), and/or cultural norms, etc. Additionally, time and day of the journey can have an impact: volumes of users can vary cyclically during the day (commuter rush hour, school hour) or during the week by different demographic groups cycling or walking for travel or leisure (for example on weekends). However, transport professionals (especially at the local level) have an ability to predict demand based on current usage. There are also models available (based on past case studies) to establish how certain amounts and types of investment increase levels of walking and cycling and ways of mapping cycling potential of different neighbourhoods. However, professionals need to remain aware that cycling and walking levels can fluctuate: for example, through modal shift as people who used to walk can switch to cycling and the other way around.

There are a number of documents that provide advice on user flows (DfT Local Transport Note '*Shared Use by Cyclists and Pedestrians'*, Countryside Agency '*Greenways Handbook*', CROW Design Manual for cyclists, Countryside Agency '*How People Interact on Off Road Routes Phase I and Phase II'* research, Federal Highway Administration USA), however they remain inconsistent. Furthermore, they either focus on one user group (cyclists or pedestrians), a non-urban context or are sourced from outside the UK. Figure 6.1 shows the list of the documents, including the flows they suggest, and comments included by the Department for Transport (2012a). As can be seen, suggested user flows per hour vary, with Department for Transport, Countryside Agency and Federal Highway Administration considering cyclists and pedestrians together and CROW looking at pedestrian flow rates separately.

Table 6.1. Various sources on advice on user flows (Department for Transport, 2012a, p45)

Source document*	Suggested flows	Comments
DfT – Local Transport Note 2/86 *Shared Use by Cyclists and Pedestrians*.	Combined peak flows of 180 cyclists and pedestrians per hour per metre width for routes with a 500 mm clearance margin to the carriageway	This figure was derived from surveys of routes with level surface segregation.
Countryside Agency – *Greenways Handbook*	200 users per hour	No indication of route width given.
CROW Design Manual for cyclists (Netherlands)	25 pedestrians per hour per metre width on traffic-free paths away from town centres.	
Countryside Agency – *How People Interact on Off Road Routes*, Phase I and II research	At least 100 users per hour on 3 m path	Actual and perceived conflict was found to be low at these flow levels.
Federal Highway Administration (USA)	150 users per hour on 3 m path	Level of Service C, taken from look-up table, assuming average modal split.

(*See References section for details.)

While these documents consider user flow in general, the volume of cyclists and the volume of pedestrians using the path would affect the comfort of different users in different ways. Research looking into a similar area was successfully conducted in the past: Jensen (2007) established that bicycle volume and speed significantly affect pedestrians' satisfaction levels on unsegregated shared-use paths. The volume of pedestrians was also identified as a factor: while Kaparias et al. (2012) stated that a higher volume of pedestrians in shared space can increase pedestrians' comfort, Kang and Fricker (2014) argued that, it is more applicable in a vehicle-pedestrian context, and is not necessarily the case in bicycle-pedestrian sharing. Therefore, for the purpose of my research, cyclists and pedestrians were also investigated separately.

It is essential to point out that path width and volume of users are often co-dependent on each other, and, in practical terms, should not be considered individually when designing the unsegregated shared-use paths. This is why, each of the documents in Table 6.1, apart from Greenways Handbook (which was pointed out in Table 6.1 comment section), put the information on user flows in the context of path width. However, the path widths suggested differ.

The tool/guideline I developed at the end attempted to combine the findings on path width and traffic volume.

6.2.3 The Direction of Traffic Flow

There has been no previous research done to establish whether the perceptions of comfort of unsegregated shared-use depends purely on the volume of users or whether the direction of the traffic flow has an impact as well. The majority of unsegregated shared-use paths will be designed as two-way facilities: hence, it is important to find out whether the fact that multiple people are travelling in the same or opposite direction as the perceiving user affects their perception of comfort.

6.3 Research Method

I chose an online survey as my research method. The questionnaire was web-based and designed to be self-completed by the respondents. The choice of quantitative research methodology was driven by the desire to obtain many responses (more than 200). The fact that the data collection method was used successfully during Stage 1 study was another factor that contributed to utilizing it again.

The survey was created with the intention to give the participants a walking or cycling experience as similar to reality as possible. Unfortunately, a real-situation perception technique was not a possibility due to practical constraints. These included:

- Limited funding to transport participants and equipment to multiple sites on one day/ multiple days.
- Limited funding to pay the participants for their attendance (real-life scenarios in different locations would demand significantly more time to complete the recordings)
- Lack of real-life case studies to showcase the range of widths and volume of users of interest.
- Lack of real-life case studies, where the only differing variable would be a path width or the volume of users (for example using a shared use-path in Hyde Park and Finsbury Park can be a completely different experience, due to lighting, presence of trees, reputation of the area etc.).
- Lack of ability to close off the shared-use paths from the public (which would disrupt the recording).

Therefore, a video technique was chosen as '*a way of 'feeling there'* when [participants] '*can't be there'* and '*a way of apprehending fleeting moments of mobile experience*' (Spinney, 2011, Abstract).

Referring to academic literature, the main benefits of relying on video-recorded scenarios include the fact that: the participants will not be exposed to any risks, as they did not have to walk or ride (Harkey et al., 1998); the variety of conditions (in this case different path widths and volumes of users) that participants can be exposed to is much greater than they would experience on site (Harkey et al., 1998); the number and diversity of case studies that respondents will rate will be higher (Jensen, 2007); and the video camera can record and allow the researcher to edit and enhance significantly more detail (Simpson, 2011). Furthermore, Stage 2 data collection is more cost-effective than if participants visited individual sites (Jensen, 2007).

The main drawbacks are that the participants will be rating an artificially designed experience. The video might fail to capture some aspects of practice (Simpson, 2011), such as sound. Kang et al. (2013) made a similar observation and stated that for participants, being physically present in the pedestrian stream might provide an experience which would affect the LOS ratings, an experience that cannot be replicated through video (Kang et al., 2013).

Table 6.2 shows a breakdown of more advantages and disadvantages identified by the researcher for the use of artificially designed video footage chosen for Stage 2 of Data Collection.

Table 6.2. Advantages and disadvantages of using artificially designed video footage.

Advantages	**Disadvantages**
● Stage 2 design allowed the researcher to present the chosen variables in a controlled	● Filming artificially designed scenarios can be a challenging process (ensuring that

environment. ● Stage 2 was designed in a way that incorporated a record of individual observations as well as a group discussion. ● Showing exactly the same footage to a number of participants allows collection of perceptions of identical reality in identical circumstances, which would not be possible if feedback were collected on site. ● The study is simple enough to be replicated in multiple countries. ● Relying on artificially designed scenarios filmed in an isolated location also reduced the risk of capturing passers-by, which could have required obtaining a consent form from anybody appearing on camera or obscuring faces of people who did not grant permission. This would be on the basis of the European Convention on Human Rights and the Human Rights Act 1998 in regard to the right of privacy and the Data Protection Act 1998, updated by the General Data Protection Regulations that came into effect in 2018.	necessary variables remain constant, choice of location, etc.) ● The process of planning and recruiting the participants can be a challenge. ● The role of the researcher was to manage the organizational side of recording and ensure that the research standards were kept. ● People with visual impairment might not have been able to participate as respondents.

The use of video in transport research has been broadly discussed. Spinney (2015) made a case for broadening out the palette of methods used to study mobility and suggested the use of video. Video is regarded as a means to *‘keep as much of the context of practice as possible’* (Spinney, 2009, p827).

Research that previously successfully used video clips as a part of their data collection was conducted by Kang and Fricker (2014). They relied on 60s long footage recorded in Chinese cities (which provided a good example of unsegregated shared-use in an urban context). These types of video clips have the benefit of reflecting reality. However, simultaneously, during a 60s footage, the circumstances on the path (type of users, speed, surroundings, etc) can change multiple times. Considering that the scenario reflected is not repeatable, it is difficult to draw universal conclusions. Hence, for this study, I chose a different approach: I decided to record artificially designed scenarios (see Section 6.4) and include short (3-5s) videos in an online survey. Relying on videos was not an attempt to show objective reality: in the case of this survey, the intention was to bring the focus onto very specific path and user characteristics.

Moreover, as pointed out by Jensen (2007), Harkey et al.'s attempt to validate a video-based methodology was successful and the technique is regarded as valid for '*obtaining realistic perspectives of bicyclists'* (p43). However, he emphasized that this applied only to stationary respondents, rather than bicyclists while cycling. Jensen successfully relied on video-based methodology while developing pedestrian and cyclist Level of Service on roadway segments in Denmark.

Hence, in summary, the survey aimed to collect the perspectives of a variety of participants based on arranging regulated screenings of video footage that captured numerous shared-use path video segments in arranged scenarios showing a variety of real-life situations. The respondents were then asked to rate their comfort. Such comfort rating of hypothetical scenarios has been used by academics previously (Geller, 2006). In that study, the focus was on different types of facilities with a brief description.

However, as with most data collection methods, there are some risks associated. Jensen (2007) pointed out multiple risks associated with collecting data using the surveys, which could have resulted in obtaining biased responses. These included: '*respondent fatigue'* and '*policy response bias'*. Considering that the Stage 2 of data collection survey was designed to be significantly longer and more repetitive than the Stage 1 data collection survey, those risks became more prominent. The survey also looked in more depth into unsegregated shared-use and included videos reflecting controlled, real-life experiences. Lack of segregation is a controversial issue in the UK, with strong opposition from a proportion of cyclists and pedestrians: hence, there was a risk of strong response bias, due to preconceptions.

In order to minimize the effect of respondent fatigue, the decision was made to distribute the survey online (rather than for example organise a focus group). That way, the respondent had full control of the time and their surroundings when completing the survey. While the policy response bias could not have been avoided completely, collecting responses from participants recruited through a diversity of sources (mailing lists, social media, personal and professional contacts, leafleting) reduced the risk.

6.4 Survey Design

6.4.1 Scenario Design

Each of the scenarios was recorded from the perspective of a pedestrian and a cyclist. In order to avoid repeating the information, the scenarios are coded with letters (instead of numbers that were used for the recordings, even numbers for cyclists and odd numbers for pedestrians).

For the path widths, in order to establish the potential minimum effective width to be investigated further it was essential to look into the width that is taken by the users. The wheelchair measurement standard is a width of 0.76m: therefore, the minimum effective width required would equal two wheelchairs being able to pass each other. Hence, the starting point for the examination of path width was 2m effective width. The other effective widths I selected to be examined were 2.5m, 3m, 3.5m, 4m, 4.5m, 5m, 5.5m and 6m. The difference of 0.5m between them was wide enough to be noticeable by the survey participants, but also allowed me to examine a big range of widths.

For the volume of users, due to the spatial limitations of the recording location, the artificial path was designed with an area of interest measuring 13.5m^2 (see Figure 6.1). This defined the number of cyclists and pedestrians.

Table 6.3 provides a summary of all the scenarios recorded. It lists the path width, total number of users present on the path (apart from the person recording), the user types and the flow direction.

Table 6.3. Video footage scenarios.

SCENARIO	PATH WIDTH	NUMBER OF USERS*	NUMBER OF PEDESTRIANS*	NUMBER OF CYCLISTS*	NUMBER OF WHEELCHAIR USERS*	DIRECTION
Scenario AW	2m	1	1	0	0	Front
Scenario BW	2m	1	0	1	0	Front
Scenario CW	2m	1	0	0	1	Front
Scenario DW	2.5m	1	1	0	0	Front
Scenario EW	2.5m	1	0	1	0	Front
Scenario FW	2.5m	1	0	0	1	Front

Scenario GW	3m	1	1	0	0	Front
Scenario HW	3m	1	0	1	0	Front
Scenario IW	3m	1	0	0	1	Front
Scenario JW	3.5m	1	1	0	0	Front
Scenario KW	3.5m	1	0	1	0	Front
Scenario LW	3.5m	1	0	0	1	Front
Scenario MW	4m	1	1	0	0	Front
Scenario NW	4m	1	0	1	0	Front
Scenario OW	4m	1	0	0	1	Front
Scenario PW	4.5m	1	1	0	0	Front
Scenario RW	4.5m	1	0	1	0	Front
Scenario SW	4.5m	1	0	0	1	Front
Scenario TW	5m	1	1	0	0	Front
Scenario UW	5m	1	0	1	0	Front
Scenario VW	5m	1	0	0	1	Front
Scenario WW	5.5m	1	1	0	0	Front
Scenario XW	5.5m	1	0	1	0	Front
Scenario YW	5.5m	1	0	0	1	Front
Scenario AV	3m	31	28	3	0	Front, Front-Back
Scenario BV	3m	23	17	6	0	Front, Front-Back
Scenario CV	3m	23	19	4	0	Front, Front-Back
Scenario DV	3m	23	21	2	0	Front, Front-Back
Scenario EV	3m	16	12	4	0	Front, Front-Back
Scenario FV	3m	16	13	3	0	Front, Front-Back
Scenario GV	3m	15	14	1	0	Front, Front-Back
Scenario HV	3m	8	7	1	0	Front, Front-Back
Scenario IV	3m	8	6	2	0	Front, Front-Back
Scenario JV	3m	7	6	1	0	Front, Front-Back
Scenario KV	3m	4	2	2	0	Front, Front-Back
Scenario LV	3m	4	3	1	0	Front, Front-Back

Scenario MV	3m	3	2	1	0	Front, Front-Back
Scenario NV	3m	10	2	8	0	Front, Front-Back

* The person recording is not included in the count.

Direction (Front/Front-Back)

Each of the Scenarios was recorded twice: during each recording, the total number of users and each user type (number of pedestrians, number of cyclists) remained constant. However, each time, the direction of users was different: in the first set of footage the participants were moving towards the scenario leader (the person recording). In the second set, half of the participants were moving with (in the same direction as) the scenario leader and the other half of participants were moving towards the scenario leader.

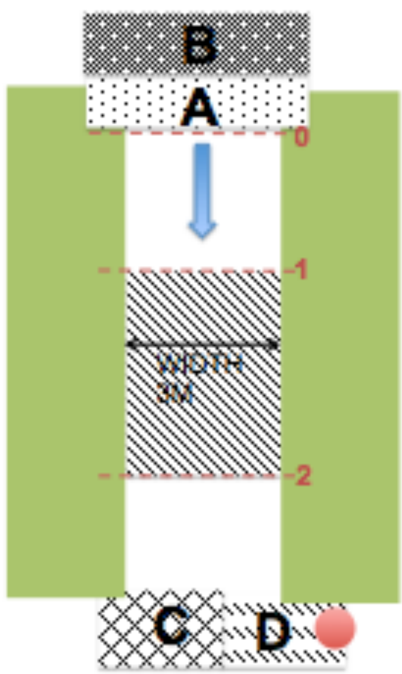


Figure 6.1. Site set-up for scenario recordings.

Looking at Figure 6.1, what it meant was that during the 'Front' recording all participants would be based in Zones A and B. After the signal, they would start moving towards the scenario leader (who was recording the footage), facing her and consequently passing her by.

During the 'Front-Back' recording, the participants were distributed between Zones A, B, C and D. After the signal, half of them (in Zones A and B), were asked to start moving towards the scenario leader. The other half, (in Zones C and D) would start moving in front of the exercise leader in the same direction as her: the scenario leader could see their backs.

User Type (Pedestrian, Cyclist, Wheelchair User)

Each of the scenarios (same width) was recorded three times: the scenario leader was passed by a pedestrian, a cyclist and a wheelchair user. This was done to establish whether the type of user passing by affected the perception of comfort of the respondents and to what extent (e.g. whether pedestrians feel more comfortable passing another pedestrian or wheelchair, but less comfortable passing by a cyclist).

Calculating the volume of users and proportion of cyclists

For the purpose of the recording (considering the limited available space on site and the aspiration to reduce the length of videos as much as possible), the decision was made to create a focus area. The idea of a designated area was thought also to assist with providing instructions for the participants during the recording and ensure better control over their distribution: to make the group of participants more manageable and to facilitate the communication.

The dimensions of the focus area were 3m x 4.5m. The width of 3m was chosen based on the most recent guideline for unsegregated shared use paths, suggesting 3m as a minimum recommended width (DfT, 2012a). The length of 4.5m was chosen as a path length that was walkable (without taking too long) and cyclable (without taking too little time). This short distance minimized the differences between the footage length for the survey designed for pedestrians and cyclists. The total size of area of interest was calculated and equalled 13.5m^2 (4.5m x 3m).

The number of individual users (cyclists and pedestrians) for each recording was established relying on an area taken by them in a static state, however with consideration of operational width for a bicycle. This was done with the purpose of simplifying the procedure: adjustments were made on site during the day of the recording. The following dimensions were chosen:

- A simplified body ellipse of 0.50 m x 0.60 m, with total area of 0.30 m^2 is used as the basic space for a single pedestrian (Highway Capacity Manual, 2000)

- The average cyclist area occupancy (in stationary conditions) was calculated as 1.35m^2. This was concluded relying on the bicycle length of 1.8m suggested in the '*Bikeway Facility Design Manual'* (Department of Transportation Minnesota, 2007) and a statement that a typical bicycle needs between 0.75 m (2.5 ft) and 1.40 m (4.5 ft) of width in which to operate (Allen et al., 1998): the minimum width suggested was chosen.

I decided not to include the additional width for essential manoeuvring space and comfortable lateral clearance (sometimes considered in bikeway design and mentioned in the 'Bikeway Facility

Design Manual') in this calculation. The reason was that this research attempted to re-establish the definition of what is regarded as comfortable and hence was looking to explore scenarios including the extreme ends of the spectrum.

The scenarios for use in the survey were designed to reflect the reality from 'overcrowded' to 'uncongested'. The sets which were used in the survey are listed below:

SET 1: Scenarios AV (31)
SET 2: Scenarios BV (23), CV (23) and DV (23)
SET 3: Scenarios EV (16), FV (16), and GV (15)
SET 4: Scenarios HV (8), IV (8) and JV (7)
SET 5: Scenarios KV (4), LV (4) and MV (3)
SET 6: Scenario MV (10)

Table 6.4 shows the calculations done to establish the maximum number of cyclists (/bikes) needed for this experiment.

Table 6.4. Estimating the number of cyclists for video recordings.

	75% cyclist	**50% cyclist**	**25% cyclist**
100% path surface 13.5m^2	13.5 x 0.75= 10.13 10.125/1.35=7.5(=8) **8 cyclists**	**5 cyclists**	**3 cyclists**
75% path surface 10.13m^2	7.59/1.35= 5.62 (=6) **6 cyclists**	**4 cyclists**	**2 cyclists**
50% path surface 6.75m^2	5.06/1.35= 3.75 (=4) **4 cyclists**	**2 cyclists**	**1 cyclist**
25% path surface 3.38m^2	2.53/1.35= 1.87 (=2) **2 cyclists**	1 cyclist	**0 cyclist**

The initial number of people needed for the recording was estimated at 35 (with a reserve in case some participants chose to not participate), based on the following calculation of 'overcrowded' scenario:

Area of interest: 13.5m^2
Area occupied by cyclists: 8 x 1.35m^2= 10.8m^2
Area occupied by pedestrians: 23 x 0.3m2 = 6.9m^2

That meant that the users were occupying an area of 17.7m^2, which was 4.2m^2 larger than the area of interest. The numbers of participants were adjusted during the recording.

The subtle differences in the total number of users within the sets were premeditated in order to create a sufficient diversity of scenarios to assess the impact of overall number of users on comfort. In the sets where number of users was similar, the proportions of cyclists and pedestrians varied.

The difference between Scenarios in Set 1 and Set 2, Set 2 and Set 3, and Set 3 and Set 4 was consistently seven to eight users. The difference between scenarios in Set 4 and Set 5 was four users. Set 6 was introduced to include a scenario where the proportion on cyclists was significantly higher (eight cyclists, two pedestrians).

6.5 Video Footage recording

6.5.1 Trial Video Recording

In order to test and evaluate the concept of artificially designed scenarios, an example of the video footage was shot on 24th January 2015 on five different paths of a variety of widths. The issues and questions faced during the first attempt to produce video footage included participants moving on set trails and with constant speeds. There was also a concern regarding the length of videos and ensuring that the respondents had enough time to be able to assess and rate their perceived comfort.

In regard to the set trails and the user speeds (considering the high number of scenarios and repeated recordings), I decided to instruct people to follow a similar trail and at a similar speed in each attempt.

The length of the videos was reduced as much as possible, due to the risk of distraction. It was designed to capture the scenario leader approaching the other users and then passing them by. It was decided that the more practical solution was to make the videos shorter but ensure that survey participants could replay them as many times as needed.

6.5.2 Equipment

The video footage was collected using a Go-Pro Hero wearable digital camera that was attached to the scenario leader (cyclist, pedestrian or wheelchair user depending on the scenario) at chest level (approximately 1.5m above the ground). The scenario leader was 175cm tall. The footage was designed be treated not as an objective or factual reflection of reality (participants' actions), but rather as a staged visual representation aiming to *'evoke a sense of subjective positions and* *experiences'* (Marshall). The camera digitally recorded a scene from the wearer's perspective and the synchronous audio sound was also recorded.

6.5.3 Video Footage Editing

After the videos were recorded, I edited them using iMovie application, available on MacBook Air OS X Yosemite. The editing relied primarily on cutting out the parts of the video that included on-site instructions and ensuring the length of the footage was between 3-5 seconds (the videos from the perspective of a cyclist were relatively shorter compared to those recorded from the perspective of a pedestrian).

It was decided that the video scenarios were artificial, the audio was therefore non-representative of the reality and was at risk of becoming a distraction for the survey respondents. Hence, it was removed in the final version.

6.5.4 Video Footage Recordings

The video footage was recorded on two separate occasions: one was dedicated to path width, the second one to the volume of users. Video recordings were made by a pedestrian and cyclist moving at a normal pace (which could have been affected by the conditions, especially the volume of users). For each recording, the person in charge of filming would walk in the middle of the artificial path. Overtaking and ride-bys and walk-bys were done as a traveller would normally proceed.

Path Width Recordings

Scenarios that reflected a variety of widths and user types passing (cyclist, pedestrian and wheelchair user) were recorded together. The location was chosen based on the proximity to PAMELA (UCL research laboratory), where the equipment (bikes, wheelchairs, artificial grass) was stored and its 'neutral' feel: concrete surface, warehouse surrounding. Practical reasons were also considered: the companies based in the nearby warehouses were closed over the weekend and the space was isolated from residential areas, reducing the risk of passers-by disturbing the recording.

Apart from the researcher, only one additional participant was needed.

The filming took place on the weekend, during off peak times to ensure that the road close by was empty, to reduce the background noise and presence of motor vehicles in the background.

Overall, 82 videos were recorded.

- **Participants:** scenario leader, (who was a cyclist, pedestrian or wheelchair user, depending on a scenario) with camera attached; another user (who is a cyclist, pedestrian or wheelchair user, depending on a scenario).

- **What happened:** The scenario leader travelled on the path and was passed by another user. Each time both users were walking on a set trail and at set speeds. The experience was filmed from a first person perspective.

- **How to achieve the diversity of widths:** Different widths were achieved by the use of fake grass carpets. Two pieces 2m wide and 20m long pieces were placed and moved accordingly to achieve different widths.

Recording the path width scenarios was easier compared with the volume of users scenarios (considering the significantly lower number of participants, a close relationship between the researcher and the other participant, and unlimited recording time). It was also a learning process (the first time the actual recording with the purpose of producing the videos for the survey took place), hence some scenarios were repeated for the best outcome. Hence, a significantly higher number of videos than required was recorded, acting as practice.

Volume of Users Recordings

Volume of Users recordings included scenarios with a variety of user volumes, with different proportion of pedestrians and cyclists, moving in same and opposite directions as the scenario leader.

The calculation revealed the need for approximately 30-35 participants to take part in the recordings. A minimum of 30 participants was needed, however the intention was to recruit more, in case some of them did not participate without any notice. The participants were recruited through a UCL departmental mailing list and PAMELA mailing list for people who in the past had expressed interest in participating in similar paid tasks.

The site used for path width recording was not sufficient to perform the volume of users recording. The location to film scenarios with different volumes of users had to be chosen based on a number of additional criteria:

- The participants were requested to participate for the period between 2-3.5 hours, hence access to a toilet and space to store personal belongings and rest was necessary.
- Since there were over 30 participants and only one person in charge, it was important to ensure that the recording was done in a safe, off-road environment.

- Sufficient storage space for the equipment.
- Access to the facility (out of the recording hours), in order to prepare the site for recording (measurements and equipment set up)
- Space had to be big enough to create an artificial unsegregated shared-use path 3m wide.

The final choice was a parking space in front of PAMELA laboratory. In order to record, a controlled environment was set up. Figure 6.2 shows a diagram of the site setup.

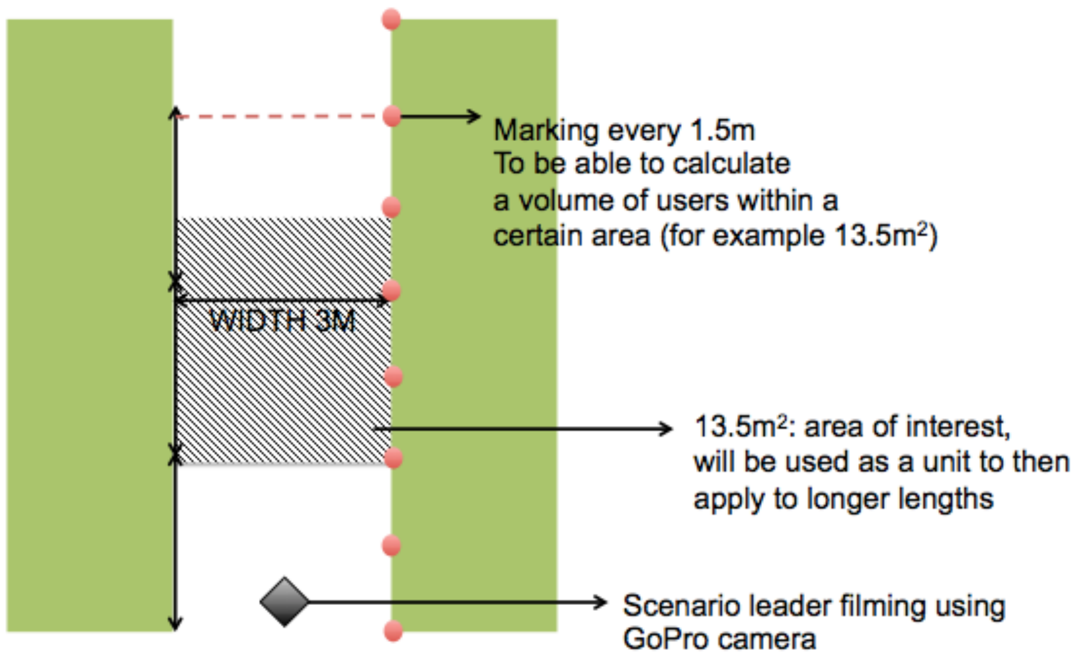


Figure 6.2. Site set-up for scenario recordings.

Participants: scenario leader (who is a cyclist or pedestrian, depending on a scenario) with camera attached; other users (who are a cyclist or a pedestrian, depending on a scenario).

What happened: The scenario leader travelled on the path of set width (medium width of 3m should allow the necessary variety of scenarios) and was passed by another user/users. Each time, users were walking/cycling on a similar trajectory and at similar speeds. The experience was filmed from the first person perspective.

Before the official recording begun, two trial videos were recorded to ensure that all of the participants understood the task.

In addition, the participants were presented before the recording with a list of rules to follow. These rules were also printed out and posted in visible places, to ensure that the participants could recall them if forgotten:

- Pedestrians were requested not to overtake other pedestrians.
- Cyclists could overtake pedestrians within their group and from the group in front (A or C). If they were in group B, they needed to be slightly more considerate, to ensure that they were fairly evenly distributed among the pedestrians.
- Participants were requested to try to keep their speed fairly similar in each scenario (it was assumed that it would have varied slightly)
- Participants were requested to not use their phones during the recordings.
- Participants were requested to be organized and quick during setting up.

These rules were essential to ensure that the recordings ran smoothly, within the budget and timeline.

6.6 Survey Content

The survey was developed using SurveyMonkey software. Opinio (the software utilised in Stage 1 of data collection) could not have been used due to the fact that it does not permit including video clips. The survey (see Appendix 2) consisted of an introduction, which explained the purpose of the research; defined 'mixed-use route'; and mentioned the approximate length of the survey and three types of questions.

1. **Hypothetical questions assessing users' comfort thresholds and tolerance when choosing to use an unsegregated shared-use path (the example used was from the survey aimed at the pedestrians).** These questions were included to challenge the existing notion that people are only willing to use unsegregated shared-use paths when they feel comfortable**:**

'You are travelling from A to B (1 mile). A substantial part of your journey (over 90%) is on an unsegregated mixed-use path. Assuming that this is the fastest, most direct route to get to your destination: what level of comfort/discomfort do you think you would you have to experience to make a decision to consider using an alternative route instead?'

An additional explanation was provided in order to ensure that the participants understood clearly what was expected of them:

‘ This question is about the decision-making process, the 'attractiveness' of the alternative route is not a factor.*
** If you are a person who does not care about the comfort level and always takes the fastest/most direct route, please choose 1: Very uncomfortable.*
** If you are a person who cares about the comfort level very much and would choose another route if the fastest/most direct route involved sharing between cyclists and pedestrians, please choose 6: Very comfortable.’*

The second question was phrased in the same way: the only difference was the part of the journey on an unsegregated shared-use path, which was less than 25%.

In the survey aimed at cyclists, the questions remained the same, however the suggested trip length was 3 miles. The trip lengths were selected based on the data available from National Travel Survey (NTS) (Department for Transport, 2015b). For cyclists, the calculation was done by dividing the average distance cycled per year (53 miles) by the average number of cycling trips per year (17 trips).

The same calculation was done for pedestrians, with the average walking trip distance of 184 miles per year and the number of walking trips equalling 200 (Department for Transport, 2015b).

2. **Rating user comfort based on the video footage:** *‘On a scale of 1 (very uncomfortable) – 6 (very comfortable), rate how comfortable would you be walking/cycling on the path pictured on the following video. *Please do not base your rating on the weather or surroundings.’*

The main body of the survey consisted of the questions where the participants were asked to rate comfort based on the scenarios in the videos. There were two different versions (for cyclists and pedestrians): the only difference was that the video was recorded either from the perspective of a person walking or a person cycling (to make it easier for the respondents to identify with it).

In regard to the Likert scale, the choice was made to stick to 1-6 scale to capture comfort levels, to avoid inconsistencies between Stage 1 and Stage 2 of data collection. Jensen (2007) previously used a similar methodology by relying on video clips, which were then rated from 1-6. Kang et al. (2013) stated *‘the use of a six-level scale as a basis for our empirical work was selected based on traditional LOS measurement approaches. However, the appropriate number of categories may merit further investigation to determine the numbers of discrete levels-of-service pedestrians are actually able to perceive’* (Kang et al., 2013, p11).

3. **Respondents' personal characteristics:** the final part of the survey enquired about participants' gender, age and postcode.

These were included in order to be able to look into the differences between genders and age groups (as was done in the Stage 1 of Data analysis) and also to gain a better understanding about the sample (in order to assess the extent to which it was representative and/or which groups dominate).

6.7 Pilot Study

After completing the initial survey design, I conducted a pilot study. 20 participants were recruited from the networks of colleagues and friends. Emphasis was put on ensuring that the respondents had no previous knowledge of the research and no or very limited knowledge of the topic of shared-use paths' design. The purpose was to assess whether the survey was easily understandable and user-friendly.

Overall, the response of the participants was positive. It turned out that the length of the survey was not an issue and the survey was taking on average less time than initially expected (12 minutes instead of the predicted 20 minutes). Some of the points raised in the feedback included:

- *'the videos feel the same'*: the differences between certain scenarios are very mild, but none of the scenarios were identical. The fact that the respondents were not aware of the differences in some cases was an important indication that perceptions do not always reflect objective reality.
- *'the scale is counter-intuitive'.*
- *'the survey becomes too repetitive'.*

The comments about the scale were taken on board and changes were applied in order to make the survey clearer and more user-friendly. The comments regarding the repeatability and 'sameness' were not regarded as a negative: all the videos included in the survey were different and the perception of differences among the videos depended on the individual.

Hence, in general, the survey required minor changes which were rectified before collecting responses.

6.8 Collecting Data

The sole criterion for inclusion in the study was that participants were based in the UK and were either a cyclist or pedestrian. In the cases when someone was both a cyclist and a pedestrian, they were asked to choose which they identified with more. Wheelchair users were encouraged to participate as ‘pedestrians’ and specify in the Question 1 comment section that they were wheelchair users.

The responses were collected in multiple stages between July and October 2017.

- **Data Collection 1 Academic contacts and personal contacts**: the initial responses were collected from associates of the research team. This included UCL CEGE and Public Health Departments’ mailing lists; contacts at the Department for Transport, Transport for London and Living Streets; personal contacts and their networks.
- **Data Collection 2 Sustrans mailing list**: relying on Sustrans resources, including their mailing list and social media accounts (Twitter, Facebook) recruited primarily cyclists.

After data collection 1 and 2, the number of respondents who identified as ‘cyclists’ was satisfactory. However, the number of ‘pedestrians’ was inadequate. Therefore, data collection 3, 4, 5 and 6 were aimed at increasing the sample of pedestrians and the advertisements/posters/leaflets included only a link to the survey for pedestrians.

- **Data Collection 3 Social media**: the second call was among the associates of the research team. While Stage 1 relied more on professional networks, data collection 3 used personal connections. The request was for the promotion of the survey on social media (Facebook and Twitter).
- **Data Collection 4 Leafleting in Camden Borough:** when the online means of distribution was saturated, I decided to add a more traditional method – door-to-door leafleting. Over 200 leaflets were distributed in residential and commercial properties in the area around Camden Town, Kentish Town, Chalk Farm and Swiss Cottage.
- **Data Collection 5 University of Glasgow**: with the purpose of diversifying the sample in regard to the location, a number of posters were posted at the University of Glasgow.
- **Data Collection 6 UCL (University College London) accommodation**: in order to increase the number of younger respondents, the posters were distributed at UCL’s student accommodation. Stage 6 resulted in achieving a satisfactory level of pedestrian responses.

6.9 Results and Discussion

6.9.1 Analysis overview

The analysis in this chapter was conducted with the following steps. First, missing data analysis was run in order to establish the number of missing values for each scenario and decide on the best way to deal with the missing responses, depending on whether the numbers were high or low.

Based on the results of SPSS analysis it was also established whether the data was missing randomly or not (see Section 6.9.3).

Then, the data was divided into multiple datasets, depending on the angle of analysis. The general approach was to focus on path width and volume of users scenarios separately (however, they were later combined to develop one of the models). The initial analysis relied on descriptive statistics and involved calculating overall mean comfort scores for each of the recorded scenarios (responses from pedestrians and cyclists combined), and the comparison of mean comfort scores between user types (cyclists and pedestrians separately). For path width scenarios, the variations between mean comfort scores of cyclists and pedestrians when different user types (cyclist, pedestrian or wheelchair user) passed-by were explored. For volume of users scenarios, the mean scores were used to compare the comfort ratings of scenarios with different directions of traffic flow and proportions of cyclists (cyclist: pedestrian ratios). The average comfort scores were also used to put the data on path width and volume of users in the context of a user's willingness to use the unsegregated shared-use path.

Two-way ANOVA analysis was run to conclude whether there were any statistically significant interactions between the characteristics of respondents (user type and gender) and the comfort scores for each of the scenarios. One-way ANOVA analysis was conducted, before developing models, to establish whether each of the variables (path width, total volume of users) and sub-variables (volume of cyclists, volume of pedestrians, direction of traffic flow, user type of the passer-by) had a significant impact on the comfort scores. This was done to determine which variables and sub-variables should be included in the models.

This was followed by the correlation analysis with the aim of studying the strength of the relationships between the variables. Again, this informed the design of the models: in the cases where strong collinearity was established between two variables, one of them was excluded from the model.

In order to establish the weight of each independent variable on comfort score, linear regression was run on different sets of scenarios. A similar approach was applied (using the same variables and sub-variables) to run ordinal regression, with the aim of being able to test which models were a better fit and predict comfort scores in the future. Twelve models were developed, as listed in Table 6.5.

Table 6.5. List of developed models, including scenarios in the data set, dependent variable and independent variables.

Model	Scenarios (Datasets) included in the data set	Dependent Variable	Independent Variables
Model 1, 2 Base-model	AW, BW, CW, DW, EW, FW, GW, HW, IW, JW, KW, LW, MW, NW, OW, PW, RW, TW, UW, WW, XW, AV, BV, CV, DV, EV, FV, GV, HV, IV, JV, KV, LV, MV, NV	Comfort Score	Path width, Number of users, User type of the respondent
Model 1a, 2a Combined	AW, BW, CW, DW, EW, FW, GW, HW, IW, JW, KW, LW, MW, NW, OW, PW, RW, TW, UW, WW, XW, AV, BV, CV, DV, EV, FV, GV, HV, IV, JV, KV, LV, MV, NV	Comfort Score	Path width, ~~Number of users~~*, Number of cyclists, Number of pedestrians, Direction of traffic flow, User type of the passer-by, User type of respondent
Model 1b, 2b Base-model Path Width	AW, BW, CW, DW, EW, FW, GW, HW, IW, JW, KW, LW, MW, NW, OW, PW, RW, TW, UW, WW, XW	Comfort Score	Path width, User type of respondent
Model 1c, 2c Path Width	AW, BW, CW, DW, EW, FW, GW, HW, IW, JW, KW, LW, MW, NW, OW, PW, RW, TW, UW, WW, XW	Comfort Score	Path width, User type of the passer-by, User type of respondent
Model 1d, 2d Base-model volume of users	AV, BV, CV, DV, EV, FV, GV, HV, IV, JV, KV, LV, MV, NV	Comfort Score	Number of users, User type of respondents
Model 1e, 2e Volume of users	AV, BV, CV, DV, EV, FV, GV, HV, IV, JV, KV, LV, MV, NV	Comfort Score	~~Number of users*~~, Number of cyclists, Number of pedestrians, Direction of traffic flow, User type of the passer-by, User type of respondent

*Number of users was eliminated from the model after correlation analysis was run.

The rationale for the choice of independent variables for each of the models was a combination of the results of Stage 1 of data collection (in particular the choice of path width and volume of users as the key variables, see Section 5.6), practicality and (as mentioned above) the correlations identified. Also, it was considered that transport practitioners might not always have all data available to use a model as complex as 1a or 2a; hence, it was decided to explore models where less data is necessary.

Finally, the results of the analyses were discussed from the viewpoint of making recommendations for future shared-path planning and design.

6.9.2 Sample

Overall, the total number of participants for Stage 2 of data collection was 1,477 (respondents who started the survey) with an average completion rate of 62%. The main factor identified as a reason for dropping out was the survey length (12 minutes on average). Some respondents were also put off by the 'seemingly' repetitive nature of the questions or expressed very negative attitude towards sharing space in the comments section for Question 1 and 2 and chose to not continue the survey.

Table 6.6 shows the total number of respondents who completed the survey as well as the composition of user types, genders and age groups.

Table 6.6. Sample: the composition of genders and age groups among cyclists and pedestrians.

	Cyclists		Pedestrians		Total	
	N	%	N	%	N	%
Total	583	65%	316	35%	899	100%
Gender						
Male	372	64%	136	43%	508	56%
Female	195	34%	174	55%	369	41%
Prefer not to say	8	1%	0	0%	8	1%
Not available	8	1%	6	2%	14	2%
Age-group						
16-24	10	2%	70	22%	80	9%
25-34	113	19%	98	31%	211	24%
35-44	163	28%	62	20%	225	25%
45-54	167	29%	39	13%	206	23%
55-64	102	18%	27	9%	129	15%
65+	23	4%	15	5%	38	4%

The total number of respondents who completed the survey was 899; 35% were pedestrians (316) and 65% were cyclists (583). In the UK, there are significantly more pedestrians than cyclists. The disproportion among the respondents was caused primarily by the process of collecting responses (see Section 6.8).

Among the 318 pedestrians, 55% were female and 43% were male. The majority of pedestrians were aged under 45: 22% were aged 16-24, 31% were 25-34, 20% were aged 35-44, 13% were aged 45-54, 9% were aged 55-64 and 5% were aged 65+. Five respondents did not provide an answer.

The number of cyclists who participated was significantly higher than for the pedestrians: 583 cyclists completed the survey. 33% of the participating cyclists identified as female and 64% as male. Eight of the participants 'preferred not to say' and another eight did not provide an answer.

In regard to age, the distribution of cyclists was as follow: 2% were aged 10-24, 19% were aged 25-34, 28% were aged 35-44, 29% were aged 45-54, 18% were aged 55-64 and 4% were aged 65 and over. Five people did not provide the answer.

6.9.3 Missing Values Analysis

Table 6.7 summarizes the result of missing values analysis. To see detailed information on each scenario please refer to Table 6.3 (see Section 6.4.1). The analysis showed that for the scenarios where both cyclists and pedestrians responded (all scenarios apart from MW, SW, TW, VW, AV, AVB) the percentage of missing responses was very low (2.5% the most, less than 1% in most cases). Scenarios MW, SW, TW, VW, AV, AVB (highlighted in grey) were not included in the Table 6.7: this is because, due to poor quality of video recordings they were missing either from the survey version for cyclists or pedestrians or both.

Table 6.7. Missing Values in the combined (cyclists and pedestrians) dataset.

	Total Number of Responses	Mean	Std. Deviation	Missing Values	
				Count	%
GENDER	877	1.6	0.49	22	2.4
AGE	889	3.2	1.32	10	1.1
USERTYPE	899	1.7	0.48	0	0.0
AW	896	4.5	1.51	3	0.3
BW	897	4.3	1.44	2	0.2
CW	896	4.4	1.50	3	0.3
DW	895	4.9	1.40	4	0.4
EW	897	4.8	1.30	2	0.2
FW	895	4.6	1.46	4	0.4
GW	896	5.1	1.28	3	0.3
HW	893	5.1	1.19	6	0.7
IW	896	4.7	1.46	3	0.3
JW	894	5.1	1.30	5	0.6

KW	896	5.3	1.15	3	0.3
LW	896	5.0	1.35	3	0.3
MW	n/a	n/a	n/a	n/a	n/a
NW	896	5.3	1.09	3	0.3
OW	896	5.1	1.30	3	0.3
PW	894	5.3	1.19	5	0.6
RW	894	5.3	1.11	5	0.6
SW	n/a	n/a	n/a	n/a	n/a
TW	n/a	n/a	n/a	n/a	n/a
UW	894	5.4	1.10	5	0.6
VW	n/a	n/a	n/a	n/a	n/a
WW	891	5.3	1.17	8	0.9
XW	895	5.4	1.08	4	0.4
AV	n/a	n/a	n/a	n/a	n/a
AVB	n/a	n/a	n/a	n/a	n/a
BV	894	1.5	0.99	5	0.6
BVB	896	1.4	0.89	3	0.3
CV	893	1.6	0.95	6	0.7
CVB	896	1.5	0.95	3	0.3
DV	894	1.6	1.00	5	0.6
DVB	895	1.6	1.06	4	0.4
EV	893	2.0	1.20	6	0.7
EVB	897	1.7	1.07	2	0.2
FV	896	1.8	1.12	3	0.3
FVB	895	1.8	1.12	4	0.4
GV	894	2.2	1.26	5	0.6
GVB	896	1.7	1.12	3	0.3
HV	891	2.3	1.29	8	0.9
HVB	896	1.9	1.20	3	0.3
IV	894	2.4	1.30	5	0.6
IVB	897	2.2	1.25	2	0.2
JV	895	2.5	1.31	4	0.4
JVB	897	2.0	1.27	2	0.2
KV	896	3.1	1.48	3	0.3

KVB	898	2.6	1.49	1	0.1
LV	897	3.8	1.54	2	0.2
LVB	894	3.5	1.66	5	0.6
MV	896	3.0	1.53	3	0.3
MVB	895	2.9	1.54	4	0.4
NV	895	1.8	1.08	4	0.4
NVB	894	1.6	0.99	5	0.6

Based on the numbers in Table 6.7, an option to discard the response sets from participants based on a few responses missing from the analysis was dismissed, as the effect on the sample size would be too impactful. Hence, the decision was made to recode the missing values as 'user or system missing' into the numerical discreet missing value '-9999'. '-9999' value was used, because this number does not appear anywhere else in the dataset. In order to ensure that SPSS omitted this number in any calculations, '-9999' was registered as a discrete missing value in variable view.

Figure 6.3 shows more detail into the patterns among the missing values. Variables on horizontal axis are ordered from left to right based on the increasing number of missing cases. Pattern 62 represented cases that had answers missing in each scenario/ for each variable: this can be assigned to the fact that some of the videos were not included in the survey versions for cyclists and pedestrians (as mentioned above).

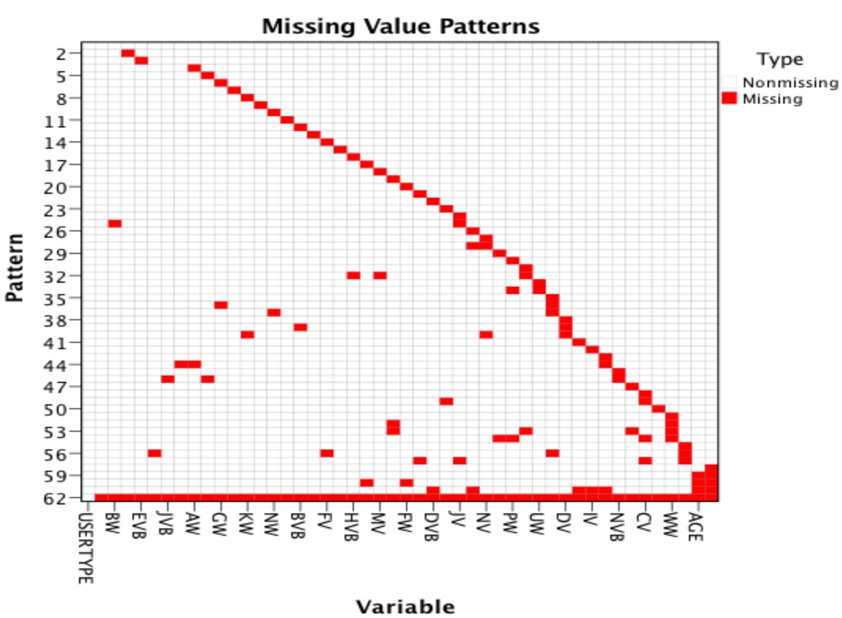


Figure 6.3. Missing values patterns.

6.9.4 Perceptions of comfort on unsegregated shared-use paths with varying path widths

Table 6.8 gives an overview of information about each of the scenarios with varying path widths, including the path width, total number of users (without the scenario leader who was recording from first person perspective), user type (of the passer by) and average comfort score.

In order to obtain these average comfort scores, which will be used as benchmarks for later analysis, the responses from survey versions for cyclists and pedestrians were combined. Such an approach was possible as the variables of interest (effective path width, total type of users and type of the passer-by user) were exactly the same in the videos in versions of the survey for cyclists and pedestrians. In further analysis, cyclists and pedestrians were distinguished.

Hence, Table 6.8 shows average comfort scores for each scenario, based on the ratings of all respondents (cyclists and pedestrians).

Table 6.8. Average comfort scores for each of the scenarios (responses from cyclists and pedestrians combined).

Scenario number	Effective Path Width (m)	Total number of users	Type of user (the passer-by)	Average comfort score* (cyclists and pedestrians combined)
Scenario AW	2.0	1	Pedestrian	4.53
Scenario BW	2.0	1	Cyclist	4.32
Scenario CW	2.0	1	Wheelchair	4.37
Scenario DW	2.5	1	Pedestrian	4.93
Scenario EW	2.5	1	Cyclist	4.83
Scenario FW	2.5	1	Wheelchair	4.64
Scenario GW	3.0	1	Pedestrian	5.09
Scenario HW	3.0	1	Cyclist	5.11
Scenario IW	3.0	1	Wheelchair	4.72
Scenario JW	3.5	1	Pedestrian	5.13
Scenario KW	3.5	1	Cyclist	5.27
Scenario LW	3.5	1	Wheelchair	5.00
Scenario MW	4.0	1	Pedestrian	5.62 (pedestrian only)
Scenario NW	4.0	1	Cyclist	5.33
Scenario OW	4.0	1	Wheelchair	5.08
Scenario PW	4.5	1	Pedestrian	5.31
Scenario RW	4.5	1	Cyclist	5.36
Scenario SW	4.5	1	Wheelchair	n/a
Scenario TW	5.0	1	Pedestrian	5.15 (cyclist only)
Scenario UW	5.0	1	Cyclist	5.40
Scenario VW	5.0	1	Wheelchair	n/a
Scenario WW	5.5	1	Pedestrian	5.31

Scenario XW	5.5	1	Cyclist	5.42
Scenario YW	5.5	1	Wheelchair	n/a

As is visible in Table 6.8, the average comfort scores do not vary significantly, despite the differences in path width. This likely due to the fact that the scenarios showed low density circumstances with only two people present on a path at one time. The lowest value is 4.32 (slightly comfortable) and the highest value is 5.42 (comfortable).

Figure 6.4 shows the graphical distribution of the average comfort scores listed in the Table 6.8 (sample of cyclists and pedestrians together). Different marker colours indicate the passer-by user types - cyclist (green), pedestrian (red) and wheelchair user (blue) -which will be distinguished in the further analysis. All of the mean ratings lay between 'slightly comfortable' and 'comfortable'. The comfort scores increased as the path width increased. There is a clear, linear relationship between comfort scores and path width: the wider the path, the higher the comfort scores.

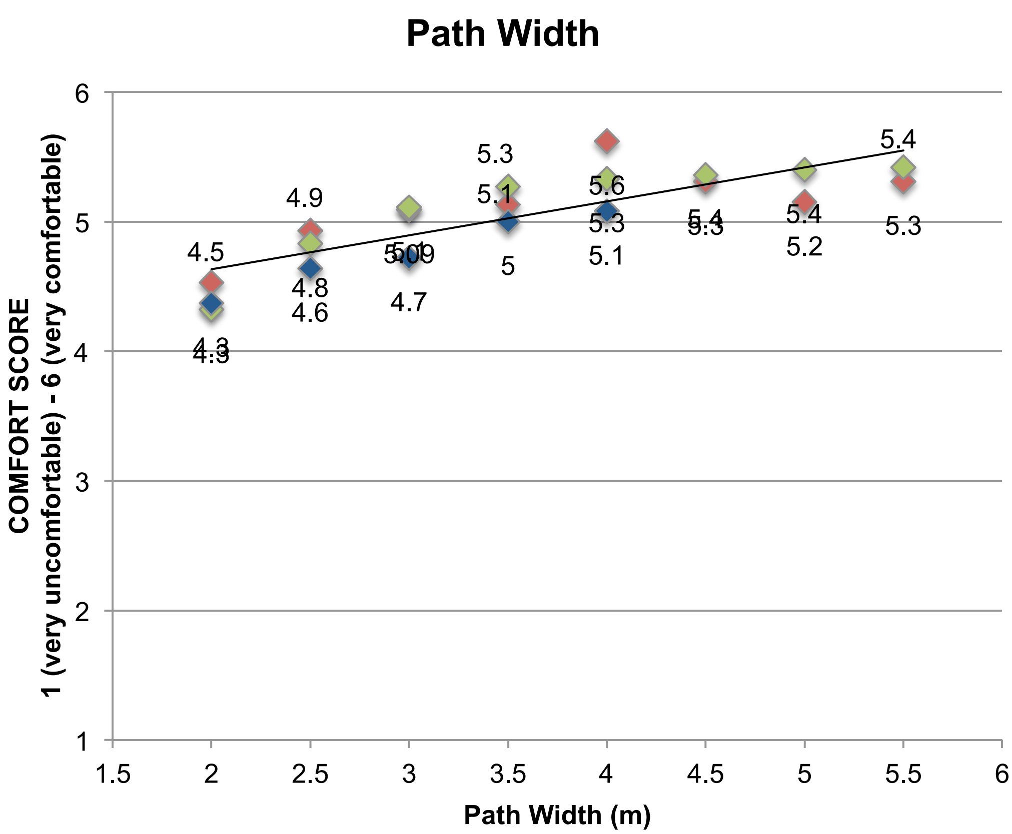


Figure 6.4. Average comfort scores for different path widths.

In order to assess which independent variables (user type, gender, usertype*gender) had significant impact on the comfort ratings (the dependent variable), a two-way ANOVA was run for each of the scenarios. The sample of responses consisted of cyclists and pedestrians combined. Table 6.8 shows the significance scores, with p<0.05 (statistically significant interactions) highlighted.

Therefore, when looking at the ANOVA breakdown for each of the scenarios, it is prominent that the impact of user type on the comfort rating is statistically significant (for almost every scenario apart from BW, HW and UW), with p<0.001 in most cases.

As far as the gender is concerned, Table 6.9 shows that there is less consistency, with a number of scenarios which showed a significant impact of gender on comfort rating (BW, DW, JW, KW, NW, OW, RW, TW and UW). However, it cannot be concluded why the comfort scores for these particular scenarios were statistically significant by gender and others were not. Similar applied to the interaction between gender and user type (user type*gender): an interaction could only be demonstrated for the narrowest path (path width 2m, scenarios AW, BW, CW, see Section 6.4.1). This is because no patterns could be identified.

Hence, the findings in Table 6.9 allows me to conclude that while gender can have a statistically significant impact in some cases, when it comes to comfort perception in relation to path width, it is the user type of the respondent (cyclist, pedestrian) that is related to perceptions of comfort on unsegregated shared-use paths.

Table 6.9. The significant associations between comfort ratings and user type and gender (independently and interdependently).

Scenario	**User Type (p value)**	**Gender (p value)**	**User Type* Gender (p value)** (Gender within user type interaction, for example female cyclists or male pedestrians)
AW	**0.000**	0.073	**0.025**
BW	0.229	**0.033**	**0.033**
CW	**0.000**	0.541	**0.016**
DW	**0.000**	**0.032**	**0.026**
EW	**0.003**	0.103	**0.049**
FW	**0.000**	0.162	0.069
GW	**0.000**	0.059	**0.018**
HW	0.111	0.077	0.078
IW	**0.000**	0.091	**0.032**
JW	**0.000**	**0.037**	**0.008**
KW	**0.001**	**0.005**	0.238
LW	**0.000**	0.056	**0.023**
MW (pedestrians only)	N/A	0.526	N/A

NW	**0.009**	**0.006**	0.207
OW	**0.000**	**0.039**	**0.015**
PW	**0.000**	0.144	**0.001**
RW	**0.002**	**0.006**	0.097
SW	N/A	N/A	N/A
TW (cyclists only)	N/A	**0.002**	N/A
UW	0.471	**0.043**	0.375
VW	N/A	N/A	N/A
WW	**0.000**	0.079	**0.018**
XW	**0.000**	0.176	0.483

Comparison of average comfort scores between cyclists and pedestrians for path width scenarios

Drawing from the analysis, which established the significance of respondent's user type to comfort rating, further interest was taken in comparing the differences between cyclists and pedestrians.

Table 6.10 shows the average comfort scores for each of the scenarios (path width) based on the ratings of cyclists and pedestrians separately. The independent sample t-test confirmed in which scenarios (where p value was <0.005, highlighted in bold) the average scores were comparable between cyclists and pedestrians.

Table 6.10. Comparison of average comfort scores by cyclists and pedestrians for different path widths.

Scenario number	Effective Path Width	Type of user (the passer-by)	Average Comfort Score Pedestrian	> More < Less = Equal	Average Comfort Score Cyclist	T-test Sig (2-tailed) p value
Scenario AW	2m	Pedestrian	5.1	>	4.2	**0.000**
Scenario BW	2m	Cyclist	4.3	=	4.3	0.642
Scenario CW	2m	Wheelchair	5.0	>	4.0	**0.000**
Scenario DW	2.5m	Pedestrian	5.6	>	4.5	**0.000**
Scenario EW	2.5m	Cyclist	4.7	<	4.9	**0.016**
Scenario FW	2.5m	Wheelchair	5.2	>	4.3	**0.000**
Scenario GW	3m	Pedestrian	5.5	>	4.8	**0.000**
Scenario HW	3m	Cyclist	5.0	<	5.1	0.309
Scenario IW	3m	Wheelchair	5.3	>	4.4	**0.000**
Scenario JW	3.5m	Pedestrian	5.6	>	4.8	**0.000**
Scenario KW	3.5m	Cyclist	5.1	<	5.3	**0.009**
Scenario LW	3.5m	Wheelchair	5.6	>	4.7	**0.000**
Scenario MW	4m	Pedestrian	5.6		n/a	n/a
Scenario NW	4m	Cyclist	5.2	<	5.4	**0.046**

Scenario OW	4m	Wheelchair	5.5	>	4.8	**0.000**
Scenario PW	4.5m	Pedestrian	5.6	>	5.1	**0.000**
Scenario RW	4.5m	Cyclist	5.2	<	5.4	**0.020**
Scenario SW	4.5m	Wheelchair	n/a		n/a	n/a
Scenario TW	5m	Pedestrian	n/a		5.1	n/a
Scenario UW	5m	Cyclist	5.4	n/a	5.4	0.911
Scenario VW	5m	Wheelchair	n/a		n/a	n/a
Scenario WW	5.5m	Pedestrian	5.6	>	5.1	**0.000**
Scenario XW	5.5m	Cyclist	5.2	<	5.5	**0.000**
Scenario YW	5.5m	Wheelchair	n/a		n/a	n/a

As shown in Table 6.10, the comparison between the average comfort scores, as rated by cyclists and pedestrians, showed that the differences are not big; all of the mean ratings lay between ‘slightly comfortable’ and ‘comfortable’. That suggests that despite subtle (less than 1) differences between cyclists and pedestrians, respondents from both user groups rated their ‘experience’ on unsegregated shared-use paths on the ‘comfortable’ side of the spectrum. However, this applies only to low density circumstances.

Pedestrians were more comfortable than cyclists in each of the scenarios, where the passer-by user was a pedestrian or a wheelchair user. Cyclists were more comfortable than pedestrians in the scenarios where the passer-by was a cyclist. Moreover, Table 6.10 also suggests that in the same condition (for example AW and CW; DW and FW), respondents feel more comfortable if the passer-by is the same type of user (for example if the respondent is a pedestrian, the passer-by is also a pedestrian) than the passer-by being a different type.

6.9.5 Perceptions of comfort on unsegregated shared-use paths with varying number of users

Table 6.11 gives an overview of information about each of the scenarios with varying total number of users, including the proportion of cyclists and pedestrians, direction of movement of passers-by and average comfort scores (level of service). The scenario leader (person recording) was not included in the count.

Similarly to the path width scenario analysis (see Section 6.9.4), the responses from survey versions for cyclists and pedestrians were combined. It was decided that such approach was possible as the variables of interest (effective path width, total number of users, number of pedestrians, number of cyclists and the direction of user-flow) were exactly the same in the videos in versions of the survey for cyclists and pedestrians.

Hence, Table 6.11 shows average comfort scores for each scenario, based on the ratings of all respondents (cyclists and pedestrians combined).

Table 6.11. Average comfort scores for scenarios with different total numbers of users (cyclists and pedestrians combined).

SCENARIO	Path Width	Total no. of users	Density Users per m^2	No. of pedestrians	No. of cyclists	Flow Direction	Average comfort score
AV	3m	31	2.3	28	3	Front* (Pedestrian only) Front-Back** (Cyclist only)	1.7 1.2
BV	3m	23	1.7	17	6	Front Front-Back	1.5 1.4
CV	3m	23	1.7	19	4	Front Front-Back	1.6 1.5
DV	3m	23	1.7	21	2	Front Front-Back	1.6 1.6
EV	3m	16	1.2	12	4	Front Front-Back	2.0 1.7
FV	3m	16	1.2	13	3	Front Front-Back	1.8 1.8
GV	3m	15	1.1	14	1	Front Front-Back	2.2 1.7
HV	3m	8	0.6	7	1	Front Front-Back	2.3 1.9
IV	3m	8	0.6	6	2	Front Front-Back	2.4 2.2
JV	3m	7	0.5	6	1	Front Front-Back	2.5 2.0
KV	3m	4	0.3	2	2	Front Front-Back	3.1 2.6
LV	3m	4	0.3	3	1	Front Front-Back	3.8 3.5
MV	3m	3	0.2	2	1	Front Front-Back	3.0 2.9
NV	3m	10	0.7	2	8	Front Front-Back	1.8 1.6

***Front:** all the participants were moving towards the scenario leader (the person recording).

****Front-Back:** half of the participants were moving with (in the same direction as) the scenario leader and the other half of participants were moving towards them.

Figure 6.5 shows graphically the distribution of overall comfort scores (sample of cyclists and pedestrians together).

All of the mean ratings were between ‘uncomfortable’ and ‘slightly comfortable’. Compared with the path width scenarios (with only one other path user) the ratings are significantly lower. The average score from path width scenarios (for 3m, GW, HW, IW, marker highlighted in red) was included in order to provide a point of reference. The comfort scores decreased as the number of users on the path increased: based on Figure 6.5 it was concluded that while the relationship is linear, with a sharp decrease in comfort between very low total number of users and the total number of users equal approximately 7. After this threshold was reached, the comfort score remained fairly constant.

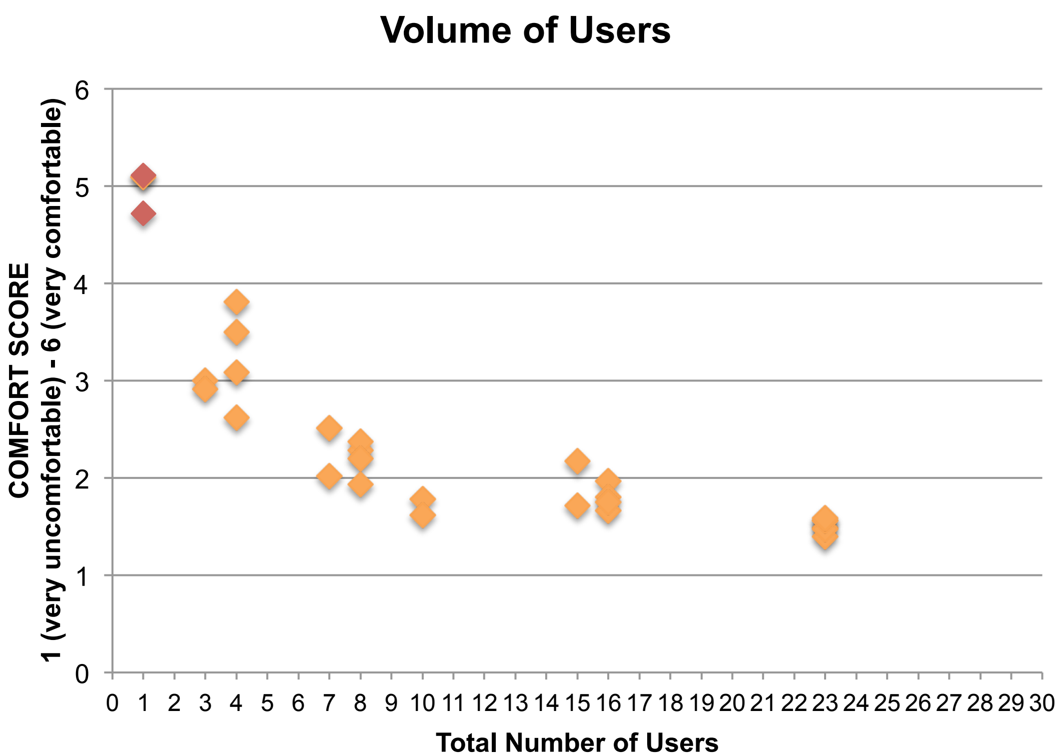


Figure 6.5. Average comfort scores for different total numbers of users.

However, based on the way the data was plotted on Figure 6.5, there could be a second way of interpreting it: that y is a function of (1/x). In order to check the assumption of y = f (1/x), a figure 6.6 was created, where 1/total number of users represented the horizontal axis. From Figure 6.6, the assumed relationship cannot be clearly confirmed.

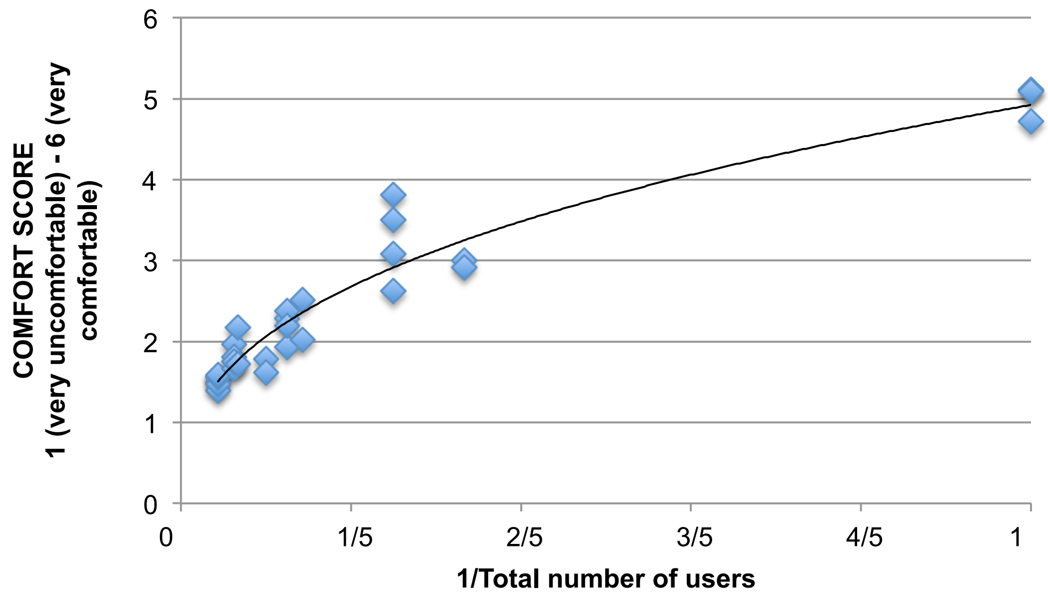


Figure 6.6. Average comfort scores for different 1/total numbers of users.

Figure 6.7 is similar to Figure 6.5: however, in order to make it comparable to some of the research which relies on user density, the comfort scores were plotted against the density of users rather than total number. The density was calculated based on the total number of users for each scenario and knowledge that the area included in the recording was 13.5m.

Hence, following the assumption that the relationship is linear, with a decrease in comfort between very low density (0.1 user per m^2) and the density of 0.5 users per m^2.

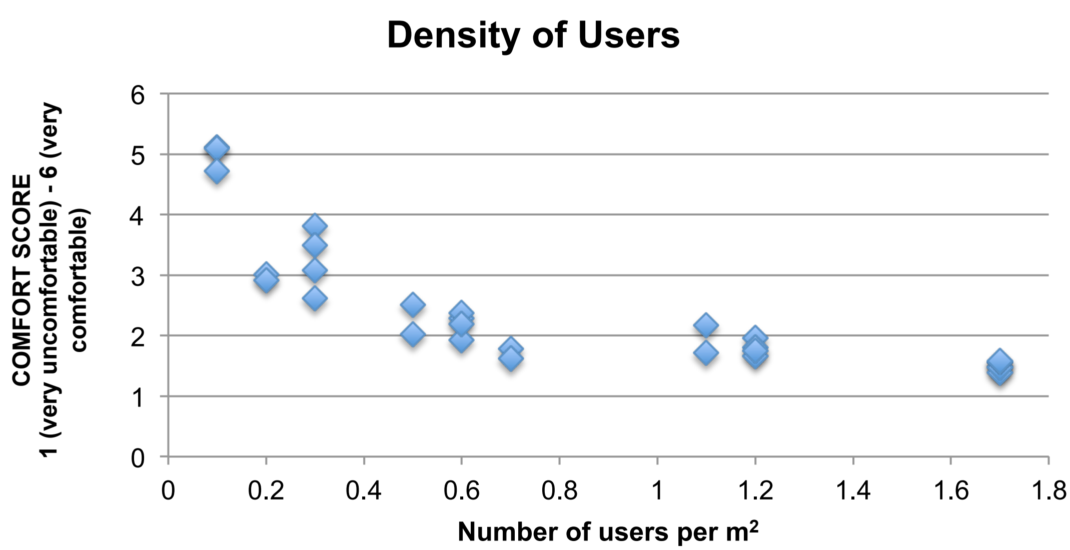


Figure 6.7. Average comfort scores for different user densities.

Similarly to the path width scenarios, in order to assess which independent variables (user type, gender, usertype*gender) had significant impact on the comfort ratings (dependent variable), a two-way ANOVA was run for each of the scenarios. Table 6.12 shows the significance scores, with $p<0.05$ (statistically significant interactions) highlighted.

Looking at the data in Table 6.12, it becomes prominent that the significance of user type on comfort ratings is present in all scenarios (apart from NVB). All scenarios apart from NVB displayed $p<0.001$, meaning that the relationship is statistically significant. For gender, on the other hand, (apart from LV scenario), there was no statistical significance. The gender and user type interaction were identified as statistically significant for a few scenarios (EVB, KV, KVB, LV and NVB), however there is no way to establish a pattern and conclude why these particular scenarios stand out.

Table 6.12. The significant associations between comfort ratings and user type and gender (independently and interdependently).

Scenario	User Type (p value)	Gender (p value)	User Type* Gender (p value)
AV	N/A	0.355	N/A
AVB	N/A	0.669	N/A
BV	**0.000**	0.389	0.472
BVB	**0.000**	0.186	0.315
CV	**0.000**	0.388	0.503
CVB	**0.000**	0.373	0.090
DV	**0.000**	0.723	0.781
DVB	**0.000**	0.147	0.329
EV	**0.000**	0.745	0.696
EVB	**0.000**	0.058	**0.027**
FV	**0.000**	0.953	0.115
FVB	**0.000**	0.983	0.286
GV	**0.000**	0.756	0.087
GVB	**0.000**	0.356	0.849
HV	**0.000**	0.225	0.714
HVB	**0.000**	0.650	0.113
IV	**0.000**	0.139	0.127
IVB	**0.000**	0.252	0.240
JV	**0.000**	0.443	**0.011**
JVB	**0.000**	0.433	0.051
KV	**0.000**	0.366	**0.002**
KVB	**0.000**	0.536	**0.026**
LV	**0.000**	**0.038**	**0.034**
LVB	**0.000**	0.177	0.057
MV	**0.000**	0.329	**0.019**
MVB	**0.000**	0.196	0.094

NV	**0.000**	0.843	0.371
NVB	0.238	0.751	**0.045**

Due to lack of association between the comfort scores and gender and gender*user type, the further analysis was conducted only with the interest in user type.

Comparison of average comfort scores between cyclists and pedestrians

Considering that ANOVA analysis identified the impact of user type on the comfort rating was statistically significant (See Table 6.12) and that the sample of cyclists and pedestrians was unequal (see Section 6.9.2), Figures 6.8, 6.9, 6.10 and 6.11 below show the average comfort scores for scenarios with increasing total number of users for cyclists and pedestrians separately.

When comparing the how the average comfort scores changed with increasing total number of path users, it is clear that not only cyclists have lower perceptions of comfort, but also the gradient of the function is less steep and the threshold point until which the comfort score decreases sharply is less prominent.

The comparison of Figures 6.8 and 6.10 showed that pedestrians are more comfortable sharing the space with cyclists than cyclists are sharing space with pedestrian, with pedestrians' comfort scores varying from 'comfortable' (when total number of users is less than five, or the density is below 0.4 users per m^2) to 'uncomfortable' (but only when the total number of users exceeds 15 users, or the density is above 1.1 users per m^2) (Figure 6.8 and Figure 6.9). Cyclists (Figure 6.10 and 6.11), on the other hand, rated their comfort level from 'slightly uncomfortable' for the scenarios with lower traffic flow to 'very uncomfortable' for scenarios with total number of users over 12. Table 6.12 shown that there are statistically significant differences between cyclists and pedestrians.

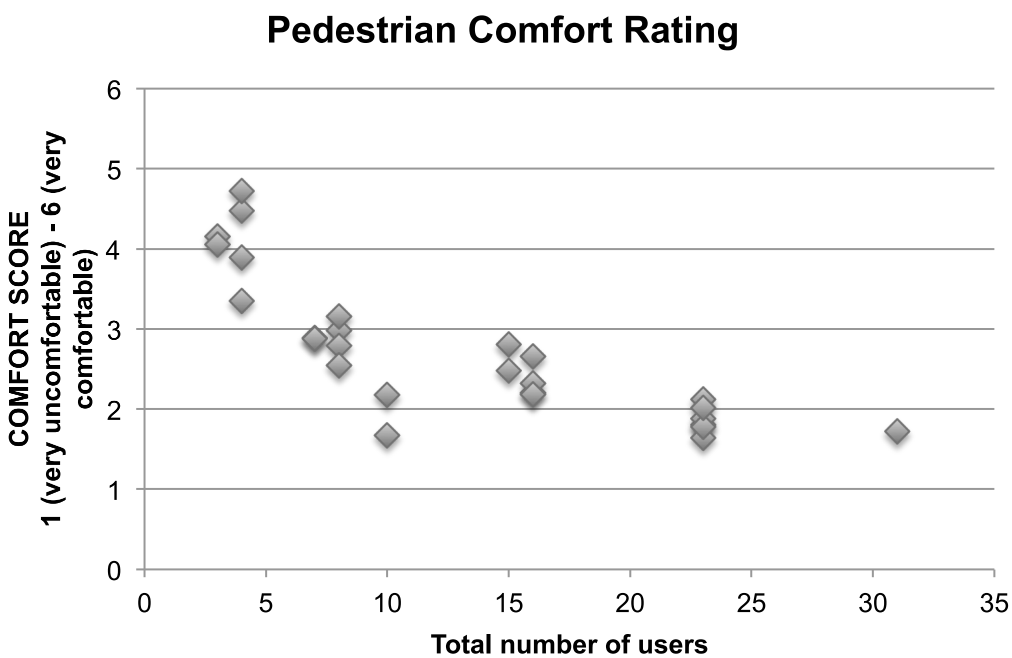


Figure 6.8. Average comfort scores for different total numbers of users, as rated by pedestrians.

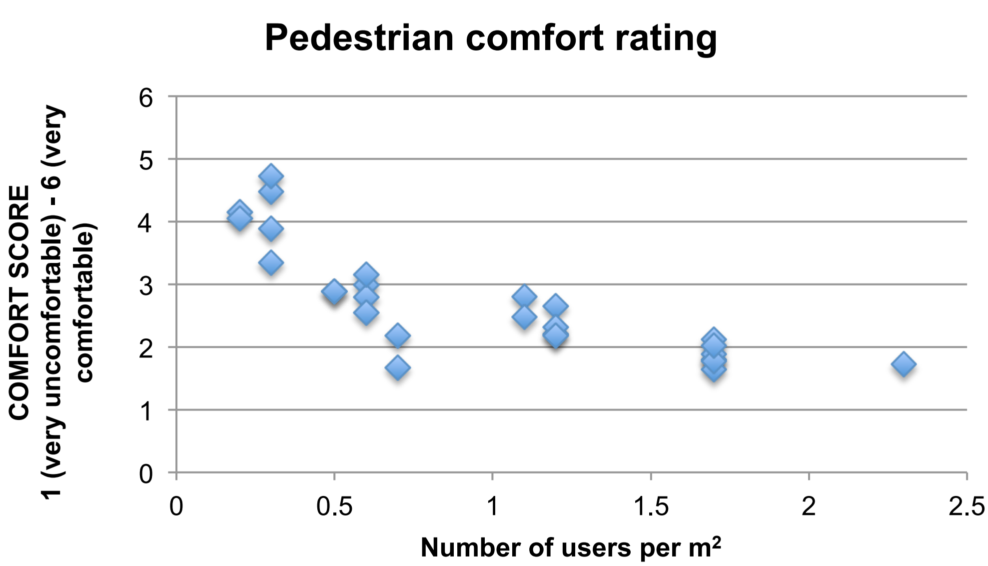


Figure 6.9. Average comfort scores for different user densities, as rated by pedestrians.

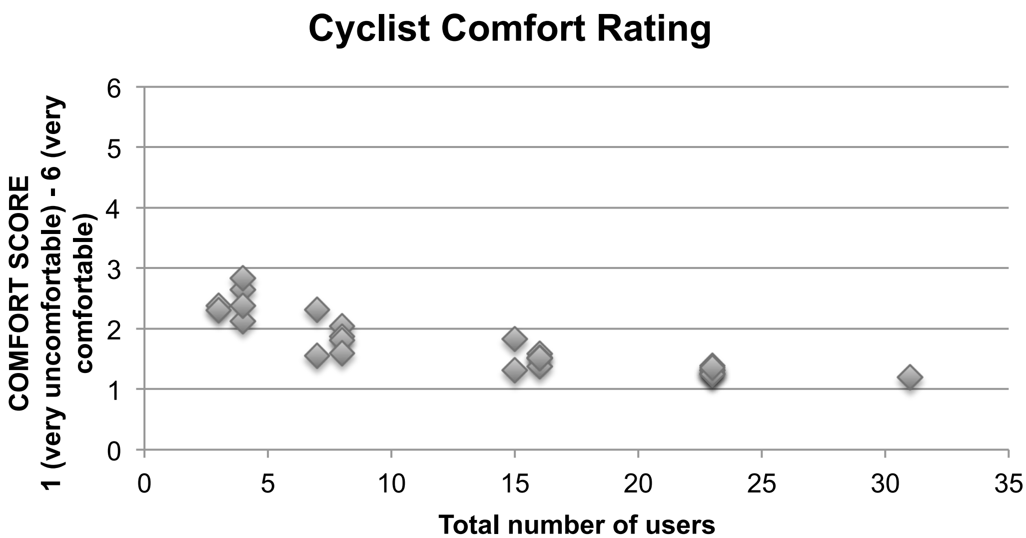


Figure 6.10. Average comfort scores for different total numbers of users, as rated by cyclists.

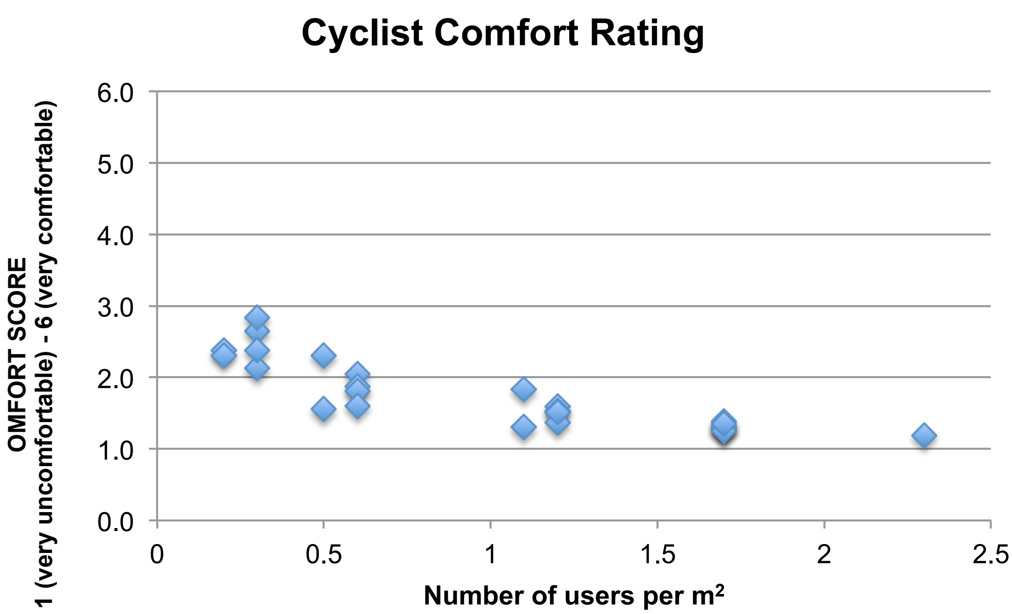


Figure 6.11. Average comfort scores for different user densities, as rated by cyclists.

6.9.6 The impact of passer-by's user type on perceptions of comfort on unsegregated shared-use paths: comparison between cyclists and pedestrians

Pedestrians

Figures 6.12, 6.13, 6.14 show the average comfort scores (as rated by pedestrians) at different widths, where the passer-by was of a specific user type: pedestrian, cyclist or wheelchair user.
As shown in Figure 6.12, the comfort scores, where the passer-by is a pedestrian, varied between 'comfortable' (5.1) and 'very comfortable' (5.6) at each of the widths. There was very little change in the comfort scores as the path got wider: the change was within 0.5 score and occurred only between 2m and 2.5m wide: the comfort scores remained constant for path widths over 2.5m.

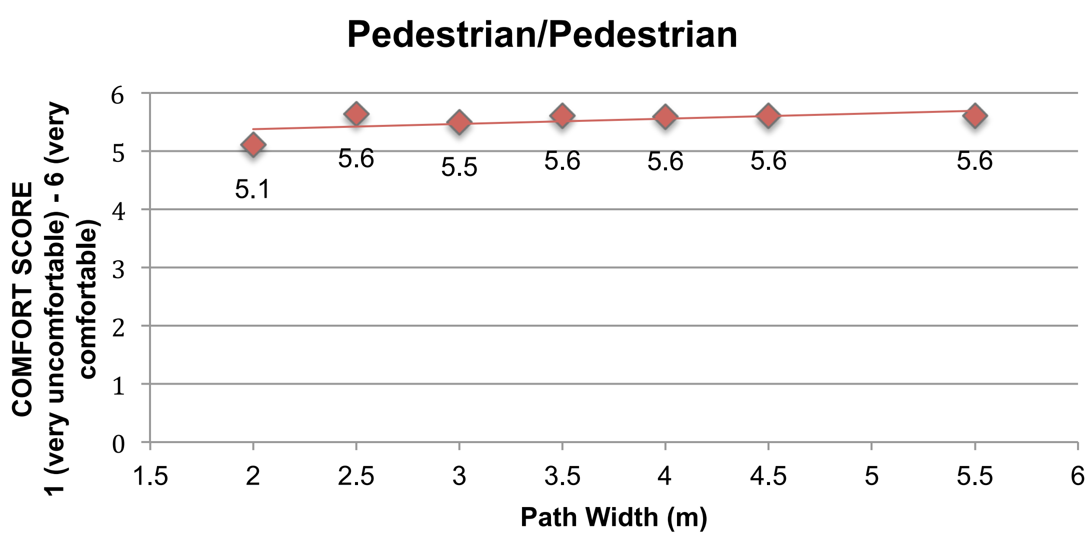


Figure 6.12. Average comfort scores for different path widths when the passer-by was a pedestrian, as rated by pedestrians.

As presented in Figure 6.13, for the scenarios where a passer-by was a cyclist (most common scenario on unsegregated shared-use paths) the comfort scores varied between 'slightly comfortable' (4.3) and 'comfortable' (5.4). Despite a slightly lower baseline compared to pedestrian-pedestrian scenarios, there was very little change in comfort ratings: the changes were within the range of 1 score. After 3m threshold, comfort scores remained almost constant.

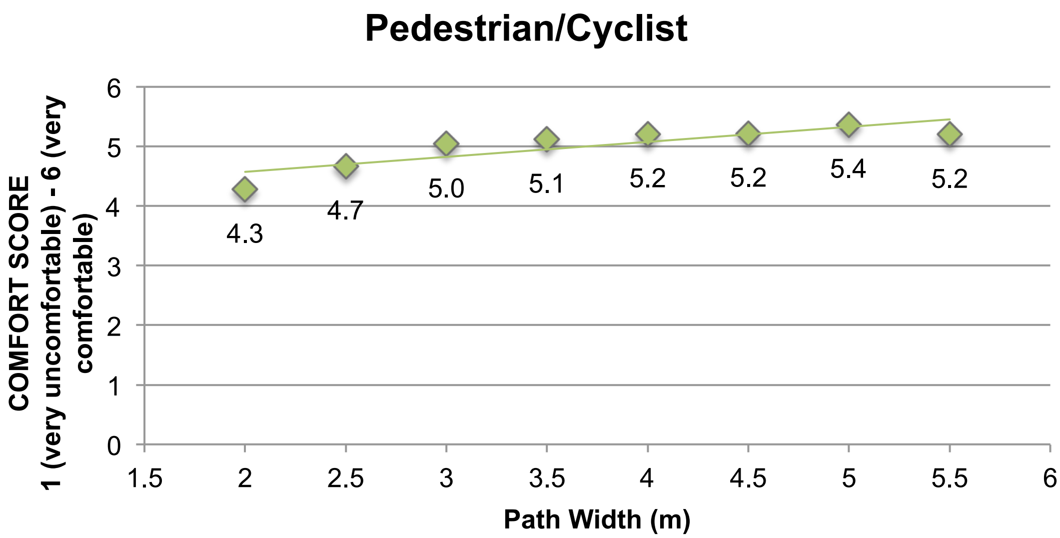


Figure 6.13. Average comfort scores for different path widths when the passer-by was a cyclist, as rated by pedestrians.

As shown in Figure 6.14, the comfort scores, where the passer-by was a wheelchair user, classified as 'comfortable' at each of the widths. Similarly to two previous cases, there was very little change in the comfort scores as the path got wider.

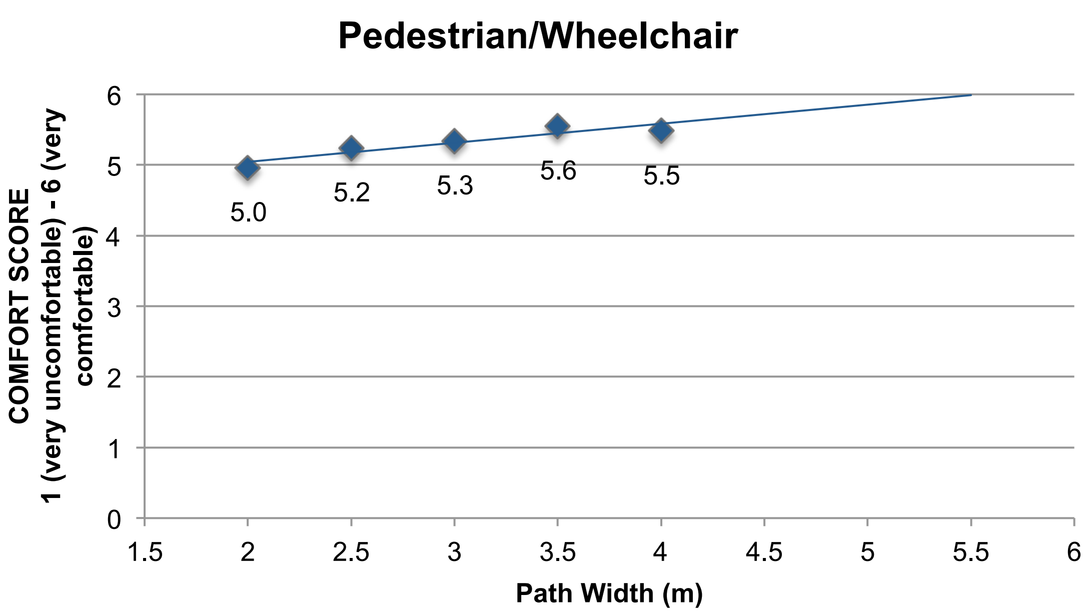


Figure 6.14. Average comfort scores for different path widths when the passer-by was a wheelchair user, as rated by pedestrians.

Overall, pedestrians were the least comfortable when being passed by a cyclist (compared with when the passer-by was other pedestrian and wheelchair user), however the difference was within 1 comfort score and at the 'comfortable' end of the spectrum. The path width did not have a big impact on perceived comfort of pedestrians, if the volume of other users (density of 0.1 user per m^2) is very low.

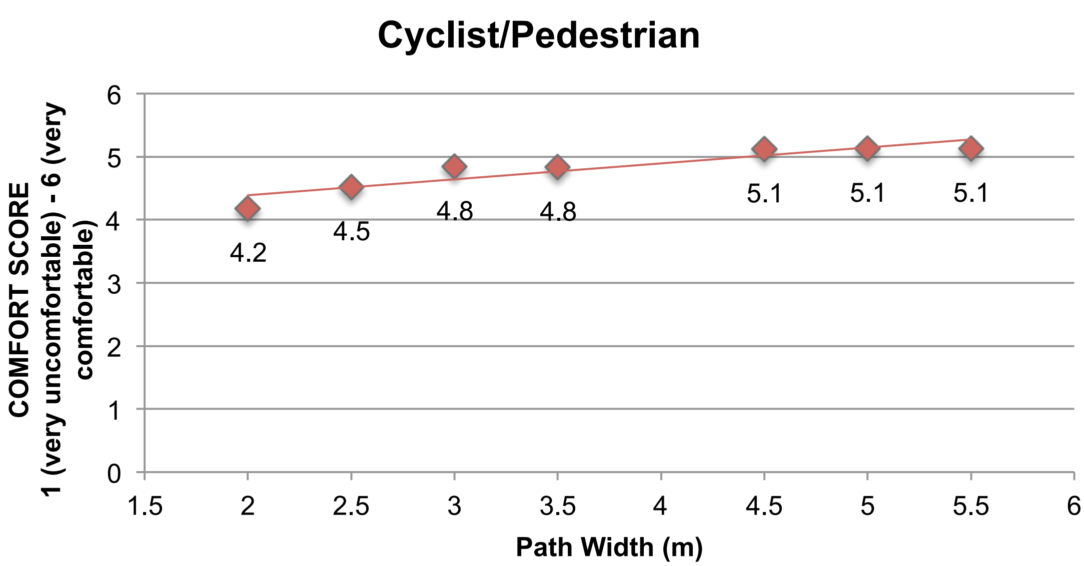
Cyclists

Figures 6.15, 6.16, 6.17 show the average comfort scores (as rated by cyclists) at different widths, where the passer-by was of a specific user type: pedestrian, cyclist or wheelchair user.

As shown in Figure 6.15, the comfort scores, where the passer-by was a pedestrian, varied between 'slightly comfortable' (4.2) and 'comfortable' (5.1) at each of the widths. There was a slight increase in the comfort scores as the path was wider, until approximately 3.5m. After 3.5m, the mean comfort scores remained constant.

Figure 6.15. Average comfort scores for different path widths when the passer-by was a pedestrian, as rated by cyclists.

As presented in Figure 6.16, for the scenarios where a passer-by was a cyclist, the comfort scores varied between 'slightly comfortable' (4.3) and 'comfortable' (5.5). The increase in comfort scores as



the path widened was gradual, but the differences remained minor, especially after the 3.5m mark, which was established as a threshold. Interestingly, it was the same threshold as for cyclist – pedestrian sharing scenarios (see Figure 6.15).

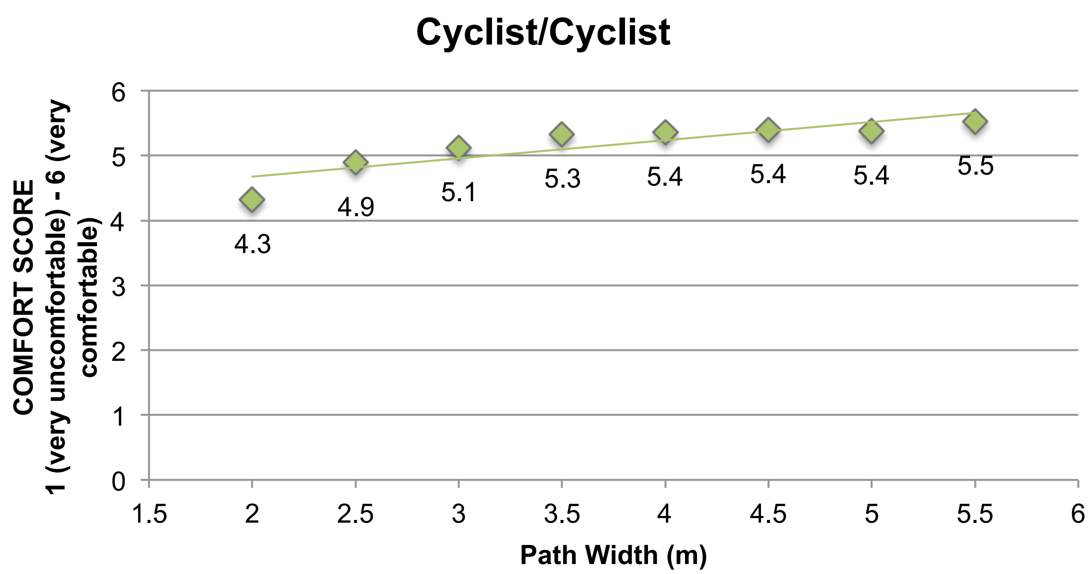


Figure 6.16. Average comfort scores for different path widths when the passer-by was a cyclist, as rated by cyclists.

As shown in Figure 6.17, the comfort scores, where the passer-by was a wheelchair user, classified from ‘slightly comfortable’ (4.0) to ‘comfortable’ (4.8).

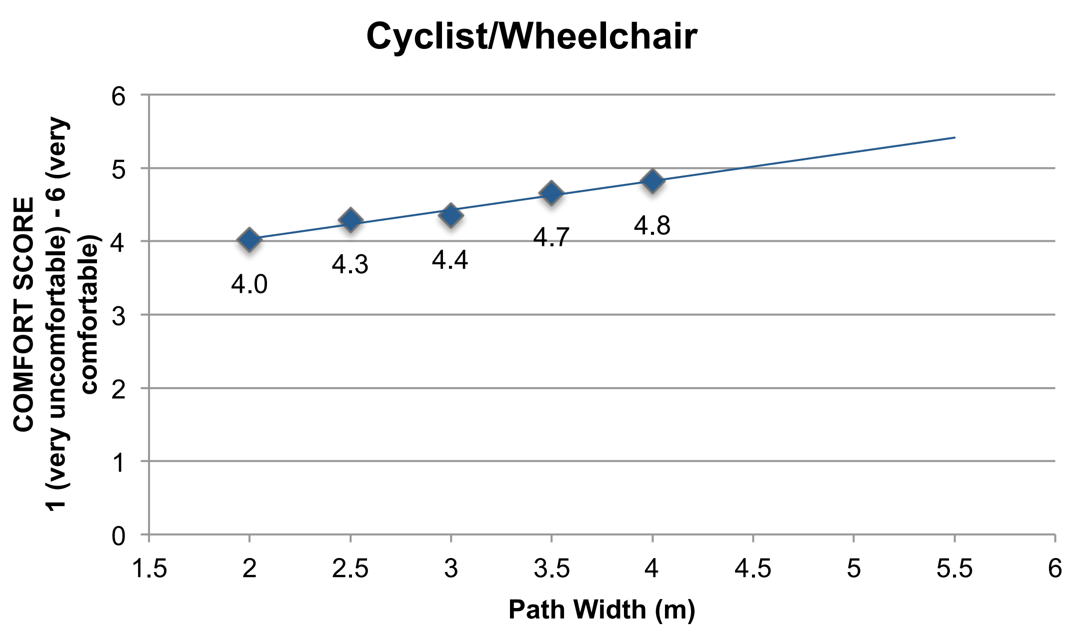


Figure 6.17. Average comfort scores for different path widths when the passer-by was a wheelchair user, as rated by cyclists.

Overall, cyclists were the least comfortable passing by the wheelchair user, however the differences were subtle, and the ratings remained at the 'comfortable' end of the spectrum. Furthermore, the path width did not have a big impact on perceived comfort of cyclists, when the volume of other users was very low (density of 0.1 user per m^2): in fact, the ratings within the range of 'slightly comfortable' and 'comfortable' suggest that cyclists felt comfortable when sharing the path with other user types.

Comparison between cyclists and pedestrians

Figures 6.18 and 6.19 allow one to draw a comparison between cyclists' and pedestrians' average comfort scores when passing different user types on different path widths.

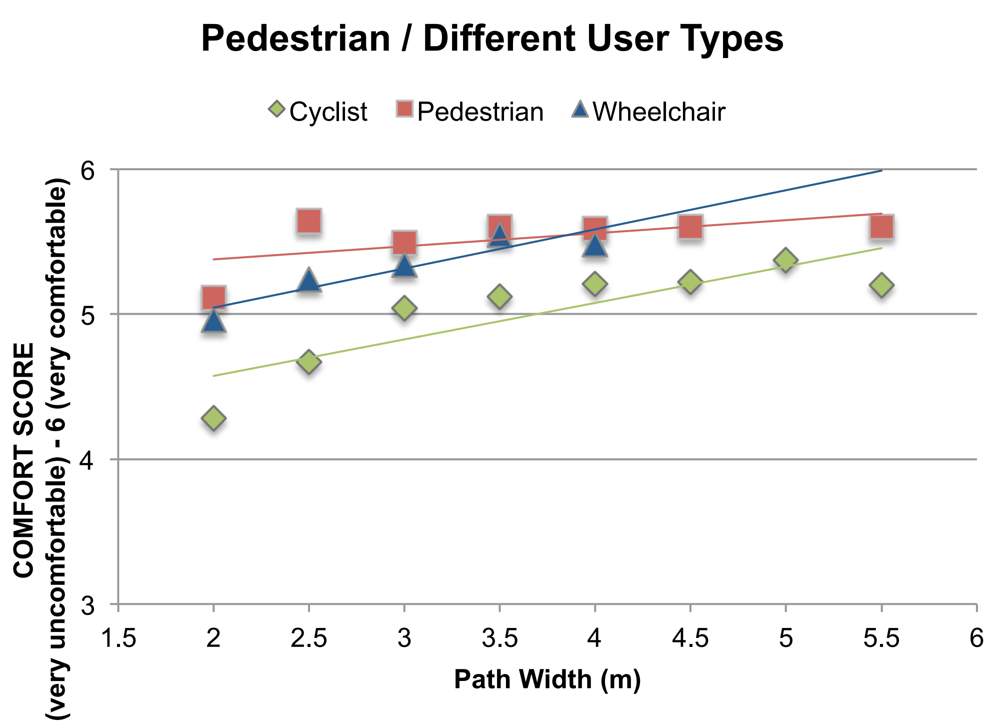


Figure 6.18. A comparison between average comfort scores for different path widths when the passer-by was a pedestrian, cyclist and wheelchair user, as rated by pedestrians.

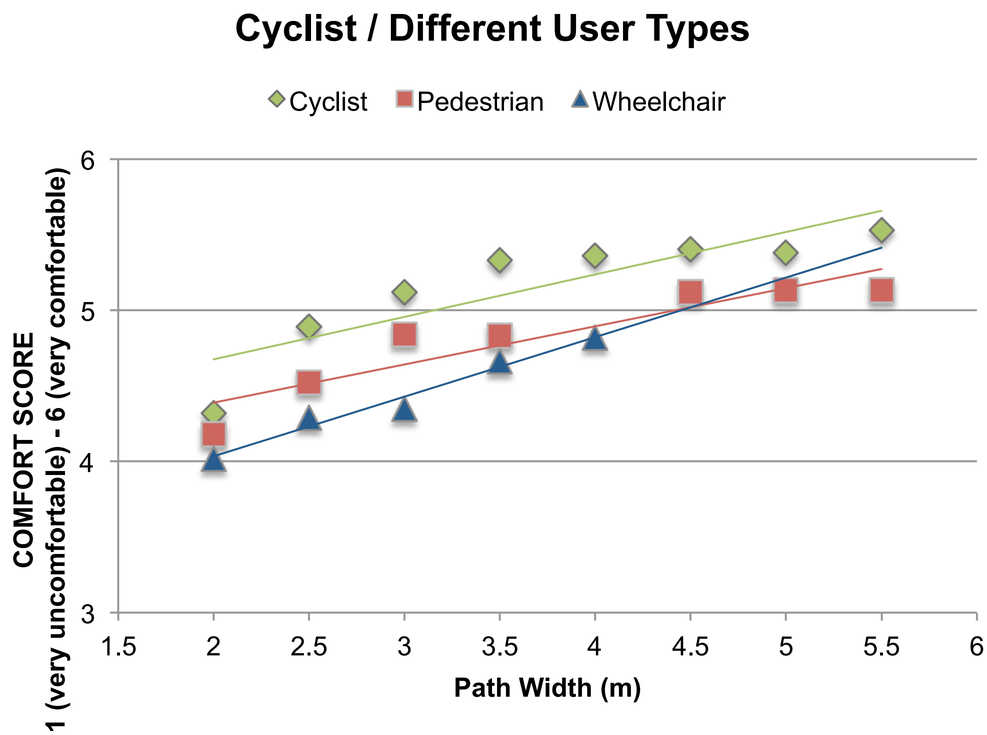


Figure 6.19. A comparison between average comfort scores for different path widths when the passer-by was a pedestrian, cyclist and wheelchair user, as rated by cyclists.

In general, both cyclists and pedestrians had very similar average comfort ratings, with mild increases in scores as the path width became wider. This suggested that sharing space between different user types could be an option (however, the scenarios examined here had only two people): and the small variations in ratings between 2m and 5.5m imply that the path width itself does not affect user comfort as much as expected where user volumes are small. Yet, what could be observed was a threshold of path width, below which respondents' comfort score decreased more (based on the decrease in path width). For pedestrians (when passing by a cyclists) it equalled 3m and for cyclists (when passing by a pedestrian) it equalled 3.5m. It needs to be emphasized that these findings are applicable only in particular conditions: with low-density traffic flow (density of 0.1 user per m^2).

The main difference between cyclists' and pedestrians' ratings would be the way the type of other users affected the comfort scores: while both user types were most comfortable sharing space with their own user mode, pedestrians found it more comfortable to pass by the wheelchair users, while the cyclists were more comfortable sharing with pedestrians. However, considering how small the differences were, it could be concluded that the user type of the passer-by was not an issue for cyclists and pedestrians when there was only one other path user.

To confirm that the impact of the user type of the passer-by on comfort score was statistically significant, ANOVA analysis was run separately for cyclist and pedestrian responses. Tables 6.13 and 6.14 summarize the results. All P-values equalled p = 0.000, suggesting that the type of passer-by was, in fact, statistically significant.

Table 6.13. ANOVA analysis for comfort scores (dependent variable) and passer-by's user types (pedestrian, cyclist, wheelchair user), as rated by cyclists.

Tests of Between-Subjects Effects

Dependent Variable: Score

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1003.213[a]	2	501.606	255.994	0.000
Intercept	243770.643	1	243770.643	124408.143	0.000
Passer-by type pedestrian	0.000	0	.	.	.
Passer-by type cyclist	0.000	0	.	.	.
Passer-by type wheelchair user	0.000	0	.	.	.
Error	21630.289	11039	1.959		
Total	281984.000	11042			
Corrected Total	22633.502	11041			

a. R Squared = 0.044 (Adjusted R Squared = 0.044)

Table 6.14. ANOVA analysis for comfort scores (dependent variable) and passer-by's user types (pedestrian, cyclist, wheelchair user), as rated by pedestrians.

Tests of Between-Subjects Effects

Dependent Variable: Score

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	305.619[a]	2	152.809	137.796	0.000
Intercept	168618.307	1	168618.307	152052.129	0.000
passerbyPED	0.000	0	.	.	.
passerbyCYC	0.000	0	.	.	.
passerbyWHEEL	0.000	0	.	.	.
Error	6960.883	6277	1.109		
Total	181379.000	6280			
Corrected Total	7266.502	6279			

a. R Squared = 0.042 (Adjusted R Squared = 0.042)

6.9.7 The impact of direction of user flow on perceptions of comfort on unsegregated shared-use paths: comparison between cyclists and pedestrians

In this section, the scenarios were paired up to assess whether the average comfort ratings differed depending on whether the users were approaching the cyclist and pedestrian from the front (for example if the total number of users was 23, in the video, the respondent would have seen all of their faces/ each user would pass him/her by while walking in the opposite direction) or from the front and the back (walking ahead of the respondent and overtaking the respondent/ moving in the same direction as the respondent).

Table 6.15 shows a comparison between average comfort scores for a combined sample (cyclists and pedestrians combined) for scenarios were all variables remained constant apart from flow direction. Independent sample t-test identified that direction of flow had a significant impact on the comfort scores for scenarios BV, EV, GV, HV, IV, JV, KV, LV and NV. In all these cases, the differences in average comfort scores were small: remained within the range of 0.5.

Table 6.15. Average comfort scores for scenarios with different flow direction.

SCENARIO	Path Width	Total no. of users	Density Users per m^2	Flow Direction	Average comfort score	T-test Sig (2-tailed) p value
AV	3m	31	2.3	Front (Pedestrian only) Front-Back (Cyclist only)	1.7 1.2	n/a
BV	3m	23	1.7	Front Front-Back	1.5 1.4	**0.037**
CV	3m	23	1.7	Front Front-Back	1.6 1.5	0.054
DV	3m	23	1.7	Front Front-Back	1.6 1.6	0.591
EV	3m	16	1.2	Front Front-Back	2.0 1.7	**0.000**
FV	3m	16	1.2	Front Front-Back	1.8 1.8	0.288
GV	3m	15	1.1	Front Front-Back	2.2 1.7	**0.000**
HV	3m	8	0.6	Front Front-Back	2.3 1.9	**0.000**
IV	3m	8	0.6	Front Front-Back	2.4 2.2	**0.003**
JV	3m	7	0.5	Front	2.5	**0.000**

				Front-Back	2.0	
KV	3m	4	0.3	Front Front-Back	3.1 2.6	**0.000**
LV	3m	4	0.3	Front Front-Back	3.8 3.5	**0.000**
MV	3m	3	0.2	Front Front-Back	3.0 2.9	0.242
NV	3m	10	0.7	Front Front-Back	1.8 1.6	**0.001**

Figures 6.20 and 6.21 show the comparison of scenarios with different total number of users for cyclists and pedestrians separately.

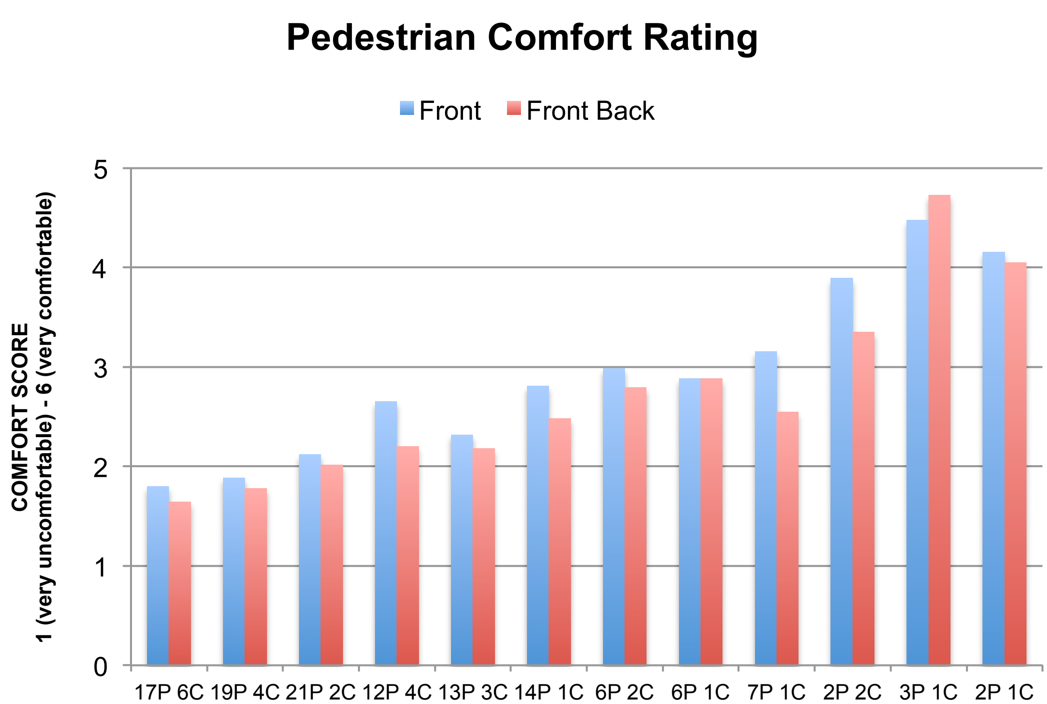


Figure 6.20. A comparison of average comfort scores for scenarios with set numbers of users (P-number of pedestrians, C-number of cyclists), with participants moving in different directions, as rated by pedestrians.

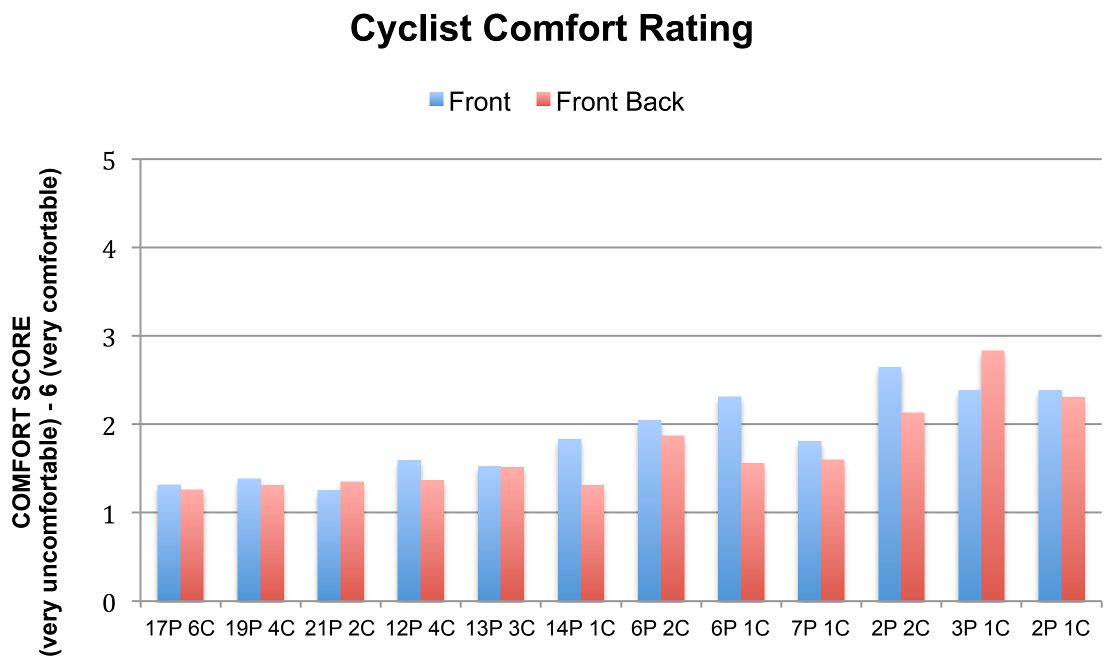


Figure 6.21. A comparison of average comfort scores for scenarios with set numbers of users (P-number of pedestrians, C-number of cyclists), with participants moving in different directions, as rated by cyclists.

While the differences were very subtle (<0.5 difference in mean comfort score), in most cases for both cyclists and pedestrians the respondents submitted higher comfort scores for scenarios where all of path users were moving from the front (walking in the opposite direction and facing the respondent). However, considering how minor the differences in scores were, despite it can be concluded that the direction of user flow has minimal impact on the comfort scores.

6.9.8 The impact of the proportion of cyclists to pedestrians on perceptions of comfort on unsegregated shared-use paths: comparison between cyclists and pedestrians

Table 6.16 shows the total number of users, the proportion of cyclists, the theoretical space occupied by cyclists, the flow direction and the average comfort scores as rated by cyclists and by pedestrians. In different colours are highlighted scenarios with equal or very similar total number of users, but different ratios of cyclists. The data is then presented graphically on Figure 6.22.

Looking at the average comfort scores, as rated by cyclists and pedestrians and highlighted in Table 6.16 and Figure 6.22, it is prominent that there is no clear pattern, which would indicate how higher or lower ratios of cyclists affect the ratings. This suggests that the proportion of cyclists does not affect the comfort of the users on unsegregated shared-use paths. Also, for there is no pattern prominent for cyclists that would suggest that they are more comfortable, when the ratio of cyclists is higher.

However, what can be observed, is that when analysing the scenarios with high total number of users (highest density), no matter the ratio of cyclists, on average, pedestrians still were more comfortable than cyclists, even for the scenarios with higher ratio of cyclists.

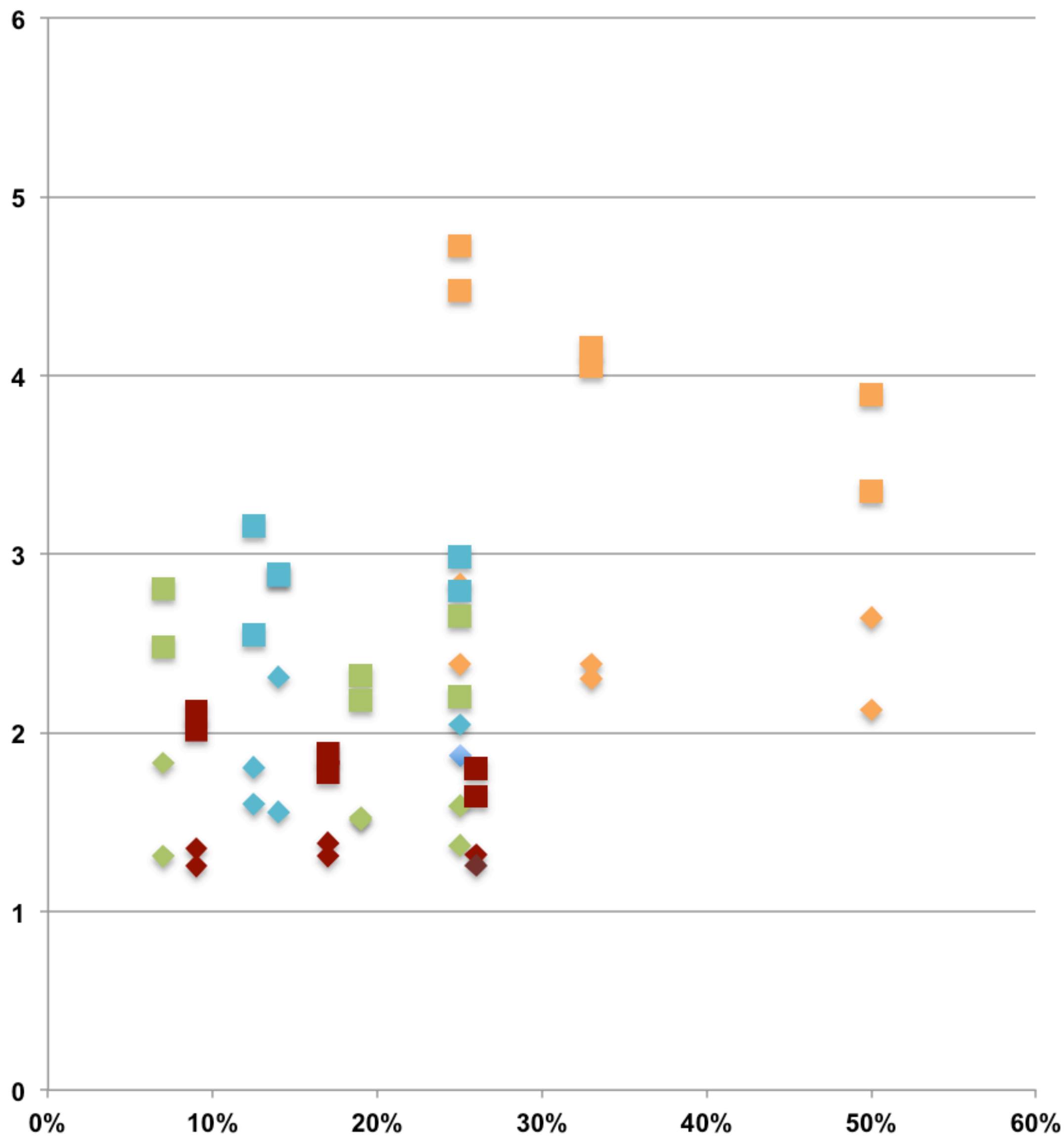


Figure 6.22. A comparison of average comfort scores, as rated by cyclists and pedestrians, for scenarios with different ratios of cyclists. Square-shaped markers represent ratings by pedestrians and diamond shaped markers represent ratings by cyclists. Colour coding is in sync with Table 6.16: same colour represents same total number of users.

Table 6.16. A comparison of average comfort scores, as rated by cyclists and pedestrians, for scenarios with different ratios of cyclists.

SCENARIO	Total number of users*	Proportion of cyclists	Space taken	Flow direction	Average comfort score Pedestrians	Average comfort score cyclists
Scenario AV	31	10%	30%	F* FB*	1.7	1.2
Scenario BV	23	26%	60%	F FB	1.8 1.6	1.3 1.3
Scenario CV	23	17%	40%	F FB	1.9 1.8	1.4 1.3
Scenario DV	23	9%	20%	F FB	2.1 2.0	1.3 1.4
Scenario EV	16	25%	40%	F FB	2.7 2.2	1.6 1.4
Scenario FV	16	19%	30%	F FB	2.3 2.2	1.5 1.5
Scenario GV	15	7%	10%	F FB	2.8 2.5	1.8 1.3
Scenario HV	8	12.5%	20%	F FB	3.0 2.8	2.0 1.9
Scenario IV	8	25%	10%	F FB	3.2 2.5	1.8 1.6
Scenario JV	7	14%	10%	F FB	2.9 2.9	2.3 1.6
Scenario KV	4	50%	20%	F FB	3.9 3.4	2.6 2.1
Scenario LV	4	25%	10%	F FB	4.5 4.7	2.4 2.8
Scenario MV	3	33%	10%	F FB	4.2 4.1	2.4 2.3
Scenario NV	10	80%		F FB	2.2 1.7	

6.9.9 Level of Service Model Development

Sections 6.9.4 to 6.9.8 provided descriptive analysis aimed at identifying patterns among the variables and sub-variables in relation to comfort ratings. This knowledge was a basis for the development of Level of Service tool.

As a part of this research, 12 models were developed. The dataset was created using Microsoft Access, by rearranging the original data, and then exported back to Microsoft Excel. Further analysis and model development were conducted in SPSS.

One-way ANOVA analysis

As a starting point to developing the models, a one-way ANOVA analysis was conducted for three sets of variables: combined (which included path width, volume of users and related sub-variables for models 1, 1a, 2, 2a), path width (for models 1b, 1c, 2b 2c) and volume of users for models (1d, 1e, 2d and 2e) (See Section 6.9.1). The dependent variable was comfort score. One-way ANOVA was necessary to confirm that there were statistically significant differences between responses within each of the independent variables and sub-variables.

Table 6.17 shows the summary of p-values obtained.

Table 6.17. One-way ANOVA analysis between comfort score and multiple independent variables.

Independent Variable	Combined	Path Width	Volume of Users
Path Width	0.000	0.000	n/a
Total Number of Users	0.000	n/a	0.000
User Type (Respondent)	0.000	0.000	n/a
Total Number of Cyclists	0.000	n/a	0.000
Total Number of Pedestrians	0.000	n/a	0.000
User Flow Direction	0.000	n/a	0.000
Passer-by's User Type (Pedestrian)	0.000	0.000	n/a
Passer-by's User Type (Cyclist)	0.000	0.000	n/a
Passer-by's User Type (Wheelchair)	0.000	0.000	n/a

The significance values were 0.000 (i.e., p = 0.000) for each case for the combined dataset, which is below 0.001 and, therefore, there was a statistically significant difference in the mean comfort scores between different user types and for different path widths, total numbers of users, total numbers of cyclists, total numbers of pedestrians, user flow directions and different passer-by user types.

Similarly, the significance values were 0.000 (i.e., $p = 0.000$) for each sub-variable within base, path width and volume of users model datasets, suggesting that each sub-variable was statistically significant for the applicable model.

Correlation Analysis

Based on the one-way ANOVA analysis results (see section above), correlation analysis between all variables (dependent and independent) was done to establish which of them could be dismissed from each of the models.

The analysis estimated sample correlation coefficients (Pearson Product Moment correlation coefficient), which ranges between -1 and +1 and quantified the direction and strength of the linear association between the two variables. The correlations between two variables were positive (meaning that higher levels of one variable are associated with higher levels of the other) or negative (meaning that higher levels of one variable are associated with lower levels of the other).

Tables 6.18, 6.19 and 6.20 summarize the results of correlation analysis for six model categories: Base Model, Combined Model, Path Width Base Model, Path Width Model, Volume of Users Base Model and Volume of Users Model. Positive and negative correlations were considered meaningful, where the Pearson correlation coefficient (r) was $1 > r \geq 0.4$ (for positive correlations) and $-1 < r \leq -0.4$ (for negative correlations) and the result was statistically significant at $p < 0.05$. Such values are highlighted in bold in the tables below. Strong correlations where $1 > r \geq 0.8$ (for positive correlations) and $-1 < r \leq -0.8$ (for negative correlations) are additionally highlighted in red.

Table 6.18 (Path Width) shows that meaningful correlations were identified between Passer-by's User Type (Pedestrian) and Passer-by's User Type (Cyclist), Passer-by's User Type (Pedestrian) and Passer-by's User Type (Wheelchair User) and Passer-by's User Type (Cyclist) and Passer-by's User Type (Wheelchair). However, those correlations were not strong enough to impact the type of variables used in the models.

Table 6.18. Correlation analysis between variables and sub-variables considered for the path width model (1b, 2b, 1c, 2c).

		Score	User Type Respondent)	Path Width	Passer-by's User Type (PED)	Passer-by's User Type (CYC)	Passer-by's User Type (WHEEL)
Score	Pearson Correlation	1	0.152	0.226	0.032	0.072	-0.115
	Significance		0.000	0.000	0.000	0.000	0.000

User Type (Respondent)	Pearson Correlation	0.152	1	0.000	0.000	0.000	0.000
	Significance	0.000		1	1	1	1
Path Width	Pearson Correlation	0.226	0.000	1	0.048	0.188	-0.266
	Significance	0.000	1		0.000	0.000	0.000
Passer-by's User Type (Pedestrian)	Pearson Correlation	0.032	0.000	0.048	1	**-0.599**	**-0.424**
	Significance	0.000	1	0.000		0.000	0.000
Passer-by's User Type (Cyclist)	Pearson Correlation	0.072	0.000	0.188	**-0.599**	1	**-0.471**
	Significance	0.000	1	0.000	0.000		0.000
Passer-by's User Type (Wheelchair User)	Pearson Correlation	-0.115	0.000	-0.266	**-0.424**	**-0.471**	1
	Significance	0.000	1	0.000	0.000	0.000	

Table 6.19 (Volume of Users) shows that strong correlation was identified between Number of Users and Number of Pedestrians. That meant that one of those variables did not have to be used in the model development, as the information it provided was redundant. No other meaningful correlations were identified.

Table 6.19. Correlation analysis between variables and sub-variables considered for the volume of users models (1d, 2d, 1e, 2e).

		Score	User Type Respondent	Number of Users	Number of Cyclists	Number of Pedestrians	Flow Direction
Score	Pearson Correlation	1	0.322	-0.382	-0.259	-0.339	-0.093
	Significance		0.000	0.000	0.000	0.000	0.000
User Type (Respondent)	Pearson Correlation	0.322	1	0.000	0.000	0.000	0.000
	Significance	0.000		1	1	1	1
Number of Users	Pearson Correlation	-0.382	0.000	1	0.373	**0.971**	0.000
	Significance	0.000	1		0.000	0.000	1
Number of Cyclists	Pearson Correlation	-0.259	0.000	0.373	1	0.140	0.000
	Significance	0.000	1	0.000		0.000	1
Number of Pedestrians	Pearson Correlation	-0.339	0.000	**0.971**	0.140	1	0.000
	Significance	0.000	1	0.000	0.000		1
Flow Direction	Pearson Correlation	-0.093	0.000	0.000	0.000	0.000	1
	Significance	0.000	1	1	1	1	

Table 6.20 (combined), similarly to Table 6.19, shows a strong correlation was identified between number of users and number of pedestrians. That meant that one of those variables was not used in the model development.

Other meaningful correlations (Pearson correlation coefficient (r) was 1 > r ≥ 0.4 for positive correlations and -1 < r ≤ -0.4 for negative correlations, all highlighted in bold) which were identified in Table 6.20 included: between the comfort score and number of users, number of pedestrians, number of cyclists, flow direction, passer-by's user type (pedestrian, cyclist and 'pedestriancyclist' both pedestrians and cyclists at one time); between number of users and number of cyclists, number of pedestrians and passer-by's user type (pedestrian, cyclist and pedestriancyclist); between number of cyclists and number of pedestrians, passer-by's user type (cyclist and pedestriancyclist); between number of pedestrians and passer-by's user type (pedestrian, cyclist and pedestriancyclist); between flow direction and passer-by's user type (pedestriancyclist); between passer-by's user type pedestrian and passer-by's user type (pedestriancyclist and wheelchair user); between passer-by's user type cyclist and passer-by's user type (pedestriancyclist and wheelchair user); between passer-by's user type pedestriancyclist and passer-by's user type wheelchair user. These correlations were not strong enough to impact the type of variables used in the models.

Table 6.20. Correlation analysis between variables and sub-variables considered for the combined models (1,2,1a, 2a).

		Score	User Type (Respondent)	Path Width	Number of Users	Number of Cyclists	Number of Pedestrians
Score	Pearson Correlation	1	0.183	0.323	**-0.652**	**-0.528**	**-0.611**
	Significance		0.000	0.000	0.000	0.000	0.000
User Type Respondent	Pearson Correlation	0.183	1	0.000	0.000	0.000	0.000
	Significance	0.000		1	1	1	1
Path Width	Pearson Correlation	0.323	0.000	1	-0.231	-0.169	-0.214
	Significance	0.000	1		0.000	0.000	0.000
Number of Users	Pearson Correlation	**-0.652**	0.000	-0.231	1	**0.624**	**0.982**
	Significance	0.000	1	0.000		0.000	0.000
Number of Cyclists	Pearson Correlation	**-0.528**	0.000	-0.169	**0.624**	1	**0.466**
	Significance	0.000	1	0.000	0.000		0.000
Number of Pedestrians	Pearson Correlation	**-0.611**	0.000	-0.214	**0.982**	**0.466**	1
	Significance	0.000	1	0.000	0.000	0.000	
Flow	Pearson	**-0.437**	0.000	-0.180	0.377	0.322	0.353

Direction	Correlation						
	Significance	0.000	1	0.000	0.000	0.000	0.000
Passer-by's User Type (Pedestrian)	Pearson Correlation	**-0.523**	0.000	-0.208	**0.501**	0.362	**0.496**
	Significance	0.000	1	0.000	0.000	0.000	0.000
Passer-by's User Type (Cyclist)	Pearson Correlation	**-0.462**	0.000	-0.097	**0.475**	**0.523**	**0.427**
	Significance	0.000	1	0.000	0.000	0.000	0.000
Passer-by's User Type (Pedestrian Cyclist)	Pearson Correlation	**-0.722**	0.000	-0.332	**0.695**	**0.594**	**0.650**
	Significance	0.000	1	0.000	0.000	0.000	0.000
Passer-by's User Type (Wheelchair User)	Pearson Correlation	0.251	0.000	-0.096	-0.280	-0.309	-0.277
	Significance	0.000	1	0.000	0.000	0.000	0.000

		Flow Direction	Passer-by's User Type (Pedestrian)	Passer-by's User Type (Cyclist)	Passer-by's User Type (PedestrianCyclist)	Passer-by's User Type (Wheelchair User)
Score	Pearson Correlation	**-0.437**	**-0.523**	**-0.462**	**-0.722**	0.251
	Significance	0.000	0.000	0.000	0.000	0.000
User Type Respondent	Pearson Correlation	0.000	0.000	0.000	0.000	0.000
	Significance	1	1	1	1	1
Path Width	Pearson Correlation	-0.180	-0.208	-0.097	-0.332	-0.096
	Significance	0.000	0.000	0.000	0.000	0.000
Number of Users	Pearson Correlation	0.377	**0.501**	**0.475**	**0.695**	-0.280
	Significance	0.000	0.000	0.000	0.000	0.000
Number of Cyclists	Pearson Correlation	0.322	0.362	**0.523**	**0.594**	-0.309
	Significance					
Number of Pedestrians	Pearson Correlation	0.353	**0.496**	**0.427**	**0.650**	-0.277
	Significance	0.000	0.000	0.000	0.000	0.000
Flow Direction	Pearson Correlation	1	0.391	0.370	**0.542**	-0.219
	Significance		0.000	0.000	0.000	0.000
Passer-by's User Type (Pedestrian)	Pearson Correlation	0.391	1	0.189	**0.721**	**-0.560**
	Significance	0.000		0.000	0.000	0.000
Passer-by's User Type (Cyclist)	Pearson Correlation	0.370	0.189	1	**0.683**	**-0.591**
	Significance	0.000	0.000		0.000	0.000
Passer-by's User Type	Pearson Correlation	**0.542**	**0.721**	**0.683**	1	**-0.403**

(PedestrianCyclist)	Significance	0.000	0.000	0.000		0.000
Passer-by's User Type (Wheelchair User)	Pearson Correlation	-0.219	**-0.560**	**-0.591**	**-0.403**	1
	Significance	0.000	0.000	0.000	0.000	

Linear regression

Linear regression was run with the aim of establishing the coefficients to establish the effect of each of variables and sub-variables on comfort score (to find out the strength of each of the predictors) and where suitable to develop a formula, which could be later used to predict the comfort scores.

ANOVA analysis showed for all models (1, 1a, 1b, 1c, 1d, 1e) p=0.000 (See Appendix 3), which proved that the regression models developed were significant and a better way than just using a mean score to predict the outcome.

Sections below reviewed model summaries, with particular focus on R Square, which identified how strong the models were, and coefficient analysis, which allowed ranking the predictors and developing a formula.

For the coefficient analysis, standardised and unstandardized coefficients were taken into consideration. Standardised values were used to rank the strength of the predictors: the standardisation takes place to eliminate the differences in units of measurement of independent and dependent variables. Unstandardized coefficients represented the amount by which dependent variable changed if specific independent variable changed by one unit, assuming that other independent variables remained constant.

Model 1 Base Model (path width, number of users, user type of respondent)

The first model developed was Base Model 1, which combined the following variables: user type of the respondent, path width and total number of users. Table 6.21 shows the model summary. R Square equalled 0.490, suggesting that approximately 49% of all the variance in the comfort scores can be predicted from the predictors, suggesting that the User Type, Path Width and Number of Users work well as a set of predictors.

Table 6.21. Model 1 summary.

Model Summary

Model	R	R Square	Std. Error of the Estimate
1	0.700[a]	0.490	1.406

a. Predictors: (Constant), number of users, user type, width

Table 6.22 shows the coefficients of the developed model: as there were multiple predictors in this model, the column of main interest was ‘standardized coefficients’ and the significance. Since for each predictor included in the model value p=0.000, which is <0.001, the conclusion was reached that each of them was statistically significant, impacting on the dependable variable in a unique way.

Table 6.22. Model 1 Coefficients analysis.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	2.638	0.034		78.619	0.000
	User type	0.724	0.014	0.176	50.222	0.000
	Width	0.487	0.009	0.185	51.467	0.000
	Number of users	-0.142	0.001	-0.610	-169.437	0.000

a. Dependent Variable: Score

Based on the values of standardized coefficients, the predictors ranked as follows (from the strongest to weakest): Total number of users (-0.610), Path Width (0.185) and User Type of Respondent (0.176).

Based on the unstandardized coefficients, the linear Model 1 formula was as follows:

Comfort Score *= 2.639 + 0.724*(Respondents User Type, 0 = cyclist, 1 = pedestrian) + 0.487*(Path Width) + (-0.142) *(Total Number of Users)*

Model 1a Combined

Model 1a Combined included the following independent variables: respondent's user type, path width, number of cyclists, number of pedestrians, flow direction and passer-by's user types (pedestrian, cyclist, wheelchair user). The procedure followed was the same as for Model 1.

Table 6.23 shows the model summary. R Square equalled 0.609 (hence approximately 61% of all the variance in the comfort scores can be predicted from the predictors). Thus, the independent variables worked well as a set. Passer-by's user types (pedestriancyclist) was excluded from the analysis by SPSS.

Table 6.23. Model 1a summary.

Model Summary[b]

Model	R	R Square	Std. Error of the Estimate
1a	0.781[a]	0.609	1.231

a. Predictors: (Constant), passer-by type wheelchair user, respondent's user type, width, flow direction, number of Cyclists, number of pedestrians, passer-by type pedestrian, passer-by type cyclist
b. Dependent Variable: Score

Table 6.24 shows coefficients analysis: all predictors included in the model had significance value p=0.000, which is <0.01, they were statistically significant. SPSS excluded passer-by's user type cyclistpedestrian (when both cyclists and pedestrians were passer-bys) sub-variable.

Table 6.24. Model 1a: unstandardized and standardized coefficients.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1s	(Constant)	5.811	0.047		124.383	0.000
	User type	0.710	0.013	0.173	56.205	0.000
	Width	0.251	0.009	0.095	28.360	0.000
	Number of cyclists	-0.143	0.004	-0.145	-37.188	0.000
	Number of pedestrians	-0.058	0.001	-0.218	-52.931	0.000
	Flow direction	-0.210	0.016	-0.049	-13.255	0.000

	Passer-by type pedestrian	-1.855	0.023	-0.423	-80.754	0.000
	Passer-by type cyclist	-1.746	0.024	-0.381	-71.513	0.000
	Passer-by wheelchair user	-2.074	0.035	-0.327	-59.981	0.000

a. Dependent Variable: Score

The predictors ranked as follows (from the strongest to weakest): passer-by's user type pedestrian (-0.423), passer-by's user type cyclist (-0.381), passer-by's user type wheelchair user type (-0.327), number of pedestrians (-0.218), respondent's user type (0.173), number of cyclists (-0.145), path width (0.095) and flow direction (-0.049).

Based on the unstandardized coefficients, the linear model formula was as follows:

Comfort Score *= 5.811 + 0.710*(Respondents User Type) + 0.251*(Path Width) + (-0.143)*(Number of Cyclists) + (-0.058)*(Number of Pedestrians) +(-0.210)*(Flow Direction) + (-1.855)*(Passer-by's User Type Pedestrian) + (-1.746)*(Passer-by's User Type Cyclist) + (-2.074)*(Passer-by's User Type Wheelchair User)*

Models: Base Path Width (1b) and Base Volume of Users (1d)

After developing models with combined predictors (1 and 1a), there was an attempt to develop two more specific linear regression base models: one for path width and one for volume of users. However, model summary tables for each (Table 6.25 and Table 6.26) revealed very low R Square values: 0.073 and 0.250 respectively. That meant that for the models developed the majority of data did not fit the regression line. Path width base model proved especially weak, with only 7.3% of all the variance in the comfort scores can be predicted from the predictors.

Table 6.25. Model 1b summary.

Model Summary

Model	R	R Square	Std. Error of the Estimate
1	0.271[a]	0.073	1.280

a. Predictors: (Constant), width, respondent's user type

Table 6.26. Model 1d summary.

Model Summary

Model	R	R Square	Std. Error of the Estimate
1	0.500[a]	0.250	1.201

a. Predictors: (Constant), number of users, respondent's user type

Despite low R Square values suggesting that the models are not a good fit for the data, it still brings value to review the coefficients for the Path Width and Volume of Users base models.

Tables 6.27 and 6.28 provide the summary with standardised and unstandardized coefficients.

Table 6.27. Model 1b: coefficient analysis.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	3.904	0.033		117.991	0.000
	Respondent's user type	0.412	0.020	0.149	20.364	0.000
	Width	0.272	0.009	0.224	30.650	0.000

a. Dependent Variable: Score

Table 6.28. Model 1d: coefficient analysis.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	2.662	0.016		167.127	0.000
	Respondent's user type	0.936	0.016	0.322	57.809	0.000
	Number of users	-0.067	0.001	-0.382	-68.626	0.000

a. Dependent Variable: Score

Analysing standardised coefficients for each of the base models provided the following conclusions regarding the strength of predictors (independent variables).

For path width base model, based on the value of standardized coefficients, path width is a stronger predictor (0.224) than user type (0.149).

For volume of users base model, total number of users was a stronger predictor (-0.382) than user type (0.322).

Models: Path Width (1c) and Volume of Users (1e)

In order to establish whether adding the sub-variables to path width and volume of users base models was going to increase their strength, two more models were developed. However, as shown in Tables 6.29 and 6.30, the R Square values remained similar to models 1b and 1d and equalled 0.076 and 0.269 respectively. Hence, despite adding more independent variables (type of passer-by to base path width model and flow direction, number of cyclists and number of pedestrians to volume of users base model), the strength was affected only slightly.

Table 6.29. Model 1c summary.

Model Summary

Model	R	R Square	Std. Error of the Estimate
1	0.276[a]	0.076	1.278

a. Predictors: (Constant), passer-by type wheelchair user, respondent's user type, width, passer-by's type pedestrian

Table 6.30. Model 1e summary.

Model Summary

Model	R	R Square	Std. Error of the Estimate
1	0.518[a]	0.269	1.186

a. Predictors: (Constant), flow direction, number of cyclists, user type, number of pedestrians

Despite low R Square values suggesting that the models are not a good fit for the data, the coefficients were reviewed (as was done for path width and volume of users base models).

Tables 6.31 and 6.32 provide the summary.

Table 6.31. Model 1c: unstandardized and standardized coefficients.

Coefficients[a]

Model	Unstandardized Coefficients	Standardized Coefficients	T	Sig.

		B	Std. Error	Beta		
1	(Constant)	4.021	0.038		105.206	0.000
	Respondent's user type	0.410	0.020	0.148	20.315	0.000
	Width	0.253	0.009	0.209	27.489	0.000
	Passer-by type pedestrian	-0.012	0.023	-0.004	-0.521	0.602
	Passer-by type wheelchair user	-0.183	0.025	-0.060	-7.232	0.000

a. Dependent Variable: Score

Table 6.32. Model 1e: unstandardized and standardized coefficients.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	T	Sig.
1	(Constant)	2.883	0.018		156.812	0.000
	User type	0.928	0.016	0.319	58.022	0.000
	Number of cyclists	-0.143	0.004	-0.215	-38.602	0.000
	Number of pedestrians	-0.058	0.001	-0.306	-54.972	0.000
	Flow direction	-0.203	0.015	-0.073	-13.267	0.000

a. Dependent Variable: Score

For Path Width (model 1c) the predictors ranked (from the strongest to the weakest) as follows: path width (0.209), respondent's user type (0.148), passer-by's user type (wheelchair user) (-0.060) and passer-by's user type (pedestrian) (-0.004). Passer-by's user type (cyclist) was excluded by SPSS because, as a predictor, it was already contained in or was redundant with other predictors.

For volume of users (model 1e) the predictors ranked (from the strongest to the weakest) as follows: respondent's user type (0.319), number of pedestrians (-0.306), number of cyclists (-0.215) and flow direction (-0.073).

Hence, linear regression worked to establish the strength of predictors for the base combined, combined, path width and volume of users base models and path width and volume of users models. However, only the combined model had an R Square value high enough to consider the model development. It confirmed that individually path width and volume of users (and related sub-variables) have little impact on the comfort scores. It is only when those variables (and sub-variables) are combined together, they become relevant.

Ordinal regression

Considering the ordinal nature of dependent variable, ordinal regression was done with the purpose of developing better fitting models for path width and volume of users and additional (potentially better fitting) model for combined predictors, which could be used for predicting comfort scores in the future. All the models were developed according to the same analytical procedure, as described below and can been seen on the example of model 2 (below) (for tables please see Appendix 3).

The model fitting information for all models (See Appendix 3) showed the significance value p=0.000. The statistically significant chi-square statistic (*p<.0001*) showed that the model gave a significant improvement over the baseline intercept-only model; which meant that the model gave better predictions than what would be based on the marginal probabilities for the outcome categories (National Centre for Research Methods, 2011).

The goodness of fit of the model describes how well the model fits the observations. The significance value was p=0.000 for all models, which meant that the data did not fit the models particularly well (See Appendix 3). However, chi-square is a test that is very sensitive to missing cells and large sample sizes; both of these occurred in the data set and could have affected the result of Goodness-of-fit analysis (National Centre for Research Methods, 2011). Hence, it was decided to rely on Pseudo R^2, which is a measure of association, to establish the goodness of fit (National Centre for Research Methods, 2011).

The test of parallel lines tests the proportional odds assumption. In other words it checks that '*the correlation between independent variable and dependent variable does not change for dependent variable's categories, also parameter estimations do not change for cut-off points'* (Ari and Yildiz, 2014, p10). For each model developed (2, 2a, 2b, 2c, 2d, 2e), the result of the parallel lines test showed significance p= 0.000 (See Appendix 3), meaning that the dependent variable's (comfort score) categories were not parallel with each other. However, in this study, the equal distance between each of the comfort scores is not of primary concern and hence, does not affect the conclusions drawn from the model itself.

The sections below highlight the values of the Nagelkerke R Square (which indicates how well the data fits the model) and the parameter estimates analysis (which allows one to rank the strength of predictors). In the parameter estimates analysis, the threshold column represents the response variable: the threshold estimate is the cut-off value. For example, the threshold estimates for [Score = 1] is the cut-off value between very uncomfortable (1) and uncomfortable (2) score and the threshold estimate for [Score = 2] represents the cut-off value between uncomfortable (2) and slightly uncomfortable (3) score. Of particular interest for this study were estimates for predictors.

Model 2 Base Model (path width, number of users, user type of respondent)

The Nagelkerke R^2=0.51 which means that 51% of variance in the outcome was explained by the variables: hence, the model developed had value. This means that the base model developed by the ordinal regression is of similar strength (1.5% more) as the base combined linear model (model 1).

Table 6.33 shows the parameter estimates for the model. All the estimates were statistically significant, with p= 0.000.

Based on the results shown in Table 6.39, if the respondent was a pedestrian (user types were coded 0 for cyclist and 1 for pedestrian) their ordered log-odds of rating their comfort score higher (by 1) would increase by 1.01 while the other variables in the model were held constant. A one unit increase in path width would result in a 0.61 unit increase in the ordered log-odds of rating comfort higher by the one score and one unit increase in total number of users would result in a 0.20 unit decrease in the ordered log-odds of rating comfort higher by the one score. It also confirmed that increase in path width has a positive impact on comfort rating, while an increase in the total number of users has a negative impact.

Table 6.33. Model 2: parameter estimates.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Threshold	[Score = 1]	-0.736	0.047	241.370	1	0.000	-0.829	-0.643
	[Score = 2]	0.419	0.046	83.342	1	0.000	0.329	0.509
	[Score = 3]	1.169	0.046	648.692	1	0.000	1.079	1.259
	[Score = 4]	1.677	0.046	1305.941	1	0.000	1.586	1.768
	[Score = 5]	2.746	0.049	3195.031	1	0.000	2.650	2.841
Location	Respondent's user type	1.008	0.020	2504.113	1	0.000	0.968	1.047
	Width	0.606	0.013	2065.131	1	0.000	0.580	0.633

Number of users	-0.200	0.002	15275.550	1	0.000	-0.203	-0.197

Link function: Logit.

Model 2a Combined Model

The Nagelkerke R^2=0.586, which suggests that 59% of variance in the outcome is explained by the variables, meaning that the model developed had value. The model developed by the ordinal regression is of similar strength to (1% less than) the combined linear model (1a).

Table 6.34 shows the parameter estimates for the model. All the results were statistically significant, with p= 0.000.

Based on the estimates shown in Table 6.34, if the respondent was a pedestrian their ordered log-odds of rating their comfort score higher (by 1) would increase by 1.10 while the other variables in the model were held constant. A one unit increase (0.5m) in path width would result in a 0.45 unit increase in the ordered log-odds of rating comfort higher by the one score. A change in flow direction from ‘front’ to ‘front-back’ would result in 0.42 decrease.

The impact of increase in number of pedestrians and cyclists was: one unit increase in number of cyclists would result in a 0.23 unit decrease in the ordered log-odds of rating comfort higher by the one score; one unit increase in number of pedestrians would result in a 0.10 unit decrease in the ordered log-odds of rating comfort higher by the one score.

As far as the type of the passer-by was concerned, the following was found: presence of passer-by cyclist would result in a 0.50 unit increase in the ordered log-odds of rating comfort higher by the one score; of passer-by pedestrian in 0.39 unit increase and of both cyclists and pedestrians in 2.48 decrease.

Table 6.34. Model 2a: parameter estimates.

Parameter Estimates

							95% Confidence Interval	
		Estimate	Std. Error	Wald	Df	Sig.	Lower Bound	Upper Bound
Threshold	[Score = 1]	-1.887	0.054	1235.276	1	0.000	-1.992	-1.782
	[Score = 2]	-0.646	0.052	151.978	1	0.000	-0.748	-0.543

	[Score = 3]	0.253	0.052	24.133	1	0.000	0.152	0.354
	[Score = 4]	0.886	0.051	297.581	1	0.000	0.786	0.987
	[Score = 5]	2.185	0.053	1704.191	1	0.000	2.081	2.289
Location	Respondent's user type	1.104	0.020	2951.188	1	0.000	1.064	1.143
	Width	0.446	0.014	962.001	1	0.000	0.418	0.474
	Number of cyclists	-0.227	0.006	1308.797	1	0.000	-0.239	-0.215
	Number of pedestrians	-0.102	0.002	2826.176	1	0.000	-0.106	-0.099
	Flow direction	-0.416	0.025	275.512	1	0.000	-0.465	-0.367
	Passer-by type pedestrian	0.392	0.038	105.002	1	0.000	0.317	0.467
	Passer-by cyclist	0.499	0.038	175.534	1	0.000	0.425	0.572
	Passer-by type pedestrians and cyclists	-2.477	0.054	2082.144	1	0.000	-2.583	-2.370
	Passer-by type wheelchair user	0[a]	.	.	0	.	.	.

Link function: Logit.
a. This parameter is set to zero because it is redundant.

Model 2b Base Path Width Model

For Model 2b, the Nagelkerke R^2=0.084. The low R^2 indicated that a model containing only path width and type of the user type of the respondent was likely to be a poor predictor of the outcome for any particular individual respondent. Considering how weak the model turned out, the parameter estimates listed in Table 6.35 were not analysed further.

Table 6.35. Model 2b: parameter estimates.

Parameter Estimates

		Estimate	Std. Error	Wald	Df	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Threshold	[Score = 1]	-2.041	0.066	957.759	1	0.000	-2.170	-1.911
	[Score = 2]	-0.894	0.054	278.407	1	0.000	-0.999	-0.789
	[Score = 3]	-0.010	0.050	0.042	1	0.839	-0.109	0.088
	[Score = 4]	0.539	0.050	116.914	1	0.000	0.441	0.637
	[Score = 5]	1.764	0.051	1176.494	1	0.000	1.664	1.865

Location	Respondent's user type	0.534	0.031	302.551	1	0.000	0.474	0.594
	Width	0.449	0.014	1052.222	1	0.000	0.421	0.476

Link function: Logit.

Model 2c Path Width

For model 2c, despite adding additional independent variables (specifically type of the passer-by), the Pseudo R square was still very low. The Nagelkerke R^2=0.087, indicating that a model containing only path width and type of passer-by was likely to be a poor predictor of the outcome for any particular individual respondent: hence it was not considered further. Parameter estimates highlighted in Table 6.36 were not analysed further.

Table 6.36. Model 2c: parameter estimates.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Threshold	[Score = 1]	-1.937	0.067	828.161	1	0.000	-2.069	-1.805
	[Score = 2]	-0.789	0.055	203.832	1	0.000	-0.897	-0.681
	[Score = 3]	0.097	0.052	3.424	1	0.064	-0.006	0.199
	[Score = 4]	0.647	0.052	156.111	1	0.000	0.545	0.748
	[Score = 5]	1.875	0.053	1231.500	1	0.000	1.770	1.980
Location	Respondent's user type	0.535	0.031	302.115	1	0.000	0.474	0.595
	width	0.424	0.014	883.798	1	0.000	0.397	0.452
	Passer-by type pedestrian	0.285	0.038	56.528	1	0.000	0.211	0.359
	Passer-by type cyclist	0.246	0.037	44.738	1	0.000	0.174	0.318
	Passer-by type pedestrian cyclist	0[a]	.	.	0	.	.	.
	Passer-by type wheelchair user	0[a]	.	.	0	.	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

Model 2d Base Model for Volume of Users

The Pseudo R-Square value (Nagelkerke) equalled 0.289: 29% of the variance in the outcome was explained by the predictors. Hence, the model was stronger than path width linear and ordinal regression models, and also stronger than volume of users linear model.

Based on the estimates shown in Table 6.37, if the respondent was a pedestrian their ordered log-odds of rating their comfort score higher (by 1) would increase by 1.51 while the other variables in the model are held constant. A one unit increase (1 user) in total number of users sharing the path would result in a 0.12 unit decrease in the ordered log-odds of rating comfort higher by the one score.

Table 6.37. Model 2d: parameter estimates.

Parameter Estimates

		Estimate	Std. Error	Wald	Df	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Threshold	[Score = 1]	-1.190	0.027	1928.962	1	0.000	-1.243	-1.137
	[Score = 2]	0.075	0.026	8.233	1	0.004	0.024	0.126
	[Score = 3]	0.983	0.028	1270.319	1	0.000	0.929	1.037
	[Score = 4]	1.705	0.031	3097.607	1	0.000	1.645	1.765
	[Score = 5]	3.207	0.046	4831.092	1	0.000	3.117	3.297
Location	Number of users	-0.121	0.002	4323.170	1	0.000	-0.125	-0.118
	Respondent's user type	1.513	0.027	3171.183	1	0.000	1.460	1.565

Link function: Logit.

Model 2e Volume of Users

The Pseudo R-Square value (Nagelkerke) equalled 0.309: 31% of the variance in the outcome was explained by the predictors. Hence, including more independent variables within the ordinal regression model did not strengthen it (2% increase).

Table 6.38 shows the parameter estimates for the model. All the results are statistically significant, with p= 0.000.

Based on the estimates shown in Table 6.38, if the respondent was a pedestrian their ordered log-odds of rating their comfort score higher (by 1) would increase by 1.52 while the other variables in the model are held constant. A one unit increase (1 cyclist) in total number of cyclists would result in a 0.24 unit decrease and 1 unit increase (1 pedestrian) in total number of pedestrians would result in 0.11 decrease in the ordered log-odds of rating comfort higher by the one score. Change in flow direction from ‘Front’ (0) to ‘Front-Back’ results in 0.426 unit decrease in the ordered log-odds of rating comfort higher by the one score.

Table 6.38. Model 2e: parameter estimates.

Parameter Estimates

							95% Confidence Interval	
		Estimate	Std. Error	Wald	Df	Sig.	Lower Bound	Upper Bound
Threshold	[Score = 1]	-1.596	0.032	2499.924	1	0.000	-1.659	-1.534
	[Score = 2]	-0.301	0.030	99.049	1	0.000	-0.360	-0.242
	[Score = 3]	0.625	0.031	402.575	1	0.000	0.564	0.686
	[Score = 4]	1.356	0.034	1622.825	1	0.000	1.290	1.422
	[Score = 5]	2.868	0.048	3566.447	1	0.000	2.774	2.962
Location	Respondent’s user type	1.522	0.027	3188.231	1	0.000	1.469	1.575
	Number of cyclists	-0.238	0.006	1392.393	1	0.000	-0.251	-0.226
	Number of pedestrians	-0.108	0.002	2983.186	1	0.000	-0.112	-0.104
	Flow direction	-0.426	0.025	283.125	1	0.000	-0.475	-0.376

Link function: Logit.

6.9.10 Under what circumstances can an unsegregated shared-use work?

While the analysis of comfort ratings for multiple variables and sub-variables (path width, volume of users, user type of passer-by, flow direction) provided a better insight and understanding of comfort perceptions and the models developed highlighted the significance of each of them to comfort score and can be used to predict comfort scores in the future, their practical application remained limited, unless it was established under what circumstances can unsegregated shared-use path work.

Two approaches were adopted in order to make an assessment. The first one assumed that the key for establishing when unsegregated shared-use would work is cyclists and pedestrians perceiving their experience on the positive side of the comfortable spectrum. Hence, the mid-point (3.5) was set in the scale used for the comfort ratings: whenever average scores were equal to or above 3.5, shared-use would work. The second approach assumed that the shared-use would work as long as cyclists and pedestrians were willing to use it. Therefore, it relied on the responses to the survey question, which was a part of Stage 2 of data collection (see Section 6.6).

These assumptions were put in the context of scenarios and average comfort scores in specific conditions (path width and volume of users).

Establishing comfort thresholds: comparison between cyclists and pedestrians

Figures 6.23 and 6.24 present pedestrians' average comfort scores for path width scenarios and volume of users scenarios put in the context of comfort threshold. Figures 6.25 and 6.26 represent the same variables, just from the perspective of cyclists.

The comfort threshold was marked on a figure as a straight horizontal line f(x) = a, where a equalled 3.5.

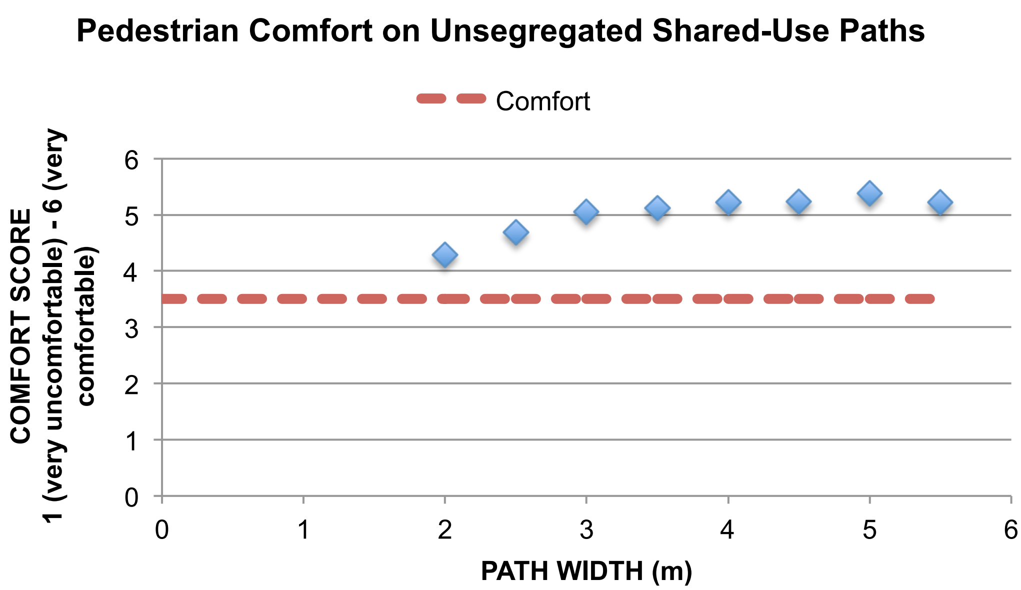


Figure 6.23. Pedestrians' average comfort scores on different path widths on unsegregated shared-use paths, in the context of comfort threshold.

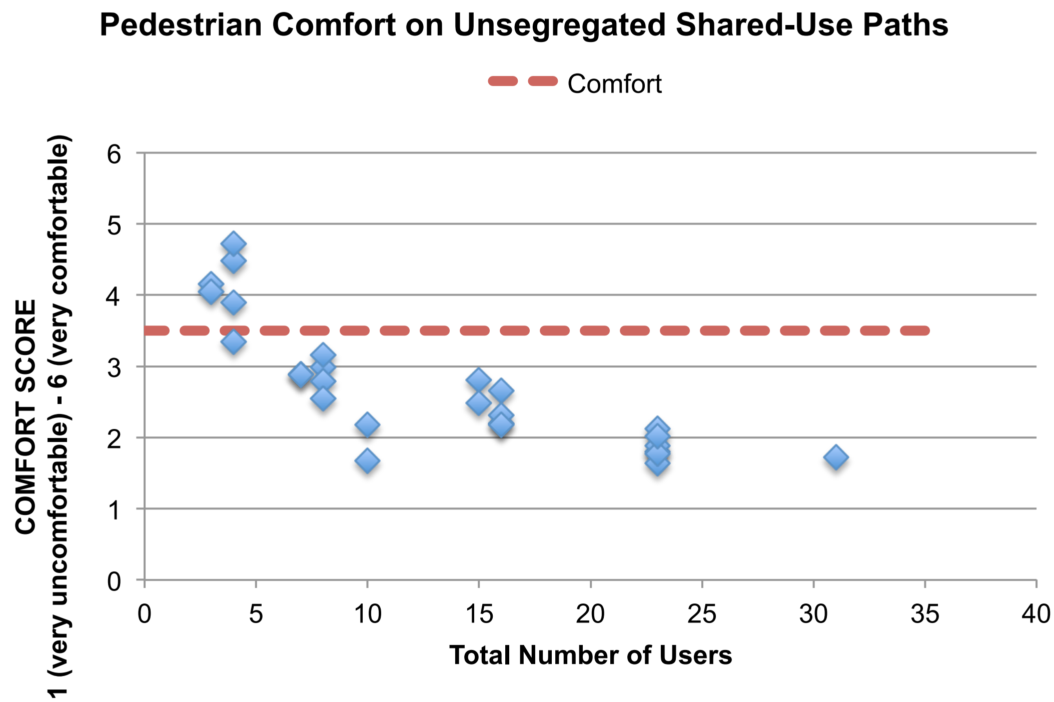


Figure 6.24. Pedestrians' average comfort scores on unsegregated shared-use paths with different total number of users, in the context of comfort threshold.

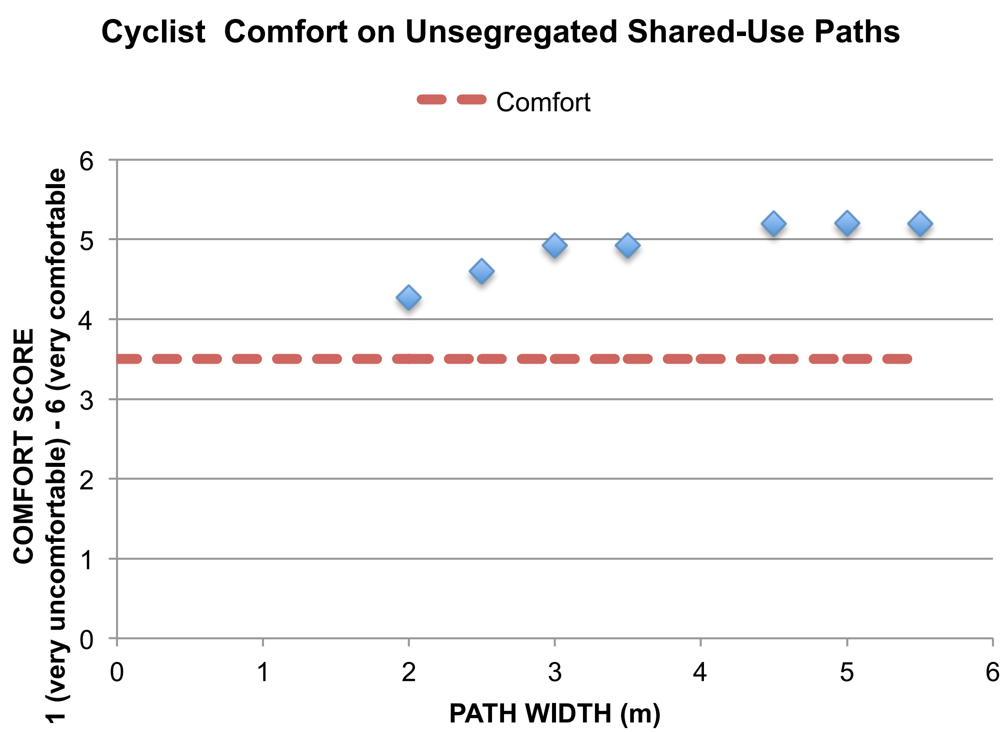


Figure 6.25. Cyclists' average comfort scores on different path widths on unsegregated shared-use paths, in the context of comfort threshold.

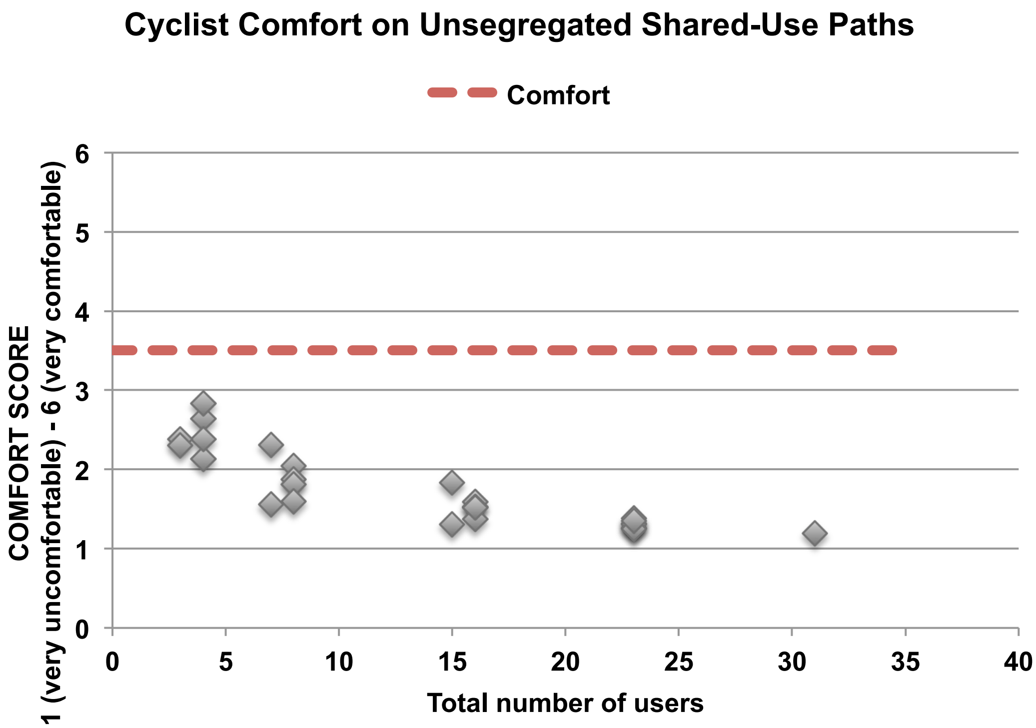


Figure 6.26. Cyclists' average comfort scores on unsegregated shared-use paths with different total number of users, in the context of comfort threshold.

For pedestrians, all scenarios with differing path width were within the threshold to be on the positive side of comfortable spectrum when using the unsegregated shared-use path (Figure 6.23). The same was observed for cyclists (Figure 6.25). Hence, this suggests that as long as the conditions on the path are very low density (approximately 0.1 user per m^2), cyclists and pedestrians are comfortable sharing, keeping in mind that previous analysis showed that if the path width is narrow (3.5m or lower) then the drop of comfort score according to (decrease of) the width is sharper than wider widths.

However, when the total number of users on the unsegregated shared use path was increased (Figures 6.24 and 6.26), the situation changed. For pedestrians, the unsegregated shared-use still worked when the number of users (cyclists and pedestrians) was below five (density below 0.4 user per m^2) on a 3m path width.

For cyclists, on the other hand, if their comfort is the main criteria, shared-use did not work in any circumstance where total number of users was above two (with a 3m path width).

However, it should be considered that in some circumstances (especially in the urban setting), pedestrians and cyclists might value other factors, such as convenience, journey time, route directness, more than their comfort. Hence, another, alternative assessment, based on willingness to use unsegregated shared-use was established below.

Willingness to use unsegregated shared-use paths: comparison between cyclists and pedestrians

Figures 6.27 and 6.28 present pedestrians' average comfort scores for path width scenarios and volume of users scenarios put in the context of an average comfort score below which pedestrian would consider looking for an alternative route (assuming that shared use path is the shortest and most direct way). Figures 6.29 and 6.30 represent the same variables, just from the perspective of cyclists.

The willingness to use unsegregated shared-use was marked on a figure as a straight horizontal line f(x) = a, where 'a' was an average comfort score respondents identified as their threshold. The purple line represents the case when the unsegregated shared-use path makes up more than 90% of the route and the orange line when less than 25% of the route.

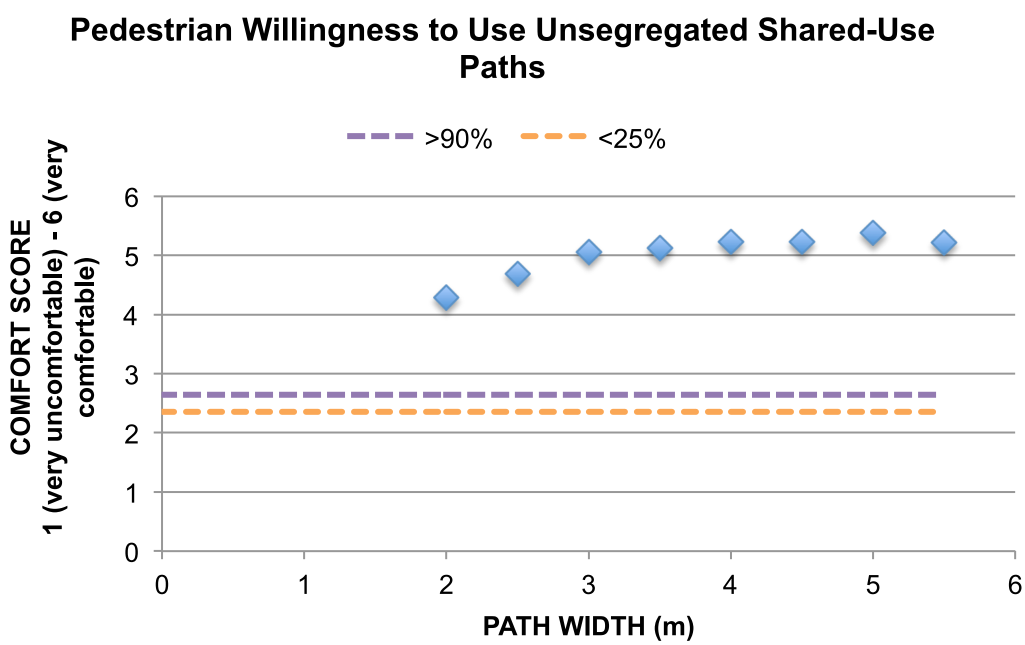


Figure 6.27. Pedestrians' willingness to use unsegregated shared-use paths, in the context of different path widths.

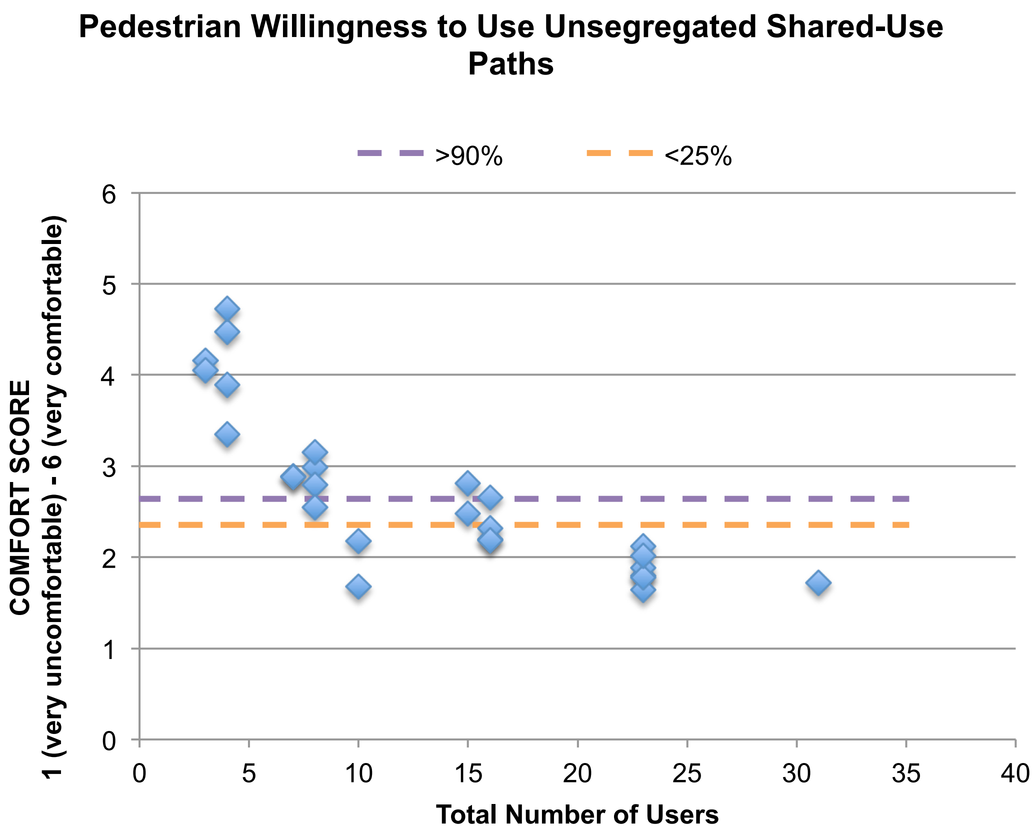


Figure 6.28. Pedestrians' willingness to use unsegregated shared-use paths, in the context of different total numbers of users.

For pedestrians, the threshold for looking for alternative route fell into the 'uncomfortable' level when an unsegregated shared-use path made up more than 90% and 'slightly uncomfortable' when it constituted for less than 25% of the route. This means that if the pedestrians felt below 'uncomfortable' and 'slightly uncomfortable' on the comfort scale for each one respectively, they would start considering using another route.

Similarly to comfort thresholds in the section above, all scenarios with differing path width were within the comfort threshold to use the unsegregated shared-use path. However, when the total number of users on the unsegregated shared use path was increased, the situation changed. As visible on the Figure 6.28, pedestrians would be willing to use the path up until the level of users reflected in scenario HV/JV (eight users) when the unsegregated shared-use path made up over 90% and up to level reflected in scenario GV/GVB (15 users) when the unsegregated shared-use path made up under 25%.

The exception was scenarios with total number of users equalling 10, which scored below the threshold of willingness to use the unsegregated shared-use path. However, these scenarios (NV and NVB) had a particularly high proportion of cyclists (80%) among all users.

As shown in Figures 6.29 and 6.30, for cyclists, the threshold for looking for alternative route fell into 'slightly uncomfortable' level, for both situations (when an unsegregated shared-use path made up more than 90% and less than 25% of the route). This means that if the cyclists felt below 'slightly uncomfortable' on the comfort scale, they would start considering using another route.

The average comfort ratings for all of the scenarios with varying path widths were within the threshold of willingness to use the unsegregated shared-use path. This means that in each of those scenarios, cyclists would continue to use the path and not look for alternatives. In contrary, all the scenarios with varying total number of users fell below the cyclists threshold, suggesting that of the volume of users is any higher, the cyclists would consider alternative routes instead of sharing.

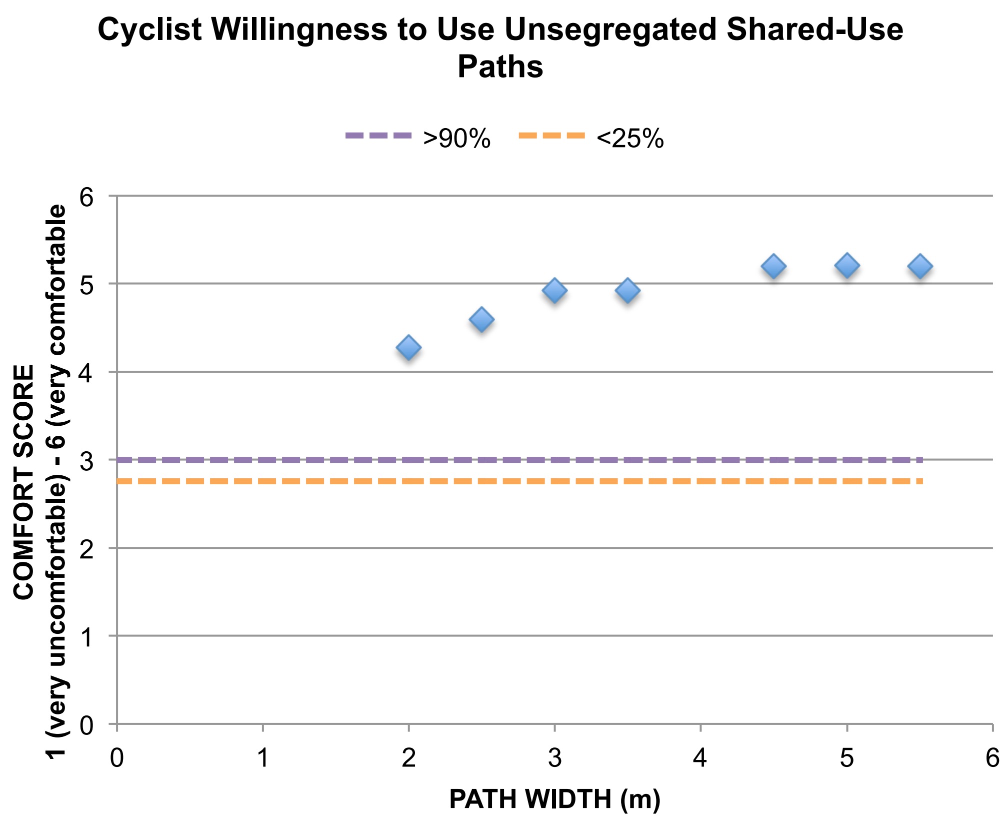


Figure 6.29. Cyclists' willingness to use unsegregated shared-use paths, in the context of different path widths.

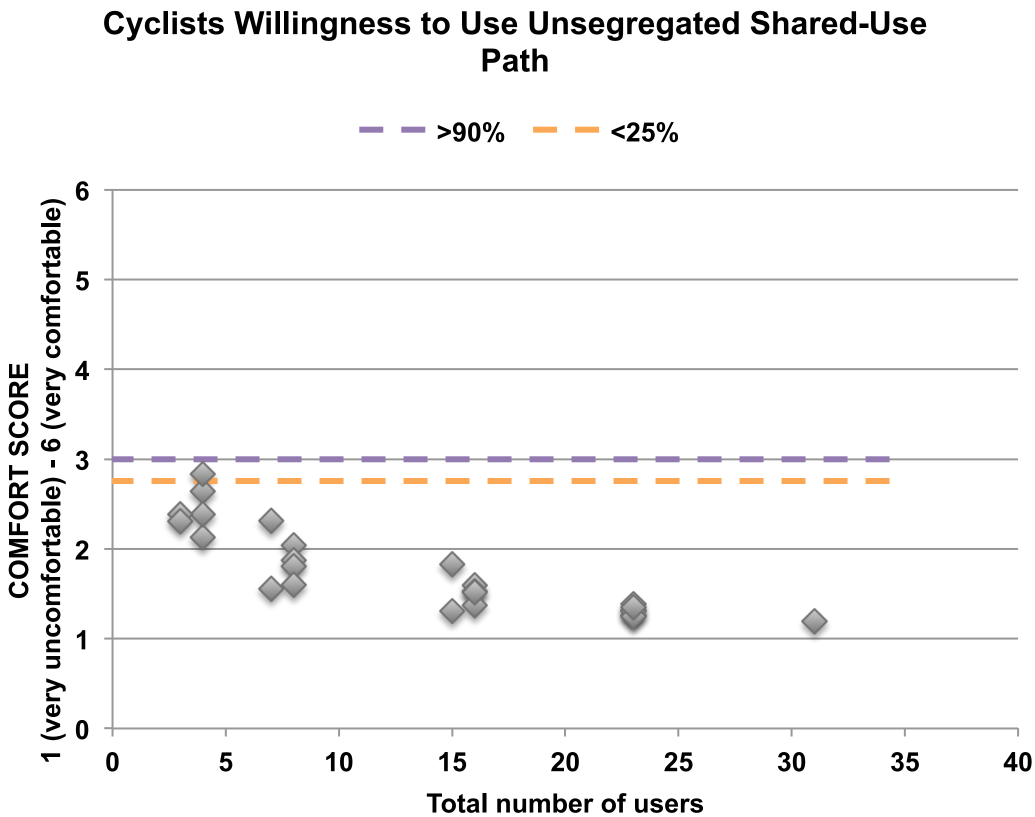


Figure 6.30. Cyclists' willingness to use unsegregated shared-use paths, in the context of different volumes of users.

6.9.11 Sensitivity analysis (application of model to reality)

Twelve models were developed using linear and ordinal regressions: Table 6.39 provides a summary of each model, including variables and R^2 and pseudo R^2 values.

Table 6.39. Summary of developed models.

	MODEL	VARIABLES	R^2 /PSEUDO R^2
LINE	Base Model 1 (Combined)	Path width, Number of users, User type of the respondent	0.49
	Model 1a (Combined)	Path width, Number of cyclists, Number of pedestrians, Direction of traffic flow, User type of the passer-by, User type of respondent	0.61
	Base Model 1b (Path Width)	Path width, User type of respondent	0.07
	Model 1c (Path Width)	Path width, User type of the passer-by, User type of respondent	0.08

A R	Base Model 1d (Volume of Users)	Total number of users, User type of respondent	0.25
	Model 1e (Volume of Users)	Number of cyclists, Number of pedestrians, Direction of traffic flow, User type of the passer-by, User type of respondent	0.27
ORDINAL	Base Model 2 (Combined)	Path width, Number of users, User type of the respondent	0.51
	Model 2a (Combined)	Path width, Number of cyclists, Number of pedestrians, Direction of traffic flow, User type of the passer-by, User type of respondent	0.59
	Base Model 2b (Path Width)	Path width, User type of respondent	0.08
	Model 2c (Path Width)	Path width, User type of the passer-by, User type of respondent	0.09
	Base Model 2d (Volume of Users)	Total Number of Users, User type of respondent	0.29
	Model 2e (Volume of Users)	Number of cyclists, Number of pedestrians, Direction of traffic flow, User type of the passer-by, User type of respondent	0.31

In order to test how the models developed can be applied in practice, further analysis was conducted. It highlighted how different models output different numbers, so allowing a better understanding your models more. For its purpose four situations were created, as summarised in Table 6.40.

Scenario 1 considered a new unsegregated shared-use path in an urban area (medium density of users, approximately 1.2 users per m^2). The shared-use was considered, as the route was previously a pedestrian footway: however, it was also a convenient link for cyclists, who used it despite the restrictions. The volumes of cyclists were quite high, but pedestrians dominated the space. The path was expected to be two-way, with the person passing other users moving from front and back. The first consideration was the recommended minimum width for unsegregated shared use (Department for Transport, 2012a), which equals 3m. After more funding became available, it was considered to widen the path to 4.5m, which was explored in Scenario 2.

Scenarios 3 and 4 considered conditions on an existing unsegregated shared-use path, located on Queen Street (between Cannon Street and Queen Victoria Street) in City of London. The path is approximately 12m wide (which is above the range of path widths explored in this research). The total number of users, cyclists and pedestrians were assumed based on observation during AM peak (scenario 3) and off-peak (scenario 4).

Scenario 5 was included as an extreme example of a very wide path with low density of users.

Table 6.40. Summary of developed models.

Scenario	Path width (m)	Total number of users	No of pedestrians	No of cyclists	Type of passer-by pedestrian	Type of passer-by cyclist	Type of passer-by wheelchair user	Type of passer-by pedestrian and cyclist	Flow direction	User type of respondent
1	3	16	12	4	1	1	0	1	FB*	P**
2	4.5	16	12	4	1	1	0	1	FB	P
3	13	37	25	12	1	1	0	1	FB	C***
4	13	21	19	2	1	1	0	1	FB	C
5	12	6	4	2	1	1	0	1	FB	P

* Front- Back
** Pedestrian
*** Cyclist

As shown in the calculations below, the predicted comfort scores dropped once more variables were included in the model (model 1 compared to model 1a).

Model 1

Comfort Score = *2.639 + 0.724*(Respondents User Type, 0 = cyclist, 1 = pedestrian) + 0.487*(Path Width) + (-0.142) *(Total Number of Users)*

Scenario 1

Comfort Score = *2.639 + 0.724*1 + 0.487*3 - 0.142*16 = 4.824 – 2.272 = 2.552 =* ***2.6***

Scenario 2

Comfort Score = *2.639 + 0.724*1 + 0.487*4.5 - 0.142*16 = 5.5725 – 2.272 =* ***3.3***

Scenario 3

Comfort Score = *2.639 + 0.724*0 + 0.487*12 + (-0.142) *37 = 2.639 + 5.844 – 5.254 =* ***3.2***

Scenario 4

Comfort Score = *2.639 + 0.724*0 + 0.487*12 + (-0.142) *21 = 2.639 + 5.844 – 2.982 =* ***5.5***

Scenario 5

Comfort Score = *2.639 + 0.724*1 + 0.487*12 + (-0.142) *6 = 2.639 +0.724 + 5.844 – 0.852 =* ***8.4***

Model 1a

Comfort Score = *5.811 + 0.710*(Respondents User Type, 0 = cyclist, 1 = pedestrian) + 0.251*(Path Width) + (-0.143)*(Number of Cyclists) + (-0.058)*(Number of Pedestrians) + (-0.210)*(Flow Direction, 0 = front, 1 = front back) + (-1.855)*(Passer-by's User Type Pedestrian) + (-1.746)*(Passer-by's User Type Cyclist) + (-2.074)*(Passer-by's User Type Wheelchair User)*

Scenario 1

Comfort Score = *5.811 + 0.710*1 + 0.251*3 - 0.143*4 - 0.058*12 - 0.210*1 - 1.855*1 -1.746*1 = 6.521 + 0.753 – 0.572 – 0.696 – 0.210 – 1.855 – 1.746 = 2.195 =* ***2.2***

Scenario 2

Comfort Score = *5.811 + 0.710*1 + 0.251*4.5 - 0.143*4 - 0.058*12 - 0.210*1 - 1.855*1 - 1.746*1=6.521 + 1.1295 – 0.572 – 0.696 – 0.210 – 1.855 – 1.746 = 2.5715 =* ***2.6***

Scenario 3

Comfort Score = *5.811 + 0.710*0 + 0.251*12 + (-0.143) *12 + (-0.058) *25 +(-0.210)*1 + (-1.855)*1 + (-1.746)*1 + (-2.074)*0 = 5.811 + 3.012 – 1.716 – 1.45 – 0.210 – 1.855 – 1.746 =* ***1.8***

Scenario 4

Comfort Score = *5.811 + 0.710*0 + 0.251*12 + (-0.143) *2 + (-0.058) *19 +(-0.210)*1 + (-1.855)*1 + (-1.746)*1 + (-2.074)*1 = 5.811 + 3.012 – 0.286 –1.102 –0.210 –1.855 – 1.746 =* ***3.6***

Scenario 5

Comfort Score = *5.811 + 0.710*1 + 0.251*12 + (-0.143) *2 + (-0.058) *4 +(-0.210)*1 + (-1.855)*1 + (-1.746)*1+ (-2.074)*0 = 5.811 + 0.710 + 3.012 - 0.286 -0.232 – 0.210 – 1.855 – 1.746 =* ***5.2***

Sensitivity analysis also indicated that in some scenarios, in particular when path width is very high and number of users is low (in this case Scenario 5, when Model 1 was applied) that the obtained comfort score can exceed the applied Likert scale. This will typically happen in situations when there is sufficient width to accommodate users comfortably or consider segregation. This was expected as the linear model was used: such outcome was accepted for the benefit of simplicity. Using ordinal regression model would have deterred potential users.

6.10 Conclusions and Implications / Applications

After Stage 1 of data collection identified path width and volume of users as path characteristics of interest for further study, Stage 2 of data collection aimed to answer research questions focused on their impact on perceptions of comfort of cyclists and pedestrians (See Section 4.3 for research questions). Also further sub-variables (flow direction, user type of passer-by) were explored.

The hypothesis was based on the literature review, and considering that all variables researched were identified in the past as having an impact on users' comfort (apart from the wheelchair user as the type of passer-by), it was expected that all those path characteristics would impact comfort score: the aim was to establish trends quantitatively.

6.10.1 Results

Overall, the results of Stage 2 of data collection built on the framework and findings established in Stage 1 (Chapter 5). Stage 1 identified path characteristics for further investigation and general trends while Stage 2 of data collection quantified them and provided further insights on sub-variables not explored in Stage 1 but identified through literature review (such as flow direction and user type of the passer-by).

Path width

This research found that in the conditions of low density (0.1 user per m^2), the overall (cyclists and pedestrians) average comfort scores varied between 'slightly comfortable' and 'comfortable' (see Figure 6.4). It was observed that there is a threshold at approximately 3.5m: the steepest increase in comfort was noticeable as the path width increased from 2m until 3.5m, after reaching this threshold average comfort scores remained almost constant. This finding was similar to the observation from Stage 1 of data collection, where (see Figure 5.14) the comparison was made how cyclists and pedestrians respond to different levels of path widths (narrow, medium, wide). A larger drop was observed in comfort ratings between medium and narrow path, than medium and wide path.

In contrary to Kang et al. (2013), which was another study that considered path width as a variable in developing LOS for unsegregated shared-use, the impact of path width proved less significant in determining perceived level of service than expected (as a variable on its own). However, it was confirmed that path width does play a role but more in context of volume of users variable (referred to by Kang et al. as pedestrian and bicycle flow). Botma (1995) also considered path width; however, the thresholds he established related more to path width in the context of hindrance and hence are not comparable.

While some PLOS tools used path width as a variable (Gallin, 2001; Mori, 1987), the fact that only pedestrian flow was considered and different approach was adopted, resulted in different conclusions. Gallin's (2001) approach was based on assigning points for different characteristics, which were then added up to reveal to final score, which was translated to LOS: path widths considered varied from 0-1m (1point), 1.1-1.5m (2 points), 1.6-2m (3 points) and more than 2m (4 points). Considering that these are below the path widths considered in this study, they are not comparable. Mori's (1987) approach was slightly more similar to the results of this study: he considered path widths between 2-4.5m and in the conditions of low pedestrian density (between 0.1 and 0.2 pedestrians per m^2) they all classified as LOS A (very good).

Volume of users / Density

In the conditions of a set 3m path width, where the total number of users varied from three to 23 (user densities from 0.2 user per m^2 to 1.7 user per m^2), all the average ratings (combined cyclists and pedestrians) equalled between 'uncomfortable' and 'slightly comfortable' (see Figure 6.5). The majority of ratings fell within the category of 'slightly uncomfortable'. The relationship was linear with a sharp decrease in comfort between very low total number of users (density of 0.1 user per m^2) and the total number of users equal approximately 7 (density of 0.5 user per m^2). After this threshold was reached, the comfort score remained fairly constant. Similarly to path width, this finding was in line with what was observed in Stage 1 of data collection (Figure 5.16), where for all cyclists and pedestrians a larger drop in comfort rating was observed between low and medium volume of users, than medium and high volume of users.

These findings can be put in the context of some of the research quoted in '*Evaluation of Safety, Design and Operation of Shared-Use Paths'* (FHWA, 2006), which stated that for bicycles, 0.1 bicycles per m^2 provided free flow conditions (Navin, 1994) and that with 0.1 bicycles per m^2 the cycling conditions were very comfortable, while density of 0.5 bicycles per m^2 forced cyclists to dismount (Yang, 1985). Interestingly, the similarities in thresholds were observed, even though the unit was different: in this study 'path user' refers to either cyclist or pedestrian.

User's characteristics

The user type of the respondent (pedestrian or cyclist) had a significant impact on average comfort ratings, both for different path widths and different total numbers of users. The user's gender was not significant in the majority of cases, and therefore the differences between males and females were not considered further (see Table 6.9).

User type of passer-by and flow direction

Kang et al. (2013) stated that *'bicycles clearly have a strong negative impact on pedestrian perceptions of LOS'* (p19). Interestingly, considering shared-use paths from the perspective of both cyclists and pedestrians proved that thresholds for sharing are higher among pedestrians than cyclists.

In the conditions where volume of users was higher (medium-high density), pedestrians were more comfortable than cyclists with sharing the space with other user types. The proportion of cyclists among the users did not impact on that.

Pedestrians were also more comfortable than cyclists in each of the scenarios where the passer-by user was a pedestrian or a wheelchair user. Cyclists were more comfortable than pedestrians in the scenarios where the passer-by was a cyclist.

The type of passer-by and the direction of user flow proved to have a statistically significant impact on comfort scores. However, the differences in average scores related to those sub-variables were not substantial.

6.10.2 Model development

Twelve models were developed using linear and ordinal regression. Based on the R^2 and pseudo R^2 values, models varied from relatively strong (models 1, 1a, 2 and 2a), which considered a combination of path width and volume of users variables (and related sub-variables) and explained approximately 50-60% of the variance in the comfort scores can be predicted from the predictors. Due to smaller data sets and lower number of variables, volume of users (model 1d, 1e, 2d, 2e) and path width (1b, 1c, 2b and 2c) based models, were weaker, with R^2 and pseudo R^2 varying between 0.07 and 0.31.

In fact, looking at the Table 6.39, it can be noticed that inclusion of a certain variables helped R^2 improvement. Path width and related sub-variables (type of a passer-by) generated the lowest R^2 values: combining them with volume of users or volume of cyclists and pedestrians and related sub-variables (flow direction), increased the R^2 values. This confirmed the findings of factor analysis conducted in Stage 1 of data collection (see Chapter 5), which concluded that there are three different groups of variables; traffic (which included volume of users, volume of cyclists and volume of pedestrians), environmental characteristics, and path width. These variables were grouped based on correlation of Stage 1 data, which meant that the groups had little correlation between themselves. This suggested that if one regression model developed missed one group of variables, its performance would not have been as good as the one which had that group (which was confirmed by model development in Stage 2 of data collection).

Based on the R^2 and pseudo R^2 values and the number and variety of independent variables, models 1, 1a and 2 and 2a were chosen as the most reliable ones for practical application.

Based on the unstandardized coefficient, the equations are as follows:

Model 1 Comfort Score *= 2.639 + 0.724*(Respondents User Type, 0 = cyclist, 1 = pedestrian) + 0.487*(Path Width) + (-0.142) *(Total Number of Users)*

Model 1a *Comfort Score* *= 5.811 + 0.710*(Respondents User Type, 0 = cyclist, 1 = pedestrian) + 0.251*(Path Width) + (-0.143)*(Number of Cyclists) + (-0.058)*(Number of Pedestrians) +(-0.210)*(Flow Direction, 0 = front, 1 = front back) + (-1.855)*(Passer-by's User Type Pedestrian) + (-1.746)*(Passer-by's User Type Cyclist) + (-2.074)*(Passer-by's User Type Wheelchair User)*

These values of unstandardized coefficients could help practitioners predict how increasing or decreasing one variable can be mitigated, by affecting another. For example, in model 1 if there was a need for increasing the number of (acceptable) users, but the intention was to keep the same comfort score, path width would have to be increased by 0.3*(increase in number of users). Hence, using the model formula, it becomes practically feasible to offset the decrease of comfort due to the number of users by increasing the width.

Based on the values of standardized coefficients, the predictors ranked differently between models 1 and 1a. For model 1 total number of users (-0.610) was the strongest, followed by path width (0.185) and user type of respondent (0.176). Once sub-variables were added, the hierarchy has changed with user type of passer-by being the strongest predictor (Passer-by's User Type Pedestrian (-0.423), Passer-by's User Type Cyclist (-0.381), Passer-by's User Type Wheelchair User Type (-0.327)), followed by number of pedestrians (-0.218), respondent's user type (0.173), number of cyclists (-0.145), path width (0.095) and flow direction (-0.049). Interestingly, adding more sub-variables did not affect the strength of respondent's user type as a predictor (which was the same for both models). This means that other variables were affected due to correlations.

Ordinal regression allowed to establish how one unit change in each variable (assuming the rest of variables is held constant) affected the comfort score. Table 6.41 summarizes the findings, which give practitioners an indication how perceptions of comfort can be affected by change in one variable: in practice, this insight can help understand how to engineer comfort through better designs.

Table 6.41. **The increase in ordered log-odds of rating comfort score higher (by 1) while the other variables in the model were held constant for models 2 and 2a.**

	The increase in ordered log-odds of rating comfort score higher (by 1) while the other variables in the model were held constant	
	Model 2	Model 2a
Respondent's user type (0 = cyclist, 1 = pedestrian)	1.01 increase	1.10 increase
Path width (one unit = 0.5m)	0.61 increase	0.45 increase
Total number of users (per 13.5m^2)	0.20 decrease	n/a
Total number of cyclists (per 13.5m^2)	n/a	0.23 unit decrease
Total number of pedestrians (per 13.5m^2)	n/a	0.10 unit decrease
Flow direction (0 = front, 1 = front back)	n/a	0.42 unit decrease
Passer-by cyclist (0 = none, 1 = if one or more)	n/a	0.50 unit increase
Passer-by pedestrian (0 = none, 1 = if one or more)	n/a	0.39 unit increase
Passer-by pedestrian and cyclist (0 = only pedestrian or only cyclist, 1 = both)	n/a	2.48 decrease

6.10.3 Assessment method

Similarly to other Level of Service tools, this research relied on the use of a six-level comfort scale based on traditional LOS measurement approaches. However, the appropriate number of categories for assessment was questioned before (Kang et al, 2013).

Hence, the consideration was that the main assessment method should lead to the decision whether an unsegregated shared-use path would work or not. Two assessment approaches were established for deciding when unsegregated shared-use would work. Approach 1 was based on comfort and assumed that the key is cyclists and pedestrians perceiving their experience on the positive side of the comfortable spectrum. The threshold was comfort score of 3.5.

Approach 2 was based on the response to survey questions and assumed that the shared-use will work as long as cyclists and pedestrians are willing to use it. The thresholds were distinguished for when unsegregated shared use-path constitutes for less than 25% and over 90% of person's journey. For pedestrians, these equalled 2.6 comfort score (for over 90% of the journey) and 2.4 comfort score (for less than 25%) and for cyclists 3.0 and 2.8 respectively.

In low-density conditions (0.1 users per m^2) within the path width range 2-5.5m, shared-use can work successfully based on both approaches for both cyclists and pedestrians. When the total number of users increases, shared-use paths would not work as well.

For cyclists, when the total number of users increases (assuming that other users are a mix of cyclists and pedestrians) above 0.1 users per m^2, they are below the comfort threshold of 3.5 (based on approach 1) and they would start considering an alternative route to their destination (based on approach 2).

Pedestrians' willingness to share is higher: they are willing to use unsegregated shared-use path when total number of users is up to 15 (density of 1.1 user per m^2). The exception is when proportion of cyclists is very high (80%, for reference see Scenario NV in Table 6.11).

Hence, based on Stage 2 of data collection, for cyclists shared-use does not work when the volume of users increases. This means that from perspective of cyclists, pedestrian cyclist shared-use paths could work in low density circumstances, for example in the countryside where pedestrians are rarely encountered pedestrians or encountered in small numbers. Pedestrians show more tolerance. Hence, for urban settings judgment of acceptability could be based on pedestrian perception (as pedestrians are often referred to as more vulnerable). Such an approach is optional, although not preferable.

Overall, approach 2 for path assessment gives more room for promoting unsegregated-shared use when the volume of users increases. However, while the initial assessment might suggest that shared-use is not a viable option, that is where knowledge from Stage 1 of data collection (Chapter 5) can benefit transport practitioners' decision-making. For example, the cluster analysis based on user personal characteristics can inform, which other path characteristics (such as path maintenance) can compensate for insufficient comfort ratings, depending on user profile.

6.10.4 Key recommendations for guidelines

Comfort thresholds

Currently the main guidance for unsegregated shared-use paths DfT's Local Transport Note '*Shared-used routes for pedestrians and cyclists'* (2012a) states that:

'*a width of 3 metres should generally be regarded as the preferred minimum on an unsegregated route, although in areas with few cyclists or pedestrians a narrower route might suffice. Where a* *significant amount of two-way cycling is expected, additional width could be required. However, the need here for additional width is not clear cut, because the absence of segregation gives cyclists greater freedom to pass other cyclists. It might therefore depend on user flows'.*

It is prominent that the guidance allows for a lot of flexibility and requires a degree of decision-making from the practitioners. This study reviewed these recommendations and provided numerical thresholds from the perspective of cyclists and pedestrians. As it turned out the minimum path width, should be regarded more as a threshold and varies slightly from the perspective of cyclists and pedestrians (3.5m versus 3m respectively). Also, these thresholds work for very low density (0.1 user per m^2). In fact, the width of 3m was explored as the basis of all volume of users scenarios and hence can be treated as a baseline for recommendations (see Section 6.10.4). Also, it was identified that in fact, the flow direction or proportion of cyclists (assuming that cyclists are present) has a small impact on comfort scores, suggesting that the consideration of high numbers (specifically) of two-way cycling in not as important.

Path width

The knowledge that path width itself is likely to be a poor predictor of the outcome for any particular individual respondent can impact the development of design guidelines in the future: right now, the main recommendations for unsegregated shared-use paths (see Section 2.4) revolve around minimum widths. Yet, based on these findings, path width matters only in the context of other characteristics, in particular number of users (user density).

Willingness to use unsegregated shared-use paths

Moreover, this research proved that in certain scenarios, convenience (the unsegregated shared-use path being the fastest and most direct way to reach their destination) is rated more highly than comfort by cyclists and pedestrians. Such a finding is important for regarding unsegregated shared-use paths as a viable option in cities in UK: cyclists and pedestrians can willingly use unsegregated shared space for minor or major part of their journey (before considering an alternative) as long as it is the most convenient.

Practical application

The process of developing Level of Service Tool resulted in development of multiple linear and ordinal models. While some might argue that the strength of obtained R-squared values does not equate for a strong model in transport engineering context, it is essential to consider the user-focused methodological approach. As the models were developed based on perceptions and subjective evaluation, it would have been challenging to further improve the strength of the models.

Hence, when interpreting the results, it is essential to consider the research method and refer to its strengths and weaknesses.

In terms of other practical considerations, the sensitivity analysis has proved that the linear models 1 and 1a can be used to estimate the comfort scores for unsegregated shared-use paths. However, some of the practicalities that practitioners should consider when reviewing the research include:

- In some cases, the obtained comfort score can be outside the original comfort scale. This is dues to assumed linear relationship between variables and comfort score and it happens only in the conditions when the path is very wide and the density of users very low.
- Path width, as a variable researched, refers to effective width. In practice, paths (especially in urban settings) are cluttered with street furniture and signage.
- Total number of users, total number of pedestrians and total number of cyclists are per $13.5m^2$ (as that was the area covered in the scenario recordings. These numbers can be translated into user density (user per m^2).
- Flow direction considered did not reflect one-way and two-way scenarios.

These are considered further in Chapter 7, as a part of study limitations and recommendations for future research.

CHAPTER 7. CONCLUSIONS

7.0 Chapter Composition

The key aim of this research was to develop an assessment tool for the unsegregated shared-use paths in the UK. The purpose was to deliver a multimodal perspective and to seek to improve transportation decision-making by looking at multiple transport modes (primarily walking and cycling) through a single analytic framework.

This study therefore investigated user comfort towards the conditions of unsegregated shared-use paths. It first explored the concepts of ‘comfort’ for cyclists and pedestrians and, based on the established hierarchy of path characteristics important for users’ comfort, then developed a Level of Service tool.

This chapter summarizes the key findings and contributions of this research to academia and the industry. **Section 7.1** provides an overview of the main conclusions. **Section 7.2** lists the research limitations, which were identified throughout the research process. This is followed by review of theoretical and industry contributions of this study (**Sections 7.3** and **7.4** respectively) and a description of how the findings will be disseminated (**Section 7.5**). **Section 7.6** summarizes the generalizability of findings. Finally, **Section 7.7** provides recommendations for future research.

7.1 Key Findings and Contributions

Listed below are the six main areas where I drew conclusions from this study:

1. Understanding comfort on unsegregated shared-use paths;
2. Establishing a hierarchy of factors and path characteristics associated with comfort;
3. Developing a level of service tool for unsegregated shared-use paths;
4. Identifying the differences between cyclists and pedestrians’;
5. User profiling; and
6. Establishing users’ willingness to use unsegregated shared-use paths.
7. Methodological findings

More in-depth conclusions based on the literature reviews and Stage 1 and 2 of data collection are listed in each chapter separately (Chapter 5 and 6 respectively).

7.1.1 Conclusion 1: Understanding Comfort on Unsegregated Shared-Use Paths

Stage 1 of data collection investigated the meaning of comfort when using an unsegregated-shared use path. Based on the literature review (Chapter 2), it was established that comfort is a commonly used term in academia and in official guidance documents, yet it often acts as 'umbrella concept'. Therefore, my research brought a better, practical understanding of what comfort means in relation to the design of unsegregated shared-use paths.

First of all, there are specific factors and path characteristics associated with comfort by users (see Sections 2.2 and 2.3): these differ depending on the user type, gender or age.

Moreover, the literature review found that comfort is often considered to be 'individual' experience. This means that there is no framework within which transport professionals can assess or affect it. However, the findings of Stage 1 of data collection suggested that factors associated with comfort can be within the control of the professionals. For example, safety perception can be affected by street and route designs. The availability of space (both physical and personal) can be based on the path width assessed against the user traffic.

7.1.2 Conclusion 2: Establishing a Hierarchy of Factors and Path Characteristics Associated with Comfort on Unsegregated Shared-Use Paths

This research established a hierarchy of factors and path characteristics associated with comfort by users of unsegregated shared-use paths. The factors of most importance when using a shared-use path were safety and space (overall, and separately for both cyclists and pedestrians). Path length and 'surroundings' were the least important.

The path characteristics of most importance for comfort, based on average comfort ratings, were path width, path maintenance, volume of pedestrians and volume of cyclists. Path width was the most important for both cyclists and pedestrians. Pedestrians put significantly more emphasis on user speed and volume of cyclists. Cyclists put more emphasis on volume of pedestrians and path maintenance.

This study also proved that the presence of the other user group (cyclists in the case of pedestrians and pedestrians in the case of cyclists) can play a role in affecting the perception of comfort. This is strongly related to traffic and path capacity.

7.1.3 Conclusion 3: Developing a Level of Service Tool

Based on my research, I applied an experimental approach to developing a LOS assessment tool for unsegregated shared-use paths in the UK. The intended tool's main measure was users' perception of comfort; the variables of interest, selected based on the outcomes of Stage 1 of data collection, were path width and volume of users. The sub-variables that were also explored further were the passers-by user type (cyclist, pedestrian and wheelchair user), user flow direction, total number of cyclists, total number of pedestrians, and the proportion of cyclists (when the total number of path users is the same).

First of all, in the process of developing the Level of Service tool, it was concluded that the relationship between path width and comfort is linear. In the conditions of low density (0.1 user per m^2), it was observed that there is a threshold at approximately 3.5m: the steepest increase in comfort was noticeable as the path width increased from 2m until 3.5m, after reaching this threshold average comfort scores remained almost constant. This finding confirmed the observation from Stage 1 of data collection, where (Figure 5.14) the comparison was made how cyclists and pedestrians respond to different levels of path widths (narrow, medium, wide). A larger drop was observed in comfort ratings between medium and narrow path, than medium and wide path.

Secondly, the conclusion was reached that the relationship between volume of users (density) and comfort is linear. A sharp decrease in comfort was noticed between very low total number of users (density of 0.1 user per m^2) and the total number of users of approximately 7 (density of 0.5 user per m^2). After this threshold was reached, the comfort score remained fairly constant. Similarly to path width, this finding confirmed the observation from Stage 1 of data collection (Figure 5.16), where for all cyclists and pedestrians a larger drop in comfort rating was observed between low and medium volume of users, than medium and high volume of users.

Two models were developed: a linear one and an ordinal one for a combined set of predictors. They established the effect of each variable and sub-variable on the comfort score (to find out the strength of each of the predictors). They can be used by transport professionals as a guiding framework to assess their existing unsegregated shared-use paths and, where suitable, to predict the comfort scores of future developments.

The linear model for combined characteristics also established the hierarchy of predictors (in order from the strongest to weakest):

Passer-by being a pedestrian > Passer-by being a cyclist > Passer-by being a wheelchair user > Number of pedestrians > Respondent’s user type > Number of cyclists > Path width > Flow direction.

Also, two alternative models, linear and ordinal, were developed with a smaller number of independent variables (respondent’s user type, total number of users and path width) for cases when transport professionals had limited access to data.

In contrary to other Level of Service tools, the outcome of this research was not trying to classify levels of services into categories which dictate whether a type of facility is acceptable or not and in what environment. Instead, there are six categories, the same as the Likert scale used for rating in the survey: 1 very uncomfortable, 2 uncomfortable, 3 slightly uncomfortable, 4 slightly comfortable, 5 comfortable and 6 comfortable. Based on those categories, transport professionals are able to assess whether the user perception of the facility is (or will be, for future developments) likely to be positive or negative. That can facilitate their decision making, especially when used simultaneously with findings of Stage 1 of the data collection but does not attempt to draw conclusions on in what conditions an unsegregated shared-use path would work and when it would not. That final decision is left for the transport professional with sufficient knowledge of the site, local community and transport network.

Additionally, the comfort scores can be categorized into four groups based on the results of willingness to use unsegregated shared-use paths (see section 7.1.6).

7.1.4 Conclusion 4: Exploring the Differences Between Cyclists and Pedestrians

This study included a comprehensive comparison of differences and similarities between cyclists and pedestrians. It is the first study that looks at unsegregated shared-use paths from the perspective of both user types.

Overall, I identified that the user type of the respondent had a statistically significant impact on the user’s rating for the majority of factors and path characteristics explored in Stage 1 of data collection and on their perceptions of the impacts on comfort ratings of path width and volume of users and their sub-variables explored in Stage 2 of data collection. In comparison, gender or age group were not always statistically significant.

Stage 1 of data collection established that cyclists and pedestrians differ in their perception of comfort on unsegregated shared-use paths. ‘Space’, ‘path length’ and ‘other users’ were rated as more important by the cyclists and ‘safety’, ‘speed’ and ‘surroundings’ by pedestrians. ‘Path width’, ‘volume of pedestrians’, ‘path maintenance’ and ‘street furniture’ were regarded as more important by cyclists and ‘verge width’, ‘lighting’, ‘user speed’, ‘volume of cyclists’ and ‘surroundings’ by pedestrians.

Stage 2 of data collection drew the comparison between how cyclists and pedestrians perceive their comfort in relation to path width and volume of users, and the associated sub variables (passers-by user type, flow direction, proportion of cyclists).

In the low-density scenarios (with only one passer-by, 0.1 user per m^2) on different path widths, the difference between comfort ratings of cyclists and pedestrians is small (less than 1 score of comfort scale). Cyclists are less comfortable than pedestrians in the scenarios where the total volume of users is equal. Moreover, they are more sensitive than pedestrians to the increases in the total number of users on the path. In the higher density scenarios, I concluded that pedestrians are more comfortable sharing the space with cyclists (than cyclists sharing space with pedestrians). Their comfort scores varied from ‘comfortable’ (when total number of users was less than five or the density is under 0.4 users per m^2) to ‘uncomfortable’ (but only when total number of users exceeded 15 users, or the density is over 1.1 user per m^2). Cyclists were ‘slightly uncomfortable’ in the scenarios with lower traffic flow to ‘very uncomfortable’ for scenarios with total number of users over 12 (density of 0.9 users per m^2).

Moreover, different user types of passers-by affected cyclists’ and pedestrians’ perceptions of comfort differently: while both user types were most comfortable sharing space with their own user mode, pedestrians were more comfortable to pass by the wheelchair users, while the cyclists were more comfortable sharing with pedestrians. However, the differences were small, and hence, it was concluded that the user type of the passer-by is not an issue for cyclists and pedestrians.

In regard to the user flow direction, the differences between cyclist and pedestrian comfort ratings were also very subtle (<0.5 comfort score). In general, both cyclists and pedestrians were more comfortable where all the path users were walking in the opposite direction and facing the respondent.

What is more, in the scenarios with a high total number of users (highest density), no matter the proportion of cyclists, on average, pedestrians were still more comfortable than cyclists, even for the scenarios with a higher proportion of cyclists.

Finally, cyclists had only a slightly lower threshold for being willing to use unsegregated shared-use paths than pedestrians.

7.1.5 Conclusion 5: User Profiling

This research classified cyclists and pedestrians into several clusters based on their perceptions of the importance of various path characteristics and the user characteristics (age and gender) of each cluster were analysed, which delivered a better understanding of the needs of users. The path characteristics of interest for user profiling were ‘path width’, ‘path maintenance’ and ‘volume of other users’. Three clusters were identified for pedestrians and four for cyclists. The summary table can be found in Section 5.6.5.

Moreover, analysis provided further understanding on how the difference in levels of path width (narrow, medium, wide), path maintenance (poorly maintained, medium, well-maintained) and volume of other users (low density, medium, crowded) affected comfort ratings. The comparison of results between clusters brought understanding of how sensitive the respondents are to the different levels of the aforementioned path characteristics.

7.1.6 Conclusion 6: Establishing Users’ Willingness to Use Unsegregated Shared-Use Paths

To put this Level of Service tool into a more practical context, it includes information about path users’ willingness to use unsegregated shared-use paths.

On average, pedestrians are willing to use an unsegregated shared-use path as long as their comfort level is higher than ‘slightly uncomfortable’ when the facility makes up more than 90% and ‘uncomfortable’ when it constitutes less than 25% of the route. Hence, when pedestrians feel below ‘slightly uncomfortable’ and ‘uncomfortable’ on the comfort scale for each one respectively, they would consider using another route.

On average, cyclists are willing to use unsegregated shared-use path as long as their comfort level is above ‘slightly uncomfortable’ level, for both situations (when an unsegregated shared-use path makes up more than 90% and less than 25% of the route). Therefore, when cyclists feel below ‘slightly uncomfortable’ on the comfort scale, they would consider using another route.

Table 7.1 summarizes the thresholds.

Table 7.1. Users' willingness to use unsegregated shared-use paths.

Comfort Score	Length of unsegregated shared-use path	Users' willingness to use unsegregated shared-use paths
Comfort score ≥ 2.6	More than 90% of the route	Pedestrians are willing to use an unsegregated shared-use path
Comfort score ≥ 2.4	Less than 25% of the route	Pedestrians are willing to use an unsegregated shared-use path
Comfort score ≥ 3.0	More than 90% of the route	Cyclists are willing to use an unsegregated shared-use path
Comfort score ≥ 2.8	Less than 25% of the route	Cyclists are willing to use an unsegregated shared-use path

7.1.7 Methodological findings

This research was focused on the process of developing a Level of Service tool, using an alternative, bottom-up approach that filled in the gaps of methodologies used in the past. It combined two stages of data collection and both aimed to explore user perceptions, which were collected through online surveys with the use of the visual aids (photoshopped pictures and video footage).

The decision to explore a methodology that has not been used before impacted on my findings in both positive and negative way. In the process, it was established that using online version of the survey facilitates its distribution: as a consequence the size of the sample was higher and a wider variety of people was reached, considering the available resources and compared to Jensen (2007), Landis et al (1997 and 2011), Mori (1987), Dowling et al. (2008), Harkey et al. (1998) and Kang et al. (2013) (see Table 4.5). Additionally, to focus on particular path characteristics and understand their impact on user comfort, videos showed artificially designed scenarios, where each of these characteristics was controlled. The distractions related to using video footage from 'real-life' paths, such as surroundings, unexpected user behaviours etc were eliminated.

Such approach allowed the responses from cyclists and pedestrians to be comparable, with the benefit of understanding the unsegregated shared-use paths from the perspective of both transport modes. It also enabled direct comparison. From practical point of view, the researcher was in full control of the process and all scenarios of interest were recorded: considering how rare unsegregated shared-use paths are in UK, it would have been impossible to obtain the same variety of path widths and user-densities relying on 'real-life' circumstances. Moreover, due to artificial nature of the scenarios, this research can be replicated elsewhere and with a different sample without impacting on the quality of results.

However, due to the innovative methodological approach to it was impossible to validate the outcomes through past research. It also meant that I was fully responsible for the design and execution of the survey, which lead to learning the following lessons:

- Designing a research method that will lead to 'simplified' outcome (in this case a user-friendly assessment tool) impacts on the quality of findings
- Distributing a survey through online channels can lead to losing control of where the survey is being promoted. It impacts on who the respondents are and can lead to a varied sample: in this case socio-demographic characteristics of cyclists and pedestrians varied, which impacted on statistical analysis and the comparability of findings between these groups
- Recording over 100 videos on limited budget requires in-advance planning and excellent organisational and leadership skills. Even when everything is planned perfectly some circumstances (such as weather) are out of researcher's control.

7.2 Limitations

Due to limited time and resources, certain compromises had to be made in the choice of research methods and in data collection. The implications for further research are listed in Section 7.7. Below main limitations of the study are identified.

- **Research methodology**

This research project was grounded in the positivist paradigm. This meant that, quantitative approach was prioritised. However, instead of using a validated survey instrument developed in previous work, it applied an original research method. Therefore, as a consequence, the reliability of the conclusions was impacted. Section 4.1 identified other paradigms, which should have been considered when establishing the theoretical framework for this study. Relying on mixed method approach that included qualitative data collection could have positively impact on the reliability of findings.

- **Sample**

Both stages of data collection managed to collect over 900 responses, which was regarded as a satisfactory number. However, in both cases the representativeness of the sample was imperfect.

The sample was uneven, with proportions of 37% pedestrians and 63% cyclists for Stage 1 of data collection and 35% pedestrians and 65% cyclists for Stage 2 of data collection. This required a certain approach towards the analysis, for example separating the datasets and running additional statistical tests to assess the statistical significance of user type of respondent and gender. It would have been beneficial if the disparity between sample sizes was smaller: to achieve that, additional outreach to pedestrians would have been necessary.

Moreover, there was a disparity between proportions of genders and different age groups among cyclists and pedestrians. For example, while the majority of cyclists in the survey were male (as is representative of cyclists), it meant there were too few female cyclists to be able to conduct analyses stratified simultaneously by both gender and travel mode. Also, the sample missed out on people who do not travel by foot or cycle, but who might if the improved facilities were available.

What is more, for the Stage 1 of data collection, to facilitate its dissemination, the survey was designed in a way that required only one online link to be sent out: the type of respondent was determined in the first question, where participants had to classify themselves as either 'regular pedestrian' or 'regular cyclist'. That meant that for practical reasons, a sample of respondents who are both cyclists and pedestrians simultaneously was not considered. Instead, those participants had to identify themselves as either cyclist or pedestrian and fill in the responses from the perspective of the chosen transport mode.

- **Choice of 'comfort'**

Comfort was chosen as the main indicator for the Level of Service Tool. The justification was drawn from existing PLOS and BLOS tools, which also relied on it as the primary measure. Additionally, it was also compatible with the on-going shift in transport industry, which favours user-led place-making approach. However, in practical terms, while this research contributed to the understanding of 'comfort', the concept still remains undefined. Some might argue that this limits the ability of this research to act as a basis for potential investment decisions. Yet, it should be considered that the way funding is allocated is changing. For example, TfL's and GLA's recently established funds such as Good Growth and Liveable Neighbourhoods put emphasis on needs of community and support Healthy Streets agenda which puts people and their experience (including their comfort) as the top priority.

- **Research method**

The fact that the research method relied on artificial scenarios (both for a picture-based questions in Stage 1 of data collection, and video-based questions for Stage 2 of data collection) can be regarded as a limitation. While it benefitted achieving the study's aim, it also had some disadvantages, including the fact that situations reflected were engineered and did not represent 'real' circumstances. These was anticipated and considered in the design of research methods (see Section 6.3).

What is more, the scenarios used in the Stage 2 of data collection considered a limited number of circumstances: for the practical reasons, the footage was recorded on two separate days with two separate set-ups. As a consequence, the Stage 2 survey considered scenarios which modified the number of users or the path width independently, but no data was collected on perceptions of comfort with different densities on different path widths. Hence, this study delivered a limited understanding of density effects (which could have been achieved by exploring different volumes of users on different path widths): it did not consider that people may judge the narrowest and widest path widths quite differently with only one other person or high volume of people. For example, some people might feel uncomfortable that the area is too open if the path was 5m wide and only one other person visible but would feel very comfortable with high densities of people at 5m.

Moreover, the way direction of user flow was approached gives little practical applicability, as the flows did not consider one-way and two-way scenarios.

Finally, with the aim of developing a level of service tool, this research adapted a simplified approach: the generalizability of findings was prioritized over understanding complex mechanisms of travel behaviour. Hence, attention was not paid to certain situations that occur on unsegregated shared-use path, which might affect users' perception of comfort. These include presence of dog-walkers, people travelling in groups, people travelling with children, cyclists using adapted cycles, etc.

7.3 Generalizability of Findings

This research was designed in a way which aimed for the findings to be as generalizable as possible. In order to achieve that, I ensured that both stages of data collection and the analyses that followed could provide insightful knowledge for current and future cycling and walking facilities in a variety of settings, not just under specific conditions.

Stage 1 of data collection aimed to provide an overview of perceptions of comfort. The factors and path characteristics were drawn from commonly used design guidelines and the existing literature: no specific case studies were used. All the terms were general expressions. Picture-based questions were also symbolic and aimed to reflect the different levels of variables (for example narrow, medium and wide path width): hence, the conclusions drawn were broad and aimed to give direction rather than particular solutions.

Similarly, Stage 2 of data collection research method did not rely on specific case studies, but on artificially designed scenarios. Since video footage was not recorded at a particular, publicly available unsegregated shared-use path, there was no risk of specific local factors to affect respondents' comfort ratings. Conditions such as weather conditions or surroundings were mentioned in the survey: it was ensured that the respondents were aware that they were not of interest for this study. Such an approach made the results applicable nationally.

Moreover, the focus was to ensure a sample size of over 900 participants for each of the surveys to increase the external validity and generalizability of the findings. The sample was also diverse enough (see Sections 5.6.1 and Section 6.9.2) and contained representatives of different gender and age groups. Also, the decision to rely on online surveys, in contrast to collecting responses on-site, allowed a diversity of respondents from a nationwide variety of locations.

Finally, lessons learnt from the Level of Service tool development can be applied in an unlimited number of situations (assuming that the transport professionals are aware of its limitations). This is due to the fact that the tool focuses on very specific variables and sub-variables rather than the real-life path environment, so the findings can be applied to any path segment. Also, the findings can be applied to all unsegregated shared-use paths, no matter the length or whether the shared space covers the whole distance or just a part of the facility.

7.4 Theoretical / Academic Contribution

This research was set in a theoretical framework, drawn from academic literature on comfort in cycling and walking and existing assessment tools for walking and cycling facilities, with the focus on Level of Service tools.

In the context of understanding comfort in non-motorised transport, my study has filled in a substantial gap and addresses lack of consistency in available theory. It provides an insight into the factors and path characteristics and their hierarchy of importance for path users. Moreover, it highlights how views on comfort are affected by respondents' characteristics, such as user type (cyclist, pedestrian), gender (male, female) and age (16-24, 25-34, 35-44, 45-54, 55-64, 65+). I used perceptions of Comfort as the main measure for the development of an assessment tool, and hence, some insight was gained on the effects of path width, volume of users, passer-by's user type, flow direction and proportion of cyclists and pedestrians on perceptions of comfort.

Regarding the contribution to the literature on available assessment tools for cycling and walking facilities, I used this research to develop an original assessment tool for unsegregated shared-use path. It is the first Level of Service tool to focus on a UK-based sample and also the first level of service tool for unsegregated shared-use paths that considers the perceptions of both cyclists and pedestrians.

Moreover, this research leads a way for user-led studies. Special emphasis should be put on the fact that both stages of data collection relied on responses from path users: the characteristics chosen for Stage 2 were selected based on the responses by people, rather than assumed. In contrast, all other Level of Service tools had path characteristics pre-selected by the researchers.

Finally, this research contributed to the field of transport research by trialling a pioneer video-based survey. While video-based methods have been used by researchers in the past (see Section 6.3), filming artificially designed scenarios which focused on particular path characteristics was an original approach.

7.5 Contributions to Industry

Cycling and walking are becoming increasingly prominent in transport policy in the UK, but the limited amount of space in urban setting is an issue. Under these circumstances, unsegregated shared-use paths can be an attractive option for planners. However, as identified in Chapter 3, there is not much background knowledge available to industry professionals in the UK to facilitate decision-making and validate the design of unsegregated spaces.

Therefore, the importance of this research to the industry is crucial: as it is the first document to provide an insight into what facility users perceive as comfortable or not.

Similarly to *Shared Use Path Level of Service* (FHWA, 2006) the main target audiences for the SUPLOS tool were identified. These include:

- Transport professionals: the main target group for this study were engineers, planners and designers in public and private sectors, who are in charge of different stages of lifecycle of transport projects. Such professionals tend to have background knowledge in the field of engineering and design of cycling and walking facilities and possibly an experience of using level of service tools. This study provided them with UK-sourced knowledge to use on a day-to-day basis to facilitate decision-making.

- Policy-makers: governmental organisations such as the Department for Transport, the Department of Health, Transport for London and the Greater London Authority would benefit from more background knowledge on unsegregated shared-use paths from the users' perspective. As established in Section 2.4, the existing guidelines have very little information on the topic, therefore this research could be the first step for putting shared space higher on the hierarchy of provision. Moreover, in the UK a lot of transport infrastructure is delivered at the local level. Local authority public health, transport and planning departments play a big part in shaping the policy and assigning funding to different projects. While these stakeholders might not have the need to apply the level of service tool, they would benefit from understanding the needs and preferences of different users.

- Advocacy organisations: national non-governmental organizations such as Sustrans or Living Streets are key players in promoting sustainable travel in the UK. They often work closely with local communities, setting the vision for the future of neighbourhoods and influencing the attitudes among potential path users. These organisations also often act as a 'middle-man' and provide coordination among other players who develop, own, and manage the facility, as well as implementing projects themselves.

- Cyclists and pedestrians: currently, unsegregated shared-use paths are regarded as a very controversial solution among cyclists and pedestrians in the UK. This study, by prioritizing both users' views through user-led research, has the potential to change their outlook and reassure them that there is background knowledge available that prioritizes their needs and preferences.

The findings of this research can have a wider practical impact on the way stakeholders above perceive unsegregated shared-use paths in the UK. The information in this thesis should be of interest to all these stakeholders. This is crucial to improving existing facilities, to guide new investments and to optimize budgets.

What is more, this research has been conducted with an equal consideration for the views of cyclists and pedestrians. Hence, this means that the result can be used to draw comparisons between the trade-offs and benefits of introducing unsegregated shared space from the individual perspective of each transport mode. This knowledge will also allow practitioners to minimize the negative impacts of sharing on both cyclists and pedestrians.

Finally, in line with the vision of Sustrans, who are driving the change for more user-friendly and user-focused cycling and walking infrastructure, this study provides insight into the views of different socio-demographic groups. There is a lot of value for the industry in understanding the needs of people of different ages and gender, especially with the drive to promote cycling and walking among women and older people.

This research should also be put in the context of the recent statement by the Disabled Persons Transport Advisory Committee (DPTAC), whose official position towards shared space criticized the guidance '*LTN 1/11 Using shared space to improve high streets for pedestrians*' as highly inadequate and in need of revision (however these consider sharing between more transport modes, rather than just cyclists and pedestrians). DPTAC also points out the report by Chartered Institution of Highways and Transportation (CIHT), which recognised current lack of evidence and evaluation methods for shared spaces. DPTAC also suggested that the implementation of shared space schemes should be paused until further evaluation of the issues related to safety of shared space users.

7.6 Dissemination of Findings

It is essential to disseminate findings effectively, so that this research brings as much benefit as possible. The following organisations will be targeted to help with dissemination to facilitate the 'research to practice' knowledge transition.

The primary target for dissemination is Sustrans, who were the industrial sponsor for this project. The research will be shared nation-wide among their employees and volunteers and disseminated among their partner organisations.

Furthermore, the policy focused summary document will be shared with networks of contacts at the Department for Transport, Transport for London, Living Streets and local authorities. Communication and interaction with wider audiences in ways that will facilitate research uptake in decision-making processes and practice: these will include delivering presentations at national and regional practitioners' conferences. The Department for Transport has also expressed an interest in me presenting the findings among their staff in-house.

The research will also be disseminated in academic circles through presentations at academic conferences and scientific journal publications.

7.7 Future Research

While the contributions of this study to the industry and to academia are significant, in the process, I have identified additional suggestions for future research. Based on my findings, and the limitations of my research, I have made the recommendations listed below. The follow-up research would allow to fill in the gaps and enhance the understanding of user perceptions of unsegregated shared-use paths.

First of all, it is essential to emphasise that my research focused on the process of developing a Level of Service tool, rather than its delivery. Experimental research methodology was only validated through existing literature, rather than past applications of other assessment tools. Therefore, further research to validate the findings would be essential to further develop a 'ready-to-use' tool for transport professionals.

Secondly, the complexities of travel behaviours often require more in-depth analysis, which can only be achieved with qualitative research methods through hearing individuals' stories and attitudes. Therefore, it is recommended to conduct follow-up research which will focus on understanding what comfort means to individual users in more detail and will explore the experience of using unsegregated shared-use paths (or why people have not used them). Such knowledge would be a good supplement to the Level of Service Tool I developed and would allow transport professionals and policy-makers to understand user perceptions better.

Thirdly, further research into how path width and volume of users interact is required. For practical reasons, this study separated path width scenarios (user volume remained low and stable while path widths changed) and number of users (path width remained constant at 3m while total numbers of users changed). However, there was very little variation where both path width and the volume of users were changed. This meant that certain situations (for example when the path is wide and the number of users is higher, but not crowded) remained unexplored, and the thresholds for pedestrians and cyclists deeming the density uncomfortable (how the number and travel mode of users interacts with the path width) are not known. The same research methods could be applied, but with a wider diversity of scenarios. This would also enable researchers to test the LOS tool I developed to evaluate whether the predicted findings are confirmed by empirical data.

Furthermore, it would be beneficial to run an assessment of the research method and compare whether online ratings are compatible with on-site perceptions of comfort. That would allow researchers to identify the extent to which the response to video-based surveys differ from on-site assessment and to normalize the results.

Moreover, to overcome sample-related limitations (see Section 7.2), this study could be repeated with a larger sample to enable further assessment of the relative importance of age, gender and user type, where there is a degree of collinearity. I also recommend exploring a wider variety of socio-demographic groups, in particular children and older people. Unfortunately, due to limited resources the focus was on participants over 16 years old: younger children were not included in the sample but are in fact one of the age groups for whom cycling and walking can be an attractive transport mode (low cost, physical activity, short-distance journeys). Also, the representation of older people was limited, potentially due to the fact that the surveys were disseminated online and also that people over 65 are less likely to be members of utilised mailing lists or be contactable via other routes used. Considering the aging society trend in the UK and population growth projections (Office for National Statistics, 2016), it is essential to consider the perceptions of people over 65 and ensure that design tools consider their needs.

Finally, as an addition to these findings, it would be beneficial to consider the needs of disabled people with a variety of impairments. This implies pedestrians and cyclists (including the users of adapted cycles). In the UK, there is currently an on-going debate around the controversy involving shared space and the concerns within the wider disabled community. While it concerns primarily sharing space with motor vehicles (cars and buses), cyclist-pedestrian sharing is also often regarded as problematic too. In order to establish whether such attitude is justified, further research is essential to understand the perceptions of comfort by people with disabilities when using unsegregated shared-use paths. This research gap and the urgent necessity to fill it in has been emphasized by the DPTAC (2018).

This research has demonstrated that examining the perceptions of cyclists and pedestrians on unsegregated shared-use paths and the ways different path characteristics impact on their comfort can provide knowledge that can be applied in practice to deliver facilities that work for most (different user types, genders and ages). This thesis suggested a new attitude towards unsegregated shared-use: instead of centring the attention on the safety-threatening interactions between cyclists and pedestrians, it focused on what users regard as comfortable and uncomfortable. The findings from this study revealed that these user perceptions can drive the design of facilities and considered thoughtfully, can have an impact on how people interact and share space, thus affecting their walking and cycling experiences.

If walking and cycling levels are to increase in the UK, especially in urban centres with limited space, unsegregated shared-use should be considered as an option: the research approach presented in this study could assist with that, along with the existing more traditional quantitative and qualitative approaches. This study delivered a framework for more informed design and policy and developed an assessment tool which can help transport professionals in their decision-making processes when considering unsegregated shared-use paths.

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APPENDIX 1. STAGE 1 OF DATA COLLECTION SURVEY

Appendix 1 includes screenshots of Stage 1 of data collection survey questions: the version designed for respondents who selected 'regular pedestrian' in question 1. The questions from 5-19 include 'walking': the version for cyclists was identical, only used term 'cycling' instead.

Mixed Use Paths Characteristics

Thank you for taking the time to complete this survey. Your participation is crucial in order to improve the quality of walking and cycling infrastructure and enhance the experience of users.
This is a part of research into perception of comfort by users on mixed use paths.

A mixed use path is a route used by **pedestrians and cyclists without any measures of segregation between them**. It is designed to enable pedestrians and cyclists to make use of the entire available width of the path. We are studying what aspects of such paths make them perceived as **'comfortable'** by **current** and **potential users.**

This survey should only take about **5 minutes** of your time. **Your answers will be completely anonymous and confidential.** Responses will not be identified by individual, but will be compiled together and analyzed as a group. The information provided on this questionnaire will be processed by University College London for research purposes.

By filling out the survey you can enter a **prize draw** for a £50 Marks&Spencer or Amazon (personal choice) gift card.

If you have any questions or concerns, please contact Pola Berent, Research Engineer at UCL at p.berent@ucl.ac.uk.

Start

Mixed Use Paths Characteristics

1. **How would you describe yourself?:**

- ◯ Regular pedestrian
- ◯ Regular cyclist
- ◯ Regular wheelchair/mobility scooter user
- ◯ Do not regularly use any of the above activities

* Some respondents would describe themselves as both cyclists and pedestrians. For the purpose of this survey please pick one and respond accordingly.

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Mixed Use Paths Characteristics

A mixed use path is a route used by pedestrians and cyclists without any measures of segregation between them. It is designed to enable pedestrians and cyclists to make use of the entire available width of the path.

2. **How often do you use mixed use routes?**

○ Often
○ Sometimes
○ Rarely
○ Never

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Mixed Use Paths Characteristics

3. **For each factor below (e.g. Space, Safety), please rate its importance for your comfort on a mixed use path using a scale of 1 (very important) – 6 (not important at all):**

	Very important (1)	(2)	(3)	(4)	(5)	Not important at all (6)
Space	○	○	○	○	○	○
Safety	○	○	○	○	○	○
Speed	○	○	○	○	○	○
Length of path	○	○	○	○	○	○
Other users	○	○	○	○	○	○
Surroundings	○	○	○	○	○	○

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Mixed Use Paths Characteristics

4. **On a scale 1 (very important) – 6 (not important at all) rate how important are the following characteristics for your comfort while using a mixed use path:**

	Very important (1)	(2)	(3)	(4)	(5)	Not important at all (6)
Path width	○	○	○	○	○	○
Verge width	○	○	○	○	○	○
Lighting	○	○	○	○	○	○
Users' Speed	○	○	○	○	○	○
Volume of pedestrians	○	○	○	○	○	○
Volume of cyclists	○	○	○	○	○	○
Path maintenance	○	○	○	○	○	○
Street furniture	○	○	○	○	○	○
Surroundings	○	○	○	○	○	○

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Mixed Use Paths Characteristics

5. **On a scale 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking on the path pictured on the following photograph:**

Very comfortable (1)	Comfortable (2)	Fairly comfortable (3)	Fairly uncomfortable (4)	Uncomfortable (5)	Very uncomfortable (6)
○	○	○	○	○	○

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Mixed Use Paths Characteristics

6. **On a scale 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking on the path pictured on the following photograph:**

Very comfortable (1)	Comfortable (2)	Fairly comfortable (3)	Fairly uncomfortable (4)	Uncomfortable (5)	Very uncomfortable (6)
○	○	○	○	○	○

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Mixed Use Paths Characteristics

7. **On a scale 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking on the path pictured on the following photograph:**

Very comfortable (1)	Comfortable (2)	Fairly comfortable (3)	Fairly uncomfortable (4)	Uncomfortable (5)	Very uncomfortable (6)
○	○	○	○	○	○

Back Next

Mixed Use Paths Characteristics

8. **On a scale 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking on the path pictured on the following photograph:**

Very comfortable (1)	Comfortable (2)	Fairly comfortable (3)	Fairly uncomfortable (4)	Uncomfortable (5)	Very uncomfortable (6)
○	○	○	○	○	○

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Mixed Use Paths Characteristics

9. **On a scale 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking on the path pictured on the following photograph:**

Very comfortable (1)	Comfortable (2)	Fairly comfortable (3)	Fairly uncomfortable (4)	Uncomfortable (5)	Very uncomfortable (6)
○	○	○	○	○	○

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Mixed Use Paths Characteristics

10. **On a scale 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking on the path pictured on the photograph below:**

Very comfortable (1)	Comfortable (2)	Fairly comfortable (3)	Fairly uncomfortable (4)	Uncomfortable (5)	Very uncomfortable (6)
○	○	○	○	○	○

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Mixed Use Paths Characteristics

11. **On a scale 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking on the path pictured on the photograph below:**

Very comfortable (1)	Comfortable (2)	Fairly comfortable (3)	Fairly uncomfortable (4)	Uncomfortable (5)	Very uncomfortable (6)
○	○	○	○	○	○

Back Next

Mixed Use Paths Characteristics

12. **On a scale 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking on the path pictured on the photograph below:**

Very comfortable (1)	Comfortable (2)	Fairly comfortable (3)	Fairly uncomfortable (4)	Uncomfortable (5)	Very uncomfortable (6)
○	○	○	○	○	○

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Mixed Use Paths Characteristics

13. **On a scale 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking on the path pictured on the photograph below:**

Very comfortable (1)	Comfortable (2)	Fairly comfortable (3)	Fairly uncomfortable (4)	Uncomfortable (5)	Very uncomfortable (6)
○	○	○	○	○	○

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Mixed Use Paths Characteristics

14. **On a scale 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking on the path pictured on the photograph below:**

Very comfortable (1)	Comfortable (2)	Fairly comfortable (3)	Fairly uncomfortable (4)	Uncomfortable (5)	Very uncomfortable (6)
○	○	○	○	○	○

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Mixed Use Paths Characteristics

15. **On a scale 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking on the path pictured on the photograph below:**

Very comfortable (1)	Comfortable (2)	Fairly comfortable (3)	Fairly uncomfortable (4)	Uncomfortable (5)	Very uncomfortable (6)
○	○	○	○	○	○

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Mixed Use Paths Characteristics

16. **On a scale 1 (very comfortable) – 6 (very uncomfortable) rate how comfortable would you be walking on the path pictured on the photograph below:**

Very comfortable (1)	Comfortable (2)	Fairly comfortable (3)	Fairly uncomfortable (4)	Uncomfortable (5)	Very uncomfortable (6)
○	○	○	○	○	○

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Mixed Use Paths Characteristics

17. **What are the barriers to walking on a mixed use path?**

	Stops me walking (1)	(2)	(3)	(4)	(5)	Is not a problem (6)
Path width	○	○	○	○	○	○
Verge width	○	○	○	○	○	○
Lighting	○	○	○	○	○	○
Path maintanence	○	○	○	○	○	○
Users' Speed	○	○	○	○	○	○
Volume of pedestrians	○	○	○	○	○	○
Volume of cyclists	○	○	○	○	○	○
Street furniture	○	○	○	○	○	○
Surroundings	○	○	○	○	○	○

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Mixed Use Paths Characteristics

18. **How often do you walk?**

- ○ Daily or 6 times a week
- ○ 2-5 times a week
- ○ Weekly
- ○ Fortnightly
- ○ Monthly
- ○ Yearly
- ○ Less Frequently
- ○ Never

Back Next

Mixed Use Paths Characteristics

19. **Of the following reasons for walking, which applies to you?**

	Frequently	Often	Sometimes	Rarely	Never
Going to work, school etc	○	○	○	○	○
To access services e.g. shops	○	○	○	○	○
For leisure, fitness	○	○	○	○	○
Other (optional)	○	○	○	○	○
Please specify 'Other'	[ ]				

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Mixed Use Paths Characteristics

20. **Your gender:**

- Female
- Male

21. **Which age group do you fit into?**

- 16-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65+

22. **Which of the following groups do you consider you belong to?**

- White
- Mixed
- Indian
- Pakistani
- Bangladeshi
- Other Asian
- Caribbean
- African
- Other Black
- Chinese
- Other ethnic group
- Prefer not to say

23. **Please fill in the first three digits of your postcode:**

Back Next

Mixed Use Paths Characteristics

24. **Thank you for completing this questionnaire. Please tick the following boxes and fill in your email address (optional) if you would like to:**

To receive a summary of findings	
To be considered for a Prize Draw	
To participate in second stage of data collection (focus group)	
Your email address:	

25. **If you have any additional comments or questions, please feel free to write them below or contact Pola Berent at p.berent@ucl.ac.uk:**

Back Finish

APPENDIX 2. STAGE 2 OF DATA COLLECTION SURVEY

Appendix 2 includes the questions included in Stage 2 of data collection survey: only two examples of video-based questions were attached here as the text was identical and it was impossible to show the diversity of videos through an image. The attached CD has all videos included in the survey. The full list of videos is included below.

Cyclists Survey

Welcome to My Survey

Thank you for taking the time to complete this survey. Your participation is very important to help Sustrans improve the quality of walking and cycling routes and enhance the experience of users. **This is a part of research into perception of comfort by users on mixed use paths.**

A mixed use path is a route used by pedestrians and cyclists without any measures of segregation between them. It is designed to enable pedestrians and cyclists to make use of the entire available width of the path. We are studying what you consider important when using unsegregated shared use paths.

This survey should only take about 20 minutes of your time. It starts with a few short questions. After that, you will be asked to view 49 short videos of between three and eight seconds. These will present artificially designed scenarios of people travelling on a mixed used path and will ask you to rate your perceived comfort. While the number of videos to score may appear high, it is necessary for the researchers to gain a better understanding of users' preferences. We will use our findings to help Sustrans deliver better facilities and promote active travel, especially in cities with limited available space.

Your answers will be completely anonymous and confidential. Responses will not be identified by individual, but will be compiled together and analysed as a group. The information provided on this questionnaire will be processed by UCL (University College London) and Sustrans for research purposes.

At the end of the survey you will be given an option to provide your email address to be entered into a prize draw with a chance to win an Amazon voucher. There will be **one prize of £150**, **two of £75**, **and three of £35**.

There is also an option at the end of the survey to give us your email address if you would like to receive a summary of our findings later on.

Your email will not be used for any other purpose.

1. You are cycling from A to B (3 miles). A substantial part of your journey (over 90%) is on an unsegregated mixed-use path. Assuming that this is the fastest, most direct route to get to your destination: what level of comfort/discomfort do you think you would you have to experience to make a decision to consider using an alternative route instead?

* This question is about the decision making process, the 'attractiveness' of the alternative route is not a factor.

* If you are a person who does not care about the comfort level and always takes the fastest/most direct route, please choose 1: Very uncomfortable.

* If you are a person who cares about the comfort level very much and would choose another route if the fastest/most direct route involved sharing between cyclists and pedestrians, please choose 6: Very comfortable.

○ 1: Very uncomfortable

○ 2: Uncomfortable

○ 3: Slightly uncomfortable

○ 4: Slightly comfortable

○ 5: Comfortable

○ 6: Very comfortable

Provide an explanation if necessary:

2. You are cycling from A to B (3 miles). A small part of your journey (less than 25%) is on an unsegregated mixed-use path. Assuming that this is the fastest, most direct route to get to your destination: what level of comfort/discomfort do you think you would you have to experience to make a decision to consider using an alternative route instead?

* This question is about the decision making process, the 'attractiveness' of the alternative route is not a factor.

* If you are a person who does not care about the comfort level and always takes the fastest/most direct route, please choose 1: Very uncomfortable.

* If you are a person who cares about the comfort level very much and would choose another route if the fastest/most direct route involved sharing between cyclists and pedestrians, please choose 6: Very comfortable.

○ 1: Very uncomfortable

○ 2: Uncomfortable

○ 3: Slightly uncomfortable

○ 4: Slightly comfortable

○ 5: Comfortable

○ 6: Very comfortable

Provide an explanation if necessary:

THIS IS AN EXPLANATION (the videos start on the next page)

The next section involves a selection of video clips. They present artificially designed scenarios of people travelling on a mixed used path. Your task is to rate your perceived comfort.

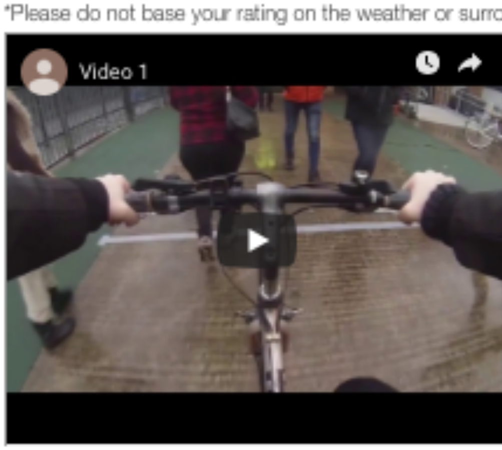
In order to play the video, please play the red arrow in the middle of the clip.

The Rating Scale:

Now you have understood how to watch and rate each video. Click 'Next' to start rating the videos.

3. On a scale 1 (very uncomfortable) – 6 (very comfortable) rate how comfortable would you be cycling on the path pictured on the following video.

*Please do not base your rating on the weather or surroundings.



	1 (very uncomfortable)	2 (uncomfortable)	3 (slightly uncomfortable)	4 (slightly comfortable)	5 (comfortable)	6 (very comfortable)
Rating	○	○	○	○	○	○

4. On a scale 1 (very uncomfortable) – 6 (very comfortable) rate how comfortable would you be cycling on the path pictured on the following video.

*Please do not base your rating on the weather or surroundings.

	1 (very uncomfortable)	2 (uncomfortable)	3 (slightly uncomfortable)	4 (slightly comfortable)	5 (comfortable)	6 (very comfortable)
Rating	◯	◯	◯	◯	◯	◯

52. Your gender:

◯ Male

◯ Female

◯ Prefer not to say

53. Which age group do you fit into?

◯ 18-24

◯ 25-34

◯ 35-44

◯ 45-54

◯ 55-64

◯ 65+

54. Please fill in your outward code (first two to four digits of your postcode. For example, NW01):

55. If you would like to:

☐ take part in the prize draw for your chance to win one of the Amazon vouchers (1x£150, 2x£75 and 3x£35)

☐ receive a summary of findings

Please submit your email address below:

CD-ROM with survey videos

Path Width Scenarios

Pedestrians:

- 2m: pedestrian passing by a pedestrian
- 2m: pedestrian passing by a cyclist
- 2m: pedestrian passing by a wheelchair user
- 2.5m: pedestrian passing by a pedestrian
- 2.5m: pedestrian passing by a cyclist
- 2.5m: pedestrian passing by a wheelchair user
- 3m: pedestrian passing by a pedestrian
- 3m: pedestrian passing by a cyclist
- 3m: pedestrian passing by a wheelchair user
- 3.5m: pedestrian passing by a pedestrian

- 3.5m: pedestrian passing by a cyclist
- 3.5m: pedestrian passing by a wheelchair user
- 4m: pedestrian passing by a pedestrian
- 4m: pedestrian passing by a cyclist
- 4m: pedestrian passing by a wheelchair user
- 4.5m: pedestrian passing by a pedestrian
- 4.5m: pedestrian passing by a cyclist
- 4.5m: pedestrian passing by a wheelchair user
- 5m: pedestrian passing by a pedestrian
- 5m: pedestrian passing by a cyclist
- 5m: pedestrian passing by a wheelchair user
- 5.5m: pedestrian passing by a cyclist
- 5.5m: pedestrian passing by a wheelchair user

Cyclists:

- 2m: cyclist passing by a pedestrian
- 2m: cyclist passing by a cyclist
- 2m: cyclist passing by a wheelchair user
- 2.5m: cyclist passing by a pedestrian
- 2.5m: cyclist passing by a cyclist
- 2.5m: cyclist passing by a wheelchair user
- 3m: cyclist passing by a pedestrian
- 3m: cyclist passing by a cyclist
- 3m: cyclist passing by a wheelchair user
- 3.5m: cyclist passing by a pedestrian
- 3.5m: cyclist passing by a cyclist
- 3.5m: cyclist passing by a wheelchair user
- 4m: cyclist passing by a cyclist
- 4m: cyclist passing by a wheelchair user
- 4.5m: cyclist passing by a pedestrian
- 4.5m: cyclist passing by a cyclist
- 4.5m: cyclist passing by a wheelchair user
- 5m: cyclist passing by a pedestrian
- 5m: cyclist passing by a cyclist
- 5m: cyclist passing by a wheelchair user
- 5.5m: cyclist passing by a pedestrian

- 5.5m: cyclist passing by a cyclist
- 5.5m: cyclist passing by a wheelchair user

Volume of Users Scenarios

Pedestrians:

- Scenario 1: front, 23 pedestrians and 8 cyclists
- Scenario 3: front-back, 23 pedestrians and 8 cyclists
- Scenario 5: front, 25 pedestrians and 5 cyclists
- Scenario 7: front-back, 25 pedestrians and 5 cyclists
- Scenario 9: front, 28 pedestrians and 3 cyclists
- Scenario 11: front-back, 28 pedestrians and 3 cyclists
- Scenario 13: front, 17 pedestrians and 6 cyclists
- Scenario 15: front-back, 17 pedestrians and 6 cyclists
- Scenario 17: front, 19 pedestrians and 4 cyclists
- Scenario 19: front-back, 19 pedestrians and 4 cyclists
- Scenario 21: front, 21 pedestrians and 2 cyclists
- Scenario 23: front-back, 21 pedestrians and 2 cyclists
- Scenario 25: front, 12 pedestrians and 4 cyclists
- Scenario 27: front-back, 12 pedestrians and 4 cyclists
- Scenario 29: front, 13 pedestrians and 3 cyclists
- Scenario 31: front-back, 13 pedestrians and 3 cyclists
- Scenario 33: front, 14 pedestrians and 1 cyclist
- Scenario 35: front-back, 14 pedestrians and 1 cyclist
- Scenario 37: front, 6 pedestrians and 2 cyclists
- Scenario 39: front-back, 6 pedestrians and 2 cyclists
- Scenario 41: front, 6 pedestrians and 1 cyclist
- Scenario 43: front-back, 6 pedestrians and 1 cyclist
- Scenario 45: front, 7 pedestrians and 1 cyclist
- Scenario 47: front-back, 7 pedestrians and 1 cyclist
- Scenario 49: front, 2 pedestrians and 2 cyclists
- Scenario 51: front-back, 2 pedestrians and 2 cyclists
- Scenario 53: front, 2 pedestrians and 1 cyclist
- Scenario 55: front-back, 2 pedestrians and 1 cyclist
- Scenario 57: front, 3 pedestrians and 1 cyclist
- Scenario 59: front-back, 3 pedestrians and 1 cyclist

- Scenario 61: front, 2 pedestrians and 8 cyclists
- Scenario 63: front-back, 2 pedestrians and 8 cyclists

Cyclists:

- Scenario 2: front, 23 pedestrians and 8 cyclists
- Scenario 4: front-back, 23 pedestrians and 8 cyclists
- Scenario 6: front, 25 pedestrians and 5 cyclists
- Scenario 8: front-back, 25 pedestrians and 5 cyclists
- Scenario 10: front, 28 pedestrians and 3 cyclists
- Scenario 12: front-back, 28 pedestrians and 3 cyclists
- Scenario 14: front, 17 pedestrians and 6 cyclists
- Scenario 16: front-back, 17 pedestrians and 6 cyclists
- Scenario 18: front, 19 pedestrians and 4 cyclists
- Scenario 20: front-back, 19 pedestrians and 4 cyclists
- Scenario 22: front, 21 pedestrians and 2 cyclists
- Scenario 24: front-back, 21 pedestrians and 2 cyclists
- Scenario 26: front, 12 pedestrians and 4 cyclists
- Scenario 28: front-back, 12 pedestrians and 4 cyclists
- Scenario 30: front, 13 pedestrians and 3 cyclists
- Scenario 32: front-back, 13 pedestrians and 3 cyclists
- Scenario 34: front, 14 pedestrians and 1 cyclist
- Scenario 36: front-back, 14 pedestrians and 1 cyclist
- Scenario 38: front, 6 pedestrians and 2 cyclists
- Scenario 40: front-back, 6 pedestrians and 2 cyclists
- Scenario 42: front, 6 pedestrians and 1 cyclist
- Scenario 44: front-back, 6 pedestrians and 1 cyclist
- Scenario 46: front, 7 pedestrians and 1 cyclist
- Scenario 48: front-back, 7 pedestrians and 1 cyclist
- Scenario 50: front, 2 pedestrians and 2 cyclists
- Scenario 52: front-back, 2 pedestrians and 2 cyclists
- Scenario 54: front, 2 pedestrians and 1 cyclist
- Scenario 56: front-back, 2 pedestrians and 1 cyclist
- Scenario 58: front, 3 pedestrians and 1 cyclist
- Scenario 60: front-back, 3 pedestrians and 1 cyclist
- Scenario 62: front, 2 pedestrians and 8 cyclists
- Scenario 64: front-back, 2 pedestrians and 8 cyclists

APPENDIX 3. STAGE 2 OF DATA COLLECTION: SPSS OUTPUTS

APPENDIX 3.1. LINEAR REGRESSION

MODEL 1

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	78753.038	3	26251.013	13270.647	0.000[b]
	Residual	82064.538	41486	1.978		
	Total	160817.576	41489			

a. Dependent Variable: Score

b. Predictors: (Constant), number of users, user type, width

Table 1. Model 1 ANOVA analysis.

MODEL 1A

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1a	Regression	97972.766	8	12246.596	8083.421	0.000[b]
	Residual	62844.810	41481	1.515		
	Total	160817.576	41489			

a. Dependent Variable: Score

b. Predictors: (Constant), Passer-by user type wheelchair, respondent's user type, path width, flow direction, number of cyclists, number of pedestrians, passer-by's user type pedestrian, passer-by's user type cyclist

Table 2. Model 1a ANOVA analysis.

Excluded Variables[a]

Model	Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
					Tolerance

1	Passer-by's user type 'pedestrian and cyclist'	.[b]	.	.	.	.000

a. Dependent Variable: Score
b. Predictors in the Model: (Constant), passerbyWHEEL, user type, width, flow direction, number of Cyclists, number of pedestrians, passerbyPED, passerbyCYC

Table 3. Model 1a: variables excluded from the model.

MODEL 1C

Excluded Variables[a]

Model		Beta In	T	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	Passer-by's user type cyclist	.[b]	.	.	.	0.000

a. Dependent Variable: Score
b. Predictors in the Model: (Constant), passerbyWHEEL, usertype, width, passerbyPED

Table 4. Variables excluded from model 1c.

<u>APPENDIX 3.2. ORDINAL REGRESSION</u>

MODEL 2

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	Df	Sig.
Intercept Only	37545.431			
Final	9726.616	27818.815	3	0.000

Link function: Logit.

Table 5. Model 2 summary.

Goodness-of-Fit

	Chi-Square	Df	Sig.
Pearson	8864.949	162	0.000
Deviance	8740.062	162	0.000

Link function: Logit.

Table 6. Model 2 goodness-of-fit.

Pseudo R-Square

Cox and Snell	0.489
Nagelkerke	0.505
McFadden	0.197

Link function: Logit.

Table 7. Model 2 Pseudo R-Square.

Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	Df	Sig.
Null Hypothesis	9726.616			
General	7642.473	2084.144	12	0.000

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.
a. Link function: Logit.

Table 8. Model 2: test of parallel lines.

MODEL 2A

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	Df	Sig.
Intercept Only	40820.967			
Final	6088.016	34732.951	8	0.000

Link function: Logit.

Table 9. Model 2a: model fitting information.

Goodness-of-Fit

	Chi-Square	Df	Sig.
Pearson	3896.693	452	0.000
Deviance	3827.687	452	0.000

Link function: Logit.

Table 10. Model 2a: Goodness-of-fit.

Pseudo R-Square

Cox and Snell	0.567

Nagelkerke	0.586
McFadden	0.245

Link function: Logit.

Table 6.11. Model 2a: pseudo R-square.

Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	6088.016			
General	5340.255	747.760	32	.000

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.

a. Link function: Logit.

Table 6.12. Test of parallel lines for ordinal regression combined model.

MODEL 2B

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	2308.028			
Final	899.869	1408.158	2	.000

Link function: Logit.

Table 6.13. Model fitting information for ordinal volume of users model.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	441.141	73	.000
Deviance	441.599	73	.000

Link function: Logit.

Table 6.14. Model 2b: goodness-of-fit.

Pseudo R-Square

Cox and Snell	.078
Nagelkerke	.084
McFadden	.030

Link function: Logit.

Table 6.15. Model 2b: Pseudo R-square.

Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	Df	Sig.
Null Hypothesis	899.869			
General	725.579	174.290	8	.000

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.
a. Link function: Logit.

Table 6.16. Model 2b: test of parallel lines.

MODEL 2C

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	3684.101			
Final	2211.090	1473.011	4	.000

Link function: Logit.

Table 6.17. Model 2c fitting information.

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	1251.143	186	.000
Deviance	1264.316	186	.000

Link function: Logit.

Table 6.18. Model 2c: goodness-of-fit.

Pseudo R-Square

Cox and Snell	.082
Nagelkerke	.087
McFadden	.031

Link function: Logit.

Table 6.19. Model 2c: pseudo R-square.

Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	2211.090			
General	2016.125	194.965	16	.000

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.
a. Link function: Logit.

Table 6.20. Model 2c: test of parallel lines.

MODEL 2D

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	9628.990			
Final	1951.699	7677.292	2	.000

Link function: Logit.

Table 6.21. Model 2d fitting information.

Goodness-of-Fit

	Chi-Square	Df	Sig.
Pearson	1443.050	83	.000
Deviance	1423.414	83	.000

Link function: Logit.

Table 6.22. Model 2d: goodness-of-fit.

Pseudo R-Square

Cox and Snell	.272
Nagelkerke	.289
McFadden	.111

Link function: Logit.

Table 6.23. Model 2d: pseudo R-square.

Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	Df	Sig.
Null Hypothesis	1951.699			
General	1895.341	56.358	8	.000

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.
a. Link function: Logit.

Table 6.24. Model 2d: test of parallel lines.

MODEL 2E

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	Df	Sig.
Intercept Only	11528.452			
Final	3195.955	8332.496	4	.000

Link function: Logit.

Table 6.25. Model 2e fitting information.

Goodness-of-Fit

	Chi-Square	Df	Sig.
Pearson	1939.483	261	.000
Deviance	1882.401	261	.000

Link function: Logit.

Table 6.26. Model 2e: goodness-of-fit.

Pseudo R-Square

Cox and Snell	.292
Nagelkerke	.309
McFadden	.121

Link function: Logit.

Table 6.27. Model 2e: pseudo R-square.

Test of Parallel Lines[a]

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	3195.955			
General	3107.081	88.874	16	.000

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.
a. Link function: Logit.

Table 2.28. Model 2e: test of parallel lines.