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Urban ‘Dis’ability: Bicycle Infrastructure as an Enabler of Mobility for Users of Wheelchairs and other Personal Mobility Devices

by

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Abstract

The majority of studies to date surrounding the use of wheelchairs and other personal mobility devices (PMDs) used by those with mobility impairments have traditionally focused on medical aspects related to health outcomes and rehabilitation. However, the social model of disability holds that disability is something imposed on those with impairments, for example, through poor design. Also, due to ageing populations and a concomitant increase in the number of those with mobility impairments in many countries around the world, there has been a rapid increase in the number of those using personal mobility devices, a trend that is expected to continue. Therefore, this study applies the social model of disability in examining the barriers to mobility faced by PMD users on a daily basis in the urban environment. Through the use of both an extensive literature review and a questionnaire completed by over 200 PMD users in the UK, the Netherlands, and Canada, this study has identified many specific infrastructure-related barriers, particularly pertaining to pavement design, that impede the movement of these individuals on a daily basis, often to the extent that limitations are placed upon their participation in society. This study proposes the provision of bicycle infrastructure as a solution to overcome many of the barriers caused by substandard pavement design, and through the use of the questionnaire, makes the finding that the majority of PMD users prefer the use of bicycle infrastructure to that of the pavement, due to its barrier-free design. Thus, bicycle infrastructure has been found to offer a transport-based solution that can eliminate many of the disabling barriers caused by poorly-designed urban environments.

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This work is dedicated to all those who have so frequently been forgotten, and whose mobility needs and requirements have so often been ignored, by the planners and designers of the built environment

It is hoped that this work will go some way towards ensuring provision of better urban infrastructure that allows greater mobility in the future for these individuals, and that it might encourage planners to always consider their needs when designing the cities of the future

Glossary

Impairment: a physical or mental limitation experienced by an individual caused by loss of related function, e.g. a mobility impairment might be caused by the loss of ability to control one's legs

Disability: a word with many conceptual definitions, but within the context of this research, the social definition will be used, which states that disability is a limitation imposed by society upon an individual who has an impairment

Mobility: ease or freedom of movement

Accessibility: a concept often incorporating mobility, it is based upon location and distance, and is often measured in terms of allowing one to reach desired goods, services, and activities, or in short, participation

PMD: Personal Mobility Device, any device designed to aid the mobility of those who have a mobility impairment, such as a wheelchair, mobility scooter, or handcycle

Pavement: the footway or sidewalk

Dropped kerb/kerb cut: a ramp that allows gradual change in elevation between the roadway and the pavement

Bicycle path: a right-of-way designed for the use of bicycles that is physically separated from the motor vehicle carriageway

Bicycle lane: a right-of-way designed for the use of bicycles that is part of the main roadway, separated only by paint

Bicycle Infrastructure: any infrastructure designed specifically for the use of bicycles, including bicycle paths, bicycle lanes, and crossings

Clear width: the width of a horizontal opening without obstructions

Introduction

To date, research in the field of transportation planning has thoroughly investigated the infrastructure and facility requirements for cars, trucks, buses, bicycles, trains, aircraft, and ships, and bespoke engineering solutions have been devised for each of these modes. However, one mode of transport that has largely been ignored so far is the wheelchair and other related personal mobility devices (PMDs) such as mobility scooters and handcycles.

The reason for this lack of research is not immediately clear, but perhaps the most plausible explanation is that many view wheelchairs and other PMDs to be medical devices rather than a mode of transport which needs to be catered for. This theory might be confirmed to some extent by the existence of a comparatively large amount of medical research relating to the design of the wheelchair itself, and the effects of its use upon the user.

However, this neglect occurs not only on the academic front, but is also reflected in transport planning practice. Unlike with a car or a bicycle, most transport planners will not have had the chance to use a wheelchair or mobility scooter in order to understand their design requirements, and their relatively low numbers in the past may also have led to them being somewhat ignored by transport planners and engineers. This lack of attention by planners has not gone unnoticed by the people they are ignoring though: 81% of wheelchair users in the UK believe that transport planners pay too little attention to their needs (MORI, 2002).

Nevertheless, whatever the reason, the pertinent fact is that this is a topic which cannot continue to be ignored. One study of wheelchair and mobility scooter users found that 84% of respondents were over the age of fifty; another more recent study of mobility scooter users revealed that around 91% of respondents were aged forty-five or older (Barham, Oxley and Board, 2006; Rica, 2014). Furthermore, in the UK, over 30% of adults old enough to receive a State Pension have a mobility impairment (DWP, 2013). Given that most users of PMDs are elderly or middle-aged, it is important to note then that the global population is both ageing and growing. Currently, there are over 800 million people aged 60 or older; this is expected to increase to over 2 billion by 2050, with the majority of the increase occurring in developing countries (UNDESA, 2012).

Furthermore, due to rapid urbanisation, over half the planet's population now reside in urban areas, a trend expected to continue. Therefore, the design of cities for elderly people, especially those suffering mobility problems, is becoming an important issue, one that has been recognised by the World Health Organisation's (WHO) guidelines for Age-Friendly Cities. In their checklist of essential features of an Age-Friendly City, the WHO lists several requirements related to the design of the urban environment, as well as public transport, which should be made suitable for use by PMD users (WHO, 2007).

Ascertaining the optimal infrastructure requirements for the ever-increasing number of PMD users in urban areas is an important consideration not just because they are an increasingly large, and therefore important, constituency, but more because they are a group of individuals who genuinely suffer limitations on their mobility due to disabling features within the built environment. Wheelchair users in the UK cite transport issues as their biggest concern at the local level, ahead of crime, housing, or health (MORI, 2002). Furthermore, 67% of wheelchair users rate the design of streets and pavements in the UK as poor (MORI, 2002). Previous research looking at the barriers to mobility for wheelchair and scooter users within cities cite problems such as a lack of dropped kerbs, bumpy and uneven pavements (which can also result in pain and fatigue), narrow pavements, and access being obstructed by pavement furniture, signs, and too many people using the pavement (Bromley, Matthews and Thomas, 2007; Pearlman et al., 2013; Imrie and Kumar, 1998). Because of these barriers to movement caused by poorly designed and maintained pavements (effectively barriers to "walking" for PMD users), those in wheelchairs and scooters who live in societies dominated by motorised transport (such as the UK) may become dependent on motor vehicles to get about, such as cars, buses, and taxis. However, because disabled people are also less likely to own a car than the general population, they depend even more on taxis and buses to travel, which would perhaps explain why 79% of wheelchair users in the UK said that they had to plan journeys well in advance (of whom, 82% are frustrated by the fact that they cannot go out on an impromptu basis) (MORI, 2002).

While wheelchair and mobility scooter users in urban areas face their own problems, the latter are increasingly viewed by many members of the general public to pose a threat to others, which has also provoked some hostility toward these scooter users. Many people appear to become befuddled by the fact that scooter users can often walk short distances, which they then interpret to mean that the scooter user is not disabled, leading to further hostility (Gentleman, 2012). A few cases of mobility scooters badly injuring or killing other pedestrians has led to calls for more regulations and safety training courses (as well as the aforementioned hostility), but an in-depth review carried out about ten years ago came to the conclusion that reported accidents involving powered wheelchairs or mobility scooters and pedestrians were rare and usually minor in severity (Blake, 2010; Barham, Oxley and Board, 2006). Nevertheless, an optimal infrastructure solution for PMDs may be one which reduces the risk of such collisions occurring, thus potentially also benefitting pedestrians.

The reason for the lack of an optimal infrastructure solution being determined for PMD users is because the research to date that *has* related to wheelchairs and mobility scooters as a form of transport has mostly focussed on either the accessibility of public transport vehicles or the barriers to accessibility within the built environment. While some guidance for designing for wheelchairs has been issued, for example with regard to pavement widths, pavement slope, dropped kerbs, and surface smoothness, there does not appear to be any bespoke solution that deals with all of the problems that PMD users face on daily basis in moving about a city. Rather, the approach appears to be more focussed on making pedestrian infrastructure suitable for PMDs as well as those with other disabilities (e.g. blindness or the inability to walk far), which will ultimately result in compromises for PMD users. This is reflected in the guidance of the GAATES (Global Alliance on Accessible Technologies and Environments) Technical Guide on Accessibility Standards for the Design of Public Spaces, which states with regard to designing for physical impairments in general (rather than for PMDs) "Some accessibility elements make it difficult to define specific technical requirements. Either the issues are too complex to provide prescriptive standards, or possible design solutions are too varied to capture as technical standards." (GAATES, 2014). As a result, even the pavements built to the best Universal Design standards may feature some negative aspects for PMD users, such as minor obstructions, or tactile surfaces that are unpleasant to wheel over; these design standards also do little to ease pedestrian crowding that can make progress slow and navigation difficult. Therefore, research is required that will take into account *all* of the technical and convenience requirements of PMDs and their users, in order to determine an optimal infrastructure solution.

As mentioned above, the design solutions for wheelchairs and other PMDs have, to date, been focussed around adapting the pavement in order to make it suitable for use by these devices. However, it is not hard to see that wheelchairs, handcycles, and to some extent, powered PMDs, share a lot in common with the bicycle. Both bicycles and PMDs ride on narrow wheels, and both are light weight. They both typically offer the ability to travel at a speed equal to or greater than a rapid walking pace, but slower than a car. Importantly, both bicycles and PMDs require more space than a pedestrian, and are liable to tip or lose control if they strike an object such as a kerb, meaning that smooth, wide, obstacle-free infrastructure is all the more important to guarantee safe and comfortable operation.

These parallels between bicycle and PMD user requirements will be touched upon throughout this piece of research. More to the point, in trying to determine an optimal infrastructure solution, the use of bicycle infrastructure by PMDs will be investigated from both a user and a device standpoint, to see whether bicycle paths and other related infrastructure might perform better than the pavement or road in meeting the requirements of a PMD and its user.

Three countries in particular will be focussed upon in both the literature review and the following original research, partly due to the number of relevant studies originating from these countries, but more because they have suitable transport backgrounds to form a good comparison for the results of the original research questionnaire; this choice will be discussed further in the methodology. These three countries are the United Kingdom, the Netherlands, and Canada.

Summary of justification

In summary, the below are the four points used to justify this research:

1) There are a growing number of PMD users within urban areas, a trend expected to continue around the globe
2) Certain design features of the built environment disable PMD users by limiting their mobility
3) The increasing number of PMD users, especially mobility scooter users, is viewed as a threat to pedestrian safety by some members of the public and lawmakers, leading to hostility and calls for increased legislation

4) Research to date relating to PMDs as a form of transport has taken a piecemeal approach, trying to integrate PMD infrastructure with that for other pedestrians, including those with other disabilities, rather than considering the complete needs and requirements of PMD users and their devices as a whole in order to devise an optimal infrastructure solution

Following this justification, the research questions below are therefore posed:

- What barriers does the built urban environment, such as that of a typical UK city, pose to the movement of a PMD user about the city?
- Of the above barriers that PMD users face, which of these does high-quality bicycle infrastructure NOT feature?
- Does high-quality bicycle infrastructure feature any barriers or benefits that pavements do not?
- When (in what situations) might bicycle infrastructure benefit PMD users, and when might it not?

Hypotheses

The author hereby states the following hypotheses:

1) High-quality bicycle infrastructure, such as can be found in the Netherlands, poses fewer barriers to mobility for PMD users than does a typical pavement.
2) The use of high-quality bicycle infrastructure is preferred to the use of pavements by PMD users.

The following aim and objectives are proposed in order to help answer the research questions:

Aim:

To quantitatively and qualitatively evaluate the mobility benefits, if any, to PMD users arising from the existence and use of bicycle infrastructure.

Objectives:

1. Define the concepts of disability and mobility; identify the factors within the urban environment which lead to transport disability/lack of mobility.
2. Quantify and qualify, from an engineering standpoint, the "disabling" features of roads, cycle paths, and pavements.
3. Determine the transport implications for PMD users arising from the use of bicycle infrastructure, both positive and negative.

Scope

The scope of this research, and especially of the literature review, will extend beyond that required only to meet the objectives. This is because it was felt that to fully understand the context of the research, a much broader background needed to be provided, since the subject area is considered quite niche from a transport planning perspective. As for the applicability of the findings, the investigation of barriers within the built environment, for example, will mostly focus on pavements/pedestrian areas and roads in the three study countries; while the barriers discovered would probably also be applicable in countries like the USA, France, or Australia, the results would be omissive of many potential barriers that would be encountered in other countries, such as a steep cobblestone path in an Italian hill town, or the street vendor clogged, motorcycle infested pavements that can be found in Bangkok. Similarly, findings regarding device usage or other issues may similarly be restricted in their applicability on a global basis.

Section I. Literature Review

Part 1. Concepts and Definitions

1.1) Defining Disability

In order to have a meaningful understanding of the barriers to movement and access that those using wheelchairs and other mobility devices face, it is important to first understand the relevant concepts that surround the issue. The first of these concepts is disability. For many, the mention of the word might evoke the image of a frail elderly person being wheeled around a nursing home, or of someone with a mental impairment unsuccessfully trying to communicate with a carer. However, the reality that the word describes is actually quite different, and far more varied. For example, 19% of the UK population have an impairment that causes disability, but these impairments are rarely visibly obvious: fifteen years ago, the Medical Devices Agency estimated that around 1.2 million wheelchairs were used in the UK, a number that constitutes just 10% of the UK's 12 million people with a disability (DWP, 2013; Barham, Oxley, and Board, 2006). Furthermore, most people are not born with their impairments – in fact, over 80% of people acquire their impairments during the life course, mostly in later life (Regan and Stanley, 2003). Importantly, it is this last fact that should be carefully noted – that it is *impairments* that are acquired, *not* disabilities. This brings the discussion to the actual concept of disability (with a focus on mobility impairments).

The definition of disability depends somewhat on which genre of academic literature one reads. This is because the medical and rehabilitation professions often equate disability and impairment as being the same thing, and Oliver (1993) argues that the latter profession often views impairment as a medical condition that requires treating, despite the fact that full rehabilitation may not be possible. Instead, "not walking" (or other incurable impairments) should stop being viewed as a medical condition, and instead be seen as "part of the normal range of human diversity" (Sapey, Stewart, and Donaldson, 2005). This idea seems to be supported by the views of a large number of wheelchair users, many of whom appear to be content despite being constrained to the use of a chair; moreover, for those who have used a wheelchair since birth, they indicated that they did not see or think of themselves as being any different to others their age (Sapey, Stewart, and Donaldson, 2004). Indeed, the use of powered mobility devices is often seen as an enabler of independent living amongst elderly people with mobility impairments (Korotchenko and Clarke, 2014). In their study of British wheelchair users, Sapey, Stewart, and Donaldson (2004) found that 78% of the participants agreed with the statement "wheelchairs can be liberating for disabled people", although perhaps importantly, only 63% agreed that their wheelchair had liberated them personally, which might indicate limitations to their use.

In contrast to the medical model of disability (where disability is due to impairment), there lies the social model of disability. This model, widely accepted by those in the disability rights movement, states that limitations are not a direct result of impairment, but rather that they are due to social and environmental barriers, such as exclusion or discriminatory attitudes from members of the public, or buildings that are designed for the able-bodied (Sapey, Stewart, and Donaldson, 2005; Imrie and Kumar, 1998). This idea was summed up well in 1975 by the Union of the Physically Impaired Against Segregation, who stated “In our view, it is society which disables physically impaired people. Disability is something imposed on top of our impairments by the way we are unnecessarily isolated and excluded from full participation in society” (Finkelstein, 1975).

While the social model may be too simplistic to fully encompass every aspect of disability, and may exclude the effects of impairment itself (even with the best environment, some impairments will ultimately still limit participation in certain activities), it nonetheless “provides an analysis of disablement that is relevant to the lived experience of wheelchair users” (Sapey, Stewart, and Donaldson, 2005). It is for precisely that reason that this research project will assume the social model to be the most accurate, and also relevant, given the context of the research topic. Perhaps the best way to understand the relationship between impairment, the wheelchair, and disability is as follows: an illness or physical condition physically impairs an individual, limiting their mobility (perhaps with regard to distance, speed, or comfort); a wheelchair or other PMD is used to counteract these negative symptoms, effectively acting as a replacement for the individual’s legs (and potentially “adding stamina”), thereby minimising the mobility loss, but only insofar as the built environment allows – physical barriers such as stairs or narrow doorways that prevent access to wheelchairs once again restrict overall mobility, thus creating disablement. Furthermore, in this way, it could be seen that to some extent, the mobility device is the bridge between the applicability of the medical model of disability (where the impairment is causing reduced mobility), and the social model of disability (where the environment is causing reduced mobility). Of course, this ignores social aspects, such as the attitudes of others being disabling, but it nonetheless allows a symbolic conceptualisation of how the wheelchair can alter the concept of disability for those with impairments that limit their mobility. It is perhaps worth noting however that reduced mobility is not necessarily the best measure of disablement, as movement or travel for the sake of travelling is generally regarded in transport planning as having little value; thus a better measure may be that of participation in society, referred to as social outcome performance measures (Jones and Lucas, 2012). This will be discussed more though in the next section regarding the concepts of accessibility and mobility.

To summarise a few of the key models of disability, an adapted version of the table by Sapey, Stewart, and Donaldson (2004) is shown in table 1.1.

Model	Beliefs	Practice
Lay	Disability is a personal tragedy	Pity and charity – disabled people as 'other'
Medical	Disability is impairment	Scientific research, improved procedures and expertise
Social	Disability is a form of oppression experienced by people with impairments	Equality training for practitioners (transport planners!), rights to services, laws to end discrimination

Table 1.1: Summary of the most common models of disability, adapted from Sapey, Stewart and Donaldson (2004)

To conclude this section on the concept of disability, and also to drive further the point regarding disability differing from impairment, it should be noted that it is not just people with impairments who can be disabled by the built environment and the way urban areas are planned. The social model of disability can be extended to include the able-bodied as well: Aldred and Woodcock (2008) and make clear that in car-based societies, those without cars (particularly the young, old, and disabled) effectively become disabled because they cannot access out of town services (such as retail parks) without a car, and their movement (as a pedestrian) about the city becomes slower, and more stressful and dangerous due to the high volume of cars on the road. Or, put another way, "the car supports the creation of distances and obstacles only it can overcome" (Aldred and Woodcock, 2008). This brings the discussion to the concepts of mobility and accessibility.

1.2) Mobility and accessibility

The terms 'mobility' and 'accessibility' are not particularly easy to define, and are sometimes even viewed as contentious. This is because as concepts, they have a wide scope, and whilst for example, mobility might be viewed as an end in itself ("increasing mobility"), or accessibility as a means to an end ("achieving access"), the reality is more complex, and varies on a spatial scale.

1.2.1) Mobility

The Oxford English Dictionary defines mobility as "Ease or freedom of movement; capacity for rapid or comfortable locomotion or travel". Rodrigue, Comtois, and Slack (2013) add that mobility "can have different levels linked to the speed, capacity and efficiency of movement". Eby, Molnar, and Kartje (2009) open their book by stating that "The ability to get from place to place is important for everyone", and mention that many consider mobility as a human right. Cahill (2010) defines mobility simply as "the ability to travel, to move from place to place", adding that the term generally has a positive meaning for many people, due to its association with the idea of freedom and overcoming boundaries of place and barriers of distance.

According to Eby, Molnar, and Kartje (2009), mobility contributes greatly toward attaining a good quality of life, by enabling people to carry out daily life and leisure activities, as well as helping them to stay socially connected. Furthermore, Cahill (2010) points out that mobility has increasingly become a requirement of the modern world: a century or so ago, people lived close together, with their family, within walking distance of their place of employment and other places they needed to visit. In contrast, people now live further from friends, family, their employer, and retail/leisure activities, which means that people often need to use a car or other form of motorised transport in order to reach their destination due to the distances involved (and the inconvenience/lack of comfort when travelling on foot); thus, those without auto-mobility are often socially excluded (Cahill, 2010).

When considering movement itself within the context of making a trip, it is generally accepted that the large majority of journeys will involve more than one mode of transport. Almost every journey will involve being a pedestrian (or using a PMD) at some point; in countries like the UK and USA, the car will also be used in the majority of journeys. Other modes of transport like buses, trams, and bicycles are also popular for moving about cities. The combination of different modes within a journey can be referred to as the "transport chain", because every link (e.g. walk, train, bus, walk) has to connect in order to complete the journey (Lavery et al., 1996). Importantly, as Lavery et al. (1996) point out, if any one link in the chain breaks, it can cause great difficulties for the person making the journey, especially if they suffer from a physical impairment. For example, if a train had to use a city's secondary (suburban) train station due to the central one being unusable, and the suburban station had many stairs and no wheelchair ramps, then a wheelchair user may be forced to get off in another city, make the journey using different modes (possibly at extra expense), or not make the journey at all. Accordingly, Lavery et al. (1996) also bring up another term, the "barrier chain", which can be used to describe the multitude of barriers potentially faced by someone at each link in the journey, such as broken and uneven pavements on the way to the bus stop, a bus arriving with the wheelchair space already taken, or the bus stop not having any shelter from the weather.

Preston and Rajé (2007) make a point of differentiating between area mobility (e.g. city-wide level of travel) and individual mobility (the level of travel by specific individuals or groups). They comment that both low levels of individual mobility and low levels of individual accessibility are associated with social exclusion. However, they also argue that because the UK has too much [car-based] private mobility, which leads to social exclusion for certain groups and individuals through, among other things, environmental pollution and community severance, the best policy response would be to focus on improving accessibility ("ease of reaching") rather than mobility ("ease of moving"). It should be noted, however, that Preston and Rajé are referring to improving social inclusion for the UK in general, and they recognise that taking an area-wide approach misses individuals or groups in an area who may be socially included or excluded, in contrast to the area as a whole. Thus, when considering those with mobility impairments, who tend to suffer both low levels of individual mobility and accessibility, improving both mobility and accessibility may be desirable.

Public transport expert Jarrett Walker (2012) is keen to make the distinction between the terms *personal mobility* and *mobility* (the latter being a more general term that can also be applied to movement of vehicles, and considered at a local or area wide scale). He defines personal mobility (within the context of public transport) as "the freedom to move beyond your walking range". Moreover, he equates this with the more simple definition "ease of moving about", and specifies clearly that this is *not the same* as "movement". Walker goes on to clarify that "ease of moving about" portrays a *degree of freedom* whereas "movement" is *exercising that freedom*. More to the point, however, Walker makes the argument that generally, our trips are not made due to the desire for movement itself, but rather that they are made due to the need to do something. Thus, he argues that in most cases, we desire access, not movement (Walker, 2012).

Authors such as Preston and Rajé (2007), Walker (2012), and others bring to light the increasing role of "virtual mobility", whereby the use of internet technology is made in order to access online services. In particular, the ability to contact friends online, to work from home, or to order groceries online for home delivery reduces the need for movement by providing increased access.

Summarising the concept of mobility

How best then to summarise the concept of mobility? It appears as though most authors are in agreement with a definition along the lines of *ease or freedom of movement; the ability to travel*. This implies that the *option* to move freely about the city exists, even if that option is not exercised. Authors point out that the ability to move between places is important, and contributes to a good quality of life through enabling social interaction and leisure activities. Sometimes, mobility is even seen as a human right, or a "merit good" (Preston and Rajé, 2007). While mobility is more necessary today than it was in the 19th century, this is somewhat offset by the advent of the internet, offering "virtual mobility", thereby reducing the need for movement. However, certain factors exist that contribute to reduced mobility, particularly for the elderly and PMD users. These factors include excess car-based mobility by the "socially included" in society, which results in longer travel distances, community severance, poorer quality public transport, and an unpleasant pedestrian environment for those who travel by active modes or public transport; and barriers in the built environment such as poor quality pavements, inaccessible public transport, and station infrastructure with outdated design. Therefore, in order to ensure better social equality for PMD users, the aforementioned factors that limit their mobility should be eliminated or reduced as much as possible.

Despite all this, it is important to consider that even if one has the ability to move about the city with ease, all of this is in vain if the goods and services one needs to access are located outside of the city area, reachable only by private car which the individual may not own or have available for use. Thus, accessibility is also an important issue, and the issues surrounding it important to understand. Therefore, this concept will now be discussed in the section below.

1.2.2) Accessibility

Accessibility, as a concept, is perhaps even more difficult to define than mobility. While mobility is looked upon as either movement or the freedom to move, accessibility is far more complex, as it encompasses many more considerations, as will be discussed below.

For a more basic definition, authors like Selberg (1996) define accessibility as "the ease with which the different road users can reach the various activities and opportunites". Selberg then goes on to mention that factors such as the quality of transport, the urban fabric, and even opening hours affect accessibility. Cahill (2010) writes that accessibility is related to the ease or difficulty of reaching a location. The Oxford English Dictionary (OED) defines accessibility as the "condition of being accessible", which in turn is defined as "Capable of being entered or approached; easy of access; **readily reached**" (my emphasis). However, the OED also lists another definition, which is important given the topic of this research: "Capable of being conveniently used or accessed by people with disabilities; of or designating goods, services, or facilities designed to meet the needs of the disabled". This second definition, which originated in the USA, and is prevalent in more medical-based literature (e.g. see Rimmer et al., 2004) can lead to some confusion, or ambiguity, when researching topics related to transport geography and planning, such as this one. For example, an "accessible bus" is probably inferred to be one that is suitable for wheelchair users or the visually impaired. However, if a building is referred to as "accessible", does this mean that it is specially designed for wheelchair users, or does it mean that one can reach it easily by car or on foot? Ultimately, this secondary definition is a derivation of the primary one, perhaps because the built environment has in the past been so unfriendly, so *inaccessible*, to those with physical (and mental) impairments. That is to say, a new definition of a word, one that is effectively an emphasis of the original definition applied to a specific group of individuals, may have been born out of the need for inclusiveness, when perhaps the original definition was considered to exclude those who were not able-bodied, or perhaps to emphasise the extra design requirements needed to make a building, vehicle, or pavement accessible for those with impairments. Given this analysis, it should be noted that for the rest of this dissertation, the terms "accessible" and "accessibility" will automatically include those with physical impairments ("the disabled"), thereby incorporating the secondary definition just discussed. Accessibility is a term that should include everyone, and should not need to be emphasised for any particular "group" of individuals, such as those who rely on personal mobility devices to move around.

The following authors go on to explore the ideas and factors involved with the concept of accessibility more deeply:

Rodrigue, Comtois, and Slack (2013) state that accessibility is based upon the concept of location and distance. This makes sense, when it is considered that somewhere located nearby will require little travel to reach, and will be accessible by a multitude of modes, whereas a distant location will not often not be accessible to those not having use of a car. Jones and Lucas (2012) provide a general definition of the concept of accessibility, saying that it gives provision for different measurements of "the degree to which people can reach the goods and services that society considers are necessary for them to live their daily lives", but just as Walker (2012) stated in reference to personal mobility, Jones and Lucas mention that the emphasis is on the potential, or capability, to reach these goods and services, rather than actual behaviour (exercising the potential). Litman (2011) provides an in-depth discussion exploring the differences between the concepts of mobility and accessibility, albeit perhaps somewhat aimed at the perspective of a highways engineer. He defines accessibility as "the ability to reach desired goods, services, activities, and destinations", and reiterates that access is the ultimate goal of most travel, rather than movement itself. Therefore, when considering accessibility, anything that prohibits people from reaching these goods, services, activities, or destinations is thus a barrier (physical, cost, or risk) that needs to be removed, either through risk reduction, mobility improvements, virtual mobility, or changes in land use that reduce distances (Litman, 2011).

Due to the scope of the concept of accessibility, it is often best to consider it at different spatial scales, especially when searching for solutions on how to remove barriers and improve it. Jones and Lucas (2012) and Litman (2011) state that generally speaking, there are three scales of accessibility: micro (e.g. wheelchair-accessible bus or a junction featuring dropped kerbs), meso (e.g. connectivity of pavements, streets, or cycle paths within a neighbourhood, ensuring consistency in design and elimination of severance), and strategic (concerning the effects of land-use patterns and transport networks for a town or region). While each of these spatial scales of accessibility have their own methods of measurement and quantification associated with them, this research will be primarily concerned with meso-level accessibility, which incorporates micro-scale design features (such as kerb cuts and pedestrian crossings, for example). Quantification of meso-level accessibility involves assessment of factors like route directness and different non-motorised level-of-service indicators (Jones and Lucas, 2012).

Summarising the concept of accessibility

Based upon the literature, there appears to be clear agreement on a general definition for the concept of accessibility. Thus, the following definition has been decided upon, and will be applicable for the rest of this body of work: accessibility is the ease of reaching, or ability to reach, the destinations, activities, goods and services that are essential for a good quality of life and participation in society. Accessibility is concerned with the potential for access – whether a journey could be made – rather than if it is actually made.

The United Nations set out certain mobility and accessibility rights that should be afforded to anyone affected by an impairment, in the Convention on the Rights of Persons with Disabilities. This is discussed further in the subsection below.

Accessibility can be considered on different scales, from the micro-level that considers specific engineering and design measures for the immediate area (e.g. a specific pavement or junction), up to the macro, or strategic, city or regional level, which considers overall road and public transport networks, as well as land-use planning. Accessibility can be improved in three primary ways: 1) reducing barriers to personal mobility, thus allowing travel; 2) achieve it via telecommunications and internet technology; or 3) relocate yourself, or the destination, potentially through land-use planning measures (Walker, 2012; Litman, 2011).

1.2.3) Is mobility or accessibility more important to achieve?

As mentioned earlier, as Litman (2011) and others have pointed out, the ultimate goal of a transport network, or the people who plan them, is to provide access to places that people want to go; a goal that not only (in most cases) requires movement, but also requires the destination to be within a comfortable range of whatever mode of transport is available to the individual making the journey. Crucially, as this work is concerned with those who rely upon mobility devices like wheelchairs and mobility scooters to move about a city, and because the built environment has been implicated in posing barriers that result in "dis-ability" and thus exclusion of these individuals from society, the most important goal to achieve is the one that will minimise these barriers and maximise participation as a result.

The entire point of a mobility device is to enable mobility, or more specifically, movement. Mobility devices are but vehicles that enable or facilitate a journey by removing some of the barriers to movement caused by a physical impairment. While the freedom that these devices provide to their users is potentially life-changing in a very positive way, the built environment is perhaps an even more powerful force in facilitating or limiting the mobility that these devices provide. Due to this fact, achieving the goal of personal mobility for PMD users is a critical one.

However, Litman (2011) makes clear that setting goals based on accessibility is a better approach [for a city] than setting them based upon measures of mobility (movement). According to Litman, this is because setting mobility goals favours movement, and thus speed and highway/public transport capacity become the primary concerns, rather than lessening distances and prioritising active modes such as walking and cycling (with these latter goals resulting in less person-miles travelled, which equates to a "reduction in mobility", at least in the minds of some). On the other hand, the concept of accessibility takes into account mobility (ability to travel) as well as improving land use accessibility (which reduces distances), and even considers "mobility substitutes" like internet social platforms and online shopping (Litman, 2011).

Furthermore, a focus on mobility alone results to some extent in the disregard for the built environment that has plagued those who are non-car users. While at the micro- and meso-levels, barriers to mobility are an important consideration for PMD users, countries such as the UK have, to date, seemingly attempted to bypass the concerns of the built environment by providing car-based mobility to those who would be severely mobility-impaired (disabled) without it. Litman (2011) states that in a car-based society, “the best way to benefit non-drivers is to help them become motorists”.

The intent of this research, however, is not to enable those with mobility impairments to become motorists. Rather, the intent is to understand how the built environment, specifically the street/pedestrian environment of urban areas, can be optimised toward the use of personal mobility devices by reducing barriers to mobility, thus helping to minimise disability and maximise social equality.

With all these considerations in mind, it would appear that trying to improve accessibility would be the best goal to aim for. As mentioned earlier, accessibility can be improved via increasing mobility, enabling virtual mobility (which is outside the scope of this research), and targeting land-use measures to ensure that destinations are accessible without the use of a car in urban areas (somewhat within the scope of this research). So, while improving mobility is perhaps the most important individual target to achieve for PMD users, focusing solely on it as a goal may result in a car-centric approach, whereas accessibility is a more encompassing concept that is also concerned with improving mobility *via* improving access to individual aspects of the built environment (such as improving access to pavements). Thus, accessibility is the true goal to aim for in eradicating transport-based social exclusion for PMD users. Also, Rodrigue & Notteboom (p.235), discuss how mobility tends to increase with income; while the global wealthy currently have the best mobility (cars for short distances, aircraft for long), the inequality is likely to shift more in future years from being an income issue to being an age issue.

The United Nations Convention on the Rights of Persons with Disabilities sets out requirements related to accessibility, personal mobility, and participation in leisure and sport that signatory nations should aim to meet. The relevant requirements and guidelines are listed in table 1.2 on the following page. As it shall be seen in the following paragraphs and sections, even most developed countries are failing to fully meet these requirements.

Article 9 - Accessibility	1. To enable persons with disabilities to live independently and participate fully in all aspects of life, States Parties shall take appropriate measures to ensure to persons with disabilities access, on an equal basis with others, to the physical environment, to transportation, to information and communications, including information and communications technologies and systems, and to other facilities and services open or provided to the public, both in urban and in rural areas. These measures, which shall include the identification and elimination of obstacles and barriers to accessibility, shall apply to, inter alia: a) Buildings, roads, transportation and other indoor and outdoor facilities, including schools, housing, medical facilities and workplaces; 2. States Parties shall also take appropriate measures: a) To develop, promulgate and monitor the implementation of minimum standards and guidelines for the accessibility of facilities and services open or provided to the public; b) To ensure that private entities that offer facilities and services which are open or provided to the public take into account all aspects of accessibility for persons with disabilities; c) To provide training for stakeholders on accessibility issues facing persons with disabilities;
Article 20 – Personal mobility	States Parties shall take effective measures to ensure personal mobility with the greatest possible independence for persons with disabilities, including by: a) Facilitating the personal mobility of persons with disabilities in the manner and at the time of their choice, and at affordable cost; b) Facilitating access by persons with disabilities to quality mobility aids, devices, assistive technologies and forms of live assistance and intermediaries, including by making them available at affordable cost; d) Encouraging entities that produce mobility aids, devices and assistive technologies to take into account all aspects of mobility for persons with disabilities.
Article 30 – Participation in cultural life, recreation, leisure and sport	1. States Parties recognize the right of persons with disabilities to take part on an equal basis with others in cultural life, and shall take all appropriate measures to ensure that persons with disabilities: c) Enjoy access to places for cultural performances or services, such as theatres, museums, cinemas, libraries and tourism services, and, as far as possible, enjoy access to monuments and sites of national cultural importance. 5. With a view to enabling persons with disabilities to participate on an equal basis with others in recreational, leisure and sporting activities, States Parties shall take appropriate measures: a) To encourage and promote the participation, to the fullest extent possible, of persons with disabilities in mainstream sporting activities at all levels; c) To ensure that persons with disabilities have access to sporting, recreational and tourism venues;

Table 1.2: United Nations Convention on the Rights of Persons with Disabilities: Articles concerning accessibility, personal mobility, and participation in leisure and sport activities. (UNCRPD, 2006)

Just as mobility in terms of actual travel is often viewed as an end in itself, it could be argued that to some extent, so is trying to achieve “accessible” (being impairment-friendly) public transport. The end-goal of the wheelchair user is not generally to ride on the bus, but rather, to get to their desired destination. A bus that is not accessible to a wheelchair user effectively acts as a barrier to their journey – in some cases, a rather significant one if the distance is great and there are no available alternative modes. However, having an accessible bus is of no use if the bus stops are not accessible from the origin or destination. Especially in the UK, it often appears as though a large focus has been placed upon things such as accessible public transport vehicles, while ignoring the transport infrastructure (e.g. stations) and pedestrian links (i.e. pavements) usually required to access them. Indeed, this assertion may to be supported by the work of Jolly, Priestley, and Matthews (2006), who found from their analysis of UK National Travel Survey data that while those with impairments reported less of a problem in recent years using the bus itself, they reported an increase in difficulty actually reaching the bus stop (although the specific cause for this is not known from the data).

Lavery et al. (1996) rightly point out that there are three main components of a journey: the person, the vehicle, and the built environment. While personal barriers (i.e. impairments) are not related to transport planning, and the vehicle is usually the responsibility of transport operators and designers, the area in which transport planners can effect the most change is in the built environment. Hence, it is the built environment on which this research primarily focuses. A truly non-disabling environment, one that puts the wheelchair or mobility scooter user at no disadvantage to other people, is one that is free of virtually all barriers to mobility, or at least offers no more barriers than the able-bodied face, and does not place any restrictions to access to the same goods, services, or social or leisure opportunities that can be utilised by able-bodied car owners.

Consequently, in conclusion, it can be said that while accessibility is more important to achieve, improving mobility should be the focus of this research, as it is not within the direct remit of transport planners to improve zoning or the siting of buildings, but rather only to ensure it is possible to make the trip there.

1.2.4) Participation as an outcome

Considering the importance of accessibility (and of personal mobility), it is therefore also important to measure whether or not these “potentials” for being able to access a location and for different forms of travel are truly realised through actual behaviour. Many researchers and organisations call for measurement of this revealed behaviour via participation or involvement in society, or “social outcome performance measures”; furthermore, considering that wheelchair and other PMD users tend to make less trips, and get less exercise, these measures of participation are considered even more critical for this group of individuals (Preston and Rajé, 2007; Jones and Lucas, 2012; Lui and Hui, 2009; Crawford et al., 2008; Law et al., 2007; Meulenkamp et al., 2013; Clarke et al., 2011; Cooper et al., 2011).

Generally, participation could be measured under such metrics as trip rates, travel distances, and activity participation rates, although interpreting the data in terms of representing accessibility success or failure can be more problematic – for example, as was discussed previously, travelling further is not always a good thing, especially if it occurs due to the closure of a more local facility (Jones and Lucas, 2012).

1.3) Equipment falling under the category of Personal Mobility Device (PMD), their history, and specifications

The concepts of disability, mobility, and accessibility have now been defined and discussed in detail, providing a firm background frame of reference from which to consider the rest of the research. Following on from this, in order to avoid causing the reader confusion, and in order to provide a better understanding the technical background surrounding this work, the subsequent two sections will define, describe, and illustrate the primary and lesser-known types of personal mobility device that are available today, as well as investigating their legal status as vehicles or pedestrians in different countries. Lastly, some medical background will be given with regard to the causes of mobility impairments, and how these conditions (and other related factors such as age) might interrelate with the type(s) of device used.

1.3.1) A short history of mobility devices for the physically impaired

According to Cooper (1998 cited in Sapey, Stewart, and Donaldson, 2005), in ancient times the vehicle of choice for those with physical impairments and who had a higher social status was the litter, a chair or small bed upon a platform that was usually carried by two or more men with poles, and typically utilised by the aristocracy. The first evidence of a wheelchair was found inscribed on a 6th century Chinese sarcophagus, although wheeled furniture may have existed before this time (Cooper, 1998; Encyclopaedia Britannica, 2014a). The first "wheelchair" to be used in Europe was probably the wheelbarrow, introduced around the 12th century (ibid); as with the litter, it may have improved mobility, but still required dependence on others in order to move. According to Encyclopaedia Britannica (2014a), the first rolling chair was probably that which Johann Hautsch created in Nürnberg in 1649; then in 1655 paraplegic watchmaker Stephan Farfler created what many consider to be the first self-propelled wheelchair, a three-wheeled device propelled by a hand-crank attached via a gear box to the front wheel (thus effectively making it a handcycle). An illustration of this device can be seen here in Figure 1.1.

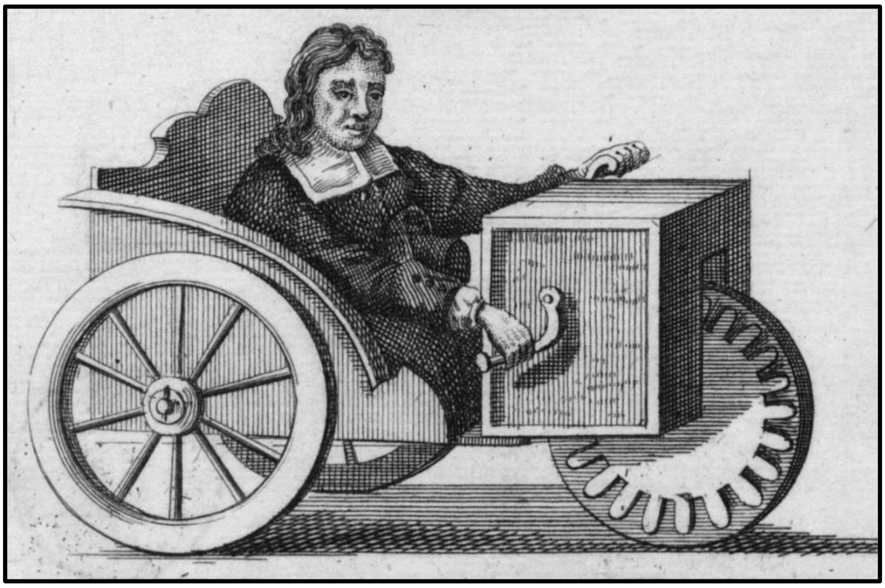


Figure 1.1: Stephan Farfler's 1655 self-propelled wheelchair. (Source: Wiki Commons)

As the designs for wheelchairs began to advance, they became referred to as "invalid chairs", a term that is still in use today, even in legal terminology (such as "invalid carriage" in the UK), despite it being increasingly viewed as a derogatory or unsuitable term (Encyclopaedia Britannica, 2014a; Baker, 2010). From the 18th century, wheelchairs began to be sold as medical devices, and became much more widely used due to the needs of war veterans following the US Civil War and subsequent conflicts. In the late 19th century, rubber tyres were introduced, and in the 20th century efforts focused on reducing weight and increasing portability (Encyclopaedia Britannica, 2014a).

1.3.2) Why the term "Personal mobility device"?

From a review of the literature, it is apparent that there is not really a specific, widely recognised term used to describe the "category" of devices used to aid the movement of those with mobility impairments, possibly due to the lack of research considering these devices as a distinct class of vehicle. While it would be inaccurate to try to group the entire range of these devices as one category (they range from the manual wheelchair, effectively a "leg replacement" allowing pedestrian movement, to the handcycle, which is more comparable to a three-wheel hand-powered bicycle, to mobility scooters that can travel upwards of 15mph), all these devices share certain traits in common. In general, they all seat one, or occasionally two people; they all typically have three or four wheels; most of them take up more room on the pavement than an individual pedestrian, but are far smaller and lighter than a car; most of them pose a slight threat to pedestrians if being used at speed, yet offer little safety protection for their occupants from cars and other heavy vehicles if used on the road; and the majority are now available as electric-assist, or fully electric vehicles.

As was discussed earlier, the term *personal mobility* can be defined as "ease of moving about", or as the freedom to move beyond one's walking range (Walker, 2012). Furthermore, the device is *personal*, as it is typically specified to the exact needs of the mobility-impaired individual, and also because it usually only seats one person. Because of these reasons, the term *personal mobility device* is favoured over the shorter *mobility device*. Both Bruneau and Maurice (2012) and Litman and Blair (2004) adopt the term *personal mobility device*, with the latter authors providing the following definition: "A *Personal Mobility Device* (PMD) is any relatively small, wheeled device that provides personal mobility and can operate on nonmotorized facilities". However, Litman and Blair (2004) also consider additional devices more often used by the able-bodied, such as skateboards, roller blades, Segways, and standard bicycles, to fall under the term, which makes sense when considering Walker's definition of personal mobility. For the purposes of this study however, only those devices which are typically considered to be of benefit to those with an illness or physical condition that result in mobility impairment will be regarded as relevant.

1.3.3) Types of device and their technical specifications

1.3.3a) Attendant-controlled wheelchair

Along with self-propelled manual chairs, these are the most popular type in the UK. These chairs are usually the cheapest and are often foldable, making them easy to store inside the home or car. They may lack the large rear wheels of a self-propelled chair, meaning that they can only be moved with the help of an attendant, although this may not be of particular concern given that they are often used in nursing homes and hospitals. However, because they require the help of another to move, these chairs could be considered to offer the least personal mobility.

1.3.3b) Self-propelled manual wheelchair

These wheelchairs typically feature large rear wheels with a push-rim around the outside so that the user can propel themselves forward. They range in weight from under 13kg to over 18kg, depending on the type, with folding models typically weighing more (Encyclopaedia Britannica, 2014b). These wheelchairs obviously require at least some upper-body strength and fitness to use, and would clearly become very difficult to use on hills – it is for this reason that ramps in the built environment, such as those leading up to buildings, should not be steeper than a slope of 1:12, with a maximum of 1:16 to 1:20 being preferable (CHRC, 2007). Due to the repetitive nature and inefficiency of pushing the hand-rim forward, and the anatomical design of the shoulder, daily use of the push-rim wheelchair can cause fatigue, and in the longer-term, overuse injuries and pain (Vegter et al., 2010; Arnet, 2012). When designing infrastructure for manual wheelchairs and their users, international best-practice guidelines recommend designing for a length of at least 1,300mm, and a width of 800mm or greater (CHRC, 2007, DfT, 2002).

1.3.3c) Power-assisted manual wheelchair, a.k.a. push-rim-activated power-assisted wheelchair (PAPAW)

This type of wheelchair is an advancement upon the standard self-propelled manual chair, much in the same way that a “pedelec”, or pedal-electric bicycle, is an advancement of the standard bicycle. Typical models feature an electromotor in the hub of the wheels, which provides metered power assistance based upon the user’s input when pushing the hand-rim (Vegter et al., 2010). Because of the power assistance, it may be possible for many individuals to climb moderately long and steep hills with these wheelchairs, thus offering greater mobility than a standard self-propelled chair, especially in hilly cities. Disadvantages include increased weight and reduced portability. Summarising a multitude of studies on the use of these devices, SCIRE (n.d.) state that the use of a PAPAW may reduce upper-body range-of-motion during use, thus lowering risk of injury, as well as reducing exertion and fatigue, thereby allowing users to travel greater distances.

1.3.3d) Power wheelchair, a.k.a. motorised wheelchair

A powered wheelchair is a wheelchair with an electric motor and battery pack, generally designed to be used full-time by the user without assistance from anyone else. Power wheelchairs usually have four to six wheels (two main drive wheels and two or four smaller caster wheels), and they are normally controlled by a joystick at the end of the armrest. While some models are smaller, looking more like heavy-duty manual wheelchairs, but with a power pack, others are larger and may have additional features such as height-adjustable reclining seats and kerb-climbers (Campbell, 2012). Power wheelchairs can often be highly customised to meet the needs of the user based upon their impairment: for example, some can be controlled by the user’s mouth via a sip-and-puff system.

Motorised wheelchairs tend to be designed with a focus either on indoor use or on outdoor use. Indoor chairs are usually smaller and more manoeuvrable in order to be suitable for use within the home, and tend to have a short distance range due to a having small battery (Barham, Oxley and Board, 2005). Outdoor power chairs have a greater range and can often be taken over rough terrain and have the ability to climb kerbs, but may be too large or unwieldy to be used indoors (ibid.). There is also a large variety of chairs that fall somewhere in-between these two categories, often referred to as indoor/outdoor chairs, or EPIOCs.

In the UK, power wheelchairs are allowed to have an unladen weight of up to 150kg. More importantly, the UK also places wheelchairs and other PMDs into three categories: Class 1 devices, such as manual wheelchairs, which are not mechanically propelled; Class 2 devices, which are mechanically propelled, but cannot exceed 4mph; and Class 3 devices, which can reach speeds of up to 8mph, and must also be fitted with lights and a horn (HM Government, 1988). Class 2 devices may only be used on the pavement, except to cross the road (unless none exists), but Class 3 devices can be used at up to 4mph on the pavement and 8mph on the road (Barham, Oxley and Board, 2005). Maximum speeds of motorised wheelchairs in other countries vary, usually depending on legislation. For a summary of this legislation in different countries, see the table in section 1.4.1.

A scan of websites in the UK indicates that prices range from around £1000 to well over £5000. Specifications listed on websites also cite operating ranges of power chairs, from less than 10 miles, to about 25 miles on a charge for some of the heavy-duty chairs. However, as Campbell (2012) points out, the actual range will vary depending upon factors such as the user's weight and terrain gradients. Operating range may be a concern for many users, as running out of power in a heavy wheelchair, for someone with little or no walking ability, could clearly be a serious problem. Edwards and McCluskey (2010) reported that almost 40% of respondents in their study worried about the battery running out while away from home, and Korotchenko and Clarke (2014) reported similar concerns from their participants. Thus, device technical limitations could be considered as an additional barrier to mobility for some users, over and above those already posed by the built environment.

In terms of device size, international best practice guidelines call for infrastructure and building designs to allow a minimum clear floor area of 800x1,300mm, the same as for a manual wheelchair (CHRC, 2007). In the UK, the maximum width for a Class 3 device is 850mm, although other countries may allow more.

1.3.3e) Mobility scooter, a.k.a. motorised scooter

Mobility scooters stand out from the other PMDs discussed here, in that they have seen the greatest increase in number of sales in recent years (except for, perhaps, electric bicycles). This increase will be discussed in more detail in the following section of the literature review.

Mobility scooters vary in their design. Rutenberg et al. (2011) write that there is no exact definition of what constitutes a mobility scooter, so they provide their own:

"Mobility scooters are three- or four- *wheel mobility aids […] they are considered to be comparable to the walking mode and can use the pedestrian rights-of-way. They are powered devices primarily intended for individuals with limited endurance for walking. Mobility scooters generally have tillers for steering and a comfortable seat, usually with back support and armrests."*

Most of the time, mobility scooters are battery-powered electric devices, and they generally weigh between 30 and 150kg; furthermore, some mobility scooters have a range of up to 80km (50 miles) on a single battery charge (Rutenberg et at., 2011), although most have a range comparable to those listed for the previously discussed motorised wheelchairs. However, one of the problems that faces mobility scooters and their users in many countries is their lack of standardisation, especially with regard to the external dimensions of the device, one not necessarily helped by the trend toward bigger and heavier scooters (ibid.). This can be problematic if the user would like to take their scooter on a bus, as some scooters are presently too big or heavy to do so; as a result, there have been calls to devise a standard for the size of a scooter which would be transportable on public transport, and to which scooter manufacturers could design (HCTC, 2010). That said, the UK Public Service Vehicles Accessibility Regulations 2000 mandate that buses have wheelchair spaces no smaller than 750x1,300mm, in order to comfortably accommodate for a standard “reference wheelchair” of 700x1,200mm (HM Government, 2000) According to Rutenberg et al. (2011), mobility scooters can range up to 1500mm in length, and 750mm in width, which should be considered when designing infrastructure. As mentioned previously, in the UK, the maximum allowable width for any Class 3 wheelchair or scooter is 850mm (HM Government, 1988). However, under Dutch law, the maximum width for such devices is 1,100mm, and the maximum length 3,500mm (Wagenbuur, 2012).

Just as with power wheelchairs, top speeds are variable for these devices, and often limited by legislation in different countries. In the UK, Class 2 and 3 scooters have the same speed limits as the respective power wheelchair categories. More broadly speaking though, mobility scooter top speeds range from about 4mph, to as much as 12mph or so in some countries (Steyn and Chan, 2008).

In a UK market study, Rica (2014a) found that the average price paid by respondents for a standard Class 2 mobility scooter was £801, and for a Class 3 was £1,681; these prices include purchases of both new and used scooters. Rica also found that the most commonly purchased type of scooter was the type that can be folded or taken apart and put in a car boot, with this type usually costing around £800 also (Rica, 2014a). Clearly, these costs are far less than those of even a relatively old used car, and thus mobility scooters have the potential to help provide urban mobility at a low overall cost.

Figure 1.2: A Dutch mobility scooter user making use of the bicycle infrastructure

1.3.3f) Handcycle / Attachable handcycle

There are two types of handcycle, also known as handbike. The first of these works as an attachment to the standard self-propelled wheelchair; it generally consists of a wheel with a vertical metal tube above it. At the top of this tube is mounted a gearwheel and pedals, much like a bicycle, albeit with the pedals being parallel (in-phase) rather than asynchronously mounted on the gearwheel. The gearwheel and wheel are typically connected via a chain drive, and often benefit from electric-assist in a similar fashion to a pedelec. This whole assembly attaches to the wheelchair via horizontal bars that attach to the lower frame of the wheelchair. An example of this type of handcycle can be seen here in figure 1.3.

Figure 1.3: A wheelchair-attachment handcycle (Source: Rio Mobility)

The second type of handcycle, the rigid-framed handcycle, could perhaps be described as a more purpose-built machine, possibly having more in common with a recumbent bicycle than a wheelchair – they are really more of a sports or fitness device than one for everyday activities. These handcycles typically have two rear wheels (about the size of small bicycle wheels), connected to a single front wheel by a chassis, upon which the user is usually seated in a slightly reclined cushioned chair. The drivetrain is similar to that of the attachment-handcycle, with a somewhat vertical drivetrain extending from the front wheel and angled towards the user. Similarly, this can be augmented with electric assistance. An example of this device can be seen in the following figure.

Figure 1.4: A mountain-bike sports handcycle (Source: Lasher)

Comparing these two types of handbike, Arnet (2012) emphasises that the rigid-framed sport handbikes are impractical for everyday activities, in part due to the limited manoeuvrability and the need to transfer to/from a wheelchair in order to move about indoors (which can be a difficult task for those with spinal-cord injury). In contrast, attach-unit systems can be attached fairly easily to the front of the standard hand-rim wheelchair, thus avoiding the need to transfer, and can be used for recreation, commuting, and even shopping, effectively increasing the range of the hand-rim wheelchair and increasing comfort for the user (Arnet, 2012).

Importantly, however, all handcycles offer the same substantial benefits when compared to the use of a hand-rim wheelchair: greater mechanical efficiency, lower peak forces upon the body, less physiological strain (Arnet, 2012). Citing many others, Vegter et al. (2010) explain that only between six and eleven percent of the user’s energy goes into the forward propulsion of the hand-rim wheelchair, compared to 20-25% for a bicycle; a handcycle can achieve between nine and fifteen percent energy efficiency (Arnet, 2012). This reduction in strain and increase in efficiency is due to the continuous application of force when pedalling the handcycle, rather than the intermittent, peaked application of force with the hand-rim wheelchair; the use of gears with a handcycle can offer even greater benefits (Arnet, 2012).

In providing the technical detail above, it should become apparent that providing the optimal infrastructure solution for PMDs will not be as straightforward as might initially be imagined. In particular, handbikes stand out from the other PMDs discussed so far: they are larger, and capable of speeds comparable to bicycles. In terms of the minimum technical specifications required for infrastructure to cater for handbikes, there does not appear to be a clear-cut answer. However, it would seem logical that their width is a primary concern, as would be corner radius (to account for their speed and poor turning circle). They would require separation from pedestrians, especially when travelling at speeds above walking pace, and if using bicycle infrastructure, removal of width-limiting bollards would probably be required.

1.3.3g) Pedelec/e-bike

While not typically considered by most as a mobility device for "the disabled", sales of these electrically-assisted bicycles in continental Europe would appear to prove otherwise. While bicycles are clearly not a good choice for those with balance problems, for those without who cannot walk far (perhaps due to arthritis or a circulatory condition), these bicycles may represent a good alternative to a mobility scooter, as within the European Union, they allow travel at speeds up to 15mph, with very little force needing to be exerted by the user.

However, as the technical requirements for optimal bicycle infrastructure, including adjustments required to cater for electric bicycles (and the elderly individuals riding them) have already been discussed in great detail in the academic literature, this dissertation will not go any further into discussing these requirements, nor will it provide any weighting to the needs of electric bicycles in considering an optimal infrastructure solution for PMDs, as the primary concern is providing for wheelchair-like vehicles.

1.3.3h) Other types of PMD: quadricycles/side-by-side tandems, tricycles, and wheelchair bikes

In addition to the aforementioned types of PMD, there are also a multitude of other devices that enable active travel for those with impairments, including those which allow two or more people to travel together. It would seem safe to state that in general, these multi-person devices are quite rare, although they are visibly more popular in the Netherlands (and perhaps other countries) than they are in the UK. Because of their rarity, they will not be discussed in great detail, but rather this overview and accompanying illustrations are to make the reader aware of their existence and potential benefits. Legislation pertaining to their usage, and the relevance of infrastructure design, is discussed in section 1.4.2a.

As will also be discussed in section 1.4.2a, the use of PMDs by more than one person is illegal in the UK; however, many stakeholders in the consultation of Barham et al. (2006) point out that this is both discriminatory and unsociable, as it may prevent a parent from travelling with a child, or make it difficult for a couple to enjoy a trip into town. Therefore, the devices described here could be seen as having the potential to increase social participation and quality of life for a group of people who typically face many barriers to their mobility. It is not known though how the following devices would even be classified in the UK.

Wheelchair bikes

These bicycles allow a wheelchair user and accompanying cyclist to travel together, either via a platform on the front of a cargo trike, or by a special attachment that allows a manual wheelchair to act as the front wheels of a two-person trike. Examples of these devices are shown below:

Figure 1.5 (GetCycling)

Figure 1.6 (GetCycling)

Figure 1.7 (Source:PinImage)

Quadricycles

These devices again allow two people to ride together, often side-by-side, although for wheelchair users they would require a transfer from their chair. Because they do not require balance, and the effort can be shared between two users, they are suitable for users with a wide range of impairments. An example, the ROAM TwinBike, is shown here:

Figure 1.8 (Source: GetCycling)

Tricycles

Lastly, it is briefly worth mentioning tricycles. Tricycles are good for those with balance problems, and are often available with electric assistance that would enable most people who have leg movement to ride them. Shown here is the German Pfiff Comfort.

Figure 1.9 (Source: Pfiff)

1.4) Legislation regarding the status and use of PMDs

1.4.1) Legal status as a vehicle and legislation on maximum allowable speeds

The legal status of various PMDs as either vehicle, pedestrian, or bicycle, frequently correlates with the speed at which they are operated, and/or the type of infrastructure they are operated on. The following table on the next page, table 1.3, is an adaptation of the table found in the work of Bruneau and Maurice (2012), and allows an easy understanding of the classification of PMDs in various countries. Most of these classifications will pertain primarily to mobility scooters and powered wheelchairs, although may also be applicable to other PMDs in certain countries. A green tick-mark signifies that a PMD is legally classified as the road user type listed at the top of the column, albeit sometimes conditionally.

Table 1.3: PMD legal status, by country. Sources: Bruneau and Maurice (2012), Steyn and Chan (2008), and Wagenbuur (2012).

	Pedestrian	**Bicycle**	**Mobility Scooter**	**Roadway Vehicle**
United Kingdom	≤ 4mph			> 4mph
Canada	✓		✓	✓
Netherlands	≤ 3.7mph	Urban cycle paths: ≤ 18.6mph		✓
United States	✓			
France	Walking speed	✓		
Switzerland	✓	✓		
Belgium	Walking speed	>Walking speed		
Norway	Walking speed	>Walking speed		?
Sweden	≤ 3mph	> 3mph		
Denmark	Walking speed	Max. 9.3mph		✓
Australia	≤ 6.2mph			> 6.2mph
New Zealand	✓			
South Africa				✓

As can be seen from the table, legislation around the world with regard to PMDs varies immensely. Furthermore, in many cases, the maximum allowed speeds are left open to some degree of personal judgement – there is no exact definition of "walking speed". In the same vein, the speed limits that do exist often appear arbitrary, albeit with the majority of pedestrian area/pavement speed limits falling somewhere within the range of human walking speeds. Stakeholder consultations, such as those carried out by Barham et al. (2006), Rutenberg et al. (2011) and Steyn and Chan (2008) all illustrate this seemingly capricious setting of limits, with a wide range of acceptable travel speeds suggested by different stakeholders. While common sense would dictate that a sensible travel speed on pedestrian infrastructure would be that which matches other adjacent pedestrians, and indeed, the primary goal of such legislation is to protect other pedestrians from being injured by these heavy devices, it nevertheless flies in the face of logic not to use an evidence-based approach, especially for the higher (cycle/road) based speed limits, when car speed limits for the road are increasingly based on safety data. This lack of an evidence-based approach could be due to a scarcity of PMD crash data and information to-date. Even if PMD speed limits are not based upon the rate of serious collisions with pedestrians (which is probably fairly low – more on that later), single-vehicle collisions involving tipping over or interacting with infrastructure should be investigated to ascertain if speed is a factor in many of them.

Importantly though, for providing context to this study, a brief comparison of the legislation in the UK, the Netherlands, and Canada is in order. In the UK, there are three "classes" of mobility device, with Class 1 being manual wheelchairs, and Classes 2 and 3 being applicable to powered devices, with maximum speeds of 4 and 8mph, respectively. The maximum limit on pavements is 4mph, and thus Class 3 devices can only be operated at their top speed on the road. In the Netherlands, like the UK, powered PMDs are effectively pedestrians when using the pavement, hence the ~4mph speed limit; however, when using bicycle infrastructure, they are apparently treated as a slower category of moped, and thus are allowed at up to 18mph in urban areas, and 25mph in rural areas (Wagenbuur, 2012). Apparently, PMDs are also allowed to use the roads there "as appropriate" (Steyn and Chan, 2008), although this may only be when pavements and cycle paths are absent. The laws in Canada appear to vary by province, with many not currently having laws specific to PMDs; however, PMDs are considered as pedestrians by default, and are expected to act in a similar manner, including with reference to speed (Bruneau and Maurice, 2012; Steyn and Chan, 2008).

1.4.2) Legislation pertaining to usage

1.4.2a) Types of infrastructure

Looking at the previous table, an idea of the types of infrastructure that can be used in those countries by PMDs can probably be gained. However, the situation is actually more complex than this. Again, looking at the three countries covered by this study, this becomes readily evident. In the UK, Class 2 PMDs can only use the pavement, except to cross the road or where pavements do not exist; Class 3 PMDs can use the pavement at up to 4mph, but have to use the road if travelling faster (HM Government, 1988). Strangely, Class 3 PMDs are allowed to use dual-carriageways, roads that often have 70mph speed limits and no hard shoulder, but are prohibited from using cycle lanes or bus lanes; furthermore, many have criticised the 8mph maximum capability as being too slow to be safe for road use (Barham et al., 2006). The situation is not clear as to which devices can be used on what type of infrastructure in the Netherlands, although it seems that most PMDs can use the pavement at pedestrian speeds, while use of bicycle infrastructure is possible by all PMDs, although manual wheelchair users might struggle to obtain a comfortably fast speed. It also seems that use of the road is as a last resort. For Canada, PMDs are only allowed on the pavement if one is available, but if not, they may use the road; use of bicycle infrastructure is not explicitly prohibited, however (Bruneau and Maurice, 2012).

It is briefly worth noting the apparent relationship between the availability of infrastructure types, and the legislation concerning types of PMD that are allowed to be used. In the Netherlands, one thing that becomes apparent to any person who visits a typical town or city for several days is that there are a wide variety of PMDs in use. Other than the normal powered chairs and mobility scooters, there are also different types of handcycle, but more noteworthy is that there are also multi-person PMDs that allow two people to travel together such as wheelchair bikes and side-by-side tandems. In the UK, under section 185 of the Road Traffic Act 1988, "invalid carriages" are defined as so:

"In this Act `invalid carriage' means a mechanically propelled vehicle the weight of which unladen does not exceed 254 kilograms and which is specifically designed and constructed,

and not merely adapted, for the use of a person suffering from some physical defect or disability ***and is used solely by such a person****"*.

(It is worth mentioning though that Class 1 and 2 vehicles are limited to 113.4kg, and Class 3 to 150kg.) As a result of this legislation, anything falling under this definition is only allowed to be used by a single person, despite recent calls to change the law (HM Government, 1988; Baker 2012). It is quite unclear where a two-person power-assist quadricycle or handcycle would fit under UK law. Regardless, many feel that multi-occupant PMDs would be too large for the pavement (Barham et al., 2006), and they would probably be so wide and slow as to cause disruption to traffic if driven on the road, perhaps causing additional risk to the user(s). Thus, the more widespread sale and use of such devices in the Netherlands may be due to the provision of infrastructure that is matched to their size and speed, i.e. bicycle infrastructure.

1.4.2b) User and safety requirements

To conclude this section on legislation surrounding PMDs, user and safety requirements will be briefly discussed in relation to the study countries.

The UK does not currently have any minimum eyesight requirements to be able to operate a motorised mobility device, and although Class 3 devices are meant to be registered (as they are a road vehicle), this is apparently rarely enforced; furthermore, mandatory insurance is not required either, with many considering that it would be discriminatory and an unnecessary financial burden (Steyn and Chan, 2008; Barham et al., 2006). However, following consultation, former Under-Secretary of State for Transport Norman Baker announced that eye-sight requirements for using Class 3 mobility scooters were being considered (Baker, 2012). Also in the UK, the minimum age to operate a Class 3 device is fourteen years old, and Class 3 devices are required to have lights, horn, and a rear-view mirror (HM Government, 1988).

In Canada, neither registration nor insurance is required in order to operate a mobility scooter or other similar device (Steyn and Chan, 2008).

For the Netherlands, users of mobility scooters and power wheelchairs must be at least sixteen years old, and hold third-party liability insurance, proof of which must be clearly displayed on the device (Steyn and Chan, 2008; Wagenbuur, 2012).

1.5) Medical conditions associated with PMD usage, and typical demographic composition of users

In order to be able to provide the infrastructure designs best-suited to those who use PMDs, it may be important to consider some typical requirements that these users have based upon the limitations which their medical conditions impose, or other concerns related to age or even gender. The concept of Universal Design is based around infrastructure being designed for everyone, of all ages and abilities. Thus, considering the specific needs of all those individuals who comprise the group of “PMD users” will help to meet the goals of a universally-designed built environment.

The other reason for adding this demographic data is to provide context to other information presented in this literature review, as well as the findings of this dissertation as presented in the analysis and discussion sections. For example, it may be discussed that not many people use their wheelchair for commuting trips, but this would make sense if it is also turns out that most wheelchair users are of retirement age.

As a final introductory note to this section, the author, in agreement with Sapey, Stewart, and Donaldson (2004), would like to comment that while the medical conditions of PMD users may occasionally be relevant from a design point of view, PMD users should not be thought of in a “sick role”, where, for example, users of wheelchairs are often portrayed as ill, medically-dependent people. Rather, many users manage to remain very healthy apart from their impairment, and therefore it should be kept in mind that PMD users, as a group, are not homogenous, with each individual having their own requirements (or lack thereof).

1.5.1) Demographic information

For this subsection, each of the attributes will be compared between studies. As the most efficient way to enable these comparisons is to use tables, these will be used below for several of the attributes. The studies being compared in these sections generally involved a substantial number of PMD users, and hail from countries including Canada, the UK, and the Netherlands.

1.5.1a) Age

One trend that is important to note is that in general, the incidence of mobility difficulties is a function of age. Picavet and Hoeymans (2002) analysed data from the Netherlands Health Interview Survey 1997-98, and reported the following incidence of mobility difficulties by age group for 12,449 people, after standardising the data for the population. For the age group 16-24, only 0.6% reported a mobility disability; this rises to 2.5% for the 25-44 age group, 8.5% for the 45-64 age group, 17.8% for the 65-74 group, and 36.7% for the 75+ age group (Picavet and Hoeymans, 2002). Figures from the UK reveal similar percentages of people affected by mobility difficulties, ranging from 3% for the 16-49 age group, up to 31% for the 75+ age group; this works out to about 9% of the UK’s total population aged over 16 (DfT, 2014b). From such data, it should be fairly easy to project the expected number of people with mobility problems in the future, based on population trends, although this would probably have to be revised upwards for countries such as the UK, due to increasing rates of obesity, for example.

Age is very important to consider when analysing the issues surrounding PMD use. Because the incidence of mobility problems increases with age, the requirement to supplement walking ability with a PMD or other more basic device (such as a rollator) to ensure continued mobility becomes more imperative. This is compounded by the fact that cognitive, visual, and psychomotor functional abilities all decline with age, possibly leading to an increased crash risk for driving a car. Furthermore, many of the illnesses that cause mobility impairments further decrease these functional abilities, and may result in an individual being declared unfit to drive (Eby, Molnar, and Kartje, 2009). Because the elderly and those who suffer illnesses that cause mobility impairments may not be able to drive a car, or may not own a car, the ability to be able to access locations in a city using only a personal mobility device (possibly in combination with public transport) is essential.

To confirm that PMD users are generally older (although some, especially those with spinal-cord injury or congenital conditions, are of course younger), the age composition of several large studies is summarised as follows in table 1.4:

Study	Wheelchair or scooter?	Measure 1 (value)	Measure 2 (value)
Sapey, Stewart and Donaldson, 2004	Wheelchair (power and manual)	Mean age (67.92 years)	Median age (72 years)
Rica, 2014b	Power wheelchair	% aged over 59 (29.4)	-
Edwards and McCluskey, 2010	Power wheelchair	-	Median age (57 years)
Edwards and McCluskey, 2010	87% Scooter	-	Median age (81 years)
Barham, Oxley and Board, 2005	Mix	% aged over 59 (65.7)	% aged over 65 (50) (median=65y)
Steyn and Chan, 2008	Scooter	Mean age (75 years)	Median age (77 years)
Rica, 2014a	Scooter	-	% aged over 64 (47)

Table 1.4: Ages of PMD users from various studies

From the table, it becomes fairly clear that the average age of PMD users in general is fairly high, which matches up with Picavet and Hoeymans' finding that mobility impairments are most common among the older age groups. This finding also reaffirms the concerns of those like Frye (2014) about the pressing need to design our cities for the elderly, especially those with mobility and other physical impairments, given the ageing of the global population.

While direct comparisons are hard to draw between studies, partly because the age groupings provided were not always the same, it appears as though the average age of wheelchair users may be lower than that for scooter users. However, it is also worth noting that many mobility scooter users are also wheelchair users: 48% of those surveyed by Rica in the UK own both types of device (Rica, 2014a). With regard to the age differences between studies, it should be noted that both Rica studies received mostly online replies, which may be the cause of the apparent age bias toward younger users; the study by Edwards and McCluskey provided ages for both user groups (albeit the wheelchair group was much smaller), hence the split in the table; also, it is believed that the responses received by Barham, Oxley and Board were mostly from power wheelchair users.

1.5.1b) Sex distribution

Considering the weighting of female to male users may be an important factor to consider. Building upon the knowledge that overall, females are less risk-taking than males, Garrard, Rose and Lo (2008) found that amongst cyclists, females showed a relatively strong preference for off-road cycle paths, demonstrating their risk-aversion to traffic. This risk aversion is also the main cited cause for the low levels of women cycling in car-centric countries like Australia and the UK, compared to the Netherlands where levels of perceived safety are high due to the extensive bicycle infrastructure and where women cycle more than men; this has even led to some calling women an “indicator species”, as countries with high levels of cycling overall also have a high proportion of female cyclists (Garrard, Handy and Dill, 2012).

With this in mind, it may therefore be wise to consider that perhaps optimal PMD infrastructure will be that which is designed toward the safety concerns of women, so that both sexes gain the greatest benefit. Furthermore, as the table below demonstrates, there is a tendency for more female PMD users than male, and therefore there is even more impetus to design for their needs.

Study	Participants: % female
Steyn and Chan, 2008	64
Sapey, Stewart and Donaldson, 2004	66
Barham, Oxley and Board, 2005	48
Edwards and McCluskey, 2010	46

Table 1.5: percentage female respondents reported by major PMD user studies

There could be a few reasons for this general trend toward female PMD users: for example, amongst the older generations, women are much less likely to possess a driving licence (Cahill, 2010), which may mean that those with some walking ability might be more likely to use a mobility scooter than a car compared to their male counterparts. However, the more likely cause would seem to be highlighted by Picavet and Hoeymans (2002), who found from Dutch national data that 4.1% of men experienced mobility difficulties, versus 10.6% of women. They note that this may be due to men typically dying younger, and women living longer but suffering higher levels of disease (Arber and Cooper, 1999, cited by Picavet and Hoeymans, 2002). This relationship appears to be illustrated very well in the following graph, taken from the results of Sapey, Stewart, and Donaldson (2004), who state that “typically, the wheelchair user is an older woman”.

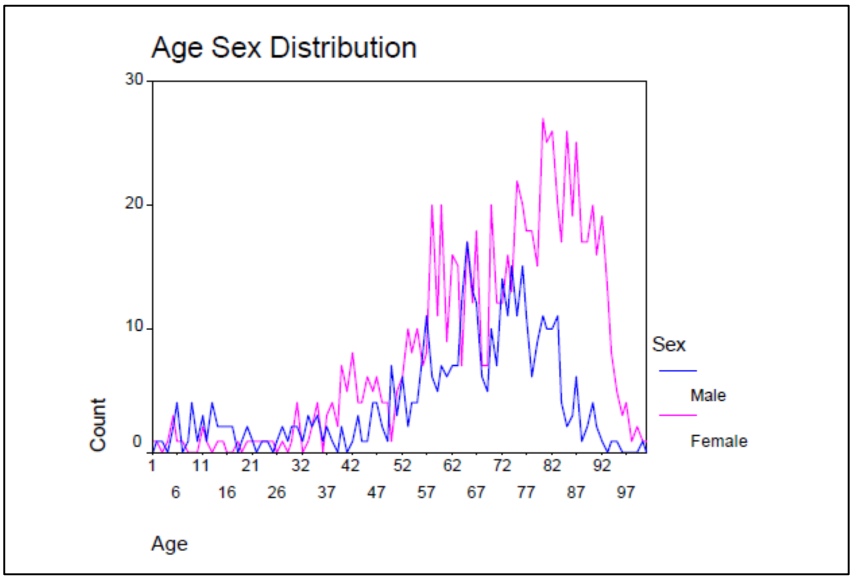


Figure 1.10: Age and sex distribution of ~1,200 UK wheelchair users, as found by Sapey, Stewart, and Donaldson (2004).

1.5.1c) Living arrangements

From their sample of 53 Canadian scooter users, Steyn and Chan (2008) noted that 45% of respondents lived in assisted living facilities, and 5% in nursing homes, and the rest in private housing. The more extensive study of Sapey, Stewart and Donaldson (2004) found that 45% of respondents live in a house, 39% in a bungalow, flat, or maisonette, with just 11% living in residential or nursing homes.

Whatever the actual representative figures are, there are a couple of points to note regarding the type of dwelling in which one lives. Those who can walk a short distance, as the majority of mobility scooter users can, might be able to leave their scooter at the front door and use a cane or rollator indoors (indeed, only 6.3% of the scooter users that Rica (2014a) surveyed used their scooter indoors). However, for those who cannot walk, the situation may be more problematic. Of Sapey, Stewart and Donaldson's respondents, 36% used their wheelchair indoors (reflecting the proportion of full-time users). For these users, a large Class 3 power chair would likely not fit in an unadapted home, and so either the house would need to be adapted (e.g. with larger doorways and turning spaces) for such a typically large device to fit, or a smaller manual or Class 2 indoor chair would need to be used, requiring a transfer between chairs. Alternatively, a compromise could involve getting a somewhat smaller indoor/outdoor power chair, which may fit inside the house, but which offers limited range and ability to handle rough urban terrain.

The other concern relating to housing affects scooter users in particular, as well as some power chair users. As mentioned before, few people use a mobility scooter inside their homes, not least because of their size and turning radius. This means, however, that the scooter must be left outside the dwelling, which may be especially problematic for those who live in apartment buildings. Parking or charging a scooter in the communal hallways presents a fire risk. Therefore, if a communal parking or storage area is not available outside, users will have to be able to fit their device inside their flat in most cases, once again limiting the type of device that can be chosen.

The situation in other countries is not known, but it should be considered that housing-related barriers such as those discussed above may also pose constraints upon device selection in those countries, perhaps leading to users having to select devices that do not optimally suit their needs for outdoor use. Similarly, users may wish to purchase more PMDs of different types to suit different situations (such as a handbike for recreation, or a Class 3 scooter for travelling across town), but may also be faced with constraints due to a lack of space for storage.

1.5.2) Typical composition of medical conditions amongst PMD users

Before looking at the statistics regarding medical conditions associated with PMD use, it is worth bringing to light the guidelines that Sapey, Stewart, and Donaldson (2004) quote from the Disablement Services in the UK, regarding the purchase of wheelchairs for patients. These guidelines categorise users as either a full-time user, long-term occasional user, or short-term temporary user. The table below reproduces these guidelines:

Table 1.6: Classification of wheelchair users based upon walking ability (Sapey, Stewart, and Donaldson, 2004; originally from "Wheelchairs: guidelines for purchasers and providers based on categories of users", November 1995, via Aldersea, 1996).

Long term, full-time user – no walking ability	High Activity	Independent mobility and lifestyle – appropriate equipment acts to reduce dependence on others, and improves quality of life.
	Restricted Activity	Unable to self-propel. Independent mobility can be achieved using a power wheelchair. These users have a degree of independence in meeting basic daily needs.
	Low Activity	Limited or no ability to self-propel. Dependent for many basic daily needs.
Long term occasional user – limited walking ability	Variable walking ability due to fluctuating condition	High degree of independence but requires wheelchair to maintain level of independence and quality of life.
	Ability to walk a short distance	Requires wheelchair on a regular basis for outdoor use, or to enhance quality of life for the user.
Short term temporary users	Normally, independently mobile	Immobile due to accident or operation – also includes those with terminal illness.

While these guidelines might be useful in that they highlight the fact that many wheelchair users are not full-time users, and that their need for the device may change over time, Sapey, Stewart and Donaldson (2004) go on to point out that these guidelines are based upon the user's level of mobility, with a bias towards active users that paints less-active users as being dependent upon others, which is not necessarily a fair representation. Furthermore, many people in society, including other wheelchair users, often view those who use power wheelchairs as being more dependent, or even mentally impaired, when in reality these users are just less able to propel themselves (as might be the case for those with cerebral palsy), and their main disability in participating in society is caused by the environmental barriers, just the same as other PMD users (Sapey, Stewart and Donaldson, 2004).

Analysing their sample of over 1,200 wheelchair users, Sapey, Steward and Donaldson (2004) found that 63% of wheelchair users were part-time users, and 37% full-time, a finding that is apparently in line with the findings of others. Not surprisingly, they also found that power wheelchairs are more likely to be used by full-time than part-time users (ibid.).

Medical conditions associated with PMD use

Rica's (2014a) report on mobility scooters provides an interesting introduction to this section. Keeping in mind that their sample probably has a younger age bias, they found that (as would be expected), 99% of participants had mobility difficulties; 62% had problems relating to stamina or fatigue, and over 43% had dexterity problems (Rica, 2014a).

The following table lists the findings from other studies, ranking health conditions by the percentage of PMD users who experienced them.

Study	Device Type	Medical condition (% users experiencing)
Steyn and Chan, 2008	Mostly mobility scooters	1) Arthritis (74%)
		2) Cardiac problems (47%)
		3) Hearing (38%)
		4) Vision (34%)
		5) Diabetes (32%)
		6) Pulmonary (26%)
		7) Stroke (21%)
Korotchenko and Clarke, 2014	Mix, small sample (n=29)	1) Spinal cord injury (SCI) (28%)
		2) Multiple sclerosis (MS) (18%)
		3) Polio (18%)
		4) Stroke (18%)
		5) Amputation (7%)
Edwards and McCluskey, 2010	Mix, 74% scooter users	1) Arthritis (40%)
		2) Cardiac problems (22%)
		3) Knee/hip replacement (15%)
		4) High blood pressure (13%)
		5) SCI (13%)
Sapey, Stewart and Donaldson, 2004	Wheelchair users	1) Arthritis (25%)
		2) Stroke (19%)
		3) Neurological disorders (MS, Parkinson's, dementia, etc.) (17%)
		4) Orthopaedic-related (6%)
		5) Cardiovascular (6%)

Table 1.7: percent of users reporting medical conditions in various PMD user studies

It is also worth noting that Steyn and Chan (2008) found that 19% of their participants suffered memory problems, and 17% balance problems. While it is hard to directly compare the studies, especially as the results are analysed in different ways (for example, Sapey, Steward and Donaldson seem to only list the primary health condition, whereas Steyn and Chan allowed listing more than one condition), there are certainly a few conditions that stand out as being the most common. Arthritis, stroke, neurological disorders (such as multiple sclerosis, Parkinson's, cerebral palsy, and dementia), and cardiovascular diseases seem to account for the large majority of mobility impairments. This finding challenges the typical view that some have of wheelchair users as “those with broken backs”, or as those having severe mental health problems. Certainly, a noteworthy proportion of PMD users, especially wheelchair users, have a spinal cord injury, but this is far from being the most common impairment among PMD users.

Sapey, Stewart and Donaldson (2004) do, however, provide some useful further analysis of their data, noting that of the roughly one-third of wheelchair users who are “full-time” users, those with amputations, neurological disorders, and victims of stroke were some of the most likely to be in this group – for example, 47% of those with neurological disorders are full-time users, versus 28% of those with arthritis.

From all this data, it is possible to conclude that as previously stated, the majority of medical conditions that result in mobility impairment leading to the use of personal mobility devices are age-related. This, therefore, continues to back the assertion regarding the need for urgency in catering for the needs of rapidly-ageing populations, especially in countries such as the USA, UK, Germany and Japan, where these pressures are perhaps most acute, and (in the case of the USA, UK, and others) exacerbated by the increasing number of obesity-related health problems. The rise of obesity-related mobility scooter use has been covered in both reports (e.g. Rutenberg et al., 2011) and the news, often as a result of increased perception of this trend by the general public (e.g. Gentleman, 2012).

Part 2. Problems faced by PMD users, and concerns caused by PMD users

Introduction

Thus far in this literature review, key concepts have been defined, the history and technical features of a variety of personal mobility devices have been discussed, and the demographics and health problems of device users have been investigated. This second section of the literature review will look into the increasing number of users and the difficulties they face, as well as the concerns relating to safety that some people have surrounding the use of PMDs. More specifically, this section will be broken down into three main subsections: the first will examine the varying estimates of the number of PMDs in the UK and elsewhere, and estimate potential future growth; the second will offer a review and synthesis of the barriers faced by PMD users when utilising their devices in the built environment; and finally, the third section will investigate claims that the use of PMDs poses a safety hazard to other pedestrians, as well as looking into some of the safety concerns affecting PMD users themselves.

2.1) Approximate numbers of PMD users in each of the study countries

In order to emphasise the importance of providing suitable infrastructure for personal mobility devices and their users, this first section will briefly look at the available statistics regarding the number of PMDs/PMD users that are currently estimated to be in each of the study countries. There will then be some attempt at estimating future numbers of users in each country, based on current PMD usage levels for those with mobility impairments.

In general, figures on the number of wheelchairs and mobility scooters are very difficult to come by. This is because devices do not have to be registered in most countries, nor are there usually requirements for companies to report sales figures; Rica (2014a) adds that the complexity of the market, including the diversity of sales and distribution channels, adds to this difficulty. Some estimates can be made from government provision data, for example looking at the number of wheelchairs provided by the NHS in the UK, but this only provides a partial picture based on provision of specific devices, although a couple of authors managed to obtain commercial sales data from manufacturers. The following subsections will list the best statistics available from each of the study countries, and then there will be a brief discussion on estimating future growth in usage.

2.1.1) UK

The NHS's purchasing agency stated that they had a "client population" of around 900,000 people about ten years ago; using data obtained from NHS wheelchair services, Barham, Oxley and Board (2005) estimated that around 5% of patients are issued with powered wheelchairs, or about 40,000 in total. Data obtained from the British Healthcare Trades Association (BHTA), who represent a substantial proportion of power PMD manufacturers, showed that private sales of power wheelchairs were about 5,600, and mobility scooters about 22,100, in 2002 (ibid.). This indicates a sales ratio of 80:20 for mobility scooters to power wheelchairs; furthermore, based on data provided by distributors, a sales ratio of 80:20 was reported for Class 2:Class 3 power wheelchair sales (ibid.). For manual wheelchairs, customs import figures and UK manufacturer sales figures showed that over 275,000 manual wheelchairs were sold in 2002 (ibid.). Around the same time, Motability reported to the authors that they estimated there to be as many as 100,000 mobility scooters and power wheelchairs in use in the UK in 2004, a figure which was felt to be realistic (ibid.). The main estimates of the total number of long-term UK wheelchair users are provided by the Audit Commission, who provided an estimate of 640,000 users in 2000, updating this to 1.2 million NHS wheelchair users in 2002, although they were not forthcoming about how they derived these estimates (ibid.; Sapey, Stewart and Donaldson, 2004).

The most recent data come from Rica (2014a and 2014b), who provide the latest estimates on power wheelchair and mobility scooter sales and usage. Rica received information from 75 of 127 NHS wheelchair services, who reported that they provided 15,000 powered wheelchairs in 2014 [*sic*] (Rica, 2014b). Assuming that the wheelchair services that did not supply data provided a similar number each, then that would imply a total of 20,000 to 25,000 powered wheelchairs being provided by NHS wheelchair services in a single year, which would represent a substantial increase over estimates of the number provided a decade ago. Rica also carried out market research into the sales and numbers of mobility scooters. They received data from the BHTA, who indicated that there are now around 80,000 mobility scooters being sold in the UK each year by its member manufacturers, far more than the 22,000 sold in 2002 (Rica, 2014a). In fact, sales of mobility scooters are now increasing by 5-10% each year, and there are now estimated to be 300,000-350,000 mobility scooter users in the UK (ibid.). The same report indicates similar growth in sales of manual and power wheelchairs (ibid.).

From the data presented here, it is apparent that sales of PMDs are rapidly increasing in the UK, with around 80,000 mobility scooters now being sold per annum, and the NHS likely providing in excess of 20,000 power wheelchairs per annum; the number of power wheelchairs being sold privately is not known, although Rica (2014b) found that under half of respondents to their survey had had their power wheelchairs part- or fully-funded by the NHS, so total power wheelchair sales may well exceed 40,000 units per year. The total number of users is harder to estimate, as many PMD users own more than one device, and other factors like typical length of ownership, and sales to the second-hand market are not really known at present. However, if the Rica estimate of 350,000 mobility scooter users in the UK is correct, then when power wheelchair users are factored in, there are likely to be in excess of 450,000 power PMD users in the UK at present. This would certainly lend credibility to the 2002 Audit Commission estimate of 1.2 million UK wheelchair users, which now seems like a potentially conservative estimate. Thus, when also considering mobility scooter users, the total number of PMD users in the UK today may well be somewhere in the region of 1.5 million.

2.1.2) The Netherlands

Data from the Netherlands was particularly difficult to come by, although this may in part be due to the language barrier. The only statistic that could be found was in Barham, Oxley and Board's (2005) report, which stated that in 2001, almost 24,000 mobility scooters and 47,000 manual and power wheelchairs were supplied. This would seem to imply similar numbers being sold as in the UK, despite the Netherlands only having just over a quarter of the population. Assuming a similar age structure to the UK, this would appear in indicate either better provision of devices to those who need them in the Netherlands, or large differences in the accuracy of PMD sales figures between countries. This can only be confirmed by obtaining more up-to-date sales figures; it is thought that since many devices were until recently provided by Dutch local/city councils under the social support act, it may be possible to obtain information via related channels.

2.1.3) Canada

Finding figures for Canada has proven even more difficult. However, Canada has a total population approximately 55% of that in the UK. If we assume similar PMD usage levels to the UK, then based on 1.5 million UK users, Canada should have around 800,000 PMD users.

2.1.4) Other countries

For the USA, Edwards and McCluskey (2010) reported that 159,000 power wheelchairs were prescribed via Medicare in 2002, which is perhaps slightly higher per head of population than the number distributed in the UK at that time.

2.1.5) Expected and potential growth in user numbers

Because most health conditions resulting in mobility difficulties and PMD use are age-related, then numbers of future PMD users can be fairly easily calculated based upon the ageing of the population. While certain factors may alter these estimates, such as new medical treatments reducing the number of people with mobility impairments, or greater levels of obesity increasing that number, it would seem fairly safe to make a baseline estimate based upon ageing alone. However, there seems to be a general consensus throughout the literature that there are also other causes resulting in faster-than-expected growth in PMD use, such as people using mobility scooters as a car replacement (for both those with and without mobility impairments), as well as there being less of a negative stigma associated with such devices than before.

Because the only reasonably good data on PMD use that have been obtained so far are for the UK, the future estimates for growth in device use will only be calculated for this country. To begin this subsection, a few estimates based upon data presented in Rica (2014a) are hereby presented:

A market analysis report by Global Industry Analysts estimating future market potential states that 122,000 mobility scooters were sold in the UK in 2011 (50% higher than the BHTA estimate), with a value of US$210m; importantly, however, they estimate that the market will be worth US$336m by 2017, a 60% increase in 6 years (Rica, 2014a). If it is assumed that unit sales prices remain the same, then this would also translate to a 60% increase in sales volume, to 130,000 or 195,000 units per year, depending on whether the BHTA or industry analyst sales figures are assumed to be correct. The same industry report estimates a 38% increase in power wheelchair and 31% increase in manual wheelchair market value over the same time period (Rica, 2014a). It is hard to draw many conclusions from this information, as the assumptions regarding unit sales prices are not provided, but the clear message presented by these estimates is that mobility scooter sales are expected to continue to grow at a much higher rate than the expected increase in the number of people with mobility impairments.

The next estimates of potential future PMD use in the UK are based upon population projection estimates provided by the United Nations Department of Economic and Social Affairs. In 2012, about 14.5 million people in the UK were aged over 60 years old; this number is projected to increase to 21.5 million by 2050, an increase of nearly 50% (UNDESA, 2012). Assuming that the number of people with mobility impairments increases at the same rate as the increase in the number of those aged over 60, and also assuming that the rate of PMD use remains constant based upon levels of mobility impairment, then it could be expected that there would be around 2.25 million PMD users in the UK by 2050.

Similarly, it might be expected that the number of power PMD users would increase from around 450,000 to roughly 700,000. Clearly, if there continues to be an increase in the uptake of personal mobility devices among those with mobility impairments, then these numbers might be expected to be even greater by 2050.

2.1.6) Conclusions regarding the number of PMD users

It is obvious from this analysis of the data currently available that there are already quite large numbers of PMD users in countries like the UK, and that these numbers will continue to grow rapidly as the populations of countries in the Global North continue to age. There appears to be growing uptake of devices, in particular mobility scooters, among people who would not have previously considered buying one, although more data needs to be collected in order to confirm this trend. The most crucial point, however, is that the total number of PMD users, and their percentage of the general population, is already substantial, and will be too great to ignore in years to come. Transport planners, urban designers, architects, and those involved with government spending, policy, and legislation will not be able to ignore the needs of this group of individuals forever, and should be proactive in taking action in order to prevent these individuals facing further social and economic isolation.

2.2) Barriers faced by PMD users

At the start of this literature review, it was mentioned that Sapey, Stewart, and Donaldson (2005) and Korotchenko and Clarke (2014) found that most respondents in their study agreed that wheelchairs could be liberating - presumably due to the mobility that they potentially allow. However, they also noted that not all of these respondents *actually felt liberated*. The authors went on to state that this mismatch between reality and expectation was due to barriers preventing full advantage being gained from the equipment.

There are many types of barriers faced by those using wheelchairs and other personal mobility devices every day. The first of these is social barriers, such as people acting in an abusive, threatening, or patronising manner towards users (see Imrie and Kumar, 1998, and Sapey, Stewart, and Donaldson, 2004). Another type is that associated with risk, whether it be perceived risk from other people or from busy traffic; thus this can either have its roots in social or infrastructural causes (Clarke et al., 2011 cover the relationship between different types of risk and participation in some detail). There are also other environmental barriers, such as weather, which typically present an inconvenience, although sometimes causing more severe problems. Steep terrain can of course also cause difficulties. However, the main barriers that are of interest to this research are those related to, or caused by, infrastructure, especially those that result in reduced mobility for users of PMDs. Some of these infrastructure-related barriers may just cause inconvenience, while others have more serious effects, such as major highways that cause community severance, or bumpy surfaces that cause pain due to shock and vibration.

To some extent, there may also be similarities with cycling, where poor, inappropriate, or non-existent infrastructure has been shown to be one of the reasons for a lack of uptake in cycling. Barriers also exist due to legislative restrictions on infrastructure use, such as those discussed in section 1.4.2. Some of the infrastructure-related barriers are not physical or mental however: for example, several reports and journals have stated that many PMD users find that the lack of consultation, and even deliberate ignorance, by planners, designers, and decision-makers acts as a barrier to the correct designs or decisions being approved in the first place. These issues and others will all be explored and discussed in the following paragraphs.

2.2.1) Infrastructural barriers and accessibility as a civil rights issue

According to Sara Zimmerman, a US-based attorney at the organisation Public Health Law and Policy, incomplete streets (those that are not accessible to all users) are a civil rights issue (Dunham, 2011). She argues that for someone with a physical impairment to not be able to safely or easily travel somewhere represents a denial of equal rights, although she also mentions that under the Americans with Disabilities Act, cities do not have an option about whether or not they make streets accessible for those with disabilities, especially when rejuvenating or building a new street (Dunham, 2011). In contrast, the 1995 Disability Discrimination Act (DDA) in the UK does not directly require accessible environments, but rather only access to facilities, goods, and services, which is probably due to it being based upon the medical model of disability (thus catering for the impairment) rather than the social model (which sees the environment as a barrier) (Bromley, Matthews and Thomas, 2007).

The result of inaccessible street environments is that participation in society becomes curtailed. Clarke et al. (2011) found that those who could not walk far (such as some mobility scooter users) were less likely to interact with others, and that when the quality of the pavement and streets was poor, such individuals were much less likely to vote than their more-mobile counterparts (voting was one of the study’s main metrics of participation); this effect was not seen when the streets and pavements were in good condition.

Another way (albeit one seldom mentioned outside medical literature) in which infrastructure is related to the rights of those who use PMDs is related to pain and discomfort. A synthesis of research by Pearlman et al. (2013) showed that shock and vibration for wheelchair users can cause back injury, muscle fatigue, neck pain, and disc degeneration, as well as an increased rate of fatigue when out and about, with the net effect of limiting participation in the community. Crawford et al. (2008) also found that PMD users who suffer from pain were less active in everyday activities. There are also some surprises when it comes to which type of infrastructure causes the most discomfort to wheelchair users: it was found that poured concrete slabs may cause more vibration and discomfort than well-laid bricks or pavers, although broken or uneven surfaces did of course cause discomfort as well (Pearlman et al., 2013). On a related note, drawing a parallel with cycling, Joo and Oh (2013) fitted a bicycle with an accelerometer and a gyroscope, and asked people to cycle a particular route. They found that when participants encountered kerbs and uneven surfaces, they slowed down, and these surfaces negatively affected perceptions of comfort and safety.

The research and arguments brought forth in this subsection demonstrate that in the UK and other countries, legislation guaranteeing a barrier-free environment is often not encompassing enough and lacks power in terms of enforceability, and in the case of the UK, does not apply to infrastructure such as pavements. Pavements and roads with poor surfaces can cause pain and fatigue to PMD users, presenting a sensory barrier to mobility that is in addition to the physical ones presented by such obstructions. This should be considered as an assault on the rights of those using PMDs, as people should not have to endure pain and physical barriers just in order to go shopping or visit the doctor's. Presenting legislation based around such ideas as the fundamental right to urban mobility without the need to use a car could potentially be a useful and powerful tool in ensuring that the infrastructure needs of PMD users are fully met in the future by planners, designers, and city officials, and should be explored further. Additionally, following in the research footsteps of Pearlman et al. (2013) and Joo and Oh (2013) by using instrument-based measurement of wheelchair shock and vibration, and combining this with levels of perceived comfort and safety (as well as speed travelled) for different types of infrastructure would likely yield some very useful data.

2.2.2) Parallels with cycling: similarities and differences between barriers for PMD users and those for cyclists

As mentioned in the introduction for section 2.2, barriers can be environmental, social, or (related to both) psychological, especially as pertains to safety. While many links are becoming fairly well established between various barriers to cycling and its uptake, the same certainly cannot be said for PMD use. Of course, one crucial difference between cycling and PMD use is that cycling is a mode choice, one which can be exchanged for other modes such as walking or driving, as conditions and parameters permit or dictate; in contrast, PMD use can rarely be completely substituted, especially for many wheelchair users, as the device acts as their legs. PMDs can be combined with other vehicles such as cars or buses as the situation allows, but in an urban environment, walking is usually at least a part of every journey, and those with mobility impairments should be allowed the same mobility, or freedom to move, as those without such impairments: any journey that can be made on foot or by bicycle should be able to be made by those using only a PMD as well. Despite bicycle use usually being optional and PMD use often essential, there may still be similarities between these two forms of transport. While certain barriers may cause a cyclist to switch to a different mode of transport, a PMD user may not have that option, and may instead decide to use a different route, travel at a different time of day, or not travel at all. Therefore, by discussing some of the known barriers that those using bicycles face in the following paragraphs, it may be possible to relate these to PMD use, while keeping in mind the aforementioned differences, in order to better understand (or at least theorise) what type of effects barriers have on PMD users.

Research by Pooley et al. (2011) found that while there was a weak correlation between the number of walking trips and connectivity (directness) between locations, no such correlation was found for cycling, thus suggesting that external factors have a role in the success of cycling. The same report found that in terms of risk, the greatest concern for cyclists was motorised traffic, while for walkers it was the threat posed by other people in quiet urban areas (ibid.). Given that PMD users are both pavement and (sometimes) road users, it might be conjectured that both types of concerns are applicable. A recent poll of three-thousand British adults by the BBC found that 52% of those asked thought that it was too dangerous to cycle on roads in their local area, with 61% of those aged 65 and over stating the same (BBC, 2014a). Therefore, it might be assumed that well over half of PMD users who have a class 3 device (or those with any other device that are forced to use the road when there are no pavements) would also experience similar concern when using their device on the road. The Cycling Embassy of Great Britain has expressed concern at the rise of shared-use paths for bicycles and pedestrians, which are often just pavements that have been converted via the use of paint; they point out that many pedestrians feel threatened by bicycles being in such close proximity, while such infrastructure is also suboptimal for cycling (CEoGB, 2013). It would be naïve to think that infrastructure that is unsuitable for bicycles would also be suitable for other semi-fast wheeled vehicles such as class 3 wheelchairs and scooters, and this is partly why a limit of 4mph has been implemented on the pavement for these devices. There is another thing that is borne in common between ensuring conditions are improved for both cycling and PMD use: political will. Giving evidence for the House of Commons Transport Committee report on cycling safety, the London Cycling Campaign stated that "political will" would be the "single most important fundamental and overarching factor that will deliver improved conditions for cycling in the UK" (HCTC, 2014). Given that better conditions for PMD use will also require funding and planning, it would also seem to make sense that political willpower will also be a factor in determining whether conditions improve for those with mobility impairments in the long-term.

2.2.3) Infrastructural barriers to the mobility of PMD users as reported in the literature

This subsection will list, and to some extent evaluate, the infrastructural barriers that have been identified by various studies to limit the mobility of PMD users. The majority of these studies used their own original research, so the findings of each are unique and should be more authoritative when combined together. There are so many findings that they will be presented in a table, with the barrier listed next to the author(s) who reported them. It should be noted that this list is not entirely exhaustive, as there are also other papers reporting barriers that were unintentionally excluded. Following the table, there will be further discussion on any relevant details that were missed out by the table.

Barrier	Author(s) reporting barrier
Lack of dropped kerbs, dropped kerbs being blocked (e.g. by a vehicle), dropped kerbs being too steep, or dropped kerbs being poorly positioned/aligned	Lavery et al., 1996; Meyers et al., 2002; Rimmer et al., 2004; Sapey, Stewart and Donaldson, 2004; Barham et al., 2006; Bromley, Matthews and Thomas, 2007; Edwards and McCluskey, 2010; Rutenberg et al., 2011; Korotchenko and Clarke, 2014
Street furniture, signboards, utility poles, refuse bins, or construction zones obstructing pavement	Lavery et al., 1996; Imrie and Kumar, 1998; Meyers et al., 2002; Rutenberg et al., 2011
Cars parking on and obstructing the pavement	Sapey, Stewart and Donaldson, 2004; Barham et al., 2006; Goodwill, 2014
Pavement too narrow for device	Barham et al., 2006; Bromley, Matthews and Thomas, 2007; Kasemsuppakorn and Karimi, 2009
Poor travel surfaces (broken pavements, uneven pavements, cobbled surfaces, un-cleared ice/snow, etc.)	Meyers et al., 2002; Barham et al., 2006; Bromley, Matthews and Thomas, 2007; Kasemsuppakorn and Karimi, 2009; Edwards and McCluskey, 2010; Rutenberg et al., 2011; Taylor and Józefowicz, 2012; Frye, 2014; Korotchenko and Clarke, 2014
Pavements crowded with pedestrians (causing congestion), or concern about risk of collision with pedestrian	Meyers et al., 2002; Barham et al., 2006; Bromley, Matthews and Thomas, 2007; Kasemsuppakorn and Karimi, 2009; Edwards and McCluskey, 2010; Korotchenko and Clarke, 2014
Lack of pedestrian crossings	Meyers et al., 2002
Pedestrian crossing time too short	Barham et al., 2006; Rutenberg et al., 2011; Korotchenko and Clarke, 2014
Feeling unsafe when using PMD on the road, or barrier caused by a busy road	Barham et al., 2006; Bromley, Matthews and Thomas, 2007; Korotchenko and Clarke, 2014
Lack of public transport	Meyers et al., 2002; Edwards and McCluskey, 2010
No disabled parking, or parking too expensive	Lavery et al., 1996; Meyers et al., 2002; Sapey, Stewart and Donaldson, 2004; Barham et al., 2006
Pavement cyclists	Imrie and Kumar, 1998
Controls are too high (e.g. for pedestrian crossing)	Lavery et al., 1996; Rutenberg et al., 2011
Narrow doorways	Lavery et al., 1996; Rimmer et al., 2004; Edwards and McCluskey, 2010; Korotchenko and Clarke, 2014
Broken, or no lifts (e.g. at train station)	Meyers et al., 2002; Rimmer et al., 2004
No ramp into building, only stairs, or ramp available but too steep	Lavery et al., 1996; Meyers et al., 2002; Bromley, Matthews and Thomas, 2007; Edwards and McCluskey, 2010
Lack of adapted toilets	Lavery et al., 1996; Meyers et al., 2002; Sapey, Stewart and Donaldson, 2004

Table 1.8: Infrastructural barriers to PMD use as reported in the literature

There were many barriers mentioned in the literature that were not included in the table. These included terrain (hills being too steep), weather, the attitudes of others (including the general public, service personnel such as public transport employees, and even civil servants), as well as constraints imposed by buildings and residences (narrow hallways and aisles, lack of storage space for device, etc.). Furthermore, some variations on barriers were also not included. For example, several studies listed "high kerbs" as a separate obstacle, probably because, just like most pedestrians, there will be times when crossing the road is desired at a point other than a pedestrian crossing, and in many cases the dropped kerb may be blocked, meaning a kerb will have to be mounted. Mounting a kerb is often possible in many devices, but only if the kerb is not too high. Also, some papers mentioning the lack of accessible public transport, or a lack of PMD capacity on public transport, were not included in the table.

Another important measure that is unfortunately not shown by the table is the number or percentage of respondents citing each barrier in the studies. In some cases, where the research only used a small sample size, the barrier was mentioned only by one or two respondents, but in some larger studies, nearly all respondents listed a particular barrier. Not every study provides a break-down of the number or percentage of respondents selecting a barrier, but here are the results from two that did:

Bromley, Matthews and Thomas (2007) asked wheelchair users in Swansea, Wales, about which barriers they encountered in the city centre. The percentage of respondents listing each barrier as a prohibitive or major obstacle is as follows: crowded pavements (68.9%), entering shops (63.2%), lack of dropped kerbs (65.5%), high kerbs (45.9%), steps (43.7%), uneven surfaces (48.3%), dropped kerbs not being adjacent (48.2%), narrow pavements (32.6%), and busy roads (36.8%). Thus, kerbs, crowded pavements, and uneven surfaces could be seen as the most important barriers (within the transport planning remit) in that study.

Meyers et al. (2002) questioned wheelchair users in two US cities, and the most relevant barriers being reported on a daily basis were "no ramps or ramps too steep" (36%), obstructed travel (24%), wheelchair problems (16%), distance too far (12%), no kerb cuts/blocked cuts (12%), no parking (12%), no public transport (12%), high kerbs (8%), and pedestrian traffic (4%). It is interesting that the barriers reported by Meyers et al. are so different in terms of relative importance to those listed by Bromley, Matthews and Thomas, although this is probably in large part due to the differing travel patterns, street layout, and urban fabric found in the US, so it is likely that the findings from Swansea are both far more relevant to this study, as well as being more representative of a busy urban environment.

While it is hard to draw any conclusions about the importance of all of these barriers for the majority of PMD users, or the frequency with which they are encountered, it is possible to get some further idea from looking at the number of papers citing each barrier in the table. A lack of dropped kerbs, obstructed pavements, crowded pavements, and poor quality/uneven travel surfaces are all cited by many studies from around the world, and this would seem to support the high percentages for some of these items noted by Bromley, Matthews and Thomas.

One more important point to consider regarding these pavement-related barriers is that even if a good pavement built to the best universal design standards were to eliminate almost all of the barriers listed in the table, they would still not allow travel at faster than 4mph or so. Being limited to such speeds effectively constrains PMD-only travel distances to those normally covered on foot; to cover more bicycle-like distances in a reasonable amount of time, travel at faster speeds is required. In order to do so, a pedestrian-free form of infrastructure would be required.

2.3.4) Barriers due to legislation on infrastructure usage

This topic was brought up previously in section 1.4.2a, so it is not worth going into any further detail on this matter. It is nevertheless worth mentioning this topic within the context of considering barriers to PMD use. According to UK law, PMDs cannot utilise cycle lanes or bus lanes, something that some stakeholders in Barham et al.'s (2006) study found unfair and discriminatory. In fact, recent research from Canada by Bruneau, Crevier and Maurice (2013) has also demonstrated that PMDs travel faster on bicycle infrastructure than on pavements and even roads, effectively implying that they do not impose a barrier on the speed of travel. Restricting PMD users from an infrastructure that they may find preferable to the pavement, and which may offer a safety benefit for both the PMD user and pedestrians, imposes both a barrier on mobility and a curb on logic.

2.3.5) Barriers imposed by failure to consult and consider

Thus far, the evidence presented in this section on barriers has revealed that the design and maintenance of infrastructure, especially pavements, has often proved to be problematic. Therefore, those responsible for the design and engineering of this infrastructure also have much to answer for. As Sapey, Stewart, and Donaldson (2004) point out, "wheelchair users know what they want, [but] may be prevented from accessing it at a point when it actually matters, and believe that regulatory force is needed in order to remedy discrimination and injustice". A theme that turned out to be common within the literature was that wheelchair users (and those with a multitude of other impairments) stated that they often felt that they had either not been consulted, or that they had been consulted too late in the process, almost as a token measure, once decisions had already been made. This view was stated by those in relation to a new shared space scheme in the study by Hammond and Musselwhite (2013), while respondents to Imrie and Kumar (1998) made the following statements, regarding feeling ignored: "the professionals all sit there in the town hall and never listen to anything we say", and feeling patronised: "as soon as they see you sitting in a wheelchair they presume you've got no brain". Other respondents to Imrie and Kumar (1998) suggested that the planners and architects who design the built environment have limited awareness about disabilities, and may not fully appreciate the problems being faced because they do not see the barriers that exist for those with different impairments; one participant recommended that "all professions should actually spend some time in a wheelchair with their eyes bound and their ears covered and find out". Poor planning, ableist design, and a lack of consultation was also cited by Bromley, Matthews and Thomas (2007), while MORI (2002) found that 81% of wheelchair users felt that transport planners paid too little attention to providing facilities that meet their needs. From these findings, it is evident that conditions will not improve until transport planners, urban designers, and others understand the barriers that are being faced, listen to the advice of those with mobility (and other) impairments, and decide to act upon this knowledge and advice.

2.3.6) Concluding remarks on barriers to PMD mobility

In essence, this section on the barriers to PMD use forms the core of what this work is all about. The key knowledge that enables an understanding of the primary impediments to movement and participation has been identified here. Sapey, Stewart and Donaldson (2004) found that the environment was the most disabling thing for wheelchair users after their impairment, and was more disabling than the attitude of others or any device-related issue. MORI (2002) added to this with their finding that transport was the biggest concern at the local level amongst those with impairments, especially for wheelchair users, and that pavement maintenance was the issue causing most dissatisfaction, more so than local buses or train services. The information obtained for this section of the literature review expands upon this finding, showing that kerbs, pavement surface, pavement obstructions, and overcrowding with pedestrians probably accounts for the majority of these impediments. These barriers will be further investigated in the analysis of the questionnaire that was carried out for this study, in order to test the accuracy of these claims.

The limiting of mobility for a particular group of people due to poor infrastructure can be considered a civil rights issue, and indeed, pushing the matter as a legal issue related to discrimination may be a powerful way to help guarantee the provision of better infrastructure in the future. Perhaps this study might even reveal findings that would be strong enough to act as evidence in making such a legal argument. On the other hand, laws that currently prohibit the use of certain types of infrastructure, such as bicycle lanes, by PMDs place further limitations upon the mobility of PMD users. Another problem that needs to be addressed urgently is the lack of consultation with PMD users in the design and planning stages when new or updated infrastructure is being considered, and similarly, designers and planners need to become more aware and understanding of the specific issues that affect PMD users, along with the potential solutions to them. However, the most important issue is that of the infrastructure design itself, which this section has determined to be particularly problematic for PMD users, with pavement-related problems seemingly being of greatest concern. As a result, many pavements should be considered as “not fit for purpose”, if that purpose is the safe and comfortable movement of those using PMDs. Consequently, better pavement design and other infrastructural options will be explored in Part 3 of the literature review, in order to try and establish an optimal infrastructure solution.

The following thoughts provide perhaps the best conclusion to this section though. Around the beginning of this literature review, it was mentioned that Sapey, Stewart and Donaldson (2004) had found a discrepancy between the percentage of people saying that a personal mobility device could be liberating, and the actual percentage who felt liberated by their device. Korotchenko and Clarke (2014) seem to have summed up the reason for this discrepancy quite well in the findings of their study: “power mobility technologies were experienced as enabling only in so far as the public and private spaces in which they were deployed were accessible and amenable to the requirements of power wheelchairs and scooters”.

2.3) Safety concerns surrounding the use of PMDs

In the past, “PMDs had relatively few conflicts with other nonmotorized facility users primarily because they were rather uncommon and slow”, write Litman and Blair (2004). However, with a rapidly increasing number of mobility scooters and other devices vying for room on the pavement, there have been increasing concerns about the threat that they might pose to pedestrians, sometimes leading to hostility from members of the public, as well as the press. Furthermore, there is also increasing concern from many in the academic community regarding risks to the safety of PMD users themselves, leading to several recent (albeit fairly small) studies attempting to gain an understanding of accident rates experienced by users of these devices. Both of these matters are of direct concern to this piece of research, as both relate to the design of infrastructure as well as its use.

Ideally, an optimal infrastructure design for personal mobility devices will be that which ensures the safety of both the device user and those in its vicinity. It may well be the case that there is no “one-size-fits-all” solution, as the weight, size, and speed of a heavy-duty mobility scooter are quite different from that of a manual wheelchair, for example. However, it is hoped that the following appraisal of the literature that relates to the safety of PMD use will provide some insight into the reality of the situation, and whether increasing fears and criticisms are with merit or unfounded.

2.3.1) Concerns surrounding the possible dangers posed by PMDs to pedestrians

In recent years, there have been an increasing number of articles in the press expressing fears over the perceived rise in pedestrian-mobility scooter crashes and the injuries that result. With there often being minimal testing of fitness to operate devices, especially if purchased online or through sometimes unscrupulous high-street dealers, many in the government are also concerned about the lack of regulation to ensure that those who operate PMDs are safe to do so. How much of a threat do PMDs and their users actually pose to other people though?

Over the past half-decade or so, a growing number of newspaper articles, and even a television documentary, have seemingly taken aim at mobility scooters and their users, projecting an image of how the devices are posing a threat to society, with writers sprinkling their articles with high profile cases that involve injuries and even death. However, these articles generally lack any real statistics and rely on quotes and headlines to make their point. For example, the BBC came out with an article entitled “A mobility scooter menace?”, while the Telegraph reported on “Safety course for mobility scooter drivers following spate of accidents”; however, never to be outdone, the Daily Mail reported that “Police crack down on mobility scooter mayhem as drunk and drug-driving pensioners become 8mph menace to society” (Holland, 2010; Blake, 2010; Camber, 2010). Two of the aforementioned articles both cited the case of 90-year-old Lillian Macey who died after being struck by a mobility scooter in a hit-and-run incident, as well as that of 2-year-old Madison McNair who suffered cuts to her head after being hit and dragged down the street by an elderly woman on a mobility scooter. While these incidents highlight the potential seriousness of crashes involving powered PMDs, the articles rely on the emotiveness of two helpless pedestrians being injured or killed in order to spark a debate, and potentially cause unwarranted fear, about the use of these devices. All of the articles went on to mention how Norfolk Police started running mobility scooter safety courses “in response to growing fears over the safety of the electric vehicles” (Blake, 2010). The Daily Mail article (Camber, 2010) also states that “around 150 people are killed or seriously injured annually as a result of incidents involving mobility scooters in the UK”. This seems a bold statement, as mobility scooter accidents were not officially reported by UK police forces at that time, at least not as a separate category of accident. However, the House of Commons Transport Committee (2010) reported that from 2013, mobility scooter accidents would be recorded in the “STATS19” police database of British road accidents). In the following paragraphs, the validity of the Daily Mail’s claim will be investigated in an attempt to estimate the actual number of serious mobility scooter incidents occurring in the UK.

Data from the “STATS19” police accident database are now available for 2013, and it is believed that this dissertation is the first work to offer a brief analysis of this dataset. Analysis is a bit complicated, due to the lack of explanation surrounding the different files available; furthermore, it does not appear to be possible to ascertain the number of injury accidents that involved both a pedestrian *and* a mobility scooter, since it is only possible to view one vehicle/user type at a time. However, the dataset *does* reveal that there were just 156 injury accidents involving a mobility scooter reported on public roads in Great Britain in 2013 (DfT, 2014a). In comparison, there were 20,049 injury accidents involving a bicycle, 115 involving a horse, and 20 involving trams (ibid.). While possibly being a misinterpretation of the data, one of the STATS19 datasets indicates that there were 124 accidents that involved injury to the rider of the mobility scooter; therefore, it might be conjectured that 32 mobility scooter injury accidents (156-124) involved injury to pedestrians or perhaps cyclists (ibid.).

It is not known how many incidents involved wheelchairs and other PMDs, as they are reported under the heading of “other”. An important thing to note when considering these statistics is that the numbers cited are the total number *involving* the type of vehicle, and do not imply fault. Since these figures are only for injury accidents that are reported however, it is likely that there are many more accidents that do not involve serious injury and go unreported, a point also raised by Barham, Oxley, and Board (2005). Lastly, it is worth mentioning that because 2013 was the first year that police recorded mobility scooters as a separate category, it may be possible that there was still some reporting of scooter incidents under “other”; whether this is true should be known when the 2014 dataset becomes available.

Looking through previous research carried out by others on the topic, a similarly uncertain picture develops. Barham, Oxley and Board (2005) carried out an extensive investigation into the number of incidents involving power wheelchairs and mobility scooters in the UK. After contacting government agencies, scouring reports, and questioning insurance companies, shopping centres, and others, they estimated that there would be one injury accident per year for 1 in every 88 to 1 in every 617 power wheelchair/scooter users, depending partly upon which part of the country they lived in (ibid.). Regarding injuries to others, they also estimated that roughly 1 in every 200,000 users of the UK's Shopmobility scheme would be involved in an incident involving an injury insurance claim, and just one out of every 15 million visitors to a typical large shopping centre would be injured in a reportable incident by a PMD (ibid.). Rutenberg et al. (2011) looked for information from Canada, but failed to find much more than a small amount of hospital data and anecdotal newspaper reports. They make the point that the scarcity of data is in part due to a lack of a specific reporting category for PMDs in police reports, as was the case previously in the UK. Rica's (2014a) survey of nearly 500 UK mobility scooter users found that while some users reported collisions with pedestrians, none reportedly resulted in serious injury. Little other evidence appears to exist in the literature regarding injuries caused to others by PMD users.

The pedestrians most at risk from collisions with PMDs are probably small children and the elderly. Pedestrians aged over 65 are over-represented in pedestrian fatality statistics, with around half of those killed in developed countries being older than 65 (Jancey at al., 2013). Eby, Molnar and Kartje (2009, citing others) explain that one of the main reasons for the higher fatality rates among older drivers in car crashes is due to their frailty, rather than poor driving, as they are more easily injured. Similarly, it could be expected that if hit by a heavy PMD, elderly pedestrians would therefore also be more likely to sustain serious injury than a younger adult. Furthermore, elderly pedestrians are more likely to experience visual and auditory impairments, and the Guide Dogs for the Blind Association has expressed concerns about pavement use of powered PMDs due to the hazards they pose to guide dog and white cane users; similar organisations such as the Disability Rights Commission and RoSPA also stated that they were aware of concerns from elderly pedestrians, especially those with mobility and visual impairments, who find it difficult to avoid PMDs on the pavement and sometimes feel their safety threatened (Barham et al., 2006).

However, when it comes to collisions between PMDs and pedestrians, it is frequently claimed to be the fault of the pedestrian, with pedestrians reportedly often walking into a stationary PMD (ibid.). Respondents to Rica's (2014a) study also stated a similar opinion. Steyn and Chan (2008) point out that PMDs inevitably take longer to stop than a pedestrian, and this is something that needs to be taken into account by both the PMD user and other pedestrians, who may for example suddenly stop in front of a PMD without thinking. This aspect, regarding stopping distances, should therefore be taken into account when considering how best to design suitable infrastructure for PMDs.

2.3.2) Risks to safety encountered by PMD users

While incidents that result in injuries to other people, such as pedestrians, caused by PMDs are certainly of concern, and are, of course, the ones that are reported on by media outlets, the likely reality is probably that most casualties in PMD-related accidents are the users themselves. This subsection will investigate any evidence for this, and will attempt to provide an understanding of the actual causes behind PMD-related crashes, as well as some of the solutions currently being suggested.

Just as incidents involving a single pedestrian or cyclist are rarely reported, at least to someone like the police, it seems likely that most PMD incidents also go unreported. Therefore, the number of accidents that are relatively minor and involve only the PMD user are likely to be far higher than would be suggested by the STATS19 police database. For example, Edwards and McCluskey (2010) surveyed over 200 power wheelchair and scooter users, and found that 21% reported having an accident in the previous year alone, with tipping over and knocking into objects being some of the most common types of accident. One-third of these accidents involved damage to the device, and 11% resulted in the user sustaining injuries serious enough to require hospitalisation (ibid.). This result potentially translates to about 1 in 50 power device users being involved in an injury accident each year, a higher number than the 1 in 88 to 1 in 617 probability that Barham, Oxley and Board (2005) estimated, although Edwards and McCluskey's study was based in Australia, and their sample size is small enough that there would probably be significant variation upon that ratio each year. This ~2% annual injury accident rate aligns somewhat with information obtained by Barham et al. (2006) from a major insurance company: just over 1% of the company's 30,000 power PMD users filed a claim each year for damage caused by, or to, their PMD. Rica (2014a) reported a similar finding to Edwards and McCluskey, albeit they asked if respondents had *ever* had an incident that had made them feel unsafe: 21% of users reported that they had. Barham, Oxley and Board (2005) managed to find some accident data from the Netherlands for the years 1998-2001, which showed that every year, around 1,400 people were treated at hospitals for "wheelchair-related accidents" (it is not clear if mobility scooters are included). Of these accidents, only 8% were traffic accidents, although it is unclear what percentage of these occurred outdoors. A study investigating mobility scooter injury accidents in Victoria, Australia, found that the incidence of injury accidents appeared to be increasing over time, concurrent with the increase in number of scooter users; 52% occurred along a road or street, while 31% occurred at home (Cassell and Clapperton, 2006). Another more recent study from Australia, Gibson et al. (2011) found that in all of Australia, there were at least 62 mobility scooter-related deaths between 2000 and 2010; moreover, visits to hospital emergency departments related to falls from mobility scooters increased by more than 250% over the same period.

In terms of accident severity, referring once again to the STATS19 datasets, of the 124 injury accidents involving mobility scooter users that were recorded by police in Britain in 2013, five were fatal, seventeen involved serious injury, and the other one-hundred and two resulted in slight injury (DfT, 2014a). This would seem to somewhat refute the claim by the Daily Mail that 150 people are killed or seriously injured in mobility scooter accidents each year, although it is unknown how many serious incidents are not being recorded by the police – for example, the STATS19 dataset does not usually cover incidents in pedestrian zones. Cassell and Clapperton (2006) found that of six recorded mobility scooter deaths over a five year period in Victoria, Australia, all were due to a fall from the scooter, and all of the users were in ill-health and with the exception of one, all in their 70s, 80s, and 90s; falls were also the most common cause of injury overall. Gibson et al. (2011) found that of the 62 recorded deaths over a decade in Australia, most involved falls from the device or being hit by a motor vehicle.

2.3.2a) Conclusions regarding accident and injury risk to PMD users

The problem with the Australian studies by Cassell and Clapperton (2006) and Gibson et al. (2011) is that they only use hospital data, and therefore only provide a real picture of severe and fatal injuries associated with mobility scooter use. In contrast, the studies conducted by Edwards and McCluskey (2010) and Rica (2014a) ask a selected group of users whether they have experienced any accident at all, and thus provide a much better picture of the scale of the problem, with at least 21% of those surveyed in each study citing they had had an accident. One ridiculous piece of research by LaBan and Nabity (2010) went so far as to search for newspaper articles in the USA about crashes between power PMDs and motor vehicles, in order to try and determine how many incidents were caused by excessive hubris, or as a form of assisted suicide (drawing parallels with "death by cop"); needless to say, such research is wholly useless in trying to ascertain anything useful about the overall picture surrounding PMD safety.

So while it seems reasonable to say that around one-fifth or more of power PMD users will be involved in at least a minor incident at some point, in terms of where and why PMD accidents are occurring, it is more difficult to draw any conclusions. While many fatal incidents involve motor vehicles, those that are not fatal appear to result from a large number of causes. As mentioned previously, Edwards and McCluskey's respondents cited the device tipping over, or hitting objects, as two of the most frequent occurrences. Those responding to Rica (2014a) stated that the most common experience was the scooter tipping over, often due to uneven or sloping pavements or turning a corner too sharply; some responded that problems relating to the mobility scooter's controls were also to blame. The Rica study also found that even after accounting for greater usage of PMDs on the pavement compared to the road, respondents were more likely to have an incident on the pavement than on the road. This limited evidence seems to point toward unsuitably designed or poorly maintained infrastructure being a key cause of PMD accidents.

2.3.3) Other concerns regarding PMD safety, and the solutions being considered by the UK government

One last issue frequently raised in the literature pertaining to both the safety of pedestrians and of device users is that of training and "fitness to drive". It is mentioned in Barham, Oxley and Board (2005) that often, "decisions about the purchasers' fitness to drive are simply the responsibility of a sales person". In a personal conversation with a member of staff at one of the NHS wheelchair services, it was stated to me that it was their experience that quite frequently, an elderly person who would be turned down by the NHS for a power wheelchair on the grounds of not being fit to operate it (e.g. due to poor eyesight) would then be taken to a private mobility equipment supplier by a family member, as these suppliers are usually more happy to sell a device to someone regardless of their fitness to operate that device. During Barham et al.'s (2006) consultation with stakeholders, the majority agreed that there should be some minimum requirement, such as an eyesight test, especially for Class 3 device users; however, at least one stakeholder stated that such a requirement would be discriminatory, given that there are no fitness requirements in order to ride a bicycle. Of course, this stakeholder does not seem to have considered that it is also illegal in most countries to ride a bicycle on the pavement. Because of safety concerns, there have also been calls to improve training in the use of devices. Rica (2014a) found that only 59% of respondents in the UK had received any training in using their mobility scooter safely, and only 34% who had purchased a scooter from an online retailer had received training. The House of Commons Transport Committee (2010) had heard how most mobility scooter accidents involving injury were caused by a lack of training and problems with steering, rather than excessive speed, and therefore recommended looking into the possibility of offering a mobility scooter handling course to users, such as is being offered by the Norfolk Constabulary. However, Rica (2014a) found that there appeared to be little difference in accident rates between mobility scooter users who had received training, and those who had not: 19% of trained users had experienced an accident, versus 23% of those who were untrained.

2.3.4) Conclusions on PMD safety

The quantity and quality of research into the safety of personal mobility devices and the risks that they pose to their users and others is very limited at present. The better studies that have been carried out are generally constrained in their findings due to an acute shortage of good quality data because of a lack of specific PMD vehicle categories used in incident reporting, a shortcoming only now being partly addressed by police in the UK. Some studies used hospital data, but again this data only relates to certain, more severe accidents. Two of the most recent studies that were reviewed questioned power PMD users, and gained perhaps the best insight yet, finding that as many as a fifth of power PMD users experience an accident each year, albeit most of these accidents being minor and not resulting in an injury or significant property damage. However, even these studies were fairly limited, and asking about accidents was not their primary aim; also, they did not include manual wheelchair users, so very little remains known about the safety of this large group of users. Ascertaining the validity of the Daily Mail's claim of 150 serious or fatal mobility scooter accidents in the UK each year has not been possible due to insufficient data, although even if it were correct, it would seem to represent a risk not dissimilar to that experienced by older pedestrians in general. The media appear to be ahead of the statistics, creating a negative attitude toward PMD users, especially those using mobility scooters, when the data available so far do not support the claims about the dangers that these devices supposedly present.

Nevertheless, there does appear to be circumstantial evidence that there are quite a large number of accidents each year involving power PMDs that cause user or pedestrian injury, or damage to the device, even though these injuries and damages are usually slight. (A high rough estimate might be 5% of around 450,000 power PMD users, or 22,500 damage/injury accidents each year, although the actual number is probably under 10,000, based on the figures presented thus far.) Therefore, preventative action should be sought before these accident numbers become substantial, given the rapid rise in PMD use, especially mobility scooter use. While obtaining data on things like accident rates, severity, and causes is a main priority, the governments of the UK and Canada are taking action toward addressing issues such as fitness-to-drive testing, training programs, and even insurance requirements. However, so far, the "elephant in the room" appears to be the investigation and realisation of infrastructure requirements, particularly in the UK. This draws significant parallels to the treatment of cycling, since the British government is far more keen to encourage the safety of cycling through driver safety training, and schemes such as Bikeability for cyclists, than it is on spending even a small amount of money on building bicycle infrastructure, despite its proven benefits. The evidence that does exist relating to typical accidents involving PMDs suggests that a substantial proportion of accidents involve devices tipping over due to badly maintained and uneven pavements, or devices hitting objects on cluttered pavements. Therefore, while device safety design standards and user training will play a role in the reduction of PMD accidents, it seems likely that hard engineering measures such as optimised infrastructure design and engineering standards have the potential to provide the greatest reduction in the number and severity of accidents involving personal mobility devices. However, the limiting factor in being able to substantiate this claim is the lack of data, so better data collection remains the main priority at present.

Conclusions to Part 2

Investigation into the numbers of PMD users reveals a rapid and steady increase in the UK and other countries. In the UK at present, there are around 450,000 power wheelchairs and mobility scooters, with this number increasing at an estimated 5-10% per annum. Combined with manual wheelchairs, there may currently be around 1.5 million PMDs in the UK, and if this number keeps increasing in-line with the ageing of the population, there could be around 2.25 million PMDs being used in the country by 2050, if not more. Therefore, this should act as a primary stimulus for the government of the UK and other countries to take notice and accommodate these devices and their users.

Many barriers exist to PMD use in countries like the UK, preventing participation in society and everyday life, while some may even cause physical pain to PMD users. The most commonly encountered barriers to moving about the urban built environment appear to be a lack of dropped kerbs, obstructed, crowded pavements, and bumpy, poor quality travel surfaces. However, the primary barrier to improvements being made may well be the ignorance and lack of knowledge of planners, designers, and officials.

Safety risks caused by PMDs to others appear to be exaggerated by somewhat sensationalist journalists. Nevertheless, there is evidence to suggest that the number of collisions is increasing with the rise in the numbers of devices, which also increases the safety risks caused to PMD users themselves. Many of these accidents are due to the infrastructure design, engineering, and maintenance, although better data collection by authorities and more research needs to be done to confirm this.

Investing in better designed, higher quality pavements and bicycle infrastructure, and allowing PMD users to use all of it, would remove barriers to movement as well as potentially reducing the safety risks to PMD users and those around them. In order to do this, planners and officials need to consult with PMD users and become aware of the problems they face, while the government needs to commit to investing in these forms of infrastructure.

Part 3. Searching for infrastructure design-based solutions

3.1) Overview of Universal Design guidelines

To begin the search for the best infrastructural designs for PMD use, this section will provide an overview of the current best practice in Universal Design as concerns personal mobility devices. Following this, there will be a brief discussion about what these designs omit that may be important.

Universal Design is simply “about making things easier for everyone to use” (Frye, 2014). The concept is that by designing things that everyone can use, no matter what age they are or impairment they might have, everyone benefits due to the level of simplicity and user-friendliness. For example, by designing a step-free environment for wheelchair users, those who cannot walk up steps and those pulling heavy rolling luggage also benefit. (Interestingly, research by MORI (2002) and others has mentioned that locations like airports are among the most accessible for wheelchair users, because they are designed to be used with rolling luggage and luggage trolleys.) Another benefit of designing infrastructure and buildings using Universal Design principles from the outset is that doing so avoids the requirement to make expensive adaptations at a later time in order to meet the needs of an ageing population (Frye, 2014). The best practice design guidelines from the UK as well as international Universal Design best practice guidelines that relate to the movement of PMDs will be presented in the following paragraphs and table.

In 2002, the UK Department for Transport (DfT) published a document entitled “Inclusive Mobility – A guide to best practice on access to pedestrian and transport infrastructure”, which provides advice on best practice guidance; unfortunately however, the guidance provided has no legal status in the UK. Following this, in 2006, the Canadian Human Rights Commission (CHRC) published “International best practices in Universal Design – a global review”, which involved a team of international experts reviewing best practice guidance and technical specifications from around the world, and then reaching a consensus on the specifications that should be considered as best practice overall. When considering the design of the infrastructure, the specifications of PMD sizes should be kept in mind. One problem with this is that devices are continually getting larger, but the current sizes for the study countries are: maximum width of 850mm (Class 3 UK device), no maximum length for UK; “reference device” that fits onto public transport in UK is 1,200x700mm; PMD length of 1,370mm (Canada), although some may be longer; for the Netherlands, a maximum dimension of 3,500x1,100mm applies for all PMDs. The eye level of wheelchair users is considered to be between 1,000mm and 1,300mm, depending on the country (CHRC, 2007). The best practice infrastructure technical specifications from the DfT and CHRC reports are presented in the following table.

Specification description:	Specification:	Report:
Minimum clear floor area to accommodate a single stationary powerchair or scooter and occupant	1,300x800mm	CHRC, 2007
Minimum clear width for pedestrian paths (protruding objects shall not reduce clear width)	1,500mm	CHRC, 2007, DfT, 2002
Minimum clear width in high traffic areas	1,830mm	CHRC, 2007
Minimum clear width for two wheelchairs to pass	1,800mm 2,000mm	CHRC, 2007 DfT, 2002
Recommended minimum clear width by shop-fronts	3,500mm	DfT, 2002
Minimum clear width adjacent to dropped kerb/kerb ramp	1,200mm	CHRC, 2007
Maximum (absolute/preferred) slope of dropped kerb/kerb ramp	1:12/1:16 1:12/1:20	CHRC, 2007 DfT, 2002
Minimum width of dropped kerb/kerb ramp	1,000mm	CHRC, 2007
Dropped kerbs shall be:	Aligned	CHRC, 2007
Minimum diameter for clear turning space at toe level for a power wheelchair to turn 180°/360°	2,250mm 2,420mm	CHRC, 2007 DfT, 2002
Minimum diameter for clear turning space at toe level for a scooter to turn 180°/360°	3,150mm 4,350mm	CHRC, 2007 DfT, 2002
Allowable height range above the ground for controls (e.g. pedestrian crossing button)	400-1,200mm 750mm	CHRC, 2007 DfT, 2002
Maximum side-reach (@90°) for controls	310mm	DfT, 2002
Cross-slope should not exceed ratio of:	1:50 1:40	CHRC, 2007 DfT, 2002
For a vertical rise of over 13mm:	Consider as a ramp – maximum slope of 1:12	CHRC, 2007
Gratings	Perpendicular to direction of travel; maximum spacing of 10mm 13mm	CHRC, 2007 DfT, 2002
Joint width between pavers	Min. 2mm, Max. 5mm	DfT, 2002
Minimum clear headroom	2,030mm 2,300mm (incl. cycle paths)	CHRC, 2007 DfT, 2002
Distance between bollards	See minimum clear device width	CHRC, 2007
Resting areas for wheelchair users provided every	150m, off the path of travel	DfT, 2002
Minimum parking space width, including access aisle	4,100mm (standard), 3,900mm (parallel parking)	CHRC, 2007

Table 1.9: Best practice design standards for pedestrian infrastructure

The above specifications show that pavement design is more complicated than it may appear to the lay person; indeed, when considering Universal Design for all, good pavement design is probably more complicated than many design engineers realise. It is hard to say exactly how wide an ideal pavement should be, and of course, areas with very high footfall such as busy shopping streets will require extra width. However, it seems reasonable that at a minimum, a power wheelchair should be able to make a U-turn on the pavement, therefore requiring 2.5 metres in total. A constant clear width (unimpeded by signboards or lamp posts) of 2 metres so that two PMDs can pass each other at any point also seems like a reasonable minimum standard. As the DfT guidelines point out, areas with shop-fronts such as high streets should be wider, with a clear width of at least 3.5 metres, presumably in order to avoid the risk of PMD-pedestrian collision should people exit shops without looking. The need to consider the placement and gradient of dropped kerbs adds additional complication, and indeed, it is also ideal that the pavement is wide enough so that wheelchair users and others can avoid the slope of the kerb ramp if they are just passing by and not using it. Furthermore, variable cross-fall (where pavements keep incorporating dropped kerbs for car access) is annoying for wheelchair users, and so should be avoided (DfT, 2002).

However, these guidelines appear to omit or not fully consider all aspects of pavement and other infrastructure design that might impede or facilitate comfortable travel for PMD users. For example, the presence of kerb ramps also necessitates the presence of tactile paving so that those with visual impairments know where the pavement ends and the road begins. This tactile paving though may add additional vibration and discomfort for PMD users. Pavement and other travel surfaces also face limited scrutiny, with only the specifications of the gaps (width and height) between adjacent surface elements being considered. The presence of pavement furniture, signboards, and light poles are considered in the clear width, but if the pavement is crowded beyond its design capacity, these items immediately come to represent obstructions for PMD users and pedestrians alike; in contrast, the roadway and bicycle infrastructure do not feature such obstacles. The guidance also fails to consider the safety ramifications of increasingly large and heavy PMDs appearing in some countries, which may require additional space, or even a separate infrastructure, so as not to pose a danger to pedestrians. Also on the topic of safety, sight lines and distances are not considered, which may be of concern, for example, if a PMD emerges from an underpass while a pedestrian rounds a corner, and could result in a collision; related to this is the issue of stopping distances. The DfT report cites Finnish guidelines that give a stopping distance for pedestrians of 500mm, and a reaction distance of 1,400mm; clearly PMDs would take even longer than this (DfT, 2002). Research into the area of PMD and pedestrian stopping and reaction distances could prove to be interesting and worthwhile. Finally, but importantly, all of these best practice guidelines effectively consider PMD users as pedestrians, travelling at pedestrian speeds; there appears to be no contemplation or regard as to whether PMD users might like to travel at higher speeds. This comes back to the issue of "designing for everyone, in every situation", which is perhaps both a strength and a weakness of Universal Design. Being a jack of all trades and a master of none means that travel speeds must be limited to walking pace, while adaptations to the pavement design for some users may cause minor annoyances or barriers for others, even if the overall design is better than a "conventionally designed" pavement. Therefore, while a pavement that meets best practice Universal Design guidelines may generally provide a good travel experience for PMD users for the majority of the time in "pedestrian situations", they appear to fail to provide a solution for higher speed travel in the 5-15mph range at which bicycles typically travel, where the objective is to reach another location rather than spend time in the one being passed through.

3.2) Urban design standards in the study countries

In order to understand how well the design of pedestrian infrastructure matches up to the ideal Universal Design specifications provided in the previous section, a comparison is required for each country based upon the official design standards used for pavement (footway) infrastructure. Additionally, an overview of bicycle infrastructure design guidance should also be provided so as to provide an additional comparison and frame of reference. Of course, this approach somewhat assumes that all pedestrian or bicycle infrastructure is built to these official design guidelines, but this is rarely the case, especially when the pavements were constructed a long time ago under previous, outdated designs, so this information has limited applicability toward the analysis of the questionnaire data presented in the Analysis and Discussion sections of this work. Nevertheless, it should at least provide an idea of the standards to which each country's latest infrastructure is being designed and constructed.

Unfortunately, there has not been time to obtain and analyse this design guidance from each of the countries, and thus a more in-depth analysis of this information should form part of the work for a related future study. However, basic information from the UK on pedestrian and bicycle infrastructure design guidelines, and basic Dutch bicycle infrastructure design parameters are briefly presented and discussed in the following paragraphs.

3.2.1) UK pedestrian infrastructure

The situation in the UK relating to design standards for pedestrian infrastructure could be described as confusing and disorganised, to say the least. For example, the primary design document for roads in the UK is the Design Manual for Roads and Bridges (DMRB), which is officially for the design of the trunk road network (main roads and motorways), although transport engineers frequently use its design guidelines for designing urban roads and streets as well. However, the DMRB does not really include design guidelines for on-road pedestrian infrastructure (such as in the case of a high street), but instead only specifies design guidelines for off-road paths for non-motorised users (pedestrians, cyclists, and equestrian riders). Generally, the specification of these off-road facilities matches the recommendations of the DfT's Inclusive Mobility guide, such as a minimum width for pedestrian pathway of 2 metres, and a maximum crossfall of 1:27 (Highways Agency, 2005, 2001). For pedestrian facilities in urban areas, the DMRB simply refers the reader to the DfT's guide, which as mentioned previously, is not legally binding. Therefore, the design of pedestrian infrastructure in the UK is a "grey area", where best practice designs are possible, but not mandated, at least at the national level. The design of the pavement appears to be at the peril of the designer's own decisions or any local standards. If a bad road design that does not meet

DMRB standards results in a car-crash fatality, there is a chance that those responsible for the design may face legal action, while it seems unlikely that the poor design of a pavement that results in death or injury would lead to such consequences for the designer, because there are few legally enforceable design standards. Because there are no national standards for pavements in the UK, it is very difficult to know just how closely the “average” pavement meets Universal Design best practice standards. This is a topic that requires further research, and is an issue that the government should address.

3.2.2) UK bicycle infrastructure

In a similar manner to pedestrian infrastructure, bicycle infrastructure design guidelines in the UK are subject to a variety of different recommendations, both from within the government and from engineering-related organisations. For off-carriageway cycle routes, the DMRB recommends a minimum width of 2 metres, with 3 metres being preferred; where cycle routes are shared with pedestrians, a minimum width of 3 metres is recommended, split equally, while the preferred width is 5 metres (3 metres for cyclists, and 2 metres for pedestrians) (Highways Agency, 2005). For on-road cycle lanes, a review of national standards shows the minimum recommended width as being 1.5 metres, with 2 metres being preferable (CCC, 2007). Of course, as mentioned earlier, PMDs are not legally allowed to use any bicycle infrastructure in the UK at present, being confined only to the pavement (Class 2 devices) or road and pavement (Class 3 devices). The brief evidence provided here shows that in general, cycle path and lane widths are wider than pedestrian infrastructure guidelines, and this bicycle infrastructure should be free from pavement furniture (although searching the internet will reveal that plenty of poor designs in the UK feature multiple obstructions, especially if they just comprise a converted pavement with paint added to make it a shared-use path). Therefore, at least in theory, bicycle infrastructure in the UK may allow for faster, less impeded movement for PMD users, if they were allowed to use it.

3.2.3) Dutch bicycle infrastructure

Design standards for bicycle infrastructure in the Netherlands are highly variable, since each bicycle path or lane is based upon parameters such as hourly bicycle volume, motorised traffic volume on the adjacent roadway, the speed limit of the adjacent roadway, the space available, and other factors. Designers are still given leeway in terms of the design that they choose, but the CROW Design Manual for Bicycle Traffic does set minimum specifications based upon the aforementioned parameters. For example, the following diagram from the CROW manual shows whether a “cycle street”, cycle lane, cycle track (path), or no special infrastructure at all should be used, based upon motorised traffic volume and speed:

<table>
<tr><th rowspan="2">Road category</th><th colspan="2" rowspan="2">Max. speed of motorised traffic (km/h)</th><th rowspan="2">Motorised traffic intensity (pcu/day)</th><th colspan="3">Cycle network category</th></tr>
<tr><th>basic network ($I_{bicycle}$ > work 750/day)</th><th>cycle route ($I_{bicycle}$ 500-2500/day)</th><th>main cycle route ($I_{bicycle}$ > 2000/day)</th></tr>
<tr><td></td><td colspan="2">n/a</td><td>0</td><td colspan="3">solitary track</td></tr>
<tr><td rowspan="3">Estate acces roead</td><td colspan="2" rowspan="3">walking pace or 30 km/h</td><td>1 - 2.500</td><td colspan="2" rowspan="2">combined traffic</td><td rowspan="3">cycle street or cycle lane (with right of way)</td></tr>
<tr><td>2.000 - 5.000</td></tr>
<tr><td>> 4.000</td><td colspan="2">cycle lane or cycle track</td></tr>
<tr><td rowspan="3">District acces road</td><td rowspan="2">50 km/h</td><td>2x1 lanes</td><td rowspan="3">irrelevant</td><td></td><td colspan="2"></td></tr>
<tr><td>2x2 lanes</td><td colspan="3">cycle track or parallel road</td></tr>
<tr><td colspan="2">70 km/h</td><td colspan="3">cycle track,moped/cycle track or parallel road</td></tr>
</table>

Table 1.10: Decision chart for deciding which type of bicycle infrastructure to construct (CROW, 2007)

There are far too many varying specifications for Dutch cycle lanes and paths to be displayed here, but to give an idea of the primary specifications, roadside cycle lanes should be between 1.5 and 2.5 metres wide (and feature an additional width of "critical reaction zone" if next to parked cars), whilst a one-way cycle path ranges from 2 to 4 metres in width, depending on cyclist volumes, and a two-way cycle path from 2.5 to 4 metres in width (CROW, 2007). Design speeds for cycle paths are 30km/h (18.6mph) for the primary route network, and 20km/h (12.4mph) for basic paths (ibid.). To give an idea of what a typical ~3.5 metre wide two-way Dutch cycle path looks like, and the clearance between cyclists riding two-abreast and a mobility scooter user, please see the following photo.

Figure 1.11: PMD user passing two cyclists on a typical modern two-way Dutch cycle path

These Dutch specifications for bicycle infrastructure in terms of width are much greater than the Universal Design best practice guidelines for pedestrian infrastructure in the majority of cases. Bicycle paths and lanes do not necessitate negotiating kerbs and usually feature a smooth and uninterrupted surface. Furthermore, a design speed of 30km/h allows for much more rapid movement than does a pavement. It is therefore understandable why Dutch PMD users are allowed to use this infrastructure whenever they wish, in addition to pavements.

-Overview of relevant engineering guidelines from DMRB, CROW, etc. BruneauMaurice

-Discussion of potential shortcomings in the design guidelines of these countries

3.3) Bicycle infrastructure as a solution

Many authors have pointed towards the potential of bicycle infrastructure to offer a solution to the infrastructural barriers posed by poor pavements and a car-based society. Indeed, the Netherlands may already offer the best example of this, and it was observing many PMD users utilising bicycle infrastructure that actually provided the inspiration for this project. Other commentators have also noticed this bike-path PMD usage in the Netherlands, such as Albrecht (2013), who commented “one thing that stuck out for me were the vast numbers of senior citizens on bicycles, mobility scooters and motorized wheelchairs using the bike paths… People with mobility challenges were equals to everyone moving throughout the public space, […] riding alongside able-bodied friends". Similar benefits have been noted in Canada, where the vice-president of the British Columbia Cerebral Palsy Association stated "I get around on a power wheelchair – it goes a lot faster than is safe on crowded sidewalks and I used to have to creep along in Downtown […] on the new separated cycle routes, I can travel at the same speed as slower cyclists and get around more efficiently" (BCCC, 2013).

Participants and stakeholders in Barham et al.'s (2006) study also stated that UK PMD users should be allowed to use cycle infrastructure, stating logical similarities such as the top speed of a Class 3 device being similar to the speed of many cyclists. Furthermore, the Cycling Embassy of Great Britain provided a response to the Parliamentary Transport Committee's inquiry on transport legislation relating to the disabled, in which they stated that bicycle infrastructure is ideally suited to those using mobility scooters and adapted bicycles and tricycles, increasing the transport options for these PMD users by providing a smooth, direct and continuous path of travel. However, they also noted that barriers currently placed across them to prevent access by motorcycles should be removed (CEoGB, 2013). It is also worth mentioning that a series of research by Jean-François Bruneau, such as is highlighted in Bruneau, Crevier and Maurice (2013), is already helping to prove the preference for bicycle infrastructure amongst PMD users, along with the travel speed advantages it can provide.

Thus, there is a small but growing body of evidence, albeit some of it anecdotal, to suggest that PMD users are already benefitting from cycle infrastructure in the countries in which it exists.

3.4) Working toward a new Level of Service (LOS) indicator

Level of service (LOS) is a measure and a concept with its roots based on the ability of a road to handle different traffic loads without becoming congested, although over the past couple of decades it has become increasingly used to rate pedestrian and bicycle infrastructure as well. Rodrigue, Comtois and Slack (2013) provide the following general definition "[Level of service is] a set of characteristics that indicates the quality and quantity of transportation service provided, including characteristics that are quantifiable and those that are difficult to quantify". Level of service is usually rated on a scale of A to F, with A being the top rating. However, while capacity-based ratings are fine for cars, pedestrians clearly care about more than just the busyness of the pavement. Despite this, Asadi-Shekari, Moeinaddini and Shah (2013) note that many early attempts at introducing a Pedestrian Level of Service (PLOS), such as that of Fruin in 1971, were based just on pavement capacity and pedestrian volume. Thankfully, more recent attempts at devising a PLOS have included metrics surrounding factors related to safety, security, attractiveness, comfort, convenience and network continuity and coherence (ibid.).

Typically, the importance of various factors to be included and their sensitivity are determined through stated and revealed preference studies, as in Koh and Wong (2013), and these are sometimes used in conjunction with video clips, as in the studies of Kang, Xiong and Mannering (2013) and Parkin, Wardman and Page (2007). Other more in-depth and accurate methods, albeit also more time consuming, involve travel journals or even walk-along interviews, such as those assessed in the research of Kelly et al. (2011). Studies such as those by Li et al. (2012) and Joo and Oh (2013) have involved research to determine important factors for cycling, which would be used to create a Bicycle Level of Service (BLOS) indicator; Joo and Oh's research is unique in that it utilised accelerometers and GPS to obtain true measurement data that can be associated with respondents' thoughts and perceptions.

However, despite the research into PLOS and BLOS, so far there has been no research into determining a level of service indicator matched to the needs and desires of PMD users. Because PMD users place extra value on things like surface smoothness, width of infrastructure, and often the ability to travel at a speed greater than pedestrian travel, their requirements are unique, even if some of them may be similar to those required by cyclists. Therefore, it is hereby proposed that research to determine the full array of barriers, facilitators, and other perceived indicators related to comfort, convenience, and quality is carried out, in order to form the basis of a new level of service indicator that is tailored to PMDs, which will tentatively be called Wheelchair Level of Service, or WLOS. When combined with PLOS and BLOS, these three measures will complete the overall active travel LOS indicator suggested by Asadi-Shekari, Moeinaddini and Shah (2013), termed Non-Motorised Level of Service, or NMLOS.

This study may be able to contribute toward an initial WLOS indicator by suggesting some barriers that are important from the literature review findings combined with the research from the questionnaire which will be discussed in the Analysis and Discussion section, although a more comprehensive study should be carried out with this goal specifically in-mind. It is suggested that this research also utilise comfort (shock) and speed measurements, such as those made in the studies of Joo and Oh (2013) and Bruneau, Crevier and Maurice (2013). Furthermore, it should include safety-based metrics, based on parameters such as PMD and pedestrian stopping distances, with the former also requiring research to determine.

There is of course debate about the accuracy and usefulness of LOS indicators, but this is a discussion best suited for a future piece of research.

Conclusions – Literature review

It is not easy to know how to summarise and conclude such a comprehensive literature review. However, the following information is thought to summarise the most important findings and new ideas of the previous 25,000 or so words.

Reviewing the concepts, it should be remembered that it is impairments that are acquired, not disability. Disability can be considered to be something that is imposed upon someone with an impairment by society, or more specifically in this case, by the built environment and its designers, and even upon those without (e.g. those not owning cars in a car-based society). Thus, those with mobility impairments can become disabled by the built environment.

Mobility is "ease or freedom of movement", but does not guarantee access. Accessibility is based upon the concept of location and distance, and describes the ability to reach desired goods, services, and activities; because of this, it can be measured in terms of participation (in society). While accessibility is more important to achieve, it can often only be achieved if mobility has been provided; therefore, unequal levels of mobility in society may result in unequal levels of participation, and this appears to be the case for PMD users. Consequently, focusing on what is achievable within the transport planning remit, this study is concerned with improving mobility and ensuring that the built environment does not disable PMD users.

The first "wheelchair" that allowed independent movement for someone without the use of their legs was probably Farfler's handcycle in 1655. Since then, designs have continually been refined, but perhaps the biggest step in enabling independence, especially for those without much upper-body strength, was the development of the powered wheelchair, and subsequently the mobility scooter. As for the users of these devices, most are older, usually in their 50s, 60s, 70s, or 80s. This fact is related to the conditions and illnesses that have caused their mobility impairment such as arthritis, cardiac problems, and stroke typically being linked to older age. Therefore, because the number of people with mobility limitations, and the consequent number of potential PMD users, is partly a function of age This is a concern that needs to be addressed by those in charge of countries with ageing populations.

Rapid growth in PMD ownership, especially of powered devices, has already been seen in the UK, where by 2050 there may be in the region of 2.25 million PMDs in use. PMD users in the UK and other countries with similarly car-based cities frequently face barriers such as obstructed, crowded pavements which are problematic to get onto and off of due to a lack of dropped kerbs, while their bumpy surfaces can slow travel and even cause pain for some. Because these barriers ultimately limit PMD users' participation in society, pursuing legislation on the basis of eliminating discrimination may be one potential solution. However, educating planners, designers and officials about the needs of PMD users may prove a more fruitful solution for effecting change. There is also a growing concern over issues related to PMD safety, although most incidents only involve the user and do not result in serious injury. Evidence points towards the quality and design of infrastructure being at least partly responsible for many of these accidents. Thus, improving infrastructure has the potential to increase safety and reduce barriers for PMD users, thereby increasing participation in society and reducing any negative impacts associated with the use of the devices.

While best practice Universal Design guidelines for pavements and other transport infrastructure are readily available, they have not been incorporated into national design guidance for such infrastructure; in fact, in the UK, there are no legally binding design guidelines for pavements as there are for roads. Looking to design solutions, the official design guidelines for Dutch bicycle infrastructure appear very well suited to offering a wide, barrier-free travel environment, often suitable for travelling at speeds of 30km/h or more. Many authors of other work have also pointed towards bicycle infrastructure as providing mobility benefits, often with a focus on the lack of barriers that it features. However, perhaps the ultimate way to compare the benefits and drawbacks of different types of different types and qualities of infrastructure for PMD users would be to create a new level of service indicator, tentatively called Wheelchair Level of Service (WLOS).

Following the discoveries made in the literature review section, the following research questions that had been presented in the introduction section can now be answered:

- **What barriers does the built urban environment, such as that of a typical UK city, pose to the movement of a PMD user about the city?**
-

The short answer to this is that the built environment poses many barriers to mobility, the most prevalent of which are related to the design and maintenance of pavements, although other problems such as buses not having enough space for PMD users, stops and stations not being accessible, the requirement to have use of a car to reach many edge-of-town locations, and the PMD users' home not having space or adaptations to allow ownership of the ideal device all present barriers to mobility.

- **Of the above barriers that PMD users face, which of these does high-quality bicycle infrastructure NOT feature?**

Typically, bicycle infrastructure does not feature obstacles such as signs or pavement furniture, and is not crowded with pedestrians; bicycle infrastructure therefore often features a greater clear width. Furthermore, bicycle infrastructure does not feature kerbs that have to be mounted and dismounted, and is usually constructed with smooth asphalt, rarely featuring the concrete slabs or stone pavers that may cause a bumpy, painful ride for PMD users on the pavements.

Section II. Methodology

It was known fairly early in on in the development of this project that the research question could not be answered by existing literature, and that therefore it would be necessary to carry out original research. From an early stage, it was decided that a questionnaire would be used for this study, with two purposes. The first of these was to substantiate the claims found in the literature, and *vice versa*, to verify the accuracy of the data obtained by comparing results against certain proven trends. The second reason was because the use of a questionnaire is one of the most efficient ways of (potentially) obtaining large quantities of data within a fairly short time-frame.

However, the initial project plan was to collect data in two stages. The first stage would involve a questionnaire of PMD users, while the second stage would involve further research with a subset of those who returned the questionnaire, and consist of using GPS tracking, and some form of travel log (such as a camera, Dictaphone, or notebook). The GPS could potentially reveal data such as route directness, average travel speed, variation in travel speed, preference for busy or quiet streets, *et cetera*, thus providing actual data on the characteristics of travel associated with different types of infrastructure. The travel log could reveal further information, such as the exact infrastructure being used (pavement/road/cycle path), as well as other qualitative information about the journey, such as overall satisfaction, or problems encountered. It was discovered after this data collection methodology had been laid out that the only other study relating to the use of bicycle infrastructure by PMDs (Bruneau, Crevier and Maurice, 2013) had used almost exactly the same methodology: the author used a questionnaire, and then followed this with collection of travel data with a GPS-camera that also had audio recording capabilities.

However, due to time constraints, carrying out the second stage of data collection using the GPS device and travel log became out of the question for this research project. This data collection will be carried out as further research following the submission of this dissertation.

Questionnaire methods

The questionnaire was written in English, and many revisions were made before around 20 pilot versions were distributed to users in Southampton. Following the return of around 10 of these pilots, and design errors were corrected, the questionnaire was further scrutinised by Dr Waterson and Prof Bruneau, and even more changes were made. It was felt that the final questionnaire that was distributed (and translated) was mature, with few design flaws.

The final Dutch (in English and Dutch) and English versions of the questionnaire can be found in the appendix.

Great lengths were taken in order to remove as much potential bias and as many potential sources of error and confounding factors as possible. Because most of the Netherlands is very flat, a hilliness index for UK cities was used (Steer Davies Gleave, 2010) to select some of the least hilly UK cities in which to distribute the questionnaire. Similarly, climate data was researched to ensure that the UK cities selected also had similar temperatures and rainfall throughout the year to some typical Dutch cities.

When deciding how to distribute the questionnaires, face-to-face surveys on the street were ruled out, for two reasons. Firstly, the number of wheelchair users passing a particular place in a city is not particularly high, and therefore it is expected that many days of sampling would be required for each city in order to obtain a reasonable sample size. Secondly, bias could be introduced, because it would be likely that only the most "active" PMD users would be sampled, leaving out people who tend to leave their home less often (which could indeed be due to lack of mobility because of a "disabling" built environment). Sampling only the most active users would be akin to sampling only frequent cyclists in the UK about how to improve conditions for cycling, when these cyclists are usually young to middle-age males with a confident riding style – i.e. not the more risk-averse people who are the ones who would benefit most from improved infrastructure in order to get cycling.

As a result, a method of distributing questionnaires to a more representative sample of PMD was desired; this could most likely only be achieved by communicating through an organisation that holds contact details of wheelchair users. Furthermore, assistance would be required by said organisation in the contacting of potential participants, and/or in distributing the questionnaires, due to confidentiality concerns in revealing the contact details of potential participants (effectively personal medical information). In the Netherlands, no fewer than eight governmental and non-governmental organisations were contacted, including those involved in health research, as well as those who provide support to people with disabilities. Unfortunately, none of the organisations were able to help initially, with most citing a lack of time or resources as the reason. However, the Dutch Institute for Social Research (SCP) suggested that the best course of action might be to try contacting those who actually issue/supply the wheelchairs. In the Netherlands, this responsibility falls upon the city council of each city – specifically, the "WMO helpdesk", the office which relates to the Social Support Act.

The WMO helpdesks of eleven cities were contacted, namely those in Rotterdam, Leiden, Assen, Groningen, Enschede, Almere, Eindhoven, Den Bosch, Zwolle, Houten, and Utrecht. Despite following these emails and telephone calls up with reminders, only the helpdesk in Almere sent a somewhat positive reply, and even they did not reply to subsequent emails. There are two potential reasons for this lack of assistance; the first of which is that many of the people at the city helpdesks seemingly did not fully understand the request, and so were not interested or able to help. The second reason is that they simply did not have the time or resources to help out, perhaps due in large part to preparing for the introduction of a new Social Support Act at the beginning of 2015 which will decentralise many support and counselling services, thereby adding significantly to the responsibilities, and thus workload, of municipalities.

The repeated failure in finding organisations that could assist with distributing questionnaires within the Netherlands led to significant delays in carrying out the research, as well as some despondency on the part of the author. However, upon reviewing some academic journal articles, it was noted that one of them was written by some researchers who work for NIVEL (the Netherlands institute for health services research), an organisation that monitors health and healthcare, as well as collaborating with the EU and WHO on healthcare research projects. The researchers were contacted and showed interest in the research topic, and agreed to distribute the questionnaire within the Netherlands. The researchers helped to provide some feedback with regard to the content and design of the questionnaire, especially for the country-specific aspects for the Dutch version. Once finalised, the questionnaire was translated into Dutch by a professional translation company. The researchers at NIVEL then made adjustments to the translation, to ensure that the more specialised subject-specific terms were correctly translated, and also to ensure that the language used was not too complicated. These corrections were discussed in some detail with the author and mutually agreed upon, leading to consensus that the English and Dutch language versions of the questionnaire should not suffer any bias due to differences in language. The questionnaire was distributed by NIVEL along with another questionnaire of their own in online-only format, to wheelchair, mobility scooter, and handbike users who form part of a national panel of around 4,000 disabled people called the National Panel of people with Chronic illness or Disability (NPCD). The questionnaire was distributed at the end of October, and the results being returned in January. Because the questionnaire was distributed during some of the colder, wetter months of the year, it cannot be ruled out that on questions regarding travel behaviour where weather may play a role, that there may be some negative bias with regard to total amount of travel, or amount of active travel, compared to if the questionnaire had been distributed within the summer months.

Within the UK, a similar approach was adopted for finding a distribution partner to the one initially tried in the Netherlands, whereby it was decided to contact the wheelchair issuing authority, which is the National Health Service. After considering the terrain and climate criteria mentioned earlier in this section, a list of appropriate cities was drawn up, and the relevant NHS wheelchair services were contacted in each. (Of note here for future research is that an increasing number of wheelchair services are being contracted out privately, to a company that showed no interest in being of help with this research.) Healthcare professionals from NHS wheelchair services in two of these cities (Reading and Hull) replied that they were interested in the research, and offered to distribute the questionnaires. In hindsight, whatever time was saved in finding distribution partners more easily in the UK, was then expended upon a very time-consuming ethics approval process which is required by the NHS for any study that involves its patients. This NHS ethics approval process was in addition to that of the university's, and had to be carried out in two separate approval stages. The first stage required the filling out of very lengthy forms, and the obtaining of signatures from everyone involved with the research and their legal representatives, in order to gain approval from the regional (central) NHS ethics committee. Once this approval had been obtained, further forms for each research site (Reading and Hull) had to be completed, and approval had to be granted by the ethics committee at each of these sites before the research could go ahead. At the last minute, the research contact in Hull telephoned to say that they would not be able to participate in the study any more, and thus a last-minute change to York (a nearby and almost-as-flat city) was made, subject to further ethics approval. The whole NHS ethics approval process took around ten weeks to complete, which caused concomitant delays to the commencement of data collection.

Following the questionnaire distribution and return, the research contacts in Reading, York, and the Netherlands were asked to provide information about the criteria they used to select potential participants, along with any other information about their total user-base.

The following is what they had to say:

> **Jacqueline Scoins-Cass MBE, Reading:**
>
> *The West Berkshire Wheelchair clinic is based at the Royal Berkshire Hospital, Reading. The team is made up of 1 full time band 7 Occupational Therapist (OT) wheelchair clinic team lead, 1 part time band 7 Paediatric specialist OT, 1 full time band 6 rotational OT, 1 part time band 6 Rehab engineer, and 1 part time band 3 Technical instructor. The team is supported by a full and part time administrator. The clinic covers the West of Berkshire which is split into 3 unitary authorities.*
>
> *West Berkshire (Lambourn to Calcot) population size: 154,000 (2011 census) a mix of villages and urban locations.*
>
> *Reading (Calcot to Earley), population size: 155,698 (2011 census) a urban area*
>
> *Wokingham (Earley to Bracknell), population size: 154,380 (2011 census) a mix of villages and urban locations.*
>
> *The Wheelchair Clinic has 3,040 active patients from the areas covered above. Some of these active patients registered with the clinic are children and therefore are not included in this research study. Other patients who lived in specialist nursing home where also not included in the research project as it was felt that they would require assistance to complete the questionnaire and may not have had capacity. (I am unable to give an exact number as our computer system is not specific and sophisticated enough to break down the number of children versus adults registered on our system.)*
>
> *The patients were selected from our computer system by a member of staff, choosing those who had their needs assessed within the last 5 years by a member of staff from the clinic, and had either a Power wheelchair, manual wheelchair or a voucher towards a wheelchair provided by the clinic. All participations had capacity and where able to consent for themselves to participate in the research project. A mix of male and female patients were selected, from across the 3 areas and from different age groups.*
>
> *A total of 70 questionnaires were posted out to patients registered with the clinic and 13 questionnaires were handed out at clinic appointments.*
>
> *A total of 13 questionnaires were returned via post and 4 where handed into the clinic.*
>
> *So in total 83 questionnaires were distributed and 17 were returned.*

Jane Thurlow, York:

The York Wheelchair Service is run from a dedicated clinic on the outskirts of York, accessible by bus and with free parking. We employ OTs, a Physio and Rehab Engineers to prescribe our wheelchairs. The North Yorkshire Wheelchair Service, of which York is a part, is run by Harrogate and District Foundation Trust. The other wheelchair clinics are at Northallerton, Knaresborough, and Scarborough. For this exercise, only adult clients at York (covered by the Vale of York CCG) were selected. They were residents across our catchment, which includes the Selby area, and a mix of rural and city dwellers. We sent 93 questionnaires to our EPIOC (outdoor/indoor powered wheelchair) users across our York catchment, which were returned direct to the researcher. The York Wheelchair Service currently has 3167 active Adult clients.

NIVEL, the Netherlands:

"As you know we asked our "patient panel" a lot of questions. One of these questions is if they use a wheelchair, (special) bike, handbike or "mobility scooter". If they answered this question positive for one or more devices, than your questions were asked.

The completion rate of the total questionnaire was 80.3%.

388 patients (of 3131) [on the NPCD] used at least one of the mentioned devices."

Limitations of the data collection

The original research relies on stated and revealed preferences, rather than investigating actual travel behaviour, a limitation due to the use of questionnaires. Similarly, collecting actual travel data, such as distances travelled, average speed, route directness, and real-time perceptions of safety, is not possible, as to do so would require participants to fill out a travel journal, and/or agree to be tracked with location equipment and filmed with audio-visual equipment, which would be far too time-consuming to be carried out for this dissertation.

Section III. Analysis and Discussion

Prologue

Rather than splitting the analysis and discussion into two separate sections, it has been decided, due to the great many topics that will be discussed relating to both the findings of the literature review and toward meeting the aims and objectives, that they will be included together often with the discussion of the data immediately following the analysis of each question, or occasionally there will be a combined discussion covering multiple questions.

There are four main topic themes presented in this section, which aim to provide a structure similar to that of the literature review: first, understanding the sample, and then going into the problems faced by the sample, and finally examining the potential solutions (with the focus being on bicycle infrastructure). The topic headings are as follows:

1.) Demographic characteristics of sample, and ownership of devices
2.) Tripmaking and perceptions of infrastructure provision and requirements
3.) Barriers
4.) Potential solutions: improving mobility

With regard to the analysis of the data, because the Dutch dataset was based upon a questionnaire that varied slightly in places to the UK and Canadian version, direct comparison and presentation of the data within the same chart has not always been possible, hence comparable charts for the two country versions will often be presented beside each other.

Topic 1. Demographic characteristics of sample, and ownership of devices

Introduction

To begin the analysis and discussion of the data, the characteristics of the sample will be presented, and then discussed in relation to how well they match the sample populations of previous studies with PMD users. Following this, the ownership of devices will be looked at, with analysis focusing upon satisfaction with device provision and ownership differences between the study countries, and the discussion will attempt to provide an understanding of these differences.

Analysis: Demographic characteristics

In total, 223 useable questionnaire returns were received from the three study countries. These included 108 from the Netherlands, 54 from the UK (21 from Reading, 29 from York, and 4 from other locations), and 61 from Canada (25 in English, 36 in French). The characteristics of the sample and information on where they live are presented in the following subsections.

Age

The age groups for the countries are shown in the following charts and are broken down by the local groupings so that the slight differences between the samples are clear. Respondents from Reading tended to be younger, and there were very few in the 65+ age group, whereas respondents from York were mostly in the older age groups; most respondents from Canada were in the middle two age categories, with those from French-speaking Canada that were in the youngest two age groups cleanly outnumbering those in the older two age groups. Therefore, it could be considered that there might be some age-related differences between responses from York, which represent the views and concerns of more elderly people, to those of French-Canada, which are biased in favour of the views of younger adults.

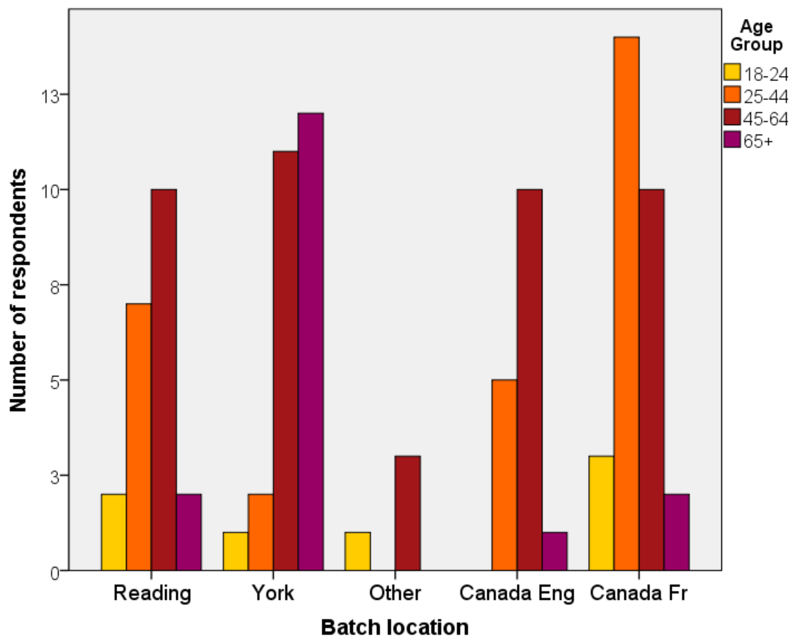


Chart 3.1: Age composition of British and Canadian samples

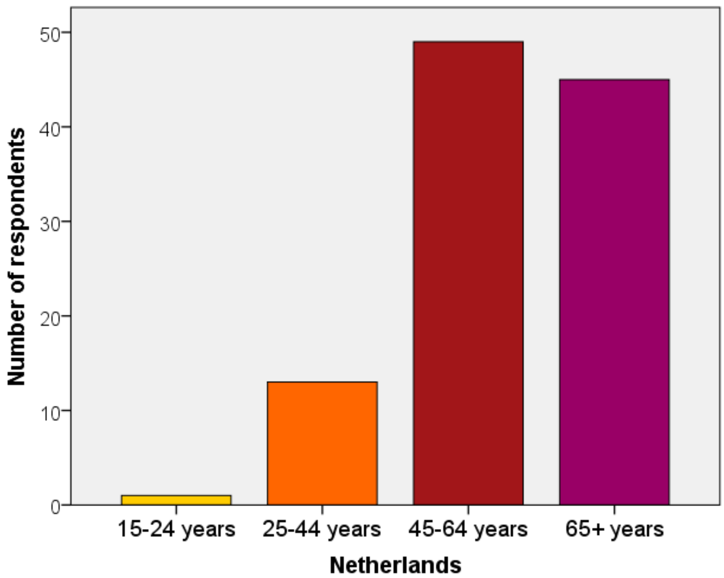


Chart 3.2: Age composition of Dutch sample

The Dutch sample bears resemblance to that of York in terms of age break-down, with heavy representation of those in the older two age categories. Finally, the last chart on the following page displays the age break-down for the total sample of all 204 respondents who provided this information. Almost half of the sample were in the 45-64 age group, followed by the 65+ and then 25-44 age groups, with only a handful of those aged 18-24. The fact that overall, the weighting is biased toward a slightly younger average age (a fully representative sample of

PMD users would likely have most users being in the 65+ category) might have the benefit that the participants on the whole are slightly more active in terms of trip making than would otherwise be expected.

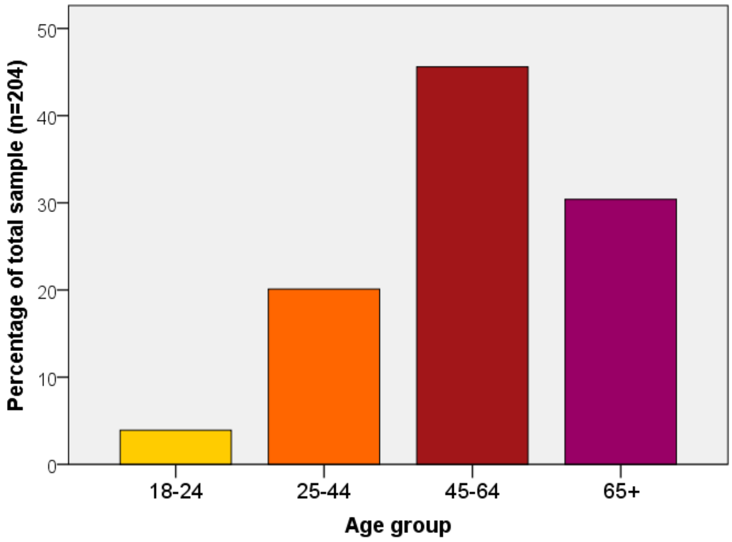


Chart 3.3: Age composition of total study sample

Sex

There was very little difference between the locations within countries when concerning the ratio of male to female participants, with females outnumbering males in all distribution locations in each country. The following chart shows that for the UK and Canada, 54% of respondents were female. Similarly, just under 56% of Dutch respondents were female. Overall, of the 204 people providing this information, 54.9% were female.

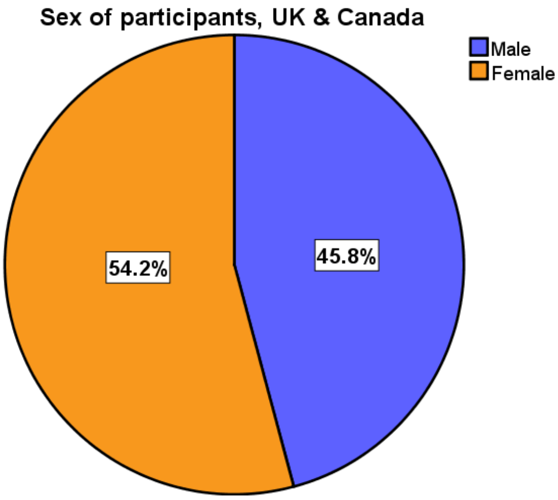


Chart 3.4: percent female/male participants, UK & Canada

The consistency of this data between locations provides a good indication that the sample is likely to be representative of the general population of PMD users, at least with respect to gender-related views.

Type of house

The questionnaire also asked about the type of dwelling participants live in, which may have an influence upon the accessibility of the property or the space available to store PMDs. The phrasing of this question, along with the answer options available, was the same as those given in the 2011 Census for England. Of course, to some extent, the type of building will also be representative of the housing stock generally available in each country. The following bar chart shows the type of dwelling that respondents reside in for the UK and Canada:

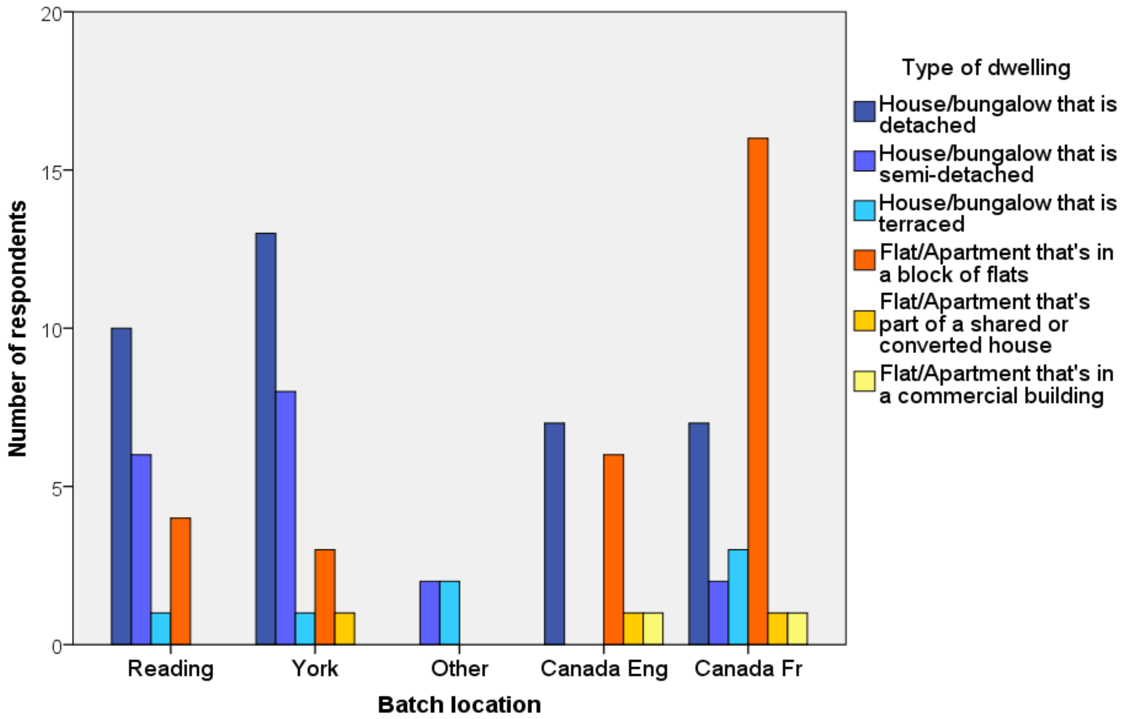


Chart 3.5: type of dwelling for UK & Canada participants

For the UK, it is clear that most participants reside in detached or semi-detached houses, with few living in apartments. However, in Canada overall, almost 60% of respondents live in an apartment. This bias towards apartments in Canada may be due to most respondents living in urban locations, especially in large cities such as Montreal, whereas many in the UK live in more outlying areas of the study cities, as well as there being quite a few who reside in small rural towns near those cities, which is not so much the case for the Canadian sample. The situation in the Netherlands is different still, with analysis revealing that 36% of respondents live in an apartment building and 38% in a terraced house; this would seem to reflect typical Dutch housing stock.

Number of other people residing in the dwelling

So as to better understand the sample, another question that had been on the 2011 Census for England and Wales was asked, this time regarding how many people live in the household. By asking this question, the potential level of support that might be immediately available from another person can be better gauged. When analysing the results, it was difficult to discern any particular trend by area, other than perhaps that York had a tendency towards having two occupants per household, with few houses having 3 or more people, whereas single and multiple occupancy appeared more common in other areas, perhaps reflecting the age differences. That is to say, more elderly respondents may be likely to be living either as a couple or as a single widower, while younger respondents in other areas might be single and never married, or living as a family. When taken as a group though overall, for the 97 respondents in the UK and Canada who answered the question, over two-thirds lived with at least one other person, and 32% were living alone. The highest number of people recorded was 28, which was presumably from someone living in an assisted-living facility, although only a few households had more than five people living together. For the Netherlands, the number of people per household showed a very similar profile to that seen in York, adding weight to the assertion above regarding the age-occupancy relationship. Just under 40% of Dutch respondents lived alone. The following charts show how many people live in households in the UK and Canada overall, followed by York and then the Netherlands, to demonstrate the aforementioned similarity.

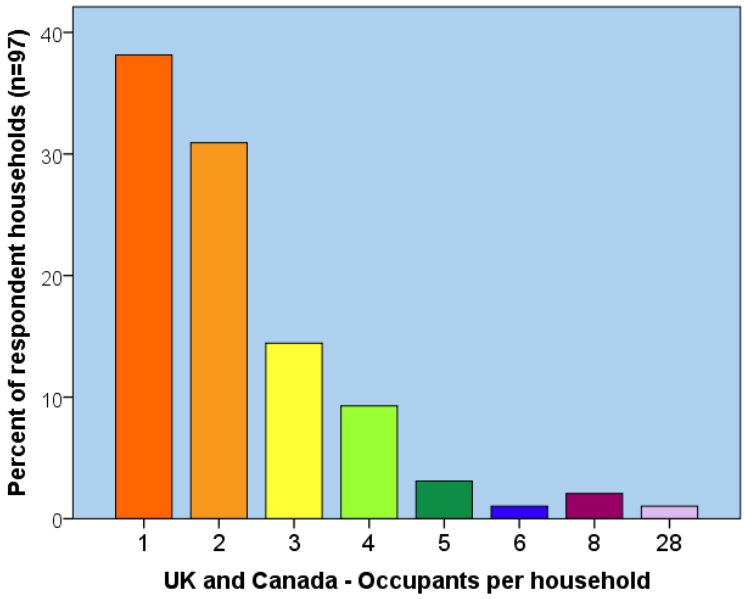
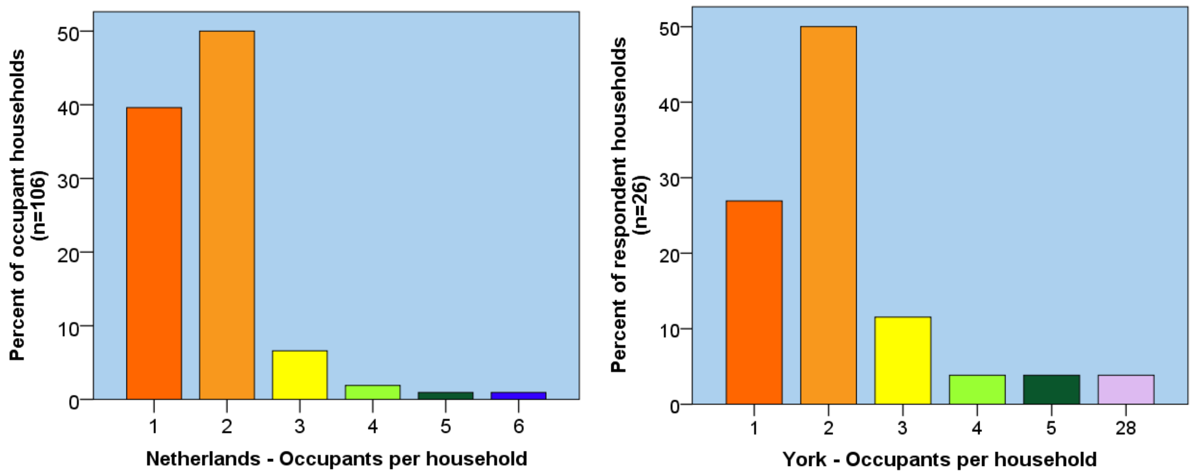


Chart 3.6: number of occupants per household, UK and Canada



Charts 3.7 and 3.8: comparison demonstrating the similarities between the older sample populations of York and the Netherlands in terms of household occupancy.

Urban/rural composition

This is perhaps one of the most important aspects to consider about the sample. Because this work is primarily concerned with urban mobility, efforts were made to try and ensure that the sample was also urban, and preferably from specific cities. However, in reality, this proved to not be feasible. As a consequence, some respondents are from rural locations or small urban areas which are outside the main study cities in the UK; for the Netherlands, the sample is taken from across the entire country, and likewise for Canada, although most Canadian responses originate from large urban areas.

For the UK, most of the respondents from York were categorised as urban or rural by the research contact at York NHS wheelchair services based upon some loose criteria given by myself, while for Reading, the NHS wheelchair services contact provided more specific respondent location information, with the job of categorising locations left to myself. Generally, a location was considered to be urban as long as it was built up to some degree, and had pavements, a shop/supermarket, and a doctor's surgery nearby. Thus, not all "urban" locations in the UK are directly comparable, and this should be kept in mind. For the Netherlands, however, a more precise measure was provided, a "degree of urbanisation", based upon the number of other addresses within a radius of one kilometre from the respondent's location, divided by the area of the circle (3.14km^2). The categories are as follows: Very Strong (>2,500 addresses per km^2), Strong (1,500-2,500 per km^2), Moderate (1,000-1,500 per km^2), Weak (500-1000 per km^2), and Very Weak/rural (<500 per km^2). It is not known how this directly compares with the UK in terms of local provision of goods and services, and so comparison between countries may not always be possible – within country comparisons may prove more accurate and useful. For Canada, categorisation was also done by myself, although partial postcodes made this job easier in Canada, since typically postcodes there only cover an urban area or a rural area, but not both, which is not the case in the UK. In both the UK and Canada, however, it was still not possible to categorise the location of some respondents, as the exact locale in which they lived was not known, or discernible from the partial postcode. These were therefore coded as “unknown”.

For the UK and Canada dataset, York had the highest proportion of rural dwellers, as well as the highest proportion for whom the location could not be ascertained. The sample from Canada had a higher proportion of urban dwellers than either UK location, with a large number of these respondents living in dense residential areas that are in much larger cities than Reading or York, and therefore this may have an impact upon provision and usage of public transport, and the necessity to own a car. Nevertheless, all UK and Canadian sample locations had the large majority of their respondents categorised as residing in an urban area. The overall situation is shown in the following chart.

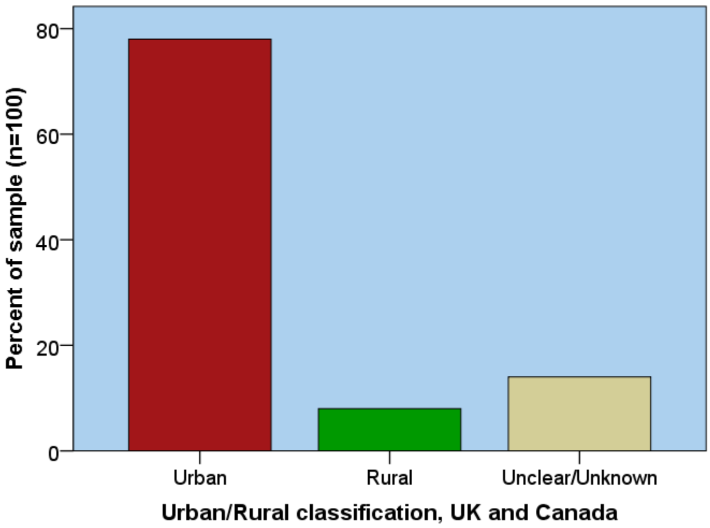


Chart 3.9: urban/rural classification of the area in which the respondent resides

As displayed by the chart, 78% of participants in the UK and Canada were determined to live in urban areas, while the classification could not be determined for 14% of them. The next bar chart shows the percentage of respondents in the Netherlands who fit into each of the five degrees of urbanisation.

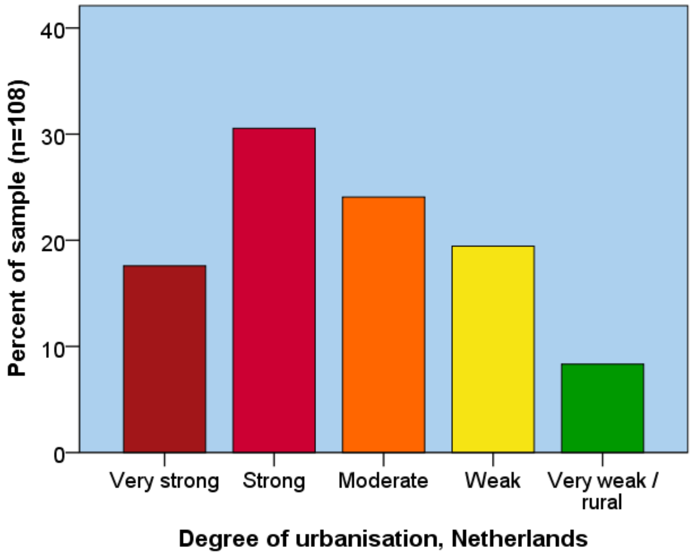


Chart 3.10: degree of urbanisation for the area in which the respondent resides in the Netherlands

The chart demonstrates that, similar to the UK and Canada, most respondents in the Netherlands live in areas that are at least somewhat urban, with 72% living in areas that are moderately or more urban (based upon the scale given). Again, it is not known just how these densities compare with what has been categorised as "urban" in the UK, nor is it known how the existence of establishments providing essential goods and services generally corresponds with these levels of urban density, but at the very least, it should allow some very useful comparisons between these urban density levels within the Netherlands.

Conclusions: Demographic characteristics

Overall, the samples from York and the Netherlands were a bit older, and as such, may be more representative of PMD users overall; the age break-down of users is in-line with that seen in other studies. Likewise, the slightly greater proportion of female respondents also matches that seen in other studies, and reinforces Picavet and Hoeymans' (2002) analysis of disability/mortality as differing between the genders. There were also differences in types of building lived in, with a relatively high number of Canadians residing in apartments. There appears to be a relationship between age and household occupancy, most likely due to different family structures being linked to age. Lastly, most respondents lived in urban areas, although the Dutch metric of degree of urbanisation is likely much more useful from an analysis perspective than the simple urban/rural classification used for the UK and Canada.

Ownership of devices

This next subsection will present the findings regarding ownership of devices, along with whether respondents were satisfied with the devices that they currently own, or whether they would like to own more. If respondents did not own all the devices that they would like to, then they were asked the reasons that prevented them from owning more.

Number, types, and characteristics of personal mobility devices owned

For the UK and Canada, for Question 1, the options for device category that the respondents could state that they owned were the same, including the Class 2/3 speed categories, even though devices in Canada are not necessarily categorised as such. Respondents were also asked if the device was purchased via the NHS (UK) or government programme (Canada). For the Netherlands, the device categories were slightly different, and respondents could select whether the number owned of each type of device, and also specify the exact top speed, if known. For more precise details of this question, and others, please refer to the full copies of the questionnaires in the appendix.

Of the 52 respondents answering this question in the UK, 83% owned a manual wheelchair, 58% a class 2 power wheelchair, 10% a class 3 power wheelchair, and 17% owned a mobility scooter of some speed category. Also, 6% said that they owned another type of PMD (e.g. trike or handbike). The proportion of UK respondents owning at least one of each type of device is shown in the following chart.

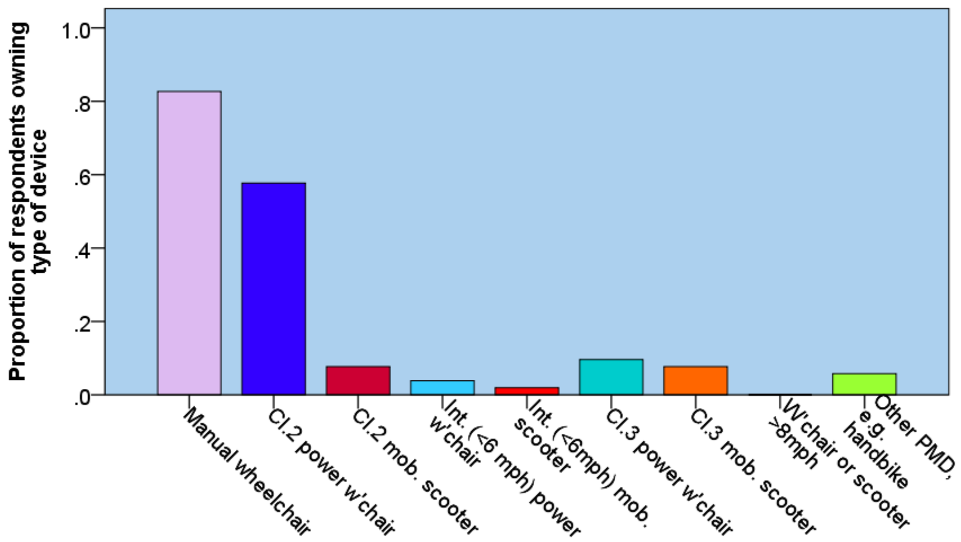


Chart 3.11: ownership of PMDs in the UK

For the Canadian sample, ownership of manual wheelchairs was just slightly lower at 72%, and much lower for the slower class 2 power wheelchairs, at only 22%. However, 17% owned a power wheelchair that could reach around 6mph, and 10% owned a wheelchair or scooter that could exceed 8mph, whereas no-one in the UK owned such a fast device. This is probably partly due to NHS prescribing guidelines, since they do not normally issue chairs capable of more than 4mph. On the other hand, many respondents from Canada indicated that they had government assistance in purchasing their ~6mph wheelchair, and even for faster devices. Compared to the 17% of those in the UK owning a class 2 or 3 mobility scooter, 23% owned one in Canada. Also, it is worth noting that 15% of those in Canada said they owned an alternative type of PMD, such as a handcycle. Overall, it is not clear just how representative device ownership is in the two countries compared to their total population of PMD users, although it would appear as though there is a clear trend towards ownership of faster powered devices in Canada. Also, there is a clear under-representation of mobility scooter users in the UK, most likely because many of the participants already have an NHS power wheelchair. Because the UK and Canada questionnaire did not allow the entry of more than one device of the same category (e.g. class 2 powered wheelchair), the total number of devices owned by each individual is not known, and the data that has been collected would be at least a slight underestimate. This means it is not possible to accurately compare the ratio of device types owned with UK sales data.

The following chart shows the proportion of Canadian respondents owning each type of device, in the same format as the previous UK chart.

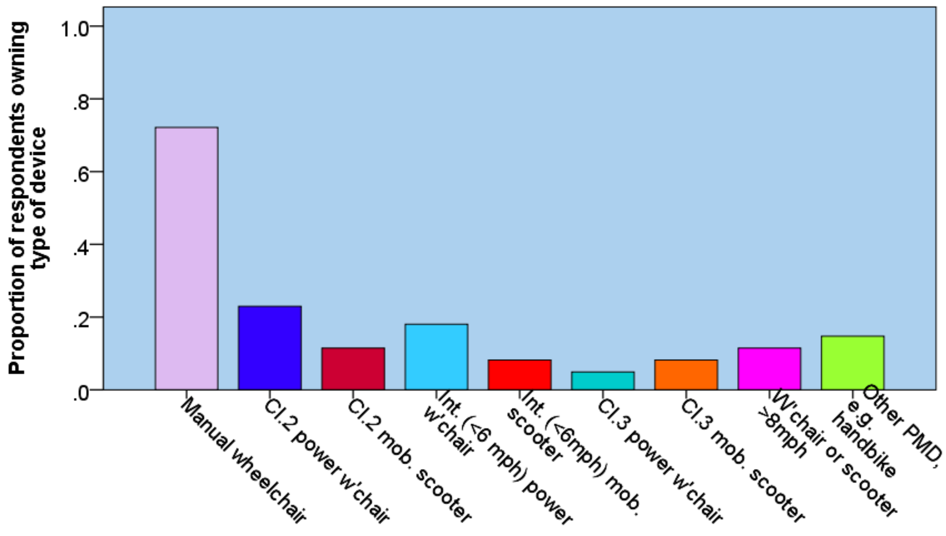


Chart 3.12: Ownership of PMDs in Canada

The main thing that is evident from viewing the Canadian data visually is that while the UK showed a very high proportion of manual and class 2 power wheelchairs, and very little else, there was a much more even distribution of power device types in Canada throughout the speed range, seemingly indicating a more diverse array of PMDs in use there. Whether this translates into greater satisfaction that device ownership needs are being met will be investigated, following presentation of Dutch ownership data.

The ownership data from the Netherlands is presented differently due to the different ownership options that could be selected, with all power wheelchairs being grouped together, and all mobility scooters being grouped together. There were more options to select a specific type of alternative PMD, such as a tricycle, handcycle attachment, sports handcycle, *et cetera*, as it was expected that ownership of these devices would be higher than in the other study countries, although at least for this sample, ownership proved to be similar to Canada, with 14% of respondents owning one. However, when considering the device types used, the age of the sample cannot be left out as a consideration. The relatively elderly Dutch sample are unlikely to use handcycles, as these are more often used by younger wheelchair users with a degree of fitness.

Overall for the Dutch sample, just 40% of those surveyed owned a manual wheelchair, and only 17% owned a power wheelchair of any speed. However, in sharp contrast to the ~20% mobility scooter ownership in the UK and Canada, 63% of Dutch respondents owned one. Chart 3.13 shows the proportion of Dutch participants owning each type of device.

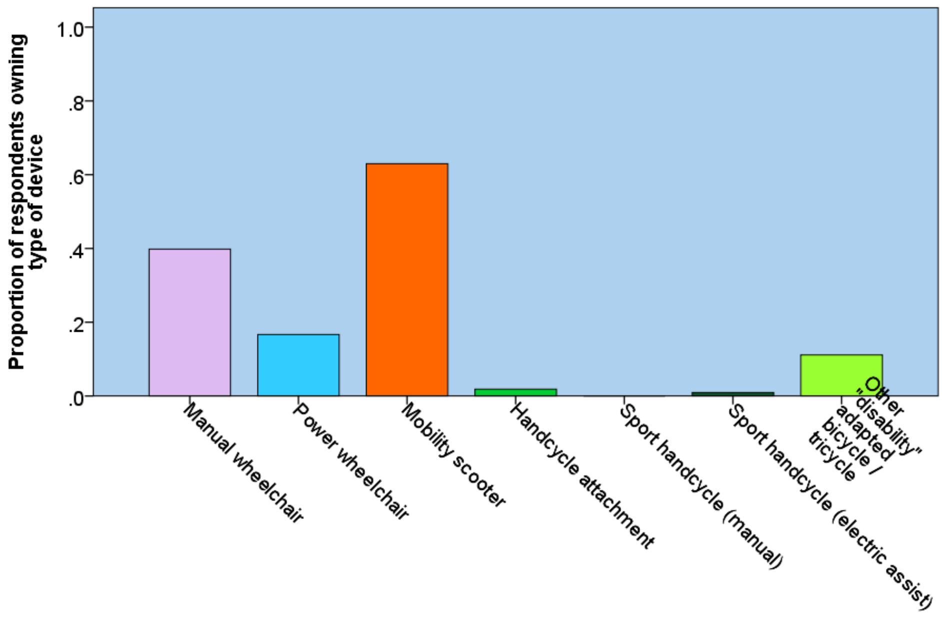
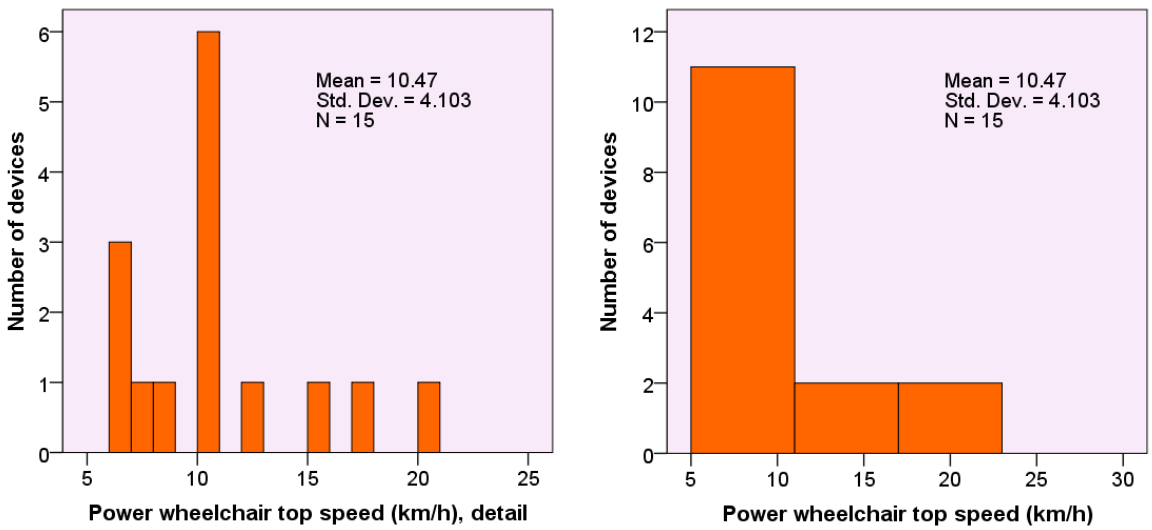


Chart 3.13: proportion of Dutch respondents owning each type of device

Overall, in terms of devices owned per respondent, an average of over 1.7 devices were owned in the UK, and over 1.6 in Canada, although due to it not being possible to select more than one device type in each category, it is not known exactly how much above this average the actual figure is.

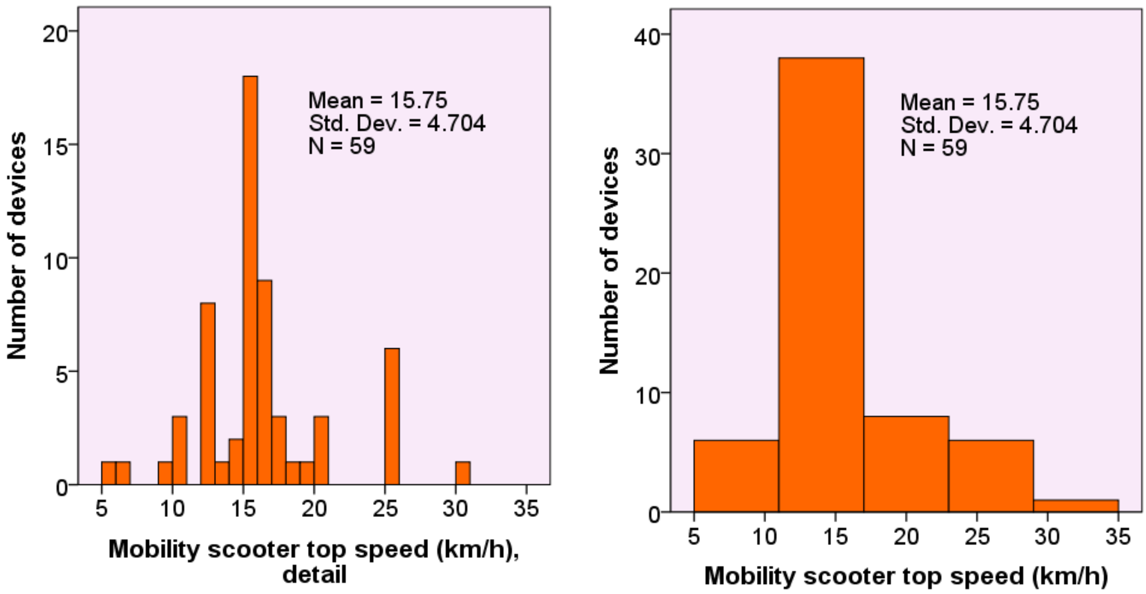
Respondents in the Netherlands were also asked to mention the top speed of their devices, and were able to provide an exact speed figure. This was also considered for the UK, but both a previous study and a small pilot trial for this study indicated that many respondents either omitted this data, or were not sure of the answer, even though many seemed to be aware of whether their device was a class 2 or class 3 model (thus indicating the speed). Of course, some respondents may still have answered incorrectly and miscategorised their device, but this seemed to be a risk worth taking in order to get some idea of the speed capabilities of respondents' devices. For the Netherlands, because it was not known if devices are generally sold under certain speed categories as they are in the UK, it was decided best to ask the exact speed of the device, if known. As most Dutch respondents provided this data, it is assumed that they are also [more] aware of the top speed of their devices. The following two histograms display the top speeds of power wheelchairs in the Netherlands; they display the same data, but have different binning for speed categories, with the one on the left providing detail, and the one on the right providing broader speed categories that are somewhat comparable to those in the UK.



Charts 3.14 and 3.15: maximum speed of power wheelchairs in the Netherlands

The left histogram shows a small spike in the number of power wheelchairs that travel at 6km/h (about 4mph – potentially these may be "pavement" models, or UK imports), and then

a larger one at 10km/h (~6mph). The right histogram shows that while the majority of power wheelchairs have a top speed of 6mph or less (making them equivalent to class 2 and intermediate class 3 devices in the UK), several of them are faster than this, with the fastest managing 20km/h (12.5mph), which happens to be about the speed of a typical person riding a bike in the Netherlands. The average top speed of power wheelchairs for the Dutch sample is 10.5km/h (6.5mph). This is higher than the average for the UK sample, which is likely to be less than 5mph based upon the number of people owning each class of device.
For Dutch mobility scooters, even higher average speeds are observed. The next two histograms, featuring the same intervals as the ones for power wheelchairs, display a couple of noteworthy things.



Charts 3.16 and 3.17: maximum speeds of mobility scooters in the Netherlands

First, noting the higher maximum value on the x-axis compared to the power wheelchair histograms, it is evident that mobility scooters are much faster than power wheelchairs in the Netherlands. Looking at the histogram on the left, there are perhaps three noteworthy spikes in the number of devices that travel a particular speed. The first of these is at 12km/h (7.5mph), which is about the same as a UK class 3 device. The second, most important, is at 15-16km/h, or about 10mph, which may be due to an EU or country-specific regulation governing what falls under the classification of a mobility scooter (e.g. devices that travel at up to 15km/h), but this is not clear. The third is a spike at 25km/h (15.5mph), which may or may not deliberately correspond with the 25km/h EU limit for electric bicycles. The histogram displayed on the right makes clear the difference in speeds between power wheelchairs and mobility scooters when they are compared. The average top speed of mobility scooters in the Dutch sample was 15.75km/h, or about 10mph, which is much faster than would ever be suitable for travelling on the pavement.

Regarding the number of devices owned per person in the Netherlands, the data indicate that it is fewer than for the other study countries, at just under 1.4 per person. For powered wheelchairs, no-one indicated that they owned more than one of the device, while five of the people owning mobility scooters owned two of this type of device.

Car ownership

Respondents were also asked about car ownership. This is likely to reflect the need to own a car (perhaps due to living in a rural area), social norms, and to some extent the amount of government and personal funding available to the individual. However, the main reason that this was asked, however, was to try and gauge an overall level of necessity for this giant "mobility device". For example, if the pavements are of too poor quality, or goods and services are located too far away, to be reached by a mobility device, and/or public transport is not able to remedy such barriers, then a car may become necessary in order to attain sufficient mobility and access. (In the next topic section, "Tripmaking", the perceived necessity of a personal car and public transport by respondents will be discussed.)

In the UK, the more elderly respondents in York were relatively less likely to have a car that they drove themselves than those in Reading, whereas they were relatively more likely to have access to a car that someone else drives them around in. Overall for the UK, 50% had a car that they were driven around in by someone else, 27% had a car that they drove by themselves, and 25% did not own or have use of a car at all.

For Canada, there were no particular differences between the two samples. Overall, 41% had access to a car that someone else drives them in, 21% had a car they drove themselves, and nearly 38% did not own or have use of a car. This lower car ownership and access in comparison to the UK may well be due in large part to the larger percentage of individuals living in urban areas, especially large cities such as Montreal.

In the Netherlands, only 28% of respondents had access to a car driven by another individual, but 50% had a car that they drove themselves, while 30% did not own or have use of a car. The reason for such a relatively high proportion of drivers in the Netherlands is not immediately clear, especially when considering that the similarly-aged population of York, where household occupancy is also similar, has only 15% of respondents driving a car themselves. However, the reason may be due to a difference in device usage, with the Netherlands having a higher proportion of mobility scooter users, who typically have some ability to walk, and therefore do not require an adapted or wheelchair-accessible vehicle, while all the respondents from York, and many from the UK overall, are power wheelchair users, who often may not be able to transfer from their chair into the driver's seat, and/or may require special controls, often making suitable vehicles more expensive and harder to procure. However, one interesting relationship was found with regard to car ownership that confirms the potential usefulness of the "degree of urbanisation" data. It is generally acknowledged that car ownership is higher in rural areas than dense urban areas out of the necessity to access more distant goods and services. The data from the Netherlands demonstrates this excellently, with 100% of the respondents who live in areas that fall under the least urban category having access to a car, while 47% of those living in the most strong urban area category did not own or have access to a car, and there being a fairly linear (and ordinal) progression in car use between these extremes of urbanisation. This relationship can be seen in the following bar chart.

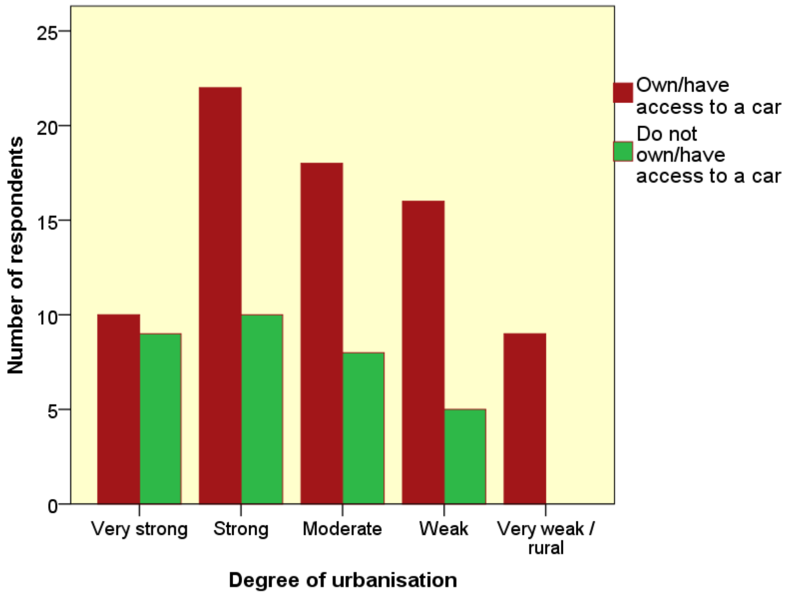


Chart 3.18: car ownership versus degree of urbanisation for the Dutch sample

Satisfaction with provision of PMDs

Question 4 was a simple yes/no question that asked respondents whether they owned all of the personal mobility devices or cars that they would ideally like to. This question was asked in order to find out whether the devices that the respondent owned met their mobility needs, and whether they desired more. The following questions, 5 and 6, asked which additional devices they would like to own, and the reasons that prevented them from owning these devices.

For the UK and Canada overall, 56% of respondents were satisfied that they owned all the PMDs that they wanted. However, Reading bucked this trend, with less than 48% being satisfied. Neither age, nor gender or urban/rural classification appeared to have any bearing on the level of satisfaction.

For the Netherlands, however, a massive 89% of respondents were satisfied that they had all the devices they wanted. Therefore, the reasons for this comparative lack of satisfaction in the UK must be investigated in order to try and determine the cause.

Desired additional device ownership

Question 5 asked which additional type of devices people would like to own. Of the 106 British and Canadian participants who were still answering questions at this point, 45 said that they would like to own another device, with each of these individuals selecting, on average, 1.5 additional devices. The following bar chart shows the proportion of the 106 UK/Canada respondents who said that they would like to own each type of device.

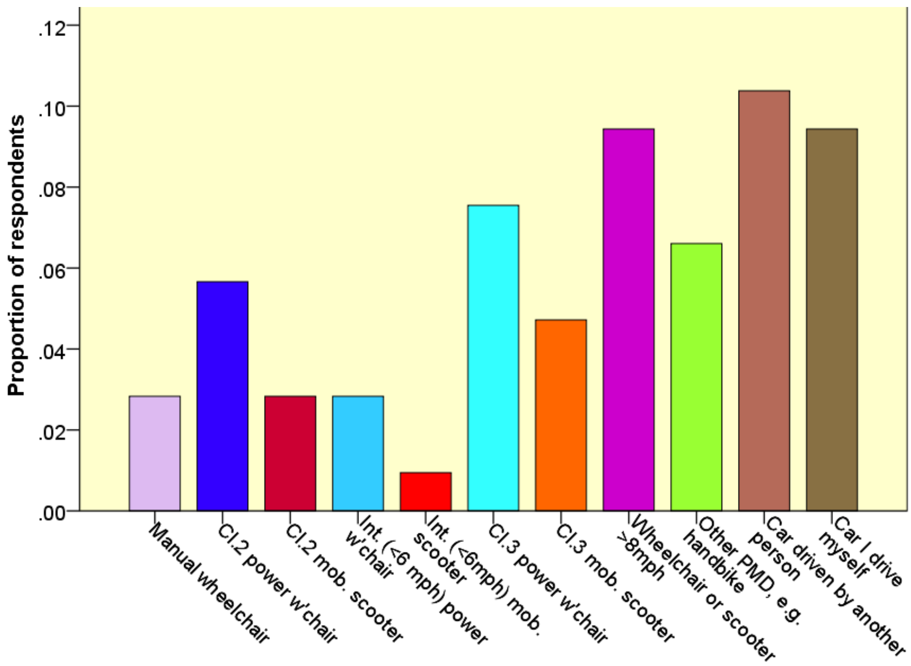


Chart 3.19: Additional device types desired by British and Canadian respondents

The general trend with desire for ownership of additional devices appears to be towards faster devices, such as class 3 devices, and those that can travel at over 8mph. Handbikes and other alternative PMDs were also desired by several respondents. Within each of the speed categories, power wheelchairs were more desired than the corresponding mobility scooter, perhaps indicating an unmet need for power wheelchairs. However, the most popular "device" that was desired was a personal car, with around 45% of those wanting an additional device selecting either a car that they can drive themselves, or one driven by another person. This result corresponds with satisfaction among car owners: those who did not own or have access to a car were less likely to be satisfied that they own all the devices that they would like to, as shown in the next chart:

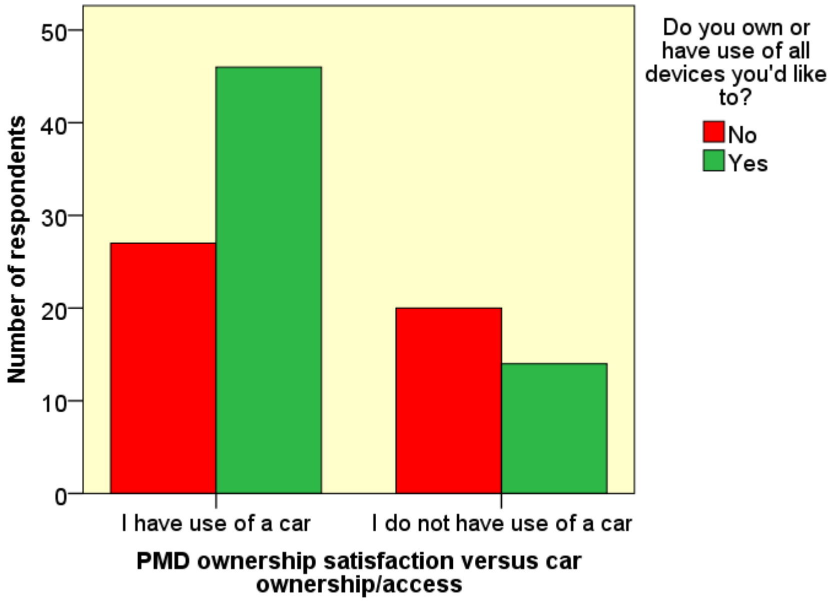


Chart 3.20: Satisfaction with device ownership compared to car ownership, UK and Canada

The reasons provided for not being able to obtain the desired devices are shown in the following chart. Of those wanting an additional device in the UK and Canada, 89% said that a lack of funding (personal or external) was a contributing cause, while the second most common reason was not having enough space at home to store the device.

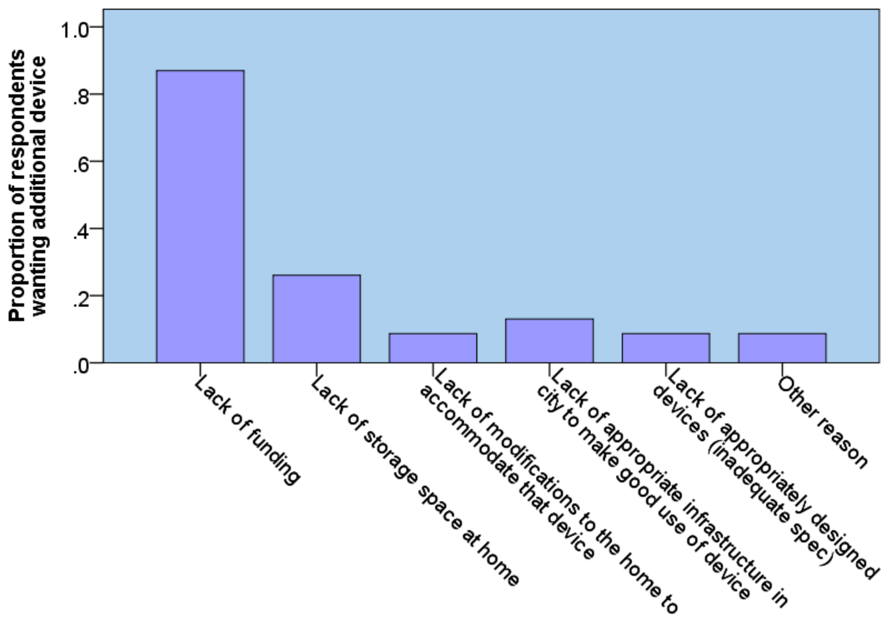


Chart 3.21: Reasons for respondents in the UK and Canada not being able to procure desired devices

For the Netherlands, only 10 respondents specified additional devices that they would like to own, with only one of these individuals wanting two additional devices. Four of these respondents (40%) wanted a car, and the other devices were spread between the categories, with two wanting a handbike, and one wanting another alternative PMD. In a trend matching that in the UK, 70% of respondents said that funding was the limiting factor, and one respondent cited a lack of storage space at home. While these reasons are similar to the UK, there still appears to be no obvious explanation for why so few people in the Netherlands desire additional devices. However, analysis of the dataset reveals that of the eight individuals citing a lack of funding, six said that the lack of funding was for a handcycle/alternative PMD, or a car, which would seem to indicate that there is almost no lack of provision of power wheelchairs or mobility scooters due to funding issues. Therefore, it might be surmised that there is much better funding provision from the government for the purchase of power wheelchairs and mobility scooters in the Netherlands than in the UK and Canada, and furthermore, that the devices meet the needs or desires of individuals than do those provided in the UK.

Topic 2. Tripmaking and perceptions of infrastructure provision and requirements

During the course of analysis and discussion for this topic, questions exploring preferred device usage, identity and needs as a transport user, the perceived need for car ownership and public transport provision, and the quality of local infrastructure will all be covered. It is hoped that this section will highlight both the needs of PMD users in terms of transport and infrastructure, as well as an overview of how well reality meets expectation with regard to this.

Preferred device usage

Those owning more than one type of PMD were asked which device was their favourite for travelling about town, and why. It is very difficult to analyse this data, as an accurate analysis would require calculating the number of times that a preferred device type is selected as a proportion of the number of times that that device is owned, which does not appear to be easy for a multiple response question. However, from studying the data, it appears that in the Netherlands, owners of handbikes and disability bikes/trikes tend to prefer them over other devices they own, with every one of the seven multi-device owners of this device type stating that it was their favourite; furthermore, only one out of the thirty-four multi-device owners who stated a preference said that the manual wheelchair was their preferred device. The qualitative data regarding preferred device type is more insightful, and some of this will be discussed in the topic section “Barriers”, with a focus on the barriers imposed upon preferred device usage.

Identity and infrastructure requirements

Question 7 asked “when using your mobility device around town, from a transport perspective, which of the following do you think that you should generally be considered as?” The intent was to see if respondents identified as a particular type of user, such as being a pedestrian, cyclist, or driver, as well as identifying with the related infrastructure (one of the answers was “none of the above: wheelchair and scooter users have their own specific requirements”).

The results from this question are very interesting, and potentially insightful, in that the results from each country were almost completely different. Further investigation needs to be done in order to fully understand the results, which is beyond the focus of this piece of work, but what is known is presented in the following paragraphs.

In the UK, 61% of respondents said that PMD users have their own requirements, not identifying with any of the other particular users. Almost 28% identified as a pedestrian, with another 8% saying they qualified as a cyclist or a pedestrian, depending on the situation.

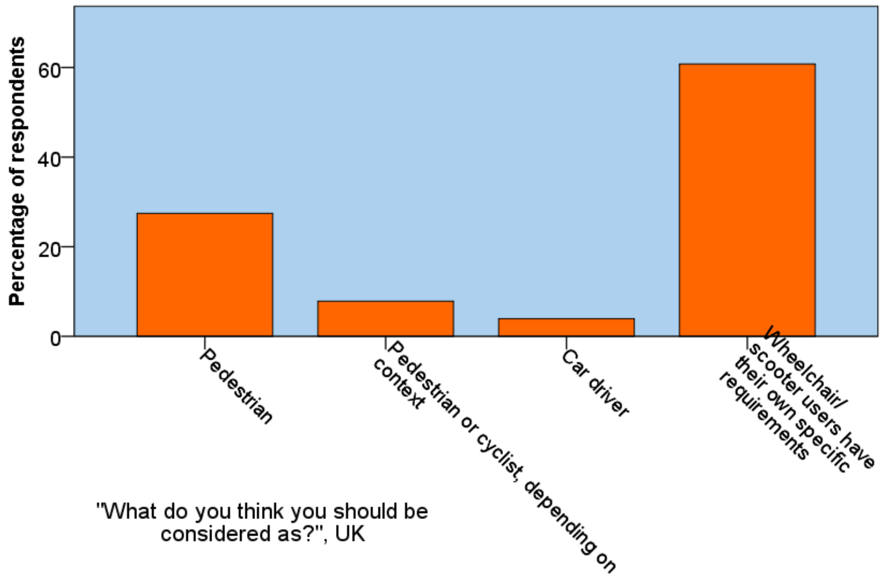


Chart 3.22: British PMD user self-identification

On the other hand, in Canada, 46% of respondents considered themselves to be a pedestrian, while a further 29% said that they were either a pedestrian or a cyclist depending on the context. The third most popular response was that PMD users have their own specific requirements, with 17% selecting this answer, and only 2% identifying as a "car driver".

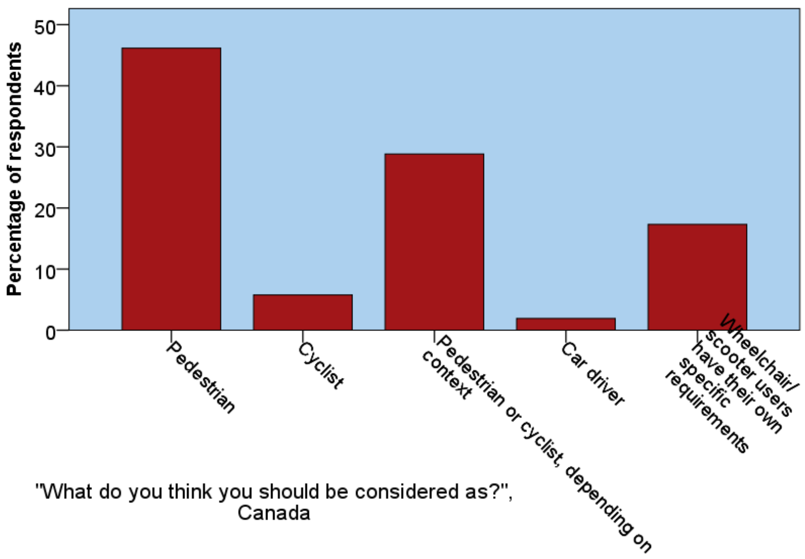


Chart 3.23: Canadian PMD user self-identification

In the Netherlands, there was an almost even split between those considering themselves a pedestrian and those considering themselves a cyclist, at about 16% for each. Furthermore, an additional 36% considered themselves as *either* a pedestrian *or* a cyclist, depending on the situation. The other 31% of respondents considered PMD users to have their own specific needs.

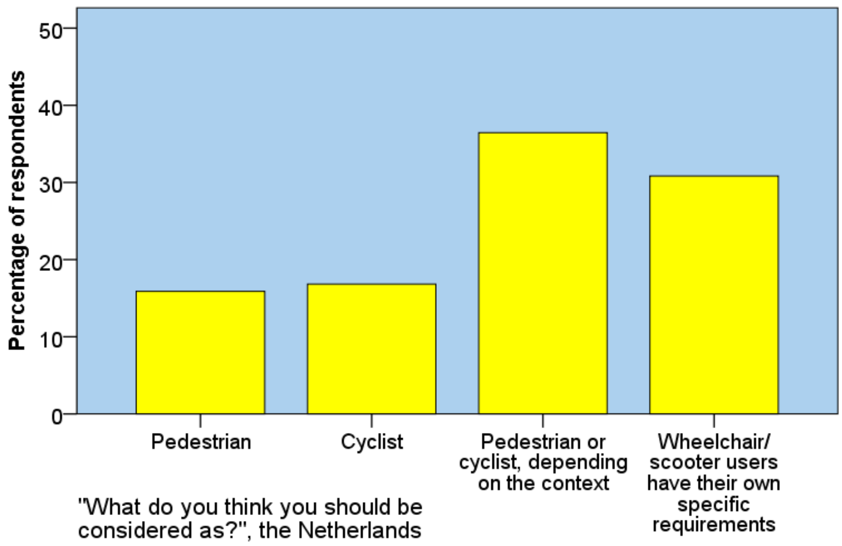


Chart 3.24: Dutch PMD user self-identification

It is hard to put forth a logical explanation that would explain this variation. However, one reason could be that people (the general population) in the UK tend to identify more strongly as a cyclist if they use a bicycle, or as a driver/motorist if they tend to drive a lot. On the other hand, few in the Netherlands would usually call themselves a cyclist, as most everyone cycles there at some point. Thus, more PMD users saying that “we have our own requirements” in the UK may just be an extension of this, identifying as a unique type of road user (i.e. PMD user). Another explanation that could be looked into is whether or not existing infrastructure influences perception of identity and need – for example, 69% of those in the Netherlands classified themselves as a pedestrian, a cyclist, or either depending on the context, whereas just 35% of those in the UK identified themselves in this way (with none identifying just as a cyclist); perhaps, the lack of bicycle infrastructure in the UK has resulted in few identifying as a cyclist in terms of infrastructural requirements, or their identity. There also appears to be a high amount of variation in the Netherlands when comparing this identity with the degree of urbanisation, although a clear trend (or reason behind this variation) is not evident, and would likely require a larger sample and the collection of qualitative data in order to understand. In summary, understanding how PMD users classify themselves as street users would potentially be an excellent topic for future research to address.

Preferred mode of transport and the necessity of motorised transportation

Questions 8a, 9a, and 10a asked respondents which mode of transport they would prefer to take to their local shopping area, favourite recreational area, and place of employment, respectively. Choices included using only their PMD, or their PMD plus another mode, such as car, taxi/community transport, or public transport; they were also told to assume good weather conditions. Three accompanying questions, 8b, 9b, and 10b asked how difficult respondents would find it to travel to each of the aforementioned locations using *only* their PMD. Additionally, question 10a allowed the collection of data on the proportion of the sample currently employed.

The purpose of asking these questions was to gain better understanding of restrictions on PMD-only mobility (just as one might want to know whether it is possible to get around a city only by bicycle or on foot). Of course, trip distances will have an impact upon this, but it is hoped that the “a” questions will also shed some light upon mode/combined mode choice, which may be useful when considered in combination with the “b” questions. Clearly, it also has direct transport planning ramifications. The three different locations were chosen in order to provide a more in-depth look at trip patterns by trip purpose.

Employment

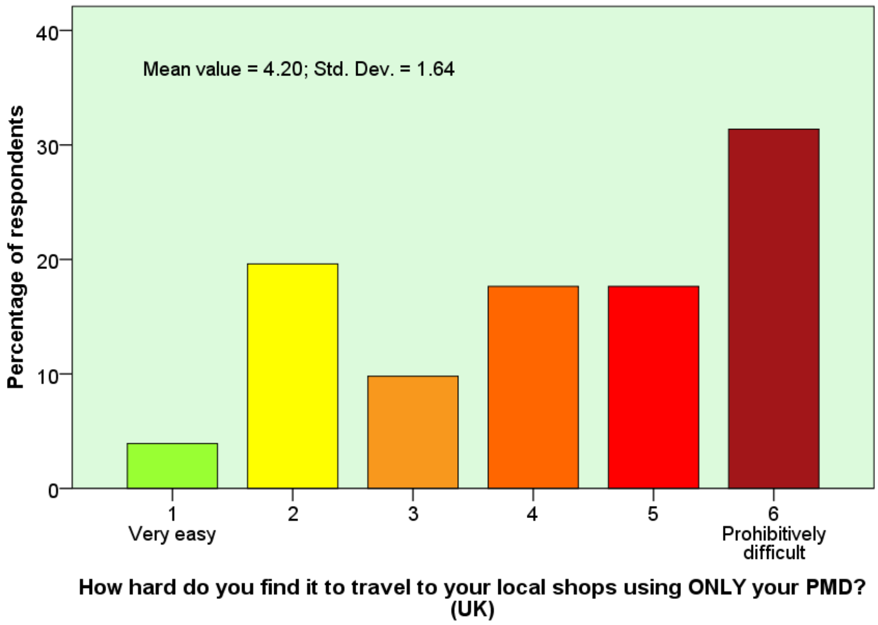
Starting somewhat in reverse order, it was found that only 30% of Canadian respondents were not employed, while 79% of those in the UK were not in employment, and 92% of Dutch respondents did not answer this question, which is presumed to imply that most are retired, or perhaps prefer not to disclose such information for one reason or another. It is likely that, given the higher age of the UK sample than the Canadian one, retirement also accounts for a large percentage of unemployed UK respondents as well. For those in Canada getting to work, the most popular combination was PMD + car (40%), followed by PMD + public transport (PT), at 23%, with just five people, or 14%, stating that they would prefer to travel using only their PMD.

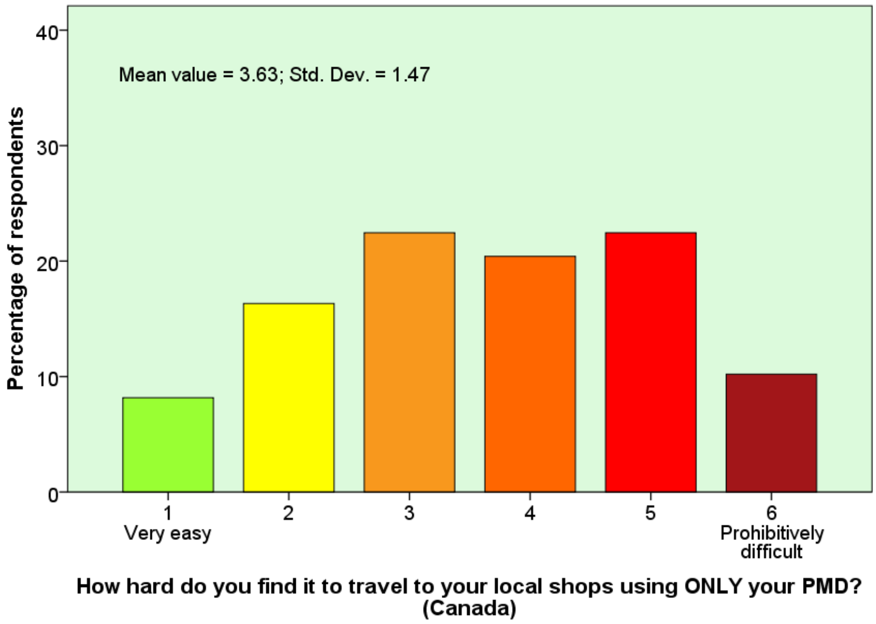
Shopping

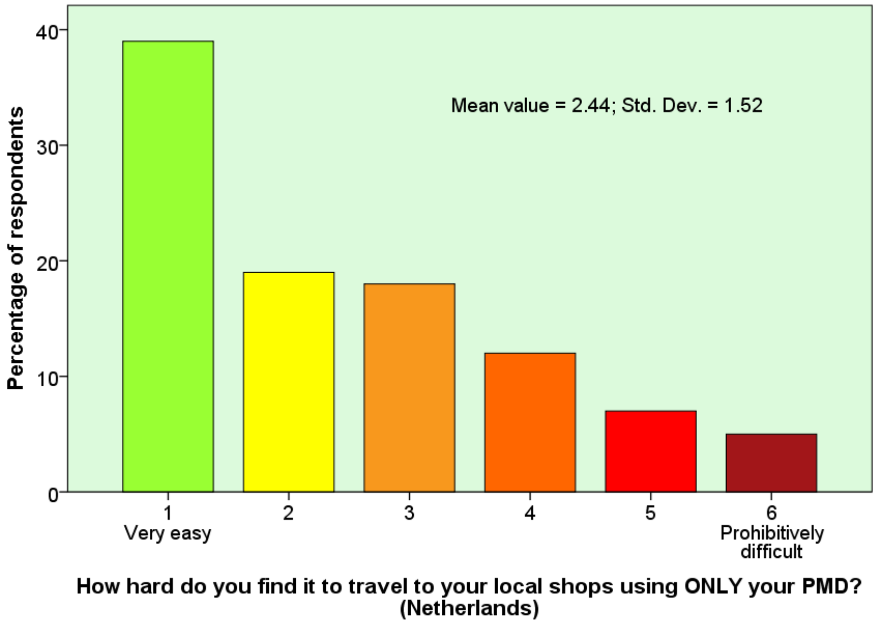
Within the UK, 62% of respondents who go shopping (n=51) said that their preferred combination would be to use the PMD + car combination, with 24% selecting to use only their PMD, and 10% saying they would prefer to use the PMD + taxi/community taxi combination; public transport use as a preference was almost non-existent. Those in Canada also favoured the car, although there was a more even distribution between modes. The PMD + car combination was stated as being preferred by 33% of participants there, while 23% opted for PMD + PT, and another 23% said they would prefer to use only their PMD; just over 12% said they would utilise the PMD + taxi/community transport option. In contrast to the UK and Canada, 49% of Dutch respondents said they would use only their PMD to go shopping. The second most popular choice was PMD + car (32%), followed by PMD + taxi/community transport (6%). There was also a mixture of "other", such as use of car only (remembering that many Dutch respondents are mobility scooter users, who can often walk at least a short distance), as well as several individuals stating preference for use of an electric bicycle, which appears to support the theory that some mobility-impaired people in countries like the Netherlands might use an electric bicycle instead of a mobility scooter.

This very high rate of preference for PMD-only travel to go shopping in the Netherlands is a somewhat exciting finding, which points towards either a lack of dependence upon other modes, or other modes being comparatively inconvenient (or shopping facilities being located closer to respondents). Because this is stated preference rather than revealed behaviour, it cannot be "taken as gospel", and will reveal further research to determine actual travel behaviour. However, comparing the scores from question 8b regarding the difficulty of reaching the local shopping area using *only* the PMD should provide some additional insight.

Comparing the responses to question 8b from the three countries, there is a clear difference in perceived difficulty of using a PMD to reach the local shopping area by respondents. Out of the three countries, those in the Netherlands said that they would find it the easiest, while those in the UK would find it the most difficult. The question was asked as a 6-point likert scale, with 1 representing “very easy”, and 6 “prohibitively difficult”. The mean score for the Netherlands (n=100) was 2.44, with a standard deviation of 1.52 and a skewness of 0.802. The distribution for Canada (n=49) was more biased towards intermediate values (skewness = 0.107), with a mean value of 3.63 and a standard deviation of 1.47. Finally, responses from the UK (n=51) were more varied, with a standard deviation of 1.64. The mean value of 4.20 for the UK seems to demonstrate that the majority of respondents would find the journey fairly difficult, with 31% selecting a value of 6, or prohibitively difficult (less than 5% of Dutch respondents selected a value of 6). The subsequent three charts display the distribution of responses in each country.







Charts 3.25, 3.26, and 3.27: difficulty in reaching the local shopping area when travelling by PMD in the UK, Canada, and the Netherlands

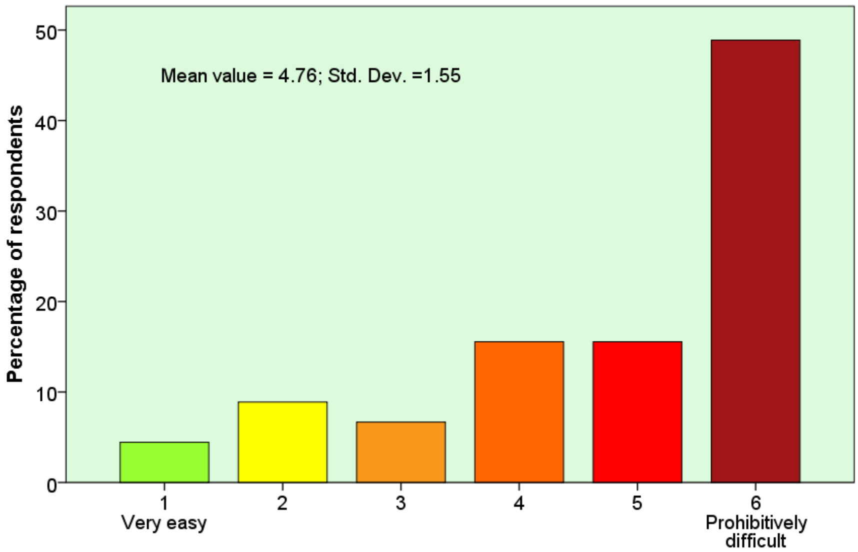
These results would seem to cement the findings from question 8a, and indicate that around half of Dutch PMD users would prefer to use their device as the primary mode of transport to go shopping at least in part because making the journey in such a way would be quite easy. However, it has to be considered that the Dutch sample also tend to use mobility scooters more, which also have a higher top speed than the devices in the UK and Canada. Unfortunately, the sample size of Dutch power wheelchair users is too small to draw any conclusions from; those with a power wheelchair still leaned towards it being an easy journey, although 4 of 18 users (22%) selected a difficulty score of 5 or 6, while only 8% of the 64 mobility scooter owners selected a score of 5 or 6. This would seem to indicate that those owning a mobility scooter may find the journey easier, either because of the speed of the device, and/or its practicality (room to store shopping), or maybe even because of some other reason, but further research needs to be done on this topic in order to reach any conclusions. Cross-analysis between degree of urbanisation and difficulty score was also carried out, although somewhat surprisingly, ratios of difficulties did not appear to vary much between urban categories, although very few respondents living in non-urban areas (category 5) responded, which could imply that in these rural areas, the journey is not possible by PMD only. This finding regarding similarity between urban densities would appear to suggest that accessibility of shopping areas for PMD users is similar in dense urban areas to more spread-out urban areas in the Netherlands.

Leisure

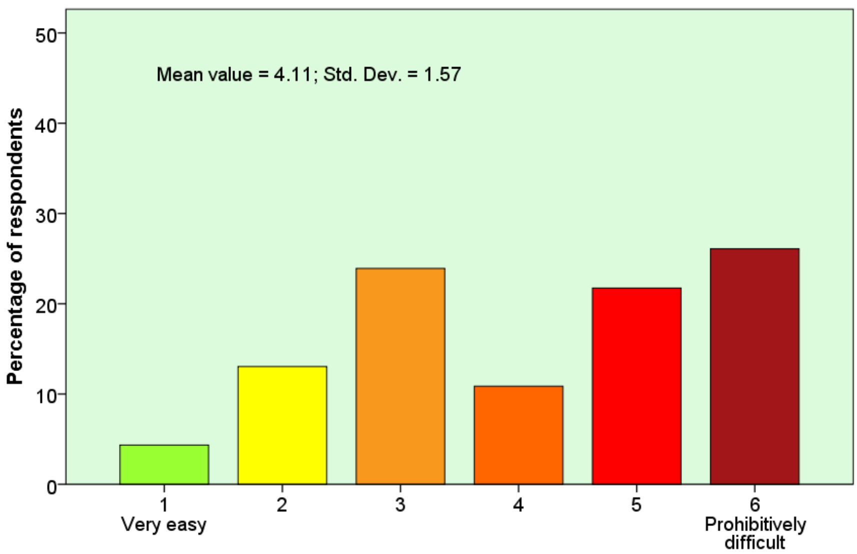
When asked what the preferred mode or mode combination of transport is to reach one's favourite recreational area, such as a park or sports facility, the responses that participants gave were very similar to those given for going shopping, so much so that it is not worth going through a list of all the figures. The ranking of mode choice (e.g. in the Netherlands, using only the PMD was the most popular choice, followed by PMD + car and then PMD + taxi) remained the same in all countries, and the ratios also remained very similar. The only notable differences were that several more people in each country said that they did not visit any recreational areas than said that they did not travel to do shopping, and in the UK, no-one said that they would use a taxi or community transport to reach a recreational area (versus 5 people saying they would for shopping).

The similarities in preferred mode choice for the two location types might suggest that despite differences in distance and location, the available infrastructure of a city perhaps acts as one of the main factors in mode choice decisions.

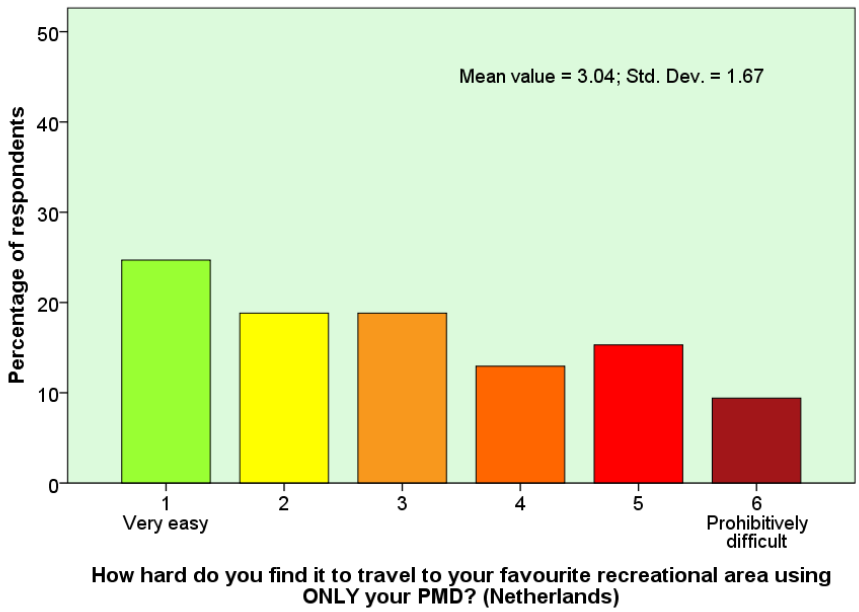
Analysing question 9b, another interesting finding comes to light, this time regarding the overall difficulty of reaching recreational areas only using one's PMD. In all three countries, the score for difficulty in reaching recreational areas on the likert scale is higher than the score for reaching shopping areas for each country, which would imply that recreational areas are universally more difficult to reach. While the questionnaire suggested a recreational area to be a park or sports facility, it is quite possible that many people also considered locations such as a cinema or sports' stadium to fall under this heading as well, which may have increased the average distance to such a location. Despite this, the ranking of the three countries remained the same, with PMD-only trips being rated as the most difficult in the UK, and easiest in the Netherlands. The scores for each country are as follows: UK (n=45) mean score of 4.76, and a skewness of -1.05, indicating just how difficult the journey is perceived to be by most; for Canada (n=46), a mean of 4.11, but a slightly odd distribution of scores that might merit further investigation, and for the Netherlands (n=85), a mean score of 3.04, with a fairly flat, symmetrical distribution (skewness = 0.32, kurtosis = -1.15). The following charts display these findings.



How hard do you find it to travel to your favourite recreational area using ONLY your PMD? (UK)



How hard do you find it to travel to your favourite recreational area using ONLY your PMD? (Canada)



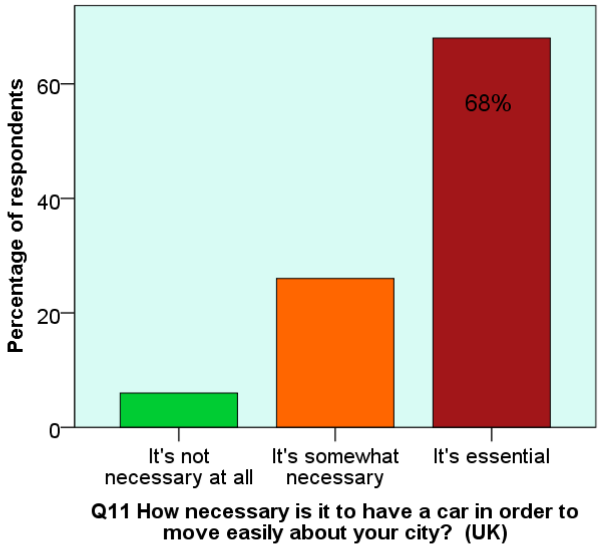
Charts 3.28, 3.29, and 3.30: difficulty in reaching respondents' favourite recreational area when travelling by PMD in the UK, Canada, and the Netherlands

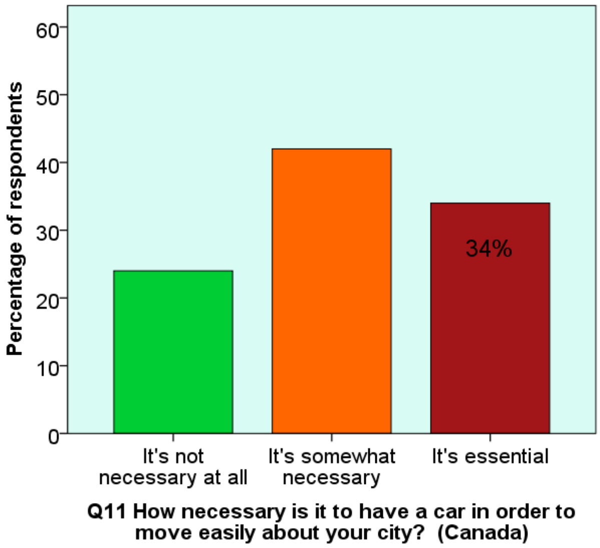
This finding, that recreational areas are rated as more difficult to reach, somewhat contradicts the findings of Taylor and Józefowicz (2012), who provided the inspiration for questions 8, 9, and 10. They found that PMD users tended to prefer visiting family and friends, and going to parks within the outer areas of cities, due to the difficulty of reaching the city centre. However, there are a few things that may account for this difference in findings, namely that the city centre had cobbled streets in their study (which is similar to York, but few other locations in this study), but more importantly, this study did not ask specifically about mode of transport to reach the city centre, only the local shopping area – perhaps asking about the journey to the city centre might have provided more insightful responses.

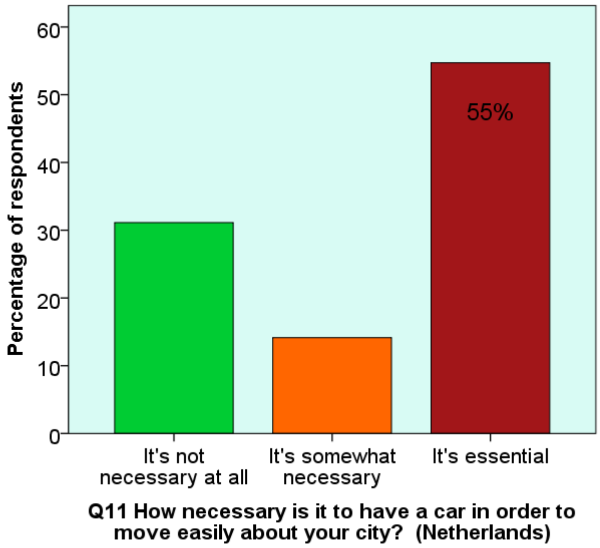
The necessity of motorised transportation

There were two more questions in the questionnaire that may be able to provide further insight into mode choice and the necessity of car ownership. Question 11 asked respondents about how much of a necessity they felt it to own or have use of a car in order to move easily about their city, while question 12 asked how much of a necessity access to good public transport was in order to move easily about the city. The three responses available for each were on a labelled likert scale, with 1 being "It's not necessary at all", 2 being "It's somewhat necessary", and 3 being "It's essential".

For question 11, both UK cities showed the same trend in responses, as did both Canadian samples, indicating consistency within the countries, or at least the sample locations. In the UK, 68% of respondents said that owning or having access to a car was essential to easy movement about the city (Q.11 mean value of 2.62), whereas only 34% of Canadian respondents said the same (Q.11 mean value of 2.10). However, in a result that appears to somewhat contradict the other findings in this section, 55% of Dutch respondents felt that access to a car was essential (Q.11 mean value of 2.24).







Charts 3.31, 3.32, and 3.33: The perceived necessity of having use of a car in the UK, Canada, and the Netherlands.

While there was greater statistical variance in the answers given by Dutch respondents to this question, this seems to confound the apparent country-based trends in accessibility and necessity of car ownership that appeared to be evident from questions 9 and 10. This matter does not become any clearer when perceived necessity of car access/ownership is compared with degree of urbanisation: while only 28% of those in the most urban areas felt it essential to have access to a car, for all other urban densities, those believing it essential were clearly the largest group.

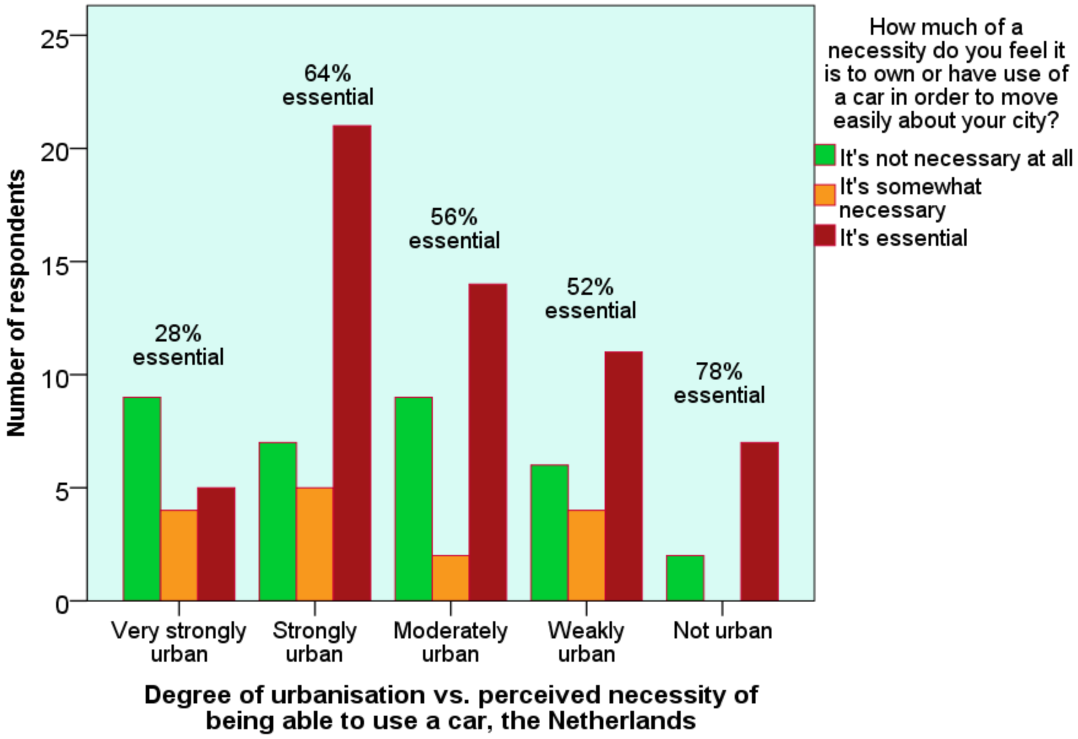
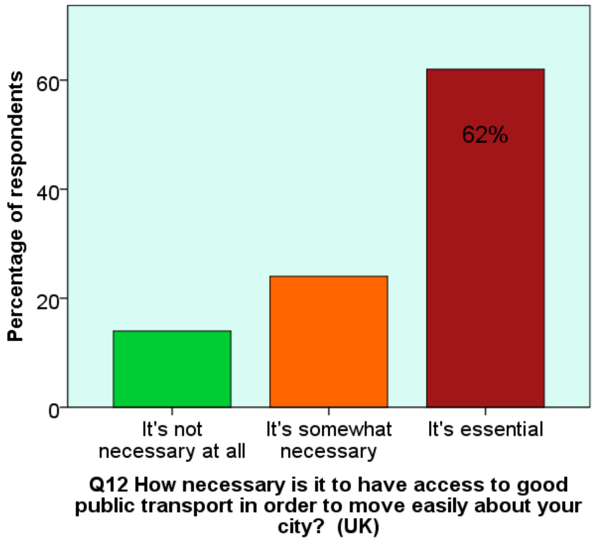
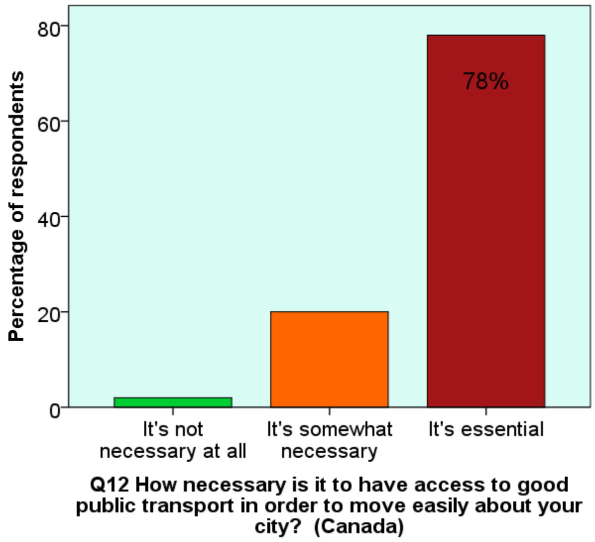
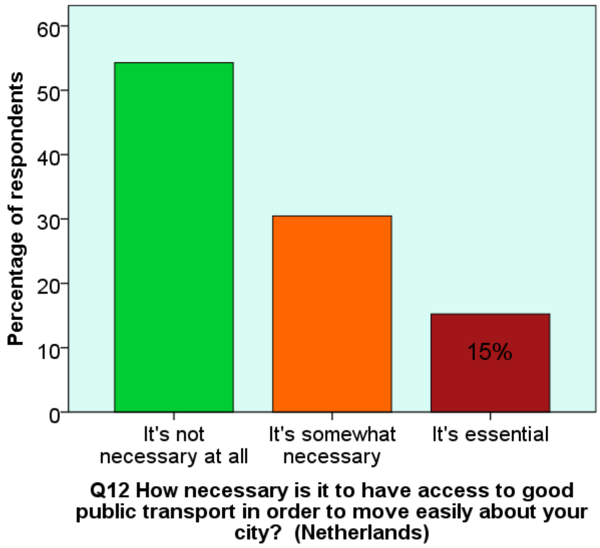


Chart 3.34: Dutch responses to question 11, asking about the necessity of car use, sorted by degree of urbanisation. The percentage of respondents in each area saying that car use is essential is written above the corresponding urban density.

However, the answers given to question 12 appear provide further insight into the issue, and perhaps give a clearer picture of urban transport in these three countries. In the UK, respondents also believed that good public transport was also necessary to move easily about their city, with 62% saying it is essential, while in Canada, an even higher percentage of respondents believed that good public transport is essential, at 78%. In contrast, only 15% of Dutch respondents replied that it is essential, while over half of the group said that it is not necessary at all. This is reflected in the following charts:







Charts 3.35, 3.36, and 3.37: The perceived necessity of having access to good public transport in the UK, Canada, and the Netherlands

These differences in the importance of public transport compared to the importance of car use in Canada and the Netherlands are pronounced and perhaps even surprising, when trends between these two countries have generally moved in the same direction, not opposite ones, in previous questions. However, the data start to make more sense when the characteristics of the samples from the three countries are considered more carefully. In the UK, many respondents live in the study cities, which could perhaps be described as fairly car-based cities, while others live in outlying towns, which might have sufficient amenities to satisfy everyday needs, such as a small supermarket and a doctor's surgery, but may then require a car or public transport in order to travel into the study cities. In contrast, as mentioned before, many of the Canadian respondents live in the large, fairly dense city of Montreal, which features extensive bus routes, and four metro (underground) lines, while a large proportion of the others live in other fairly large cities across the country. It therefore makes sense that many respondents feel that these public transport services are essential in order to allow easy access about their cities, as they likely connect them to all the places they need to travel, and perhaps making the car less of a necessity there. For the Netherlands, respondents come from all types of settlement across the country, from rural areas with low population densities, up to large cities with high population densities. By once again providing cross-analysis between degree of urbanisation and the question of interest, this time question 12, a revealing pattern becomes apparent:

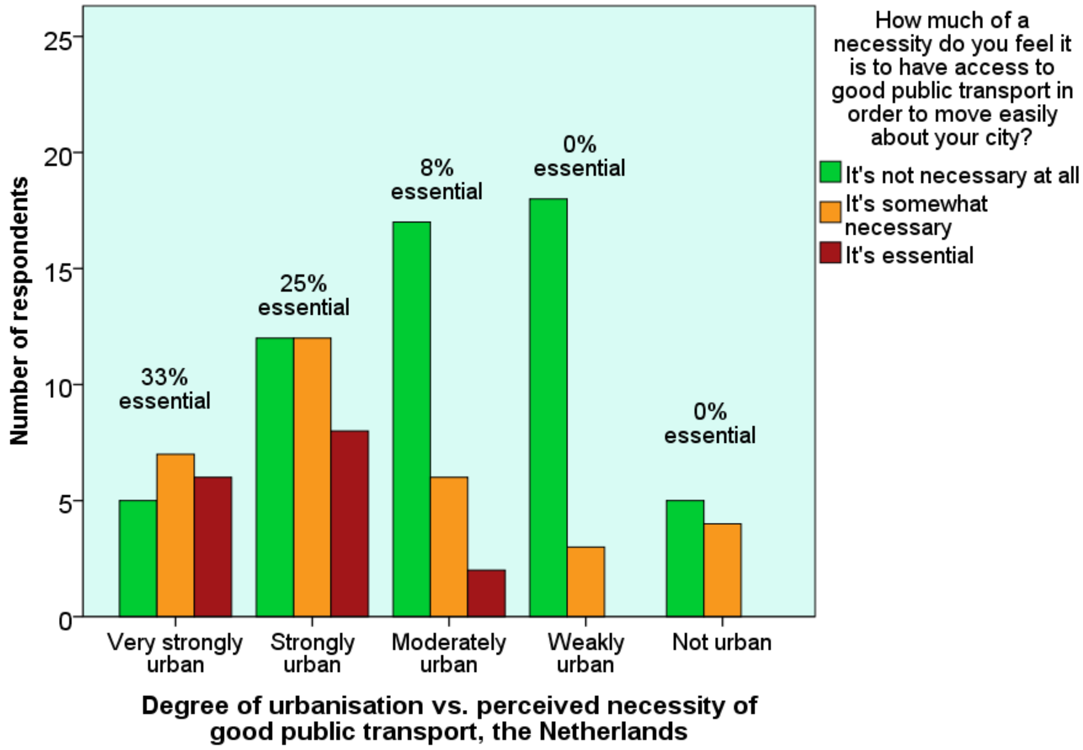


Chart 3.38: Dutch responses to question 12, asking about the necessity having access to good public transport, sorted by degree of urbanisation. The percentage of respondents in each area saying that good public transport is essential is written above the corresponding urban density.

The trend seen here for question 12 is almost a mirror image of the trend seen in the data for question 11, but this time the increasing statistic is the number of people saying that public transport is not essential as urban density falls. More importantly, however, is the less noticeable reciprocal trend, whereby no-one in the two least urban area categories stated that good public transport is a necessity, and then a rising percentage of people starting with the moderately urban area, at 8%, up to the most urban area, at 33% of respondents stating that it is a necessity. Note that previously, it was mentioned that only 28% of respondents in the most dense urban area stated that being able to use a car was essential, compared to 64% of the participants living in the second most dense urban areas, and 34% of Canadian respondents. It seems likely that those living in the most dense areas are frequently living in cities such as Amsterdam or Rotterdam, which have fairly extensive public transport networks; these networks would likely be comparable to those in Canada, in that they would probably provide access to most places within the city that respondents would like to travel, thus substituting for the private car in most cases. On the other hand, those living in less dense urban areas in the Netherlands likely experience less comprehensive public transport services (this appears to be confirmed by the responses to question 17, discussed later), and therefore would tend to feel that a car may be more necessary for longer journeys across town (with some of the slightly larger, denser towns and small cities requiring longer journeys, hence the greater perceived need for car use in these large towns and small cities). So, while most respondents in the Netherlands may find it easy to reach their local shops or recreational area by just using their PMD, perhaps thanks in part to good infrastructure or short travel distances, for those occasional journeys that are too long or difficult to make by PMD, a car is still necessary in areas where public transport is not extensive enough to link all the desired locations. Conversely, those in large cities may benefit from almost all of the locations that they want visit being within that city, accessible either by PMD or by a comprehensive public transport network, and hence the need to use a car occasionally is almost eliminated.

Of course, this narrative to explain the conflicting data uncovered in questions 11 and 12 is to a large extent speculative, and further research would be required in order to gain a better understanding of the situation, perhaps through using tools such as travel journals. Any further findings that may confirm or refute this narrative will be presented in this analysis.

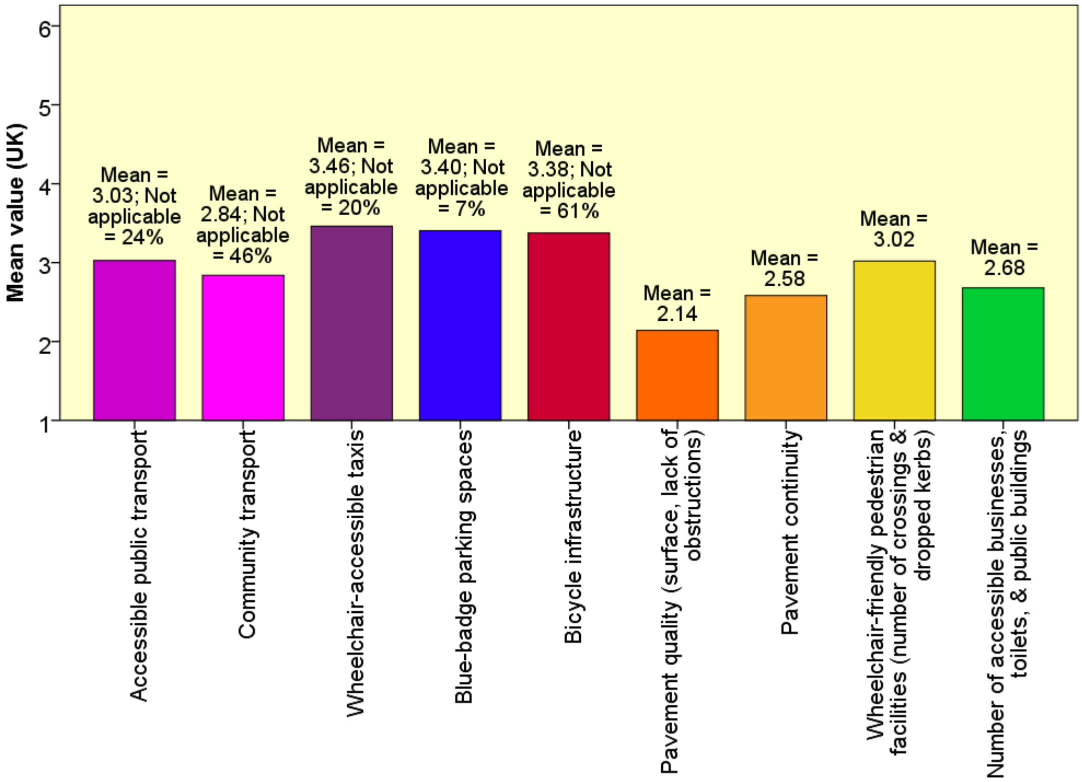
Conclusion: preferred mode of transport and the necessity of motorised transportation

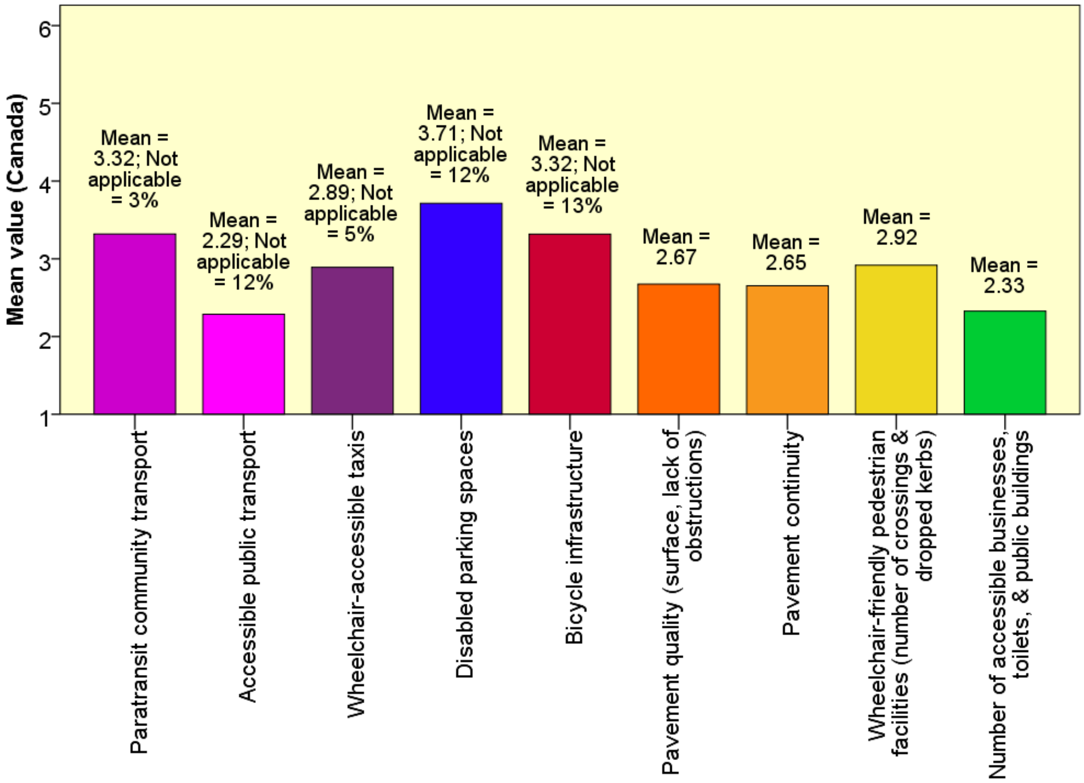
While a solid conclusion is difficult to draw from these stated preference questions, there are some consistent trends in the data that point toward truths that may exist. Overall, respondents said they would find it more difficult to reach recreational areas than shopping areas on their PMD, which may be related to distance, or a lack of suitable infrastructure, but implies a lower level of accessibility for recreational areas than for shopping areas. Both for shopping and for visiting recreational areas, British respondents stated that they would encounter the most difficulty if travelling only by PMD when compared to those from other countries, while Dutch respondents said they would have the least difficulty. Once again, it is theorised that there is likely an infrastructural reason contributing to this discrepancy, or perhaps that the distances are usually shorter in the Netherlands, but in any case, accessibility of shopping areas and recreational areas is better in the Netherlands. Another factor that may contribute toward the Dutch finding PMD-only travel easier could be related to the devices themselves, when it is considered that powered Dutch PMDs, especially mobility scooters, are faster than those in other countries on average, but further research needs to be done in order to draw conclusions about this potential role of device technology. The difficulty in accessing popular locations in the UK by PMD is reflected in respondents' preferred choice of transport there, which is usually combining PMD use with a car. This would seem to demonstrate a necessity for the use of a car in the UK, which adds greatly to the costs of travel for PMD users, as well as government and charity spending for the transport/welfare programmes that sometimes help to provide these vehicles. As referred to previously, just under a fifth of the total sample in the UK and Canada desired to own or have access to an car as an additional device, whereas less than 4% of the Dutch sample desired the same, despite the total percentage of those not owning or having access to a car being similar in all three countries, thereby demonstrating a lack of actual necessity for a car in the Netherlands. Furthermore, those without a car in a country like the UK become increasingly disadvantaged and "transport poor", as journeys made without one are difficult or even impossible. For example, 49% of respondents in the UK said that accessing their favourite recreational area using only a PMD would be "prohibitively difficult". Thus, for any of these users that do not have access to a car or public transport, reaching their favourite recreational area will not be possible most of the time.

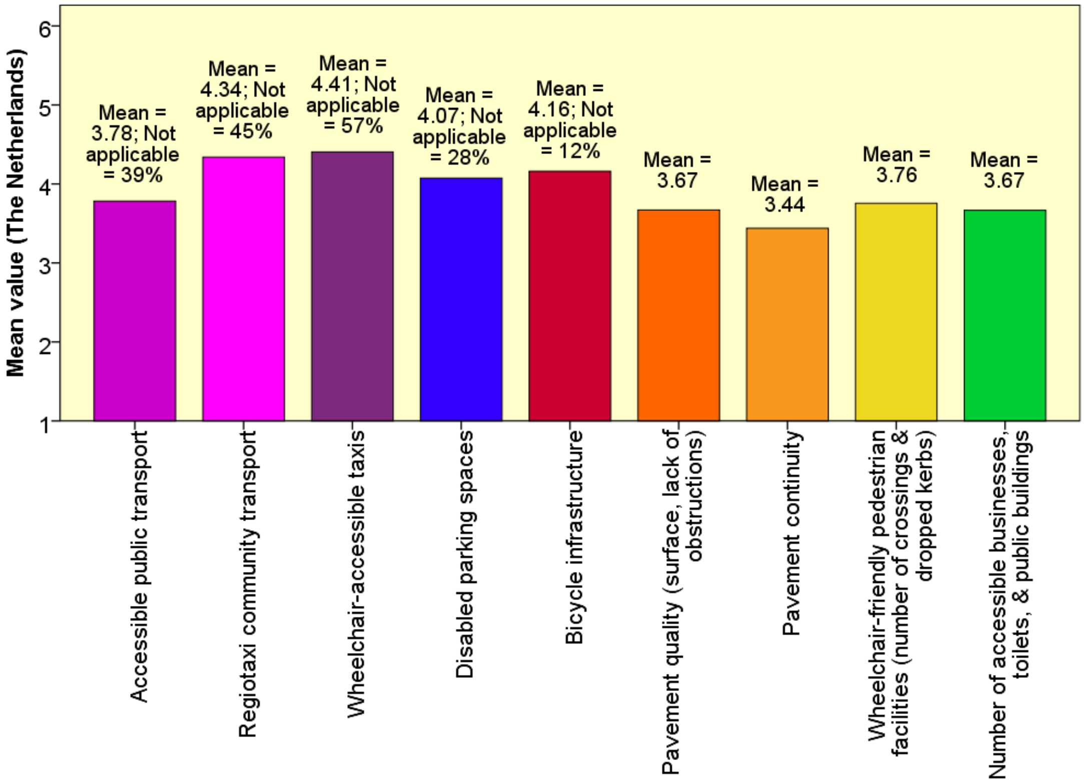
Perceived quality of infrastructure

Question 17 asked how satisfied respondents were with the provision and quality of infrastructure and transport options, such as "accessible" public transport, wheelchair friendly taxis, and pavement quality. While this question is perhaps a little imperfect in terms of its phraseology due to its broadness, it is hoped that the results it provides might still be of some use.

The following charts provide the mean values for the scores that respondents gave the each attribute, as well as (for the first five attributes) the percentage of respondents replying that it was "not applicable" to them. Once again, the Netherlands scored highly: in fact, the Netherlands scored higher than the UK or Canada in all nine measures, which almost makes one consider whether the likert scale is truly comparable (reliable) between sample groups. However, trends in response patterns for different attributes still varied enough amongst Dutch respondents to allay concerns that this may be the case.







Charts 3.39, 3.40 and 3.41: average likert scores for nine infrastructure and transport attributes given by British, Canadian, and Dutch respondents

While these average scores provide some idea of overall satisfaction, they also conceal some interesting trends in the data that are worth exploring. While there is not time to look at all of these trends in detail, a couple of the more interesting ones will now be briefly investigated. The first of these is in the UK, where there are two very specific peaks in the rating of community transport. Analysing the data by city reveals that the most common score that those in Reading gave was 4 out of 6, with half of the twelve respondents giving this score, while for York, seven of the twelve respondents rated community transport at just 1 out of 6, indicating great discontent. Therefore, it would seem safe to conclude on this point that community transport in the UK varies a lot in quality by area. (In Canada, satisfaction with "paratransit" was slightly higher than for the UK; in contrast, in the Netherlands over 60% of respondents gave the "Regiotaxi" community transport a score of "5" or "6", indicating a high level of satisfaction.) Another interesting difference within the UK is the rating for pavement quality: 58% of the 26 respondents from the York sample rated pavement quality as "1", whereas only 20% of those in Reading were similarly dissatisfied. It may be that the cobbled streets of York contributed toward this particular dissatisfaction.
However, the most important aspects from question 17 must now be looked at, and it will be seen as to whether the evidence provided by the data from this question fits into the unfolding narrative, or presents a contradiction. These aspects are public transport, pavement quality, pavement continuity, and bicycle infrastructure; data from other parts of the question will be referred to when useful.

Public and community transport

Starting with public transport, 12% of the Canadian sample, 24% of the British sample, and 39% of the Dutch sample said that the question was not applicable to them. This immediately reinforces the findings earlier in this analysis that the Canadian respondents are the most dependent upon public transport, while the Dutch are the least. Despite this, the Dutch respondents were also the most satisfied with the public transport offerings that were available, giving an average score of 3.78, while those in the UK gave the lowest score, at 3.03 on average. Analysing the Dutch score in more detail, there definitely appears to be a correlation between the rating of public transport and the degree of urbanisation, although it is not significant at the 5% level (Spearman coefficient = 0.122, n=60). To give an idea of the difference though, 85% of respondents in the "strongly urban" areas gave public transport a score of 4, 5, or 6, whereas only 55% of those in weakly urban areas did the same. This makes complete sense, given that good public transport provision is typically associated with larger, denser urban areas. So, while Dutch respondents in the most urban areas said that public transport was more important to them than those in less urban areas, these city-dwellers were also the most satisfied with the quality of the public transport (and presumably its wheelchair-accessibility as well). Once again, it is worth noting though that the Dutch respondents may have more walking ability on the whole, and so wheelchair access for buses may be less important, although a cross-analysis by device type owned did not seem to reveal any differences. One last point relating to public transport in the Netherlands is that the Dutch respondents gave the Regiotaxi community transport a high average rating; while the details of how the service compares in its operations are not known, a scan of local Regiotaxi websites indicates that these demand-responsive transport services typically operate from 6am to 1am on weekdays. In stark contrast, the Dial-a-Ride in York must be booked 24 hours in advance, and picks up users in the morning and returns them in the afternoon, so it is hardly surprising that respondents from York were very unhappy with this service. The point though is that Dutch community transport services appear to be so good that they offer a viable alternative to wheelchair users who may not be well-served by standard public transport, and this may form part of the reason why few Dutch respondents stated that it was essential to have good public transport for easy movement about their city, especially in the less-dense cities. In the UK, there was also a pronounced difference between Reading and York when it came to public transport satisfaction, with 60% of those in Reading giving a score of 4, 5, or 6, but only 25% of those in York giving the same scores. Thus, in summary, provision of public and community (demand-responsive) transport services varies markedly depending on where one lives, with those in and around York expressing heavy dissatisfaction with both, while those in Reading were generally more satisfied with both. Likewise, those living in dense urban areas in the Netherlands tended to be more satisfied with public transport services, while this was not true in Canada; although, as mentioned before, Canadian respondents felt that these services were more essential to their mobility, so more research needs to be done to look at why public transport services are not fully meeting expectations there.

Pavement quality and continuity

Pavement quality and continuity more-or-less represented the lowest scores out of all of the attributes for each of the three countries. Respondents were asked to rate pavement quality, considering its surface and the typical presence of obstructions, in their city, followed by the question about pavement continuity. Once again, the Netherlands scored best in both measures, and the UK worst in both measures. Unfortunately, however, it has just been realised that “pavement continuity” was incorrectly translated on the Dutch questionnaire as “pavement flatness”, so it is not applicable for this comparison (although respondents were somewhat satisfied with this flatness). More unfortunate still is the incorrect translation of pavement quality as “road quality” in Canada for this question, making the score for pavement quality inapplicable. In the UK, pavement quality was rated worse than continuity, possibly highlighting just how bad participants consider pavement quality to be in the UK. While the few rural respondents in the UK rated pavements as being worse than those from urban areas, it did little to affect the overall score. A mentioned earlier, those in York were more dissatisfied with pavement quality than those in Reading (an average score of 1.92 versus 2.35). In the Netherlands, there appears to be a slight trend towards better pavement ratings in the slightly less-dense urban areas, but this is not a strong correlation; if this is the case, this might have something to do with some of the older big cities like Amsterdam having plenty of cobbled streets, but more investigation will be needed on this issue. Because of the small sample sizes, it is hard to ascertain if the type of device used has any influence upon the perception of pavement quality. Regarding pavement continuity, almost no-one out of the Canadian sample gave a rating of 5 or 6, indicating that there is clearly room for improvement, and the UK did not fare any better.

In summary on the issue of pavements, providing that the likert scale results are truly reliable for making comparisons between countries, then it seems safe to say that Dutch pavements are the best, and British pavements the worst.

Bicycle infrastructure

Just over 10% of respondents in both the Netherlands and Canada responded that rating bicycle infrastructure was not applicable, versus 61% in the UK. This would seem to imply that most Dutch and Canadian respondents make use of this infrastructure at least some of the time, while this is the case for only a minority of the respondents in the UK, most likely due to the lack of bicycle infrastructure that exists here. Interestingly, the average score in the UK for bicycle infrastructure was slightly higher than that in Canada; whether this is due to the small number of respondents in the UK (n=16) rating this infrastructure, or because the bicycle infrastructure quality was just so much better than the quality of the pavements (achieving an average score of 3.38 versus 2.14), is unknown. Of course, being the global masters of bicycle infrastructure, the rating was best in the Netherlands, at 4.16. To present the scores another way, 70% of those in the Netherlands gave a score of 4, 5, or 6, against

50% in the UK and 39% in Canada. *However, the key statistic is this:* in both the UK and the Netherlands, bicycle infrastructure was given a higher rating than pavement quality. Because “bicycle infrastructure” and “pavement quality” are not exactly directly comparable terms, since the measure of the bicycle infrastructure is not being specified, a firm inference cannot be made from comparing the ratings of the two. Nevertheless, this finding would seem to point towards greater satisfaction being associated with bicycle infrastructure than with pavements. In the Netherlands, there was no correlation between the rating for bicycle infrastructure and the degree of urbanisation, although the respondents in the second-most dense urban area category were the most likely to give a rating of 4, 5, or 6, with 84% doing so. In summary, as expected, the Netherlands achieved the best score for bicycle infrastructure, which also somewhat adds confidence to the reliability of the likert scores between countries. Furthermore, respondents in all of the countries ranked bicycle infrastructure above pavement quality, possibly indicating a preference for bicycle infrastructure; this potential preference will be discussed more in later sections.

Number of accessible businesses, toilets, and public buildings

A quick comment should be made regarding accessible buildings and facilities: while not necessarily obvious, there appears to be a link between the accessibility of buildings and the devices that people use, as indicated by the qualitative responses to some of the questions (this will be discussed later). It is worth noting that while the Netherlands once again came away with the best score, in this case, the UK ranked better than Canada, albeit not by that much. There is almost certainly a link with the disabled-accessibility legislation, and the implementation of that legislation, in each of the three countries, although going into the details on this is outside the scope of this study. However, it is worth noting that a fifth of the 30,000 shops and restaurants recently audited by DisabledGo were not accessible by wheelchair (BBC, 2014b). Therefore, it might be assumed that a somewhat similar proportion of businesses are not wheelchair-accessible in Canada also.

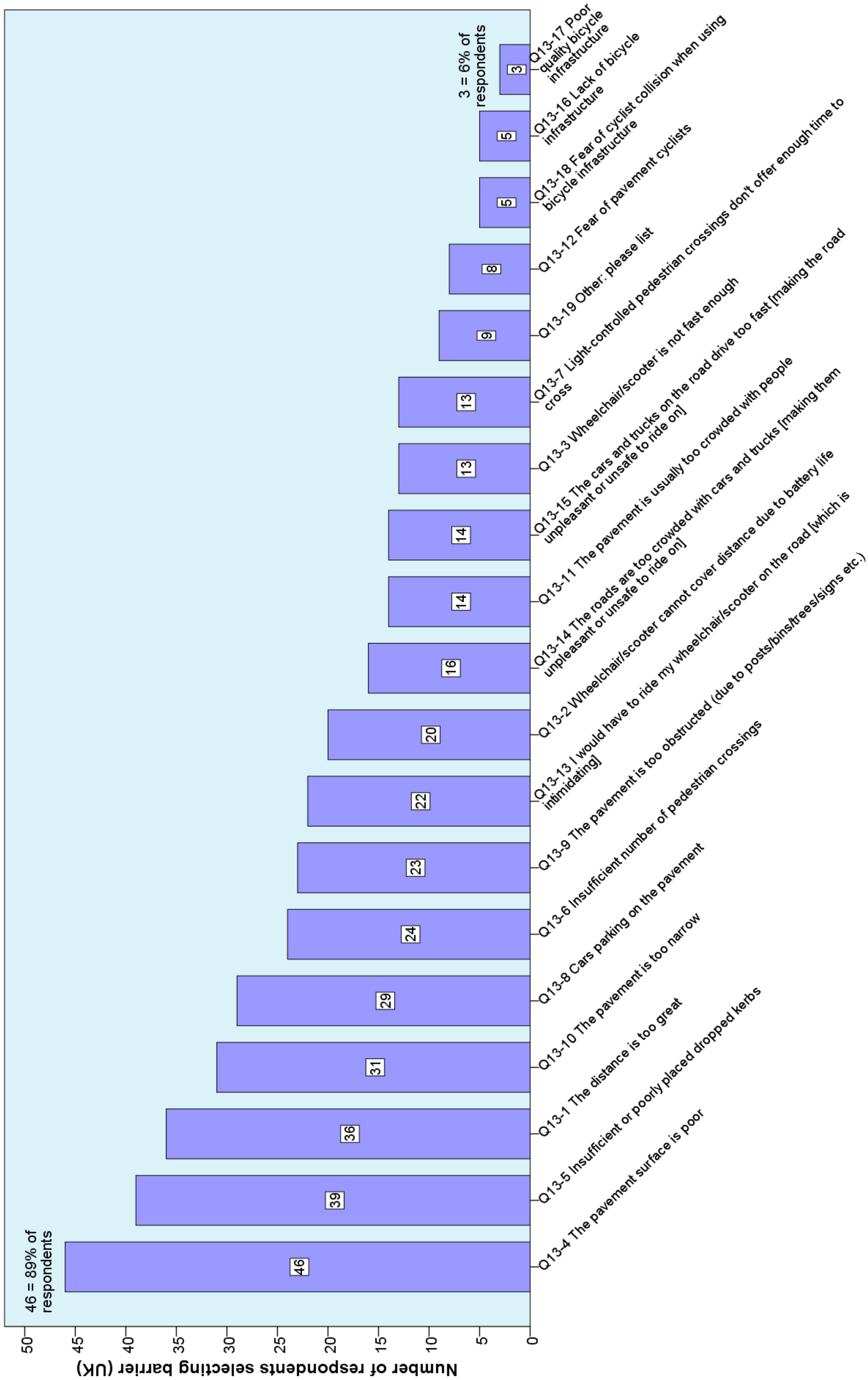
Respondents' perceptions about whether their needs are being considered by city planners and the city council

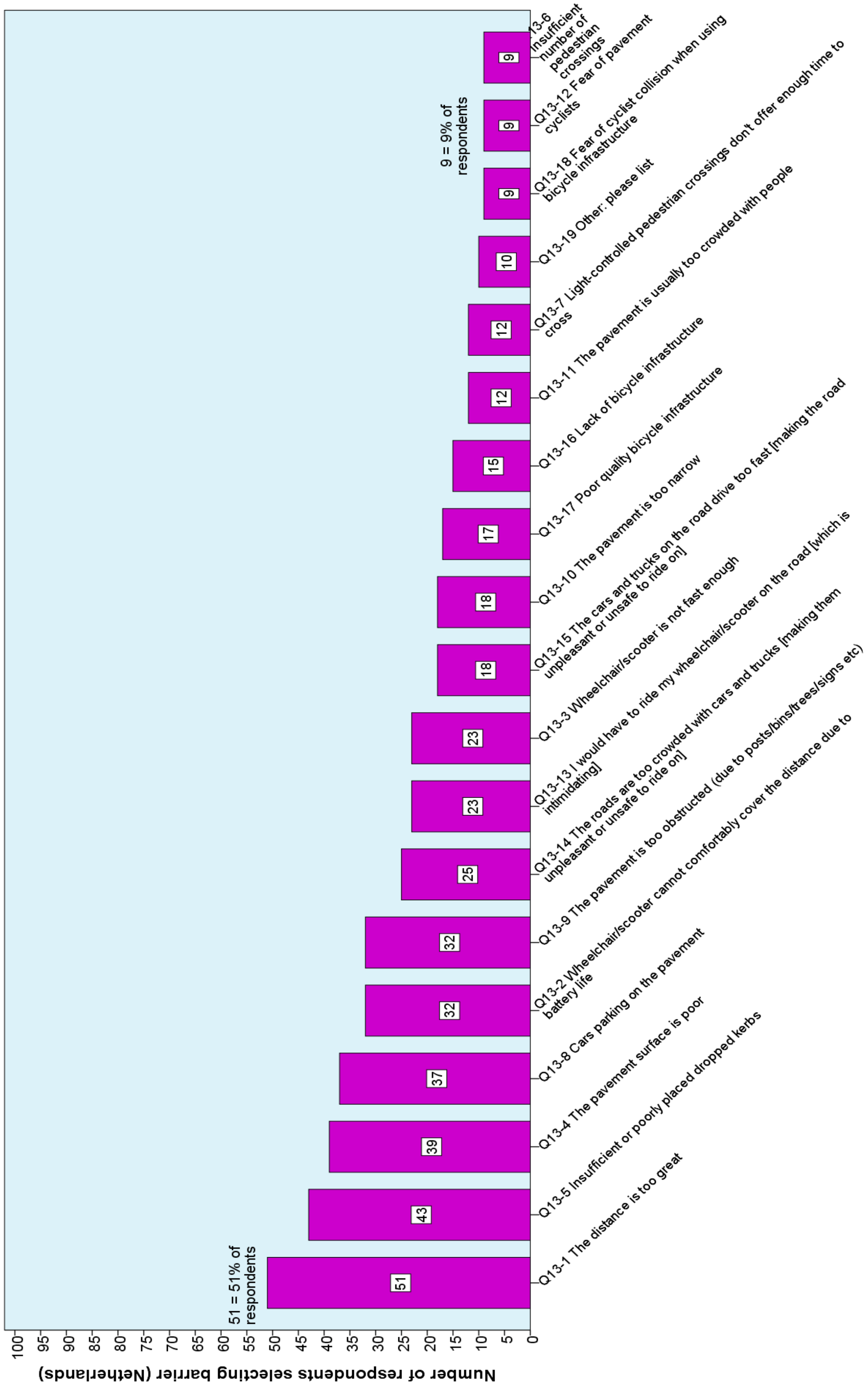
During the literature review, it was found that PMD users frequently felt ignored by transport planners, architects, and the local authority. Therefore, question 16 asked how often respondents felt that their needs as a PMD user were considered by city planners and the local council, using a scale from 1 to 6, with "1" being "Not at all", and "6" being "All the time". It seems likely that these results will reflect both the system of citizen participation put in place (such as the process for public consultation on a new project), and the satisfaction with current infrastructure and public/community transport services. For the different sample areas, the view in Reading was fairly middling to negative, while those in York were a bit more polarised, albeit with the majority selecting a score of 1 or 2. While the English-speaking Canadian sample were fairly evenly distributed, there was a resounding dissatisfaction amongst those in the French-speaking Canadian sample, with all but one respondent giving a score of 1, 2, or 3. This would seem to indicate that there is either a problem with the process of citizen involvement in Quebec, or that a particular aspect (such as accessible public transport, perhaps) is so dissatisfactory that they feel that all their needs are being ignored. The mean score for the UK was 2.76, for Canada was 2.29, and for the Netherlands was 3.08, showing that once again, the Dutch respondents were the most satisfied, although not overly so in this case – 36% of Dutch respondents still selected a score of 1 or 2, which would indicate that they felt their needs were being quite strongly ignored. More research should be conducted in order to understand the exact reasons why some PMD users feel their needs are being considered, while others feel completely ignored, as it is difficult to spot any trends in this data regarding probable causes.

Topic 3. Barriers

Barriers experienced during a PMD-only journey to the shops, a recreational area, or place of employment

During the literature review, many barriers to the mobility of PMD users were identified; it was conjectured from the data available and number of citations for each barrier that the most common barriers were a lack of dropped kerbs, obstructed or crowded pavements, and poor quality travel surfaces. Question 13 in the questionnaire asked respondents to list all barriers that they would encounter on a PMD-only journey to either their local shops, their favourite recreational area, or their place of employment. The conjectured 3 main types of barrier effectively formed the top 3 barriers of the choices available, in both the Netherlands and the UK. The following two Pareto charts show the results from the UK and the Netherlands, with the barriers ordered in terms of their “popularity” among respondents. Unfortunately, due to a translation error in the French-Canadian questionnaire (translating “pavement” as “road”), six of the parameters were affected, so the chart is not shown; however, where still relevant, the results from Canada will be mentioned.


Number of respondents selecting barrier (UK)
0
5
10
15
20
25
30
35
40
45
50
46 = 89% of respondents
3 = 6% of respondents
46
39
36
31
29
24
23
22
20
16
14
14
13
13
9
8
5
5
3
Q13-4 The pavement surface is poor
Q13-5 Insufficient or poorly placed dropped kerbs
Q13-1 The distance is too great
Q13-10 The pavement is too narrow
Q13-8 Cars parking on the pavement
Q13-6 Insufficient number of pedestrian crossings
Q13-9 The pavement is too obstructed (due to posts/bins/trees/signs etc.)
Q13-13 I would have to ride my wheelchair/scooter on the road [which is intimidating]
Q13-2 Wheelchair/scooter cannot cover distance due to battery life
Q13-14 The roads are too crowded with cars and trucks [making them unpleasant or unsafe to ride on]
Q13-11 The pavement is usually too crowded with people
Q13-15 The cars and trucks on the road drive too fast [making the road unpleasant or unsafe to ride on]
Q13-3 Wheelchair/scooter is not fast enough
Q13-7 Light-controlled pedestrian crossings don't offer enough time to cross
Q13-19 Other: please list
Q13-12 Fear of pavement cyclists
Q13-18 Fear of cyclist collision when using bicycle infrastructure
Q13-16 Lack of bicycle infrastructure
Q13-17 Poor quality bicycle infrastructure


Number of respondents selecting barrier (Netherlands)
51 = 51% of respondents
9 = 9% of respondents
Q13-1 The distance is too great
Q13-5 Insufficient or poorly placed dropped kerbs
Q13-4 The pavement surface is poor
Q13-8 Cars parking on the pavement
Q13-2 Wheelchair/scooter cannot comfortably cover the distance due to battery life
Q13-9 The pavement is too obstructed (due to posts/bins/trees/signs etc)
Q13-14 The roads are too crowded with cars and trucks [making them unpleasant or unsafe to ride on]
Q13-13 I would have to ride my wheelchair/scooter on the road [which is intimidating]
Q13-3 Wheelchair/scooter is not fast enough
Q13-15 The cars and trucks on the road drive too fast [making the road unpleasant or unsafe to ride on]
Q13-10 The pavement is too narrow
Q13-17 Poor quality bicycle infrastructure
Q13-16 Lack of bicycle infrastructure
Q13-11 The pavement is usually too crowded with people
Q13-7 Light-controlled pedestrian crossings don't offer enough time to cross
Q13-19 Other: please list
Q13-18 Fear of cyclist collision when using bicycle infrastructure
Q13-12 Fear of pavement cyclists
Q13-6 Insufficient number of pedestrian crossings

Previous pages: charts 3.42 and 3.43, showing the number of respondents selecting each type of barrier in the UK and the Netherlands

In terms of a country-wide overview, there is one important thing to note. In the UK, the top two barriers were selected by 89% and 75% of respondents, while in the Netherlands, the two most selected barriers were chosen by just 51% and 43% of respondents (with Canada in-between at 69% and 58% of respondents). This is important to note, because while the *order* of importance/popularity may be similar between countries, the *absolute percentage* of respondents selecting that barrier is often quite different. The fact that such a high percentage of British respondents selected certain barriers fully supports the finding from earlier questions that the UK is much more inaccessible for making PMD-only journeys, with many barriers present in every journey.

For the UK, Netherlands, and Canada, "insufficient or poorly placed dropped kerbs" was one of the top three barriers reported, confirming this as an important barrier. Similarly, "the pavement surface is poor" was also one of the top three for all of the countries, although because of the translation issue, this cannot be officially determined for Canada. If questions 13-8, 13-9, 13-10, and 13-11 (see chart) representing narrow pavement width, pavement parking, pavement obstruction, and pedestrian overcrowding are considered together to represent "pavement obstruction/overcrowding", then this would easily be another one of the top three in the UK and the Netherlands. Therefore, it appears that the data from the questionnaire supports the assertion made in the literature review about the three most important, or frequently encountered, types of barrier.

The other single barrier that makes the top three in all three countries is "the distance is too great". This sends a clear message that distance is an important barrier, at least for some trips, whatever the country. It should be emphasised again though that 51% of Dutch respondents selected this, versus 69% of British respondents. The fact that this was the most important barrier in the Netherlands, versus the third most important in the UK, perhaps also shows the relative lack of other infrastructural barriers in the Netherlands. For example, just 39% of Dutch respondents selected poor pavement surface as a barrier, compared to 89% of British respondents.

There are also many other differences in relative importance between countries worth noting (keeping in mind that while many barriers were "tied" for a spot, each was given a ranking of 1-19 based upon the charts, so that the rankings could be compared between countries). The first of these is that the sixth most important barrier in the UK was an "insufficient number of pedestrian crossings”, with 46% of respondents selecting this barrier; in contrast, this was a minor problem in Canada and the Netherlands, with just 27% and 9% selecting this barrier, respectively. It would be interesting to know whether this is due to possibly less usage of pavements in Canada and the Netherlands, or because there are more frequent pedestrian crossings, or perhaps there just less need to cross the road; this would be something that also needs further investigation. In the UK, 42% of PMD users said that they would have to drive their device on the road to make the journey in mind, which seems completely unacceptable; perhaps somewhat surprisingly, 23% of Dutch respondents also said that they would have to do so, which seems on the high side considering that if a pavement is not available in the Netherlands, a cycle path usually is, although on some quieter neighbourhood or access roads, pavements do not exist and the road must be used. Therefore, this is also another aspect worth investigating further, as having to use the device on the road would likely be intimidating for many PMD users, as it frequently is also for pedestrians and cyclists. A similar percentage of respondents in each country stated that device battery life could act as a barrier, ranging from 32% - 40% of respondents. Interestingly, a similar percentage of respondents in the UK and Netherlands said that their device was not fast enough, at around 25%, which is perhaps interesting when it is considered that Dutch devices are much faster on average. This result matches well the finding of Barham, Oxley and Board (2005), who also found that around a quarter of UK powered device users felt that their device was too slow. Another barrier frequently cited in the literature as a safety concern, and one that likely puts the elderly off making journeys, is that the time given to cross the road is too short. While only 12% of Dutch respondents stated this to be the case, 25% of British and 42% of Canadian respondents stated that this was a barrier for them, implying that this is an issue that needs to be resolved by highway engineers in both the UK and Canada. Regarding bicycle infrastructure, unsurprisingly, few British respondents said that a lack of bicycle infrastructure, or poor quality bicycle infrastructure, was a barrier for them. In sharp contrast, 46% of Canadian respondents said that the lack of bicycle infrastructure was a barrier, and 31% also stated that the poor quality of it was also an issue, which seems to suggest a strong dependence on this infrastructure by Canadian PMD users to be able to move about easily. For the Netherlands, these figures were 15% and 17%, respectively, showing that bicycle infrastructure rarely presents a barrier for Dutch PMD users. Also worth noting is that just 9% of Dutch, and 23% of Canadian users stated that fear of a collision with a bicycle while using bicycle infrastructure was a concern for them, representing a much lesser perceived risk

than that posed by motor traffic, and in perhaps also reflecting upon the high level of safety design and engineering that goes into Dutch bicycle infrastructure.
Overall, for question 13, far more analysis would be needed to fully understand these data, and interviews with participants should also be carried out in order to confirm the validity of the results in each country, as, for example, the fact that for almost every single barrier, a lower percentage of Dutch respondents selected them than did British respondents, seems almost too good to be true. Furthermore, in an ideal situation, the order of barriers could have been switched for each questionnaire, in order to prevent a possible positive correlation that might occur for items that appear at the top of a long list (as respondents might not be bothered to read all of the 19 barriers to the bottom). However, it would appear to be safe to say that overall, Dutch respondents face the least barriers when travelling only by PMD, whilst British respondents faced the most. The most frequently occurring barriers involve poor quality travel surfaces, obstructed or crowded pavements, and a lack of dropped kerbs, while fear of the risks associated with motor traffic far outweighed fear of the risks posed by cyclists.

Changing travel patterns to avoid pavement congestion

Because it was thought that pavement overcrowding could be an issue based on the findings in the literature, another related question was asked to respondents. Question 15 asked how often respondents change the time of day, day of the week, or route that they take, in order to avoid having to navigate crowds of pedestrians. Again, a scale of 1 to 6 was used, with “1” being “never make changes”, and “6” being “make changes all the time”. For the UK, the average score was 3.14, with a variance of 3.51. Those in York seemed to make changes more frequently, with 8 of 27 respondents selecting a score of “6” in York, while no-one felt this strongly in Reading. It appears as though there may also be a correlation with age, as two-thirds of those in the 65+ age group selected a score of 4, 5, or 6, but a larger sample size would be required to determine this with certainty. For Canada, the mean score was 3.10, with a smaller variance of 2.64. Respondents in French-speaking Canada reported making changes less often than those in the rest of Canada; however, a larger proportion of the 25-44 age group frequently made changes than did the 45-64 age group, which seems to refute the finding from the UK, meaning that there may be some other variable than age that affects this tendency. In the Netherlands, the mean score was 2.66, implying that changes were less frequently made to travel patterns in order to avoid crowds. The responses were also more consistent, with a variance of 2.34. There was a statistically significant positive relationship (p=0.01) between degree of urbanisation and how frequently changes were made, with more those in the two most urban areas making changes more often. Significance was also checked for age and gender, with older female respondents appearing to make changes more frequently, although neither was significant at the 5% level.

These changes to travel patterns make sense when considered within the context of the barriers discussed from question 13. In the UK, 60% of respondents had said that pavements were too narrow, and 27% said they were too crowded; in the Netherlands, these figures were 18% and 12%, respectively. That is to say, narrow pavements are more likely to be crowded for a given level of footfall, and crowded pavements are likely to cause a barrier that results in PMD users feeling that they can only go out at certain times of day, or on certain days of the week.

A disabling urban environment?

Question 14 asked respondents, on a scale of 1 to 6 (with "1" being "not at all disabling" and "6" being "very disabling") how disabling they felt the built environment was when using their PMD. Because of the wording of the question, it may have been a little confusing for some, or too unspecific, so results to it should be treated with caution.
The mean scores for the UK, Canada, and the Netherlands were 4.50, 4.10, and 4.07 respectively. This similarity between countries is a little surprising, considering that generally the Netherlands scored a lot better in terms of ease-of-travel and lack of barriers in comparison to the UK and Canada. This result was tested for correlation with degree of urbanisation in the Netherlands, which was found not to be significant. However, there was a weak association with age (p=0.16), with older participants finding the urban environment more disabling, which makes sense.
The results from this question appeared to be somewhat inconclusive, or at least, they were not fully logical when considering the findings from the other questions. Therefore, it is quite possible that the slightly vague wording (in defining the built environment) might have resulted in a rather vague result.

Environmental barriers on device usage

Briefly moving back to the findings of question 2, the qualitative answers provide some interesting insight into the link between device usage and the built environment. To recap, question 2 asked respondents about which of the devices they owned was preferred for moving about their town or city.

Some respondents liked a device for its ability to allow socialisation: for example, a mother stated how she preferred her power wheelchair over her manual one because it allowed her to keep up with her young daughter, while a more elderly lady preferred her manual chair because she felt that it helped to ensure that she and her husband could stay together while out. Some liked their manual wheelchair because it gave them a workout, while others had a preference for their power chair due to a lack of strength, or because they faced barriers such as hills that would be difficult to overcome otherwise. Many respondents stated that they preferred their power wheelchair or mobility scooter because it allowed them greater independence and was more convenient, echoing the findings of other studies. However, it appears that similar to the findings of Korotchenko and Clarke (2014), these power devices are only as enabling as the environments in which they are used. The following responses demonstrate some of the barriers to device use that users face:

In the UK:

"[My] electric chair [is] too big and cumbersome for crowded places"(Female, age group 65+)

"Poor pavements cause leg spasms when using power chair" (Female, aged 45-64)

"[I prefer] the manual chair, as my husband drives the car and he can't get my electric chair in the boot, so he pushes me around town." (Female, aged 65+)

In Canada:

"I will use my manual wheelchair if the destination is accessed by Access Calgary wheelchair buses or by Calgary Transit and is less than 1 block from my drop off. If more, I will use my power wheelchair. I prefer to use my manual chair because of difficulty in accessing older buildings"(Unknown details)

"[Manual wheelchair for its] ease of use. It is light weight and quick for getting in and out of cars, and I can be helped up stairs. It is also easier to get into and out of restaurants etc." (Male, aged 45-64)

"For my movements in inaccessible places and when I have a companion, I am in a manual chair most of the time. Otherwise, when I know that it's a place which is accessible enough, I get around without a companion with my motorised chair which also has the feature of a seat which raises to access counters which are too high for my small size" (Female, aged 25-44)

"I prefer to use my walker instead of my manual wheelchair because the descents [ramps off] the sidewalks are often blocked by parked cars, or badly cleared snow in winter, or they are in a bad condition. Equally because the great majority of places where I have to go do not have an accessible entrance (stairs at the entrance, door threshold too high). Equally because certain places which say they are accessible (entrance without steps for example) do not have accessible toilets. It is truly complicated when I have to go to the bathroom. Some have adapted toilets, but badly adapted (too small which ensures that the wheelchair cannot turn round, or again the cubicles are big enough but without a handle on the inside of the door which allows me to close the door myself). It goes without saying that I NEED to get around with my manual wheelchair (paid for by the RAMQ) because of muscular dystrophy but that most of the time I have to go out with my walker because there is never anything adapted as it should be. This means that I get much more exhausted with my walker VS the wheelchair, so my social, professional and family life takes a big hit. In fact, it's my quality of life which is missing. ***My illness does not make me appear to be a handicapped person, I feel handicapped when I have to confront places that are inaccessible or then badly adapted!****" (Female, aged 25-44)*

"[The manual chair] because I can then go in a bathroom, which I can't do in a scooter... unless the bathroom is very big. Otherwise, I would take the scooter." (Female, 45-64)

These results from the UK and Canada provide a great deal of insight into the barriers that either facilitate or prevent the decision to use a certain device. While the positive reasons for preferring to use either a power device or a manual wheelchair were fairly similar, and involved either overcoming the mobility disability caused by their impairment or some other barrier such as hilly terrain, or even keeping fit, the negative reasons that forced the decision to use a non-ideal device were quite different between the two countries. While in the UK crowded, bad quality pavements or the necessity (real or perceived) to use a car necessitated the use of a particular device, in Canada, there were no fewer than seven responses indicating that inaccessible buildings, toilets, and pavements forced the user to adopt a device that would not normally be their preferred device. This supports the finding from question 17, where a very poor score was given for the number of accessible businesses and facilities in Canada. *This is also a fundamental finding which does not appear to have been acknowledged before: a lack of accessible buildings actually affects the transport choices of those with mobility impairments, as PMD users are unique in that they are the only group within society who have to take their transport "vehicle" inside their origin or destination*.

Thus, this finding accentuates the need for a truly integrated approach to be taken between all areas of urban design, from architecture to transport infrastructure and vehicle design.
One respondent (above) from Canada was even kind enough to perfectly prove the validity of the social model of disability in her comment: "*My illness does not make me appear to be a handicapped person, I feel handicapped when I have to confront places that are inaccessible or then badly adapted!"*
For Dutch respondents, the reasons for using a power device were similar, usually due to their limited strength or endurance to move far in a manual wheelchair. Because many Dutch respondents are mobility scooter users, they frequently specifically mentioned an ability to walk, but only for very short distances; thus, the power mobility device is seen as a tool for allowing the travel of distances that are much greater than could be made on foot. Several respondents also stated that they preferred to use adapted bicycles or tricycles, as these devices similarly allow independence to be maintained (and are probably a mode of transport that they have used their whole lives). While British respondents living outside town centres sometimes stated a need to use a car, one Dutch respondent proved that the combination of a mobility scooter and a bicycle path (or possibly a local access road) is sufficient for covering greater distances there:

"I live in a remote village and this [a mobility scooter] is the only possibility for transport outside the village" (Female, aged 45-64, using 15km/h mobility scooter)

(The above participant also gave responses that indicated that she felt that getting to her local shop and favourite recreational area was quite easy, although also seemed to indicate that the battery life of her device might be a concern.) Another respondent using a 19km/h mobility scooter stated that it was their preferred device because it allowed them to travel at distances of up to 40 kilometres.
With the exception of one reply indicating that a manual wheelchair was necessary to enter a friend's house, there were seemingly no building-related limitations on the mobility choices of Dutch respondents. Rather, there was a strong propensity toward statements that indicated true independence:

"I can control how, where and when I want to go somewhere" (Female, aged 45-64, preferring their mobility scooter)

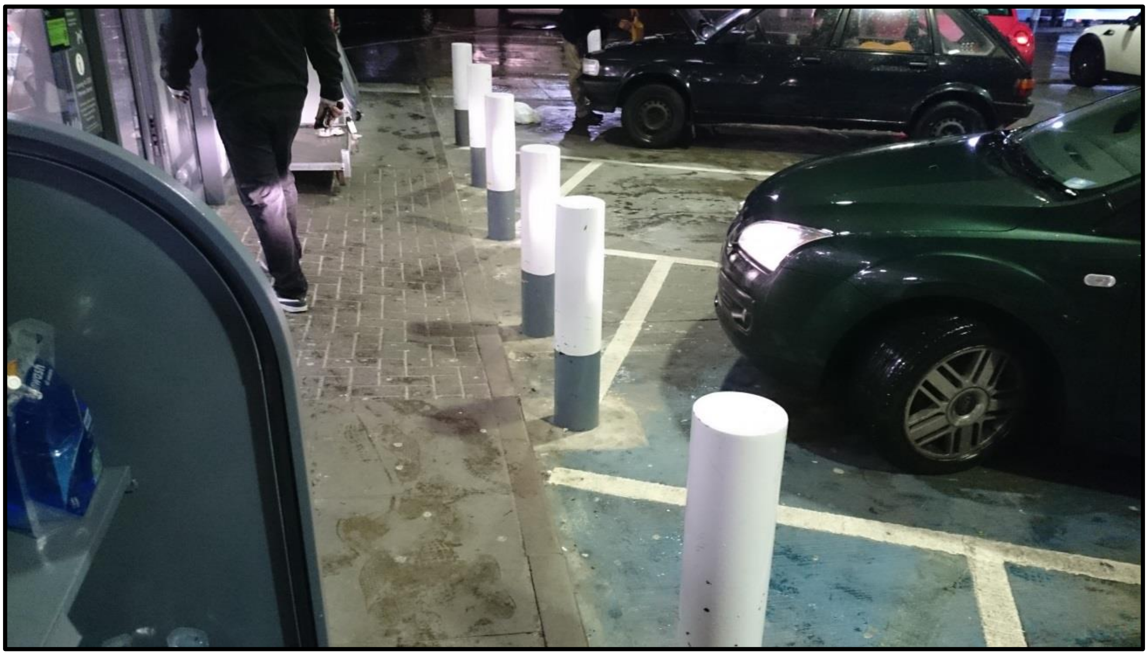
Indeed, mobility devices are not just an enabler of mobility… often, they are *essential* for mobility, as this response demonstrates:

"Without my mobility scooter I would be helpless and not be able to go places near my house or to go shopping." (Female, aged 65+)

Overall, the Dutch qualitative responses to this question were more positive than for the UK and Canada, and indicated far fewer barriers being placed upon the choice of device usage. This qualitative information adds weight to the more quantitative data from other questions by affirming the apparent lack of barriers in the Netherlands to PMD usage when compared to the other two study countries.

Barriers affecting other modes

Barriers to mobility for PMD users do not only occur when making "walking" trips with their device. Even when travelling by car, PMD users can be thwarted by poor infrastructure design when arriving at a destination. Take, for example, this fuel station photographed by the author in outer London, shown in figure 3.1. The "disabled" parking space (in front of the ATM) appears to be designed somewhat to the correct specifications. However, the fuel station owner then goes on to disable the wheelchair user by blocking the adjacent walkway leading inside the fuel station with a display stand for barbecue supplies. This might be tolerable, if the wheelchair user were at least able to move around the back of other parked cars and then access the entrance directly in front of the shop. However, as can be seen in figure 3.2, the entrance may also potentially be blocked by parked cars, meaning that the fuel station pictured is effectively completely inaccessible by wheelchair at times.



Figures 3.1 and 3.2: complete wheelchair inaccessibility for a fuel station in outer London

Conclusions regarding barriers to mobility for PMD users

Matching the findings of the literature review, it was found that the most frequently encountered barriers to PMD use in the urban environment were a lack of dropped kerbs and poor-quality, obstructed and crowded pavements. Respondents, especially from the UK with its narrow, crowded pavements, replied that they often made changes to their travel schedules and route choices in order to avoid these crowded pavements, which presumably cause stress and reduce travel speeds. Another barrier to many journeys was the need to use the road, which may instigate feelings of fear in many due to the presence of motorised traffic. Despite its widespread presence in the Netherlands, "poor quality bicycle infrastructure" and a fear of cyclist collisions was cited by few.

Respondents in the UK rated the built environment as more disabling than those in other countries. Often, the built environment placed limitations upon the type of mobility device that could be used to get around, thereby limiting the freedom and independence that could potentially be obtained by a preferred device. In the UK, these environmental limitations were due to things like bumpy travel surfaces or the need to use a car that could not accommodate the device, while in Canada, a not insignificant proportion of total respondents were forced to use a non-optimal device due to buildings and facilities not being PMD-accessible. The Netherlands, in contrast, appeared to place few environmental-barrier constraints upon device choice. To the contrary, several respondents with mobility scooters (albeit ones with top speeds higher than those in the UK) were able to travel long distances with their devices, even from rural communities, without the need for a car or public transport. Such travel would clearly not be feasible without user-friendly infrastructure that suits the device; therefore, infrastructure can be seen as either a barrier or a facilitator to the use of a personal mobility device.

Topic 4. Potential solutions: improving mobility

The last few questions in the questionnaire were mainly focused on the use of bicycle infrastructure, in order to try and meet the primary research aim, i.e. "To quantitatively and qualitatively evaluate the mobility benefits, if any, to PMD users arising from the existence and use of bicycle infrastructure."

These questions asked British and Canadian respondents whether they had used bicycle infrastructure before, and the reason why or why not. If they had used it, they were asked whether they felt the experience was better than, worse than, or similar to that of using the pavement. Participants in these two countries were then asked whether they thought their city should have more or less bicycle infrastructure. Lastly, they were shown a photo of a high-quality Dutch segregated cycle path, where it intersects with a side road (with priority for cyclists). Based on this photo, respondents were asked whether they would be more, or less likely to use such a cycle path than the pavement, and to give the reasons why or why not.

Dutch respondents were provided with a slightly different set of questions. They were first asked the question of whether their city should have more or less bicycle infrastructure than at present. However, the next question inquired about the percent of trips where bicycle infrastructure was utilised for at least part of the trip. Then, as in the UK/Canadian version, respondents were asked whether they found the experience of using bicycle infrastructure better than, worse than, or similar to that of using the pavement. Lastly, they were given a free-response box in which they could provide their own thoughts regarding the use of bicycle infrastructure.

While all of these questions involve bicycle infrastructure, the first question to be analysed for this section, question 18, asks respondents (using a scale of 1 to 6) whether they would prefer improvement of road infrastructure (bus and car facilities) or pedestrian infrastructure (more pedestrianisation and wheelchair-friendly pedestrian facilities) in their city. While this question might be considered a little "unfair", it nevertheless gauges whether respondents would prefer, and value more, the improvement of roads and public transport, or the improvement of pedestrian facilities. Of course, in a town where pavements are great, but public transport is poor, respondents may opt for more public transport, and vice-versa. If anything, this question will hopefully gauge the level of satisfaction with the existing "status quo" in participants' towns and cities, giving an idea of whether the balance of road infrastructure and pedestrian infrastructure is currently satisfactory or not.

Roads or pavements?

For this question, as mentioned in the previous paragraph, a rating scale of 1 to 6 was used. A score of "1" represents "more road infrastructure", while a score of "6" represents "more pedestrian infrastructure". It is therefore assumed that a mean score of more than 3.50 implies an overall desire for more pedestrian infrastructure, and a score of less than 3.50 a desire for more road infrastructure and road-based transport.

For the UK, there appeared to be a strong overall desire for more pedestrian infrastructure, with a mean score of 4.53 and a variance of just 1.63. This desire was especially prevalent in York, with 46% of participants there selecting a value of 6. This most likely reflects upon the poor quality of pedestrian infrastructure currently in York, especially with regard to the large proportion of areas that feature cobbled streets, which are particularly problematic for PMD users. In Canada, the mean score was 4.08, still indicating an overall preference for more pedestrian infrastructure, but with greater variance, at 2.29. This may reflect a slightly higher quality pedestrian infrastructure already in place compared to the UK, but the middling score is more likely a manifestation of the perceived necessity of public transport amongst Canadian respondents (question 12) crossed with the low level of satisfaction with its current quality and provision (question 17-2). Therefore, it might be fair to conjecture that Canadian respondents desire both improved public transport and improved pavements, with both improvements being important. For the Netherlands, there was a clear desire for more improved pedestrian infrastructure, with a mean score of 4.45, while a small variance of just

1.17 demonstrates the small number of respondents desiring increased public transport and road infrastructure (less than 20% selected a value of 1, 2, or 3). Again, this may reflect the necessity for public transport stated in question 12, which in the case of the Netherlands was low. Likewise, in question 17, Dutch respondents had already indicated a reasonable level of satisfaction with public and community transport, whilst pavements were the worst rated parameter, so the results from question 18 seem to affirm the validity of the data for question 17. In summary, there is great need for improvement in pedestrian infrastructure in the UK, a car-based society that has neglected active travel, while in Canada, improvements to both public transport and pavements are likely desired. In Netherlands, the provision and quality of public transport already appears to be satisfactory, with improvements desired to the somewhat-average pedestrian infrastructure (even though it is still the best of the three countries).

Use of bicycle infrastructure

In the UK and Canada, question 19 asked respondents about whether respondents had used their PMD on a cycle path/shared use path before, and the reasons why or why not. In the UK, 36% of respondents stated that they had used a cycle path before. This finding is actually lower than what was found by Barham, Oxley and Board (2005), where over two-thirds of respondents in the UK said that they had previously used bicycle infrastructure. Whatever the true representative figure, it should be considered that it is technically illegal for PMD users to utilise this infrastructure in the UK, and thus this “high” figure indicates either a lack of knowledge about the law, or more likely, an absolute necessity to use bicycle infrastructure at times. In comparison, 77% of Canadian respondents said that they had made use of cycle paths before, which makes sense considering the greater presence of cycle lanes and segregated bicycle paths in cities like Montreal, and considering that their use by PMD users is not illegal in Canada, or, at least not in Quebec. For Dutch participants, question 20 asked about what percentage of journeys involved the use of bicycle infrastructure. There was not a choice to say “I do not use bicycle infrastructure”, although the lowest of the five categories was “less than 10% [of journeys]”, and it can be assumed that some percentage of people selecting this option to not use bicycle infrastructure. The other choices were given as a set percentage, rather than a range of values, as a rough approximation was the best that could be expected in the absence of a travel journal. The other options were 25%, 50%, 75%, and "greater than 90%" of journeys. The percent of respondents selecting each level of usage are represented in the following chart.

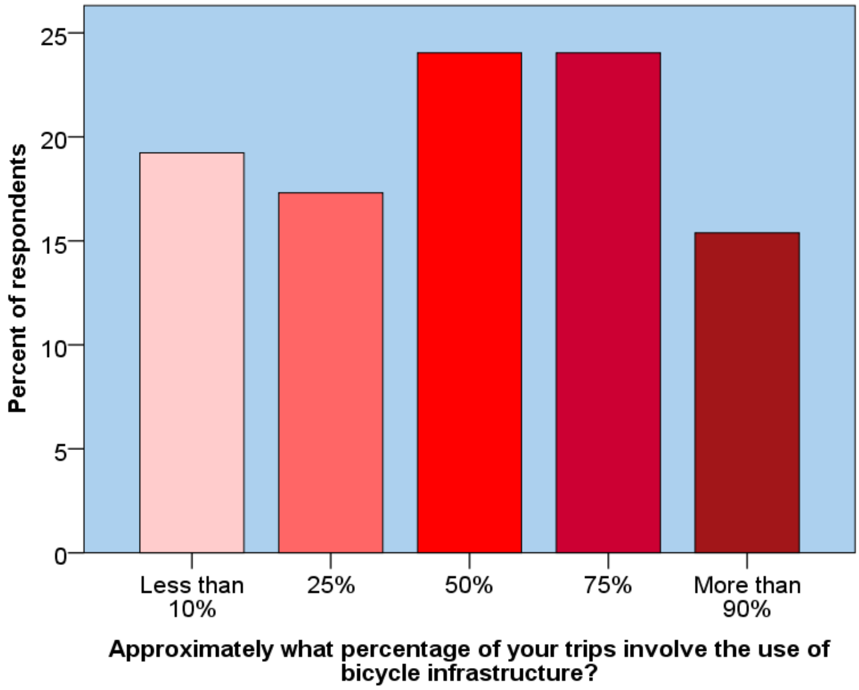


Chart 3.44: percent of journeys involving the use of bicycle infrastructure by Dutch respondents

As can be seen from the chart, almost all Dutch PMD users incorporate bicycle infrastructure at into at least some of their journeys; less than one-fifth of respondents indicated that fewer than 10% of their journeys involved it. Therefore, it might also be guessed that only around 10-15% of Dutch PMD users never use bicycle infrastructure (which concurs with 12% of Dutch respondents saying that rating bicycle infrastructure was "not applicable" for them in question 17). Importantly, 63% of users said that about half or more of their journeys involved bicycle infrastructure, emphasising the importance of this infrastructure type in the everyday mobility of Dutch PMD users.

Now that it has been ascertained that a high percentage of Dutch and Canadian respondents have used bicycle infrastructure, while less than half of British respondents reported having done so, the reasons behind this usage, or lack thereof, in the UK and Canada will be explored via the use of a table. All qualitative answers that were provided are in the table, separated by country, and whether or not the respondent has used a bike path before.

Country	Have used cycle path before?	Reason
UK	Yes	Space and safety
		Work being done on path [so] no space for wheelchair
		Only path available at the time
		The pavement was totally inadequate so I had no choice but to use cycle path
		Thought [it] would be easier, but then got shouted at by cyclists instead of pedestrians!
		To keep off the road, but cyclists are then abusive
		Narrower pavements end on road (along with on-going traffic) cycle pathway smoother and you get there as bikes go around you. Definitely better option [?]
		No other choice; shared [demarcated] paths are safer without having to watch for bikes passing
		Easy to use, not congested, only pedestrians and bikes to consider, close to nature with trees, bushes, flowers, birds etc.
		I use the bike route as it has easy [gentle?] pavement bumps, as it's painful to use pedestrian pavement.
		Better ground surface than the road and unobstructed
		It was a shared path. One of the difficulties was [that] it also had lumps where large tree roots existed and I had to keep going on the grass verge to get round them.
		Safer than road, and pavement was in very poor condition. I was worried that cyclists might not expect me to be there.
		Volume of pedestrians on narrow path
	No	None seen
		Find it unsuitable
		None exist in Boroughbridge
		None in area
		I haven't really seen any cycle paths in the nearby towns!
		Because where we live I haven't one. I would use one if I came across one.
		Hardly any exists so find it difficult
		None exist
		Don't think there's any on my local route
Canada	Yes	Yes - used cycle path to move faster
		It was/is paved.
		I use a viper from teamhybrid.co.uk; without it, i cant see how i would have job, have friends, shop and hell even bother to live.
		Usually the pavement on the cyclepath is smoother than the sidewalk, because the former is made of asphalt and the latter is made of concrete with bumpy joints.
		most direct route to my destination
		Using the bicycle path is sometimes quicker than using the pedestrian path.
		less pedestrians, more efficient, much less bumpy; less painful to drive long distances
		walk my dog
		Less obstacles than the pavements (sidewalks), surface more even.
		I cannot remain silent (I cannot ignore this)! How to explain! The cycling on the greater part of the cycle paths goes on as if it were the Gilles Villeneuve circuit, without paying attention to anyone! For they believe they are King and Master of these paths! Yes the Speed, and the lack of citizenship [civility] are strongly evident. They appear from nowhere having no restriction on their departure, no lights in front and an electric battery at the rear, almost not on the

		sides, mostly with no warning horn [Klaxon] or small signalling bell to warn of their arrival for those with whom they are called to share the route as do the drivers of vehicles, cars, lorries, motorcycles, buses, trains, snowmobiles, mobility aids, mobility scooters, motorised wheelchair! Bizarre! Don't you think? But fortunately they have a helmet.
		There are no footpaths.
		It was there but it is rare (unusual)
		Even if I take them, it's not the way I favour, for I feel that I harm the cyclists, because my PMD is much slower than a bicycle.
		I have used the cycle path because when riding on the footpath, there are many cracks and bumps and the shocks are hard on the back. I can't travel on the roadway because it is dangerous for me on account of my slight visual deficiency.
		I don't often use cycle paths because they are a long way from my places (locations) but I like the cycle paths.
		Safer than the footpaths or the road!
		More practical and the carriageway is more pleasant to use than the footpath.
		The cycle path is adjacent to the footpath but it is new and doesn't have cracks every five feet.
		I use it to be able to pass over a motorway.
		To go out/to go for a walk/go for a ride
		To avoid the cars which hit me.
		Need to use cycle path when the footpath cuts off at an unwanted place. Need to use cycle path when it's too crowded because the sidewalks are not wide enough and the people are too badly brought up to allow me space.
		To get about we don't have footpaths everywhere so we are often obliged to use the cycle path
		So as not to be killed by careless motorists.
		The surface is smoother on a path so there is less of a shock to the spine (spinal column)
		Just because the pavements (sidewalks) are damaged.
		Less cars and I can go at my pace less traffic lights
		Yes but sparingly. I go there but I avoid the crowded cycle paths. [?]
		The cycle path is protected by reflective posts.
		Essential for access to the banks at Verdun. [river banks]
		It is more pleasant to ride on a cycle path than on a sidewalk. The state of the sidewalks is often poor.
		To go long distances: no cracks in the pavement that do harm, less crowding.
	No	Whatever exists in our city was not created for mobility aids to travel on because designers did not consider this form of transportation in the design.
		Because I have just obtained my motorised equipment.
		Too far, I would have to take the adapted transport (Paratransit) to access it.

Table 3.1: Reasons provided by British and Canadian respondents for using or not using a bicycle path

While it might be considered slightly excessive to include all of the comments received in the table above, it was felt useful to do so in order to allow the reader to fully understand the large scope of reasons for using or not using cycle infrastructure.

The reasons provided by respondents from both countries showed a good deal of similarity. In the UK, people frequently complained of poor pavements, which may cause them pain, and said that the cycle path usually offered a smoother surface. Several said that the cycle path was the only choice because of a lack of pavements, or because the pavement was blocked off due to construction, and others said that using it allowed them to stay off the road, enabling them to feel safer. British respondents also mentioned that the cycle paths were unobstructed, and allowed them to avoid pavements crowded with pedestrians. However, there were also some negative comments regarding its use, with several participants saying that they received abuse from cyclists (although one also received abuse from pedestrians when on the pavement), whilst another was concerned that cyclists might not expect their presence, although they still felt that using it was safer than the road. In terms of reasons for not using bicycle infrastructure, these were all due to it not existing in their area, while no-one cited its use being illegal as a reason.

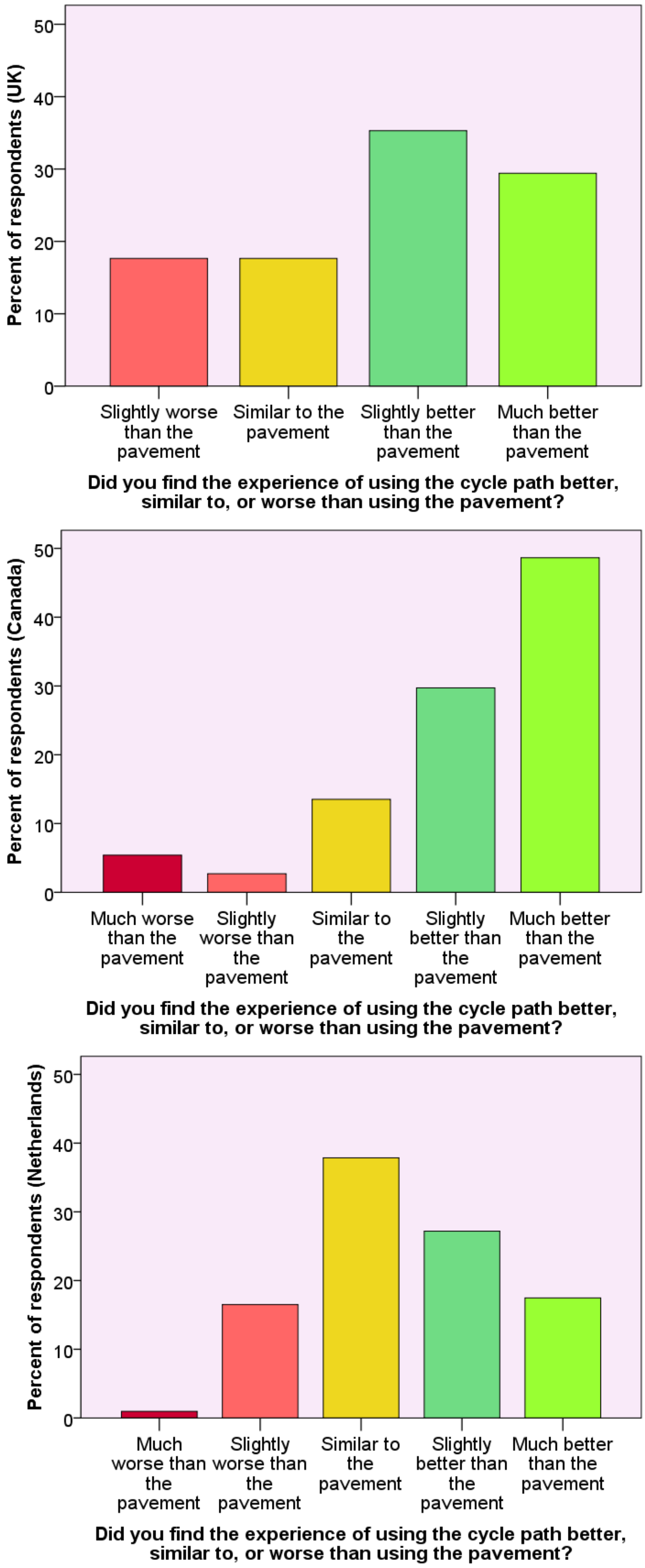
Canadian responses frequently highlighted benefits such as a smoother surface (causing less pain), less pedestrians and obstacles to get in the way, and not having to interact with road traffic. Other descriptives included "faster", "more direct", "quicker", and "more efficient". In terms of surface, one participant specifically stated that the asphalt of the cycle path was smoother to ride over than the concrete-slab pavements which have frequent joints. As in the UK, sometimes it was the only choice of infrastructure, or it allowed the PMD user to avoid the road when no pavement was available; fear of being hit by a car when using the road seems to be a real concern for some. Only one participant appeared to raise concerns about the speed of cyclists, although another stated that they were troubled that they might hold up cyclists due to their PMD being too slow. This highlights the need for cycle paths that are sufficiently wide to allow passing manoeuvres with room to spare. Lastly, another participant stated how the cycle path enabled them to use their Viper handcycle attachment, which they feel allows them to live a more complete life because of the independence it provides.

These qualitative responses highlight just how important cycle paths are to some PMD users, and how much of a better travel experience they can potentially offer compared to the pavement. Respondents found them useful for a variety of reasons, and even for those who perhaps prefer to use the pavement, they offer a useful and safe alternative to having to use the road when a pavement is not available or in too bad shape to use. Furthermore, the data here adds weight and verification to the infrastructure ratings given in question 17 and the barriers listed in question 13.

Is the experience of using bicycle infrastructure better or worse than that of using the pavement?

Question 20 on the UK/Canadian questionnaire, and question 21 on the Dutch questionnaire was probably the most important question for the study. Those in the UK and Canada who had said that they had used cycle infrastructure in the previous question were asked to rate the experience on a labelled likert scale, with a value of "1" corresponding with "much worse than the pavement", "2" for "slightly worse than the pavement", "3" for "similar to the pavement", "4" for "slightly better than the pavement", and "5" for "much better than the pavement". The Dutch question was effectively the same, although it was asked to all respondents as it was assumed that most had used cycle infrastructure at least once in the past.

Seventeen respondents in the UK answered this question. The most popular choice was "slightly better than the pavement", followed by "much better than the pavement"; no-one selected "much worse than the pavement". While it is perhaps somewhat erroneous to calculate an average score for a labelled likert, as each number corresponds to a particular answer, the mean will be provided anyway in order to give an overall indication as to whether the majority found the experience better or worse than using the pavement. For the UK, the mean was 3.76, closely corresponding to the mode. In Canada, 37 people provided an answer to this question, with the most popular response being "much better than the pavement", although two people said that it was "much worse than the pavement". The mean was 4.14. For the Netherlands, there was a slight surprise, with the most popular response being "similar to the pavement", followed by "slightly better than the pavement", although only one of the 103 respondents selected "much worse than the pavement". The mean score was 3.44. The following charts show the composition of responses.



Charts 3.45, 3.46, and 3.47: respondents' views on the experience of cycle infrastructure use as compared to using the pavement

When analysing the data from this question, an important thing to keep in mind is that the experience is *relative*. If the country already has excellent pavements, then even if the bicycle infrastructure were also excellent, then the experience would likely be somewhat comparable. In contrast, if the pavements are terrible, but the cycle infrastructure is of average quality, then the cycle infrastructure may nonetheless be rated as being much better. It seems that this may be the case here, and this theory can be supported by using the data from question 17. In question 17, British respondents gave pavements an average rating of 2.14, and cycle infrastructure a rating of 3.38, while Dutch respondents gave ratings of 3.67 and 4.16 respectively. Looking at these scores more closely, it should also be noted that the UK cycle infrastructure score was 1.24 higher than the pavement score, while the Dutch scores only varied by 0.49. Furthermore, these scores are justified by fewer Dutch participants reporting particular pavement-related barriers in question 13. Considering the responses to question 20 (Dutch question 21) within the context of this information, the relative rating of the cycle paths to the pavements for each country begins to make more sense. British pavements were given a poor score for their quality, while the cycle infrastructure was given an average score, and overall the cycle infrastructure experience was rated as being slightly better or much better than that of using the pavement by the majority of respondents. In contrast, the Dutch had rated their pavement quality as average, and their bicycle infrastructure slightly higher than this, and thus, the majority of Dutch respondents said that using bicycle infrastructure was similar to, or slightly better than using the pavements. Because of the Canadian translation error affecting the pavement scores in questions 13 and 17, it is not possible to give such a definitive explanation regarding the relationship between pavements and bicycle infrastructure there, although it is clear that the large majority of respondents there find using bicycle infrastructure to be much better or slightly better than using the pavement. Of course, for all countries, the actual explanation is likely more complicated and dependent upon a multitude of other factors, relating to everything from urban design and density to the speed limit for cars. However, the proposed explanation provided above to explain the relative experiences of using both types of infrastructure seems to fit in with the data obtained from other questions, and is also fairly logical.

There are a couple of key messages to understand from this data. The first is that in all three countries, people found using bicycle infrastructure better than using the pavement, meaning that bicycle infrastructure would likely be the preferred choice of infrastructure for the majority of PMD users in the majority of situations. Even though having what may be considered as good quality pavements in the Netherlands may erode some of the advantages of bicycle infrastructure, bicycle infrastructure is nevertheless still considered better. This brings about the second key point to understand. If one wanted to improve the mobility of PMD users and had to choose between upgrading the pavements and building cycle paths, then building cycle paths would most likely be the best option, since pavements can never offer as few barriers as cycle paths. Of course, there are many situations when pavements are still desired and the preferred choice, such as when going shop-to-shop or "strolling" with a pedestrian; furthermore, pavements are also used by people with all sorts of other impairments, carrying out all types of activities, and so as a result, pavements are still the more important of the two types of infrastructure. Ideally, pavements would be built to a high standard, following Universal Design guidelines, and would be complemented by high quality bicycle infrastructure, thus giving PMD users a choice of which they want to use depending upon the situation.

More bicycle infrastructure?

Question 21 (UK and Canada) and 19 (the Netherlands) asked if respondents thought that their city needed less bicycle infrastructure or more bicycle infrastructure. This was again rated on a scale of 1 to 6, with "1" being "less bicycle infrastructure", and "6" being "more bicycle infrastructure"; as in question 18, the 6-point scale was used in order to force respondents to choose either a greater or lesser outcome, not allowing them the option of being indecisive. Despite this, over half of the 49 UK respondents selected a score or 3 or 4, seemingly indicating that they either did not know, or did not feel strongly about the matter. Very few people selected a score of 5, but then another 25% chose a score of 6, indicating a strong desire for more of it. Therefore, British respondents could perhaps be grouped into two groups, one being unsure, and the other being strongly in favour of more. The mean score for the UK was 4.06, reflecting a general desire by the majority of participants for at least a bit more cycle infrastructure.

In Canada, 88% of respondents said they would like more cycle infrastructure, with 42% selecting a score of 6, and a mean score of 4.85, indicating a strong desire for further cycle network development in Canadian cities amongst PMD users. The strength of this finding is noteworthy, and Canadian planning officials should be made aware.

For Dutch respondents, there was a general desire for more bicycle infrastructure as well, although not quite as strong as that seen in the Canadian sample. The mean score there was 4.27, with no-one selecting a score of 1, one person selecting 2, and only 19% of the sample choosing a score of 3. Forty-three percent chose a score of 4, while 5 was the second-most popular answer. This response of the Dutch sample makes sense, reflecting the already relatively high provision of bicycle infrastructure, but with a desire for it to be further expanded or improved.

Impressions of an ideal cycle path

For the last question in the British and Canadian questionnaire, participants were shown the following photo of a cycle path in a Dutch town, with the idea that many people, especially those in the UK, would not have an idea of how good a bicycle path could potentially be.

Figure 3.3: photo from question 22 of the UK questionnaire

The only accompanying information provided was this: "The cycle path pictured is one-way, with priority over side-road traffic". Respondents were then asked to use a scale of 1 to 6 to rate how likely they would be to use a similar path on their PMD compared to the pavement, with "1" being "less likely" [to use than the pavement], and "6" being "more likely".
For the UK, around 10-15% of respondents selected each score for 1 to 5 inclusive, and then 41% selecting a score of 6. The mean was 4.53, and 75% chose a score indicating that they would be more likely to use it than the pavement. This result indicates that a cycle path that is wide, smooth, and potentially safer would be very attractive to British PMD users. In Canada, this desire to use such a path was even higher, perhaps because Canadian respondents are already more familiar with the use and characteristics of cycle paths, and so would fully

embrace a path with such a high quality design. Given the opportunity, 89% of Canadian respondents said that they would use such a path over the pavement, with a mean score of 5.11. In order to understand why respondents would or would not like to use such infrastructure, respondents were provided with a free-answer box allowing them to share their thoughts on the matter.

Thirty-four British respondents shared their reasoning. Of that number, ten responses indicated that the user would feel safer on the cycle path, seven mentioned a safety concern due to speeding cyclists, and four cited concern that cars might fail to give way to users of the cycle path. Furthermore, five respondents mentioned the benefit of its smoothness, while another five mentioned the lack of dropped kerbs and its lack of slope. Many others made general comments regarding how it looked like it would make travel easier, while some also noted the lack of pedestrians and its width. Despite this, some people said they would prefer to use the pavement as they often travel with someone else (of course, perhaps they had not considered that their partner might not be able to also use the cycle path with them on a suitable device), while one participant did make the point that a one-way cycle path could be problematic in certain cases. Overall, the background provided by these textual responses adds insight to why or why not British PMD users would like to use such a cycle path, and indicates that while it may look good to most from an engineering standpoint, concerns over fast or abusive cyclists may put some off using it, as might the risk posed by bad drivers at intersections with streets. However, in reality, in a society where everyone cycles such as the Netherlands, women cycle more than men, and cycling speeds are lower, with trips being made on utility bikes instead of racing ones. Therefore, it is likely that if these users actually had a chance to try out using it, many of their concerns would not materialise. Perhaps a cross-country exchange for PMD users between the UK and Netherlands could form an interesting future research exercise.

Thirty-four Canadians also wrote responses. Of these, seven mentioned that the cycle path would offer more safety and security, while five mentioned a risk posed by cyclists, although some of these comments were not about the risk of collision so much as the attitude of cyclists who do not want a PMD user using “their” cycle path, prompting one respondent to suggest that legislation should be passed that clearly states that PMD users have the right to use the cycle path. A couple of respondents made the point that a one-way cycle path would reduce the risk of collision with a cyclist, with the risk further abated due to the width of the path. Only one user was concerned about motorists failing to yield at the junction. Fourteen of the responses indicated positive feelings with regard to the smoothness, width, lack of obstacles and crowding, and not having to negotiate dropped kerbs. Other positive comments related to the overall design, clear markings, and colour of the path (the red-pink colour makes it immediately obvious as a cycle path). Lastly, one respondent commented on the requirement for snow-clearing in the winter; it should be noted that in northern Europe, there is specialist equipment which is designed for this task already being used. To summarise the results from Canada, responses were largely positive, but with some stating concerns over the attitudes of cyclists, although these were fewer in number than from the UK, as would be expected in a country where more users have actual experience of the use of the infrastructure. While some respondents did not particularly care whether they used the pavement or the cycle path, it is evident that the majority were in favour of their use, and appreciated the inclusiveness of their design.

The last question is, what do the respondents in the Netherlands, most of whom have the chance to use such high-quality infrastructure every day, have to say about using it?

The Dutch experience

The last question on the Dutch questionnaire asked respondents to write any thoughts that they had about the use of bicycle infrastructure compared to the use of the pavement with their PMD. Twenty-six provided answers to this question. Only four of these responses related to the danger posed by, or poor attitude from, cyclists: two mentioned students taking up the whole path by riding 3- or 4-abreast, and two the bad attitude occasionally arising from students and even adults, while one of them also mentioned the problems posed by kerbs at the edges of cycle paths that are not wide enough to allow easy passing. None of the respondents actually indicated that they had ever been in a collision with a cyclist, so it appears that the main concern generally relates to inconsiderateness; furthermore, none of the comments mentioned cyclists travelling at excess speed, backing up the earlier assertion that this would not be a problem in a cycling society. There were three responses citing problems with poor maintenance of cycle paths in their area, with two of these relating to tree root growth: "*Bike paths are often poorly maintained. Those who designed them are clearly not aware of the fact that trees have roots*". Some of the more rural respondents stated that they have to make use of "polder" access routes (often single-width local roads with little traffic). Another complaint was that on-road cycle lanes are often too narrow to offer proper safety. Generally though, participants indicated that they preferred the cycle paths to pavements, especially for their better surface, which some also commented was better than that of the

road as well, while others said that there was not enough cycle infrastructure in their area. Thus, overall, the comments that were provided indicated that bicycle infrastructure usually offered a preferable experience to that provided to using the pavement or the road in the Netherlands, whilst the only problems encountered were inconsiderateness, poor maintenance, and occasionally the path or lane not being wide enough.
However, perhaps the most telling response received was from a mobility scooter user, who said "*I consider a mobility scooter on the open road a substitute for a bicycle, and in a shopping mall for walking; my use of the road is accordingly*" (presumably a cycle path was not available). Thus, it is apparent that for such an individual, the device not only acts as their legs, but also as their main form of transport (a bicycle) when making journeys, and therefore it is important to ensure the provision of both suitable infrastructure and suitable buildings to allow for both uses.

Discussion and conclusion of results

When this project was started, it was never imagined that 223 responses would be received to the questionnaire from three countries, in three different languages. By this metric, the project has exceeded all initial expectations. However, it has taken a huge amount of work, cooperation, and assistance from people and organisations in each of the study countries to make this possible.

In terms of the demographic composition of the sample, the age of respondents was within the range expected, although the older samples obtained for York and the Netherlands are probably more representative of the national population of PMD users. While the differences in age for the different areas (especially between Reading and York) may have affected the how representative the results obtained are, as long as this variation is kept in mind when analysing the data, then there should not be a problem. The older age of the Dutch sample probably also had some effect on the type of PMDs owned (giving a larger number of mobility scooter numbers), although again, the Dutch sample is almost certainly the most nationally representative, so this is fine. Also, it helps to balance the somewhat wheelchair-heavy UK sample, although it would be best in future research to analyse whether the views of power wheelchair users vary much from those of mobility scooter users. A slightly higher percentage of female participants than male participants matches the trend seen in other studies, and is most likely an accurate representation of the overall population of PMD users.

The degree of urbanisation measure from the Netherlands proved to be a useful analysis tool; such a classification for UK and Canadian participants would have further aided data analysis and understanding. Overall, it appears that the goal of achieving an urban sample was achieved, as was the goal of sampling people from areas with few hills, making the data more comparable. While there were some rural users in the sample, they were a small minority, and the data they provided along with their views helped to provide a more in-depth understanding of issues, often providing a counter-point that allowed the effects of urban areas to be more readily apparent.

In terms of device ownership, the British sample was biased towards manual and Class 2 power wheelchair ownership, which is in large part due to the participants being selected through NHS wheelchair clinics. This meant an under-representation of the views of British mobility scooter users. In contrast, Canadian and Dutch respondents owned a more diverse mix of devices. Many of these devices had higher top speeds than those owned in the UK, with Dutch mobility scooters being particularly fast: the average top speed of these devices was about 10mph. Mobility scooters tended to be faster than power wheelchairs. As for car ownership and usage, a quarter of British and around one-third of Dutch respondents did not own or have use of a car, with that figure rising to 38% in Canada. In the Netherlands, access to use of a car was lowest in the densest urban area category, and highest (at 100%) for rural areas.

More importantly with regard to device ownership, 89% of Dutch respondents were satisfied that they owned all of the devices and cars that they wanted, compared to just 56% of those in the UK and Canada, despite the fact that on average, the Dutch respondents owned slightly less devices per person (1.4 versus ~1.7). This likely indicates that Dutch respondents own devices that better meet their needs. Specifically, many in the UK and Canada desired a faster device, while there was also a more widespread desire for car ownership in these two countries as well.

Interestingly, when examining identity as a specific type of user, British users were the most likely to consider themselves specifically as a PMD user, having their own particular requirements related to infrastructure, and less than a third identified themselves as a pedestrian. In contrast, the majority of Canadian respondents identified as either a pedestrian or pedestrian/cyclist depending on the context. In the Netherlands, users seemed almost equally divided between identifying as a pedestrian and identifying as a cyclist, or both, with less than a third identifying themselves as a PMD user. There could be many reasons for these differences, including the fact that more of the Dutch users probably have slightly more walking ability than those in the UK, and may have less “demanding” requirements (e.g. regarding smoothness or height of crossing controls) due to less severe impairments, although this is just conjecture. However, if the requirements of the users are similar, then it is hypothesised that perhaps a lack of quality infrastructure existing in the UK forces users to say that they have their own needs (which are not currently being met), whilst those in the Netherlands have their “pedestrian” and “cyclist” needs better met by the infrastructure (which may be built to Universal Design standards), and thus they may not recognise their special needs, because poor design has not caused them to notice. Therefore, those in the Netherlands might be happy to identify simply as a pedestrian or a cyclist, depending on the type of infrastructure that they are currently using.

One of the most important findings was that Dutch PMD users reported finding it much easier than those in the UK and Canada to travel to a shopping or recreational area using only their PMD, and moreover, the PMD was the most popular choice of transport for Dutch users to make such a trip. Interestingly, distance was described as a barrier to making one of these trips by more Dutch than British respondents, but other barriers were all chosen by less participants in the Netherlands than in the UK. This therefore implies that despite distance, infrastructure acts as a powerful enabler of mobility for PMD users.

Similarly, the Dutch respondents were the least likely to feel that good public transport was essential to their urban mobility, with only those living in the most dense Dutch urban areas saying that is was essential; despite this, the Dutch participants that did use public transport appeared to be very happy with it. In contrast, Canadian respondents were more likely to use public transport, and were much more likely to consider it essential, yet they were also very dissatisfied with its provision and quality. It seems likely that a dependence upon public transport, in an area where pavements and other built infrastructure are poor quality is likely to result in strong disappointment when public transport does not live up to expectations (e.g. one has to wait 20 minutes for another bus because the wheelchair ramp is broken). It should also be noted though that the Dutch and Canadian city-dwellers felt the least need for use of a car, so good public transport is likely required in order to meet most of the travel requirements (e.g. travelling across the city) that a car would normally meet. For the UK, the data reveals that access to a car or public transport is a necessity for many users just to be able to visit the shops or a recreational area, whilst the same is not true in the Netherlands with its high-quality pavements and cycle infrastructure. This car-dependence in the UK means that those without access to motorised transport will likely have to forego trips or plan them well in advance, not allowing for spontaneity and limiting social participation.

Concerning the quality of infrastructure and transport services, the Dutch seemed to be the most satisfied for all of the measures, including pavement quality, bicycle infrastructure, and even community transport. As mentioned before, the infrastructure ratings also correspond generally with journey habits, with the good infrastructure in the Netherlands often eliminating the need to use a car or public transport for many local trips. In contrast, in Canada the lack of accessible buildings and facilities placed limitations upon the choice of device usage. Canadian PMD users also felt the most ignored by planners and the local council, and Dutch users the least ignored, although none of the countries fared particularly well in this aspect.

Primary barriers reported by respondents matched those that were predicted based upon the literature review findings, although distance was also a barrier for many trips, and pavement parking was also more of a reported problem than the literature would seem to suggest. Almost all of the barriers were less frequently reported by Dutch respondents than by British or Canadian respondents. Also relating to barriers, Dutch respondents reported making changes to their travel plans due of crowded pavements less frequently than their British and Canadian counterparts, most likely due to either wider pavements or the ability to bypass the crowding by using the cycle path. Furthermore, Dutch and Canadian respondents considered the built urban environment to be less disabling than those in the UK.

Both Dutch and British participants showed a strong desire for improved pedestrian infrastructure over road and public transport improvements, but for the Netherlands this may be because public transport is already sufficiently good, while for the UK it likely represents the need to correct decades of neglect and underinvestment in pedestrian infrastructure.

Experience with bicycle infrastructure usage is lowest in the UK, due to a lack of its availability, whilst almost all Dutch PMD users appear to have used it before. Furthermore, 63% of Dutch PMD users said that bicycle infrastructure use featured at some point in at least half of their journeys. British, and especially Canadian, respondents both found bicycle infrastructure to offer a better travel experience than the pavement, whereas the amount of positive difference in the Netherlands was not quite as great, which is probably due to there being higher quality pavements in the Netherlands, thus limiting the potential of cycle infrastructure to excel in comparison. Respondents in all three countries also showed a general desire for the construction of more bicycle infrastructure, although a less strong result in the UK appears to be due to a lack of familiarity with cycle path use. For example, many in the UK made comments suggesting that they were apprehensive about the possibility of using urban cycle paths more often, due to potential risks posed by speeding cyclists and inconsiderate motorists at junctions. Dutch comments about their use would suggest that these concerns are unfounded though.

The main benefits that respondents in the three countries stated with regard to bicycle infrastructure usage were smoothness, width, not having kerbs to deal with, lack of obstructions, speed and directness, and safety. The main negative attributes were the attitudes of others, and occasionally, cyclists travelling too fast (Canada).

Thus, to summarise the findings, it would appear that Dutch PMD users receive or own the most suitable devices for their needs, have use of the best quality pavements, experience the best provision of high-quality bicycle infrastructure, have access to the most convenient dial-a-ride services, and also have the most accessible buildings out of the three study countries, and consequently, appear to experience the fewest barriers to their mobility in urban environments.

Based upon the results obtained from the data, the remaining two research questions can now be answered:

- **Does high-quality bicycle infrastructure feature any barriers or benefits that pavements do not?**

Bicycle infrastructure may feature some additional barriers, primarily the presence of cyclists who are inconsiderate at times; some users may have a greater level of safety-related fear when using a cycle path than when using pavements. Of course, any barriers that cycle infrastructure does not typically feature, such as bumpy travel surfaces, could be considered as a benefit not usually offered by the pavement. However, in terms of unique benefits, the primary one offered by bicycle infrastructure compared to the pavement is the potential to travel at higher speeds, and doing so in relative safety when compared to the roads.

- **When (in what situations) might bicycle infrastructure benefit PMD users, and when might it not?**

Bicycle infrastructure appears to be ideally suited to situations where the PMD user desires to travel quickly and directly between locations in safety and comfort, effectively allowing the PMD to be used as a substitute for a bicycle (or where the PMD is a handcycle, tricycle, or similar, then the infrastructure acts as the primary enabler of its use in all situations). Bicycle infrastructure may not be so useful for when the user wishes to move as a pedestrian, such as when window-shopping for example; in these cases, high-quality pavements should be provided. Furthermore, bicycle infrastructure may not be so suitable for users who are particularly concerned about the minor risks posed by cyclists, or for those using devices that move very slowly (e.g. walking pace).

Conclusions

This study has attempted one of the most comprehensive investigations ever carried out into the use of wheelchairs and other personal mobility devices from a transport planning perspective. As such research could easily have comprised a comprehensive PhD thesis, the time pressures to get the project completed on-time have been immense, especially considering the multiple delays encountered in obtaining final datasets. As a consequence, there are a few sections of the literature review that have been omitted or are not as complete as desired, and the discussion of the data, especially with reference to the literature, has also not been completed to the desired standard or level of refinement. Nonetheless, it is hoped that the reader will have enjoyed reading the document, and found the literature background and analysis of findings from the questionnaire both interesting and insightful.

The literature review provided a technical background on the concepts and terminology important to this project, as well as on the specifications of devices. Demographic and health information on the profile of a "typical" PMD user was also provided, and this helps to justify the urgency with which the problems and barriers facing PMD users need to be addressed, as the ageing population of many countries means that PMD user numbers will increase rapidly in coming years.

The literature review also uncovered the failings of the built environment in meeting the mobility needs of PMD users, who frequently face barriers to efficient, safe, and comfortable movement when travelling, especially on the pavement. However, it was also found that potential solutions may exist, not only in the form of improvements to pavement design standards, but also in the form of a different type of infrastructure. Bicycles share many technical similarities with PMDs, and infrastructure that has been optimised for their use may also work well for PMDs, by providing an almost barrier-free environment and enabling greater travel speeds. From the literature, it also became clear that a better method of assessing the suitability of infrastructure for use by wheelchairs and other PMDs was necessary, and hence it was decided to propose a new level of service indicator, named Wheelchair Level of Service, or WLOS. From the findings of the literature review and the data analysis, it is suggested that WLOS should likely include parameters related to smoothness/vibration, clear width, pedestrian flow as a percentage of pedestrian design capacity, dropped kerb and pedestrian crossing frequency (distance separation), the presence of local laws on pavement parking, the "speed limit" of the infrastructure itself (e.g. "walking pace") or its design speed, and the speed limit of the adjacent road combined with the distance of separation, amongst other things. However, determining these parameters should form the basis of several future studies.

The full findings from the questionnaire have already been discussed in the conclusion of the previous section and therefore will not be repeated. However, the key findings are these:

1) PMD-only travel is easier, and the most preferred travel choice for making every-day urban journeys in the Netherlands
2) Dutch PMD users also appear more satisfied that their mobility device needs are being met than their British and Canadian counterparts
3) Distance was more frequently named as a barrier by Dutch PMD users than British ones, yet PMD travel was easier in the Netherlands, which implies that infrastructural barriers are the true cause of difficult PMD-only travel.
4) Access to use of a car or good public transport was more important for British, and to some extent, Canadian PMD users due to infrastructural barriers and the inaccessibility of locations like supermarkets that are only accessible by car.
5) Bicycle infrastructure, even of sub-par quality, is preferred to pavement use by the majority of PMD users in all three study countries due to its lack of barriers along with its advantages in comfort, speed, and safety.
6) There appears to be a net safety benefit to PMD users making use of bicycle infrastructure for both themselves and others, although this would require further investigation.
7) To gain full benefit from improved street infrastructure, the accessibility and convenience of buildings and facilities must be ensured to as to not limit the choice of device usage.
8) The full support and compliance of planners, officials, lawmakers, and others in the government will be required to improve current conditions, and education, participation, and financial investment will also be part of the solution.

In conclusion, bicycle infrastructure offers a better solution to the mobility needs of PMD users in urban environments; by removing barriers, disability is also removed, thereby allowing PMD users to travel to all the same destinations, in the same amount of time, and for the same low cost as other inhabitants of their city.

Following these conclusions, the author proposes the following recommendations of action, as well as suggestions for future research, arising from this study:

Recommendations arising from this study

1) Create a British equivalent of the Dutch NPCD (national panel of people with disabilities and chronic illness). The existence of this organisation and its large panel of members more-or-less guaranteed getting a nationally representative sample, and also enabled the provision of high-quality demographic data and other metrics, such as the degree of urbanisation of where the respondent lives. Having such a panel of individuals in the UK would greatly facilitate the process of carrying out research involving those with physical and other impairments.

2) Create a new level of service indicator, Wheelchair Level of Service (WLOS), to be used as a general measure of infrastructure quality as relates specifically the needs and desires of Personal Mobility Device users.
3) Better educate and inform planners, designers, architects and officials regarding the needs of PMD users, and guarantee stakeholder consultations early in the design stage of any project.
4) Create official government best practice Universal Design guidelines and requirements for pavement and bicycle infrastructure design and engineering.
5) With immediate effect, allow all PMDs to legally use bicycle infrastructure
6) Once more suitable (better designed) infrastructure exists, revise the maximum allowable speeds upwards for powered mobility devices to allow faster travel, and also allow two-person PMDs
7) Design homes and businesses with PMD accessibility in mind, with (fire resistant) device storage and charging areas.
8) Invoke a nationwide ban on all pavement parking
9) Pursue anti-discrimination legislation to help guarantee high quality, Universal Design pedestrian and bicycle infrastructure
10) Optimise funding support mechanisms for the provision of ideal devices to meet users' needs: clearly the desire of those in the UK to own more devices that go faster indicates that the devices owned are not satisfactory.

Limitations of the study

1) The user samples across the countries were not uniform and potentially not representative, especially in the UK.
2) There were a few translation errors in the questionnaire limiting the applicability of some of the results.
3) There was not sufficient time to fully analyse the data and perform more advanced statistical tests.
4) The questionnaire and analysis relied upon stated and revealed preferences rather than actual behaviour.
5) More qualitative data would have been helpful in understanding certain trends in the data.
6) Having a degree of urbanisation metric for British and Canadian respondents' locations as in the Netherlands would have further aided the data analysis.

Suggestions for Further Study

1) Conducting a cost-benefit analysis examining a 'business as usual' scenario versus one in which there is greater investment in pedestrian and bicycle infrastructure with regard to PMD users and based upon factors related to societal inclusion and participation may help to provide a better understanding of the economic case for doing so.

2) Carry out extensive research into issues related to the creation of the new WLOS indicator including an analysis of infrastructure design guidelines and research to gain a detailed understanding of PMD user travel patterns and characteristics.
3) Conduct research to understand how well current pedestrian infrastructure in the UK meets best practice Universal Design recommendations.

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Appendices