MOBILITY FOR ALL: HOW BICYCLE INFRASTRUCTURE GREATLY FACILITATES MOBILITY FOR THOSE USING WHEELCHAIRS, MOBILITY SCOOTERS, AND OTHER PERSONAL MOBILITY AIDS

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ABSTRACT

The population of the UK and many other developed countries is rapidly ageing, and with this, the number of people who are living with mobility impairments is growing. Furthermore, an increasing number of people who have difficulty walking are deciding to use mobility scooters or other powered mobility aids, and with double-digit annual sales growth of these devices in some countries, providing appropriate infrastructure and transport options for their use is becoming ever-more important. Research on these Personal Mobility Aids (PMAs) to-date has been fairly scarce, with most of the existing focus being on their use from a medical or social science perspective. While quite a few of these studies have recognised the importance of barriers in the built environment, none have truly examined PMAs from a transport planning perspective, which is perhaps surprising when considering that the ultimate purpose of PMAs is to provide mobility. This paper examines a diverse selection of existing literature on PMAs to provide background on their use and an overview of the intangible and infrastructural barriers which they face, before presenting a brief overview of the results from a multi-national study of PMA users that explores whether bicycle infrastructure is able to overcome some of the most frequently encountered infrastructural barriers.

1. INTRODUCTION

The use of wheelchairs and popularity of mobility scooters is growing rapidly, yet these mobility devices are seemingly the only category of transport that has yet to be fully examined by research in the field of transport planning. These devices, designed to increase the mobility of those with mobility impairments, can be grouped together and classified as Personal Mobility Aids (PMAs), although they are also often referred to as Personal Mobility Devices (PMDs), a designation sometimes shared with additional devices like bicycles, Segways, and foot scooters. The growth in PMA use is primarily being driven by the ageing of populations, causing a rise in the number of people living with mobility impairments, but improvements in device technology and a reduction in social stigma surrounding the use of mobility scooters also appears to be playing a role. Despite the increase in PMA usage, the infrastructural demands of these devices have never been fully assessed, especially not from a transport planning standpoint; the reason why is not immediately obvious, although this may be partly due to many seeing them as medical devices, rather than as a form of transportation.

This conference paper will provide a transport-planning focused overview surrounding various aspects of PMAs, including device specifications and the infrastructural barriers to their use, before presenting the findings of a multinational study that assessed the potential of bicycle infrastructure to overcome these barriers that PMA users face.

2. METHOD

A thorough literature review of around 120 journals, books, reports, and news articles was completed for this study, the most relevant findings of which are outlined in several of the following sections. Following this, the findings of a study that was carried out in three countries (the UK, the Netherlands, and Canada) will be presented and related to the literature where applicable. This study involved the distribution of a questionnaire to over 600 PMA users in the study countries, with 223 usable responses received (108 Netherlands, 54 UK, 61 Canada). The questionnaire was tested extensively, including a pilot that went out to approximately 10 PMA users in the UK. The questionnaire was then translated into both Dutch and French. The questionnaire was distributed in the UK via the NHS wheelchair services in Reading and York (which involved a thorough ethics approval process), in the Netherlands by NIVEL (the Netherlands institute for health services research) via the National Panel of people with Chronic illness or Disability (NPCD), a nationally representative panel of over 3,000 people, and in Canada via a research group organised by a professor at the University of Sherbrooke. The questionnaires were administered both online and by paper in the UK, while they were completed online only in the Netherlands and Canada; translation of responses back into English was also carried out by professional translators.

3. CONCEPTS, DEFINITIONS, AND BACKGROUND INFORMATION ON PMA USE

3.1 Concepts and Definitions

This paper assumes the social model of disability, which advocates the idea that disability is largely a consequence of societal oppression, where an “ableist society” does not design for those that do not meet a particular “perfect” body type, thereby making the lives of those with bodies that are limited in some way more difficult (Korotchenko and Clarke, 2014). Sapey, Stewart and Donaldson (2005) concisely sum up the distinction between impairment and disability in this context, stating that impairment “refers to the physical problems that may give rise to a person’s immobility, while disability refers to the limitations that are caused by the failure of a society to take into account the presence of wheelchair users within it”.

While the advent of virtual (internet) mobility and home deliveries has effectively increased accessibility of many services, mobility is still both desirable and essential for many everyday activities. To be able to provide mobility though, each part of the journey, or 'transport chain', must be accessible, from bus stops and buses to the requirement for uninterrupted footpaths that connect them with origin and destination.

3.2 Personal Mobility Aid types

While there is not a common standard definition of what constitutes a PMA/PMD, Bruneau and Maurice (2012) provide the following: 'A *Personal Mobility Device* (PMD) is any relatively small, wheeled device that provides personal mobility and can operate on nonmotorized facilities'.

In 1655 watchmaker Stephan Farfler created what many consider to be the first self-propelled wheelchair, a three-wheeled device propelled using a hand-crank (Encyclopaedia Brittanica, 2014a). The use of wheelchairs as medical devices increased rapidly from the 18th century following the US Civil War and subsequent conflicts, and more recent improvements like rubber tyres, reductions in weight, and increases in portability have improved their practicality (ibid.). In the UK, there are three different classes of mobility device: Class 1, such as manual wheelchairs, which are not mechanically propelled; Class 2, which are mechanically propelled and have a top speed of up to 4mph; and Class 3, which can attain speeds of up to 8mph and must have lights and a horn (HM Government, 1988). While Class 2 devices can only use the footway except to cross the road, Class 3 devices can use either, but only at up to 4mph on the footway (Barham, Oxley and Board, 2005). Maximum speeds of these devices vary notably in other countries, often depending on legislation. The following are brief descriptions of the most relevant types of PMA.

Attendant-controlled wheelchair

These popular wheelchairs usually lack the large rear wheels of self-propelled chairs, thereby requiring someone to push, and consequently they could be considered to offer the least personal mobility.

Self-propelled manual wheelchair

These wheelchairs feature large rear wheels with a push-rim that allows the user to self-propel; some amount of fitness and upper-body strength is required for use. Due to the repetitive nature and inefficiency of pushing the hand-rim forward, and the anatomical design of the shoulder, frequent use of these wheelchairs can cause fatigue, pain, and overuse injuries (Vegter et al., 2010; Arnet, 2012).

Power wheelchair, a.k.a. motorised wheelchair

A wheelchair with an electric motor and battery pack, normally designed to be used full-time without assistance from others, with control typically being via an armrest-mounted joystick; however, many are highly customised to the needs of the user: for instance, some can be controlled by the user's mouth via a sip-and-puff system. They range from smaller basic indoor models with a short travel range, up to large outdoor devices (which may be too big to use inside) that have features such as reclining seats and kerb-climbers (Campbell, 2012).

Mobility scooter, a.k.a. motorised scooter

Mobility scooters vary in design, and there is no exact definition of what constitutes one, so Rutenberg et al. (2011) 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"

The range of mobility scooters can be up to 50 miles per charge, although most have a similar range to power wheelchairs (~10 - 25 miles). Sizes vary, with some being up to about 1,500mm long by 750mm wide. A lack of standardisation with regard to the size of these devices, however, may be problematic when it comes to transporting them on buses or trains, which has led to calls for a standard size guideline for public transport-friendly devices (HCTC, 2010). Device speeds in the UK are as mentioned previously, but in many countries they tend to be faster than power wheelchairs, attaining up to 12mph or more.

Handcycle

There are two types of handcycle, the more common being a wheelchair-attachable device that effectively turns the wheelchair into a hand-powered tricycle, often equipped with pedelec-style electric assist. Handcycles offer greater mechanical efficiency (9-15% vs. 6-11% for a wheelchair), lower peak forces upon the body, and less physiological strain (Arnet, 2012; Vegter et al., 2010). Due to their size, manoeuvrability, and bicycle-like speed, the ideal infrastructure for handcycle use would not feature tight radii, interaction with pedestrians, or any of the obstructions usually present on footways.

Pedelec/e-bike

While not typically considered a mobility aid, pedelec bicycles (bicycles that feature electric power-assist) or tricycles may represent a good alternative to a mobility scooter for those who cannot walk far, and therefore this option should be considered when thinking about personal mobility for an ageing population.

3.3 Demographics and Medical Conditions associated with PMA use

The concept of Universal Design is based on designing infrastructure and facilities for everyone, regardless of age or ability. Therefore, it is important to understand specific user requirements and recognise that PMA users do not comprise a homogenous group in order to meet the aims of Universal Design.

Demographics

Perhaps the most important trend in relation to the topic of PMA use is that the incidence of mobility difficulties is largely a function of age. In England, 3% of the 16-49 age group have mobility difficulties, increasing to 31% of the 75+ age group; this translates to around 9% of England's population over the age of 16 (DfT, 2014). When designing infrastructure, it is also worth noting that cognitive, visual, and psychomotor abilities all decline with age, and some illnesses that cause mobility impairments may further decrease these functional abilities (Eby, Molnar, and Kartje, 2009). Because some older users may not be able to drive a car, it is even more important that they be able to access urban locations using only their PMA (possibly in combination with public transport). As might be expected, previous studies involving PMA users show the average age to be well over 50 years old, although an exact figure in not known.

Gender issues may also be worth considering: Garrard, Rose and Lo (2008) found that female cyclists had a stronger preference for off-road paths, demonstrating greater risk-aversion to traffic; it does not seem unreasonable to extend this idea to PMA use, and therefore by designing for the safety concerns of women, everyone will benefit from the greatest levels of safety.

Medical conditions associated with PMA use

Other than age and gender, another user-related aspect worthy of consideration is that of the medical conditions associated with PMA use. It could be considered that there are three categories of PMA user, based on walking ability: short term temporary users, who are immobile due to an accident, operation, or terminal illness; long term *occasional* users with limited walking ability, whose requirements for PMA use may vary in some cases upon a fluctuating condition; and long term *full-time* users with no 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). Several studies (Edwards and McCluskey, 2010; Korotchenko and Clarke, 2014; Sapey, Stewart and Donaldson, 2004; Steyn and Chan, 2008) noted the medical conditions of users that resulted in mobility impairment; from them, it appears that arthritis is the most common condition, especially for mobility scooter users, while stroke, neurological disorders (such as multiple sclerosis, Parkinson's, cerebral palsy, and dementia), and cardiovascular diseases seem to account for most of the other common causes of mobility impairment. Specific limitations that are associated with some of these medical conditions should be taken into account in infrastructure design to make it accessible for all.

3.4 Growth in PMA use

How many PMA users are there?

At present, there are effectively no accurate official statistics on the number of PMAs/PMA users in any country, partly because neither device registration nor sales reporting is required in most places. It is worth noting that Rica (2014b) found that 48% of mobility scooter users they surveyed also owned a wheelchair.

In the UK, the NHS's purchasing agency (who likely provide the majority of wheelchairs) claimed a "client population" of around 900,000, while the Medical Devices Agency gave a figure of 1.15 million (Sapey, Stewart and Donaldson, 2004; Barham, Oxley and Board, 2005). The market is continuing to grow at 5-10% per year for both power wheelchairs and mobility scooters (Rica 2014a). Rica (2014a) estimates that there are now up to 350,000 mobility scooter users in the UK, and based on a scooter to power wheelchair sales ratio of about 4:1, it could be projected that there are perhaps 100,000 power wheelchair users, although it should be kept in mind that some people own both types of device. Consequently, a figure in excess of 1.2 million PMA users in the UK, including around 450,000 powered-PMA users, seems quite likely, with an increasing percentage of them owning powered devices. This translates into approximately 1.8% of the UK's total population using a PMA.

Expected and potential growth in user numbers

Because most health conditions that result in mobility difficulties and PMA use are age-related, a baseline model of future PMA user numbers could be created based upon the estimated ageing of a country's population; taking into account the more rapid growth in powered devices would also be useful in determining infrastructural requirements.

To provide an example of potential base growth, in 2012, there were about 14.5 million people over the age of 60 in the UK; by 2050, this number is predicted to increase to 21.5 million, or an increase of around 50% (UNDESA, 2012). Assuming that the number of people who experience mobility difficulties increases linearly with age-based population growth, then the number of PMA users should increase from the previously estimated 1.2 million, to 1.8 million – and this is before taking into account increasing rates of mobility scooter uptake and the other aforementioned variables. Consequently, the issues faced by PMA users will increasingly difficult for policymakers, planners and designers to ignore.

4. BARRIERS TO PMA USE

4.1 Intangible Barriers to PMA Use

In their studies of PMA users, Sapey, Stewart, and Donaldson (2005) and Korotchenko and Clarke (2014) found that most respondents 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. Broadly speaking, it could be considered that there are two categories of barrier to PMA use: intangible barriers, and infrastructural barriers. Intangible barriers could include legislation, social barriers, financial constraints, media stigma associated with PMA use, and barriers related to living arrangements, whilst infrastructural barriers relate to physical constraints imposed by the built environment and related safety concerns. Other potential barriers also include hilly terrain, regional climate conditions, and social barriers such as abusive, threatening, or patronising behaviour aimed at PMA users. A brief overview of some of the more relevant barriers is provided below.

Legislative barriers

Legislative barriers to PMA use may restrict where they can be used, how they can be used, and in some cases, who can use them. Specifically, there are laws that relate to the types of infrastructure that can be used, the speeds at which devices are able to travel, general device specifications, and even minimum user requirements.

Typically, the laws of most countries consider PMAs to be classified as either a pedestrian, bicycle, or road-going vehicle, often depending on the type of infrastructure being used; rarely are they considered to be their own category of vehicle. Furthermore, the speeds that PMAs are permitted to travel at typically relate to the type of infrastructure being used (e.g. pedestrian), and appear to be set arbitrarily rather than, for example, being based upon user or device capabilities.

Bizarrely, in the UK, Class 3 PMAs are permitted to use dual carriageways, yet they are not permitted to use cycle paths or bus lanes. Such a ban on the use of bicycle infrastructure is both illogical and discriminatory, since many motorised PMAs are similar in size and speed to bicycles, and would also benefit from the protection and directness that bicycle paths offer; additionally, research in Canada by Bruneau, Crevier and Maurice (2013) has shown that, in practice, PMAs travel faster on bicycle infrastructure than on both footways and roads, thereby offering a mobility benefit in terms of speed.

Legislation has also been used in some countries to limit the design of PMAs to a certain specification, which in the case of the UK rules out multi-person designs. Consequently, the more sociable PMAs seen in the Netherlands that cater for two people, such as wheelchair bikes, dual-seat mobility scooters and side-by-side tandems are likely not permissible under UK law, which could be seen as a form of discrimination against those with mobility limitations, since most other forms of transport vehicle are available in multi-seat versions. Conversely, it could be argued that multi-person PMAs would be too large to use the footways (Barham et al., 2006) and would cause an obstruction if used on the road, and that it is the presence of bicycle infrastructure in countries such as the Netherlands that makes the use of such large devices feasible.

Lastly, legislation exists relating to user requirements. For example, in the UK, one must be fourteen years old to operate a Class 3 device, and while there is no requirement for insurance (unlike in the Netherlands), minimum eye-sight requirements are being considered for Class 3 mobility scooters (HM Government, 1988; Baker, 2012).

Public transport barriers

Due to their size, mobility scooters are often too large to fit on buses or trains. Furthermore, it is common to find reports in the news and academic literature of wheelchair users being unable to board buses, either because the wheelchair space(s) are already occupied, or because the wheelchair ramp is inoperable. Consequently, many PMA users may have to wait twice the normal headway to board a bus, and in some cases, may not be able to board at all. So, despite the fact that those with disabilities place a greater importance on public transport, and are much less likely to own a car than able-bodied people (Jolly, Priestley, and Matthews, 2006), it is often much less practical for them to use it, and if the footways leading to bus stops are not accessible for PMAs, then public transport becomes even less of an option.

Planning barriers

A theme that turned out to be common within the literature was that wheelchair users 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. For example, respondents to the study of Imrie and Kumar (1998) indicated they felt ignored: “the professionals all sit there in the town hall and never listen to anything we say”, and patronised: “as soon as they see you sitting in a wheelchair they presume you’ve got no brain”, while others suggested that the planners and architects who design the built environment have limited awareness about disabilities, 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”.

Barriers imposed by living arrangement

Unless a home is adapted with features like wider doorways, then either the ability to own a larger wheelchair may be restrained (thus potentially limiting speed/capability or medical features), or the choice of homes in which to live could become limited (unless one is able to use two sizes of wheelchair). Mobility scooter users may also face some constraints on either their device or living choice: because the device is often too large to bring inside, parking and charging is an issue, especially in apartments, where they are usually prohibited from being parked in communal areas due to the fire hazard posed. Thus, it can be seen that living arrangements may have a negative impact on an individual's mobility due to it constraining the types of device that can be owned.

4.2 Infrastructural Barriers to PMA use

The importance of limiting infrastructural barriers to a minimum cannot really be overstated. In the USA, the Americans with Disabilities Act has made it so that cities have little choice about whether to make streets accessible for those with mobility impairments (Dunham, 2011), whereas in the UK, the Disability Discrimination Act is less prescriptive, requiring *access* to facilities, goods, and services, rather than *accessible environments*, and hence, why provision of blue-badge parking spaces and low-floor buses may be viewed as doing enough. The British approach fails to take account of a plethora of issues, however. For example, a synthesis of research by Pearlman et al. (2013) showed that shock and vibration (from poor footway surfaces) can cause wheelchair users 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. Thus, infrastructural barriers may not only limit or deny the right to basic mobility, but also impose pain on people in the process.

There is an extensive variety of barriers that are encountered by PMA users when moving about urban areas, so numerous that they cannot all be listed. However, to give an idea of some of the barriers most commonly mentioned in the literature, the following table contains a list of barriers the authors that report them in their studies.

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 footway	Lavery et al., 1996; Imrie and Kumar, 1998; Meyers et al., 2002; Rutenberg et al., 2011
Cars parking on and obstructing the footway	Sapey, Stewart and Donaldson, 2004; Barham et al., 2006; Goodwill, 2014
Footway too narrow for device	Barham et al., 2006; Bromley, Matthews and Thomas, 2007; Kasemsuppakorn and Karimi, 2009
Poor travel surfaces (broken footway surface, uneven footways, 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
Footways 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 PMA 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
Footway 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: Infrastructural barriers to PMD use as reported in the literature

While this table does not provide a break-down of the percentage of people in each of the studies that reported a barrier, it is quite apparent from the number of studies citing issues concerning surface quality of the footway, obstruction/crowding of the footway, and those related to dropped kerbs, that these are likely to be the types of barrier most commonly encountered in countries such as the UK. However, the study by 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 was as follows: crowded footways (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 footways (32.6%), and busy roads (36.8%). This therefore adds evidence to the idea that issues with dropped kerbs, crowded/narrow/obstructed footways, and uneven surfaces are some of the most problematic or most commonly encountered types of barrier.

5. POTENTIAL SOLUTIONS: FINDINGS FROM THE QUESTIONNAIRES

5.1 Sample Demographics and Device Ownership

The sample obtained via the questionnaires appears to have been fairly representative in terms of age and sex (the largest number of respondents were from the 45-64 age group, followed by the 65+ age group; 54.9% of respondents were female). Just under 40% of people in the study countries lived alone, and the large majority of respondents (very roughly, 85%) were deemed to live in areas that could be classified as urban to some extent.

In the UK, 83% owned a manual wheelchair, 58% owned a Class 2 power wheelchair, 10% owned a Class 3 power wheelchair, and 17% owned a mobility scooter, while 6% owned a device such as a handcycle or trike. In Canada, 23% owned a mobility scooter, while ownership of power wheelchairs was less biased towards the slower 4mph models, with some owning devices capable of more than 8mph. The Dutch sample was older than the overall sample in the UK or Canada, and this seems to have resulted in a different, and perhaps more representative (of all PMA users) device ownership: only 40% owned a manual wheelchair and 17% a power wheelchair, whilst 63% owned a mobility scooter. The top speed of devices in the Netherlands also varied more greatly, with a mean top speed of 6.5mph for power wheelchairs and 9.8mph for mobility scooters (with the fastest models being able to reach about 16mph). Overall device ownership in the UK was over 1.7 in the UK and 1.6 in Canada, whilst the Dutch owned on average only 1.4 devices per person. In the UK, 25% of respondents did not own or have access to a car, whilst 38% in Canada and 30% in the Netherlands did not own or have access to one. Interestingly, despite those in Canada and the UK owning the most devices, only 56% were happy that they owned all the PMAs and cars that they wanted, whilst 89% of Dutch respondents were satisfied with their level of PMA and car ownership. When asked what other devices they would like to own, the most commonly selected answers were power wheelchairs or scooters that could travel at 8mph or more, a handcycle, and a car to be driven by them or someone else. This finding points towards an unmet need for faster PMAs in the UK and Canada, as well as a requirement for private cars, perhaps due to shortcomings in pedestrian infrastructure or public transport and the slow speed of their PMAs. The most common reason by far for not being able to own these additional devices was lack of funding, followed by lack of storage space at home.

5.2 Measuring mobility

When asked about how respondents liked to travel when going shopping, 62% of those in the UK said that they prefer to use a PMA + car combination, while 24% said they would take their PMA only, and almost no one said they would take their PMA + public transport. In Canada (which had more of the sample living in large urban areas like Montreal), 33% said they would use the PMA + car combination, 23% PMA + public transport, and similar to the UK, 23% said they would use their PMA only. The Netherlands showed a different preference, with 49% saying they would use their PMD only, and 32% PMD + car; few said that they would use public transport. PMA + taxi/community transport was chosen by between 6% and 12% of people in each country. Thus, it can be seen that in the UK and Canada, over 75% respondents were reliant on some form of road-based motorised transport to make their shopping trip, while only half of those in the Netherlands were. Respondents were also asked how they would travel to their favourite recreational area, such as a park or sports facility, and the ranking of preferred mode choice/combination was the same as for shopping in all three countries, with similar percentages selecting each mode.

Respondents were then asked to rate (on a Likert scale of 1 to 6, with 1 being “very easy”, and 6 being “prohibitively difficult”) how hard they would find it to travel to their local shops using *only* their PMA. The mean value for the UK (min. 1, max. 6) was 4.2, while for Canada it was 3.63, and for the Netherlands 2.44, indicating that they found it the easiest. This difference is made very clear graphically by the following two charts of the scores for the UK and the Netherlands.

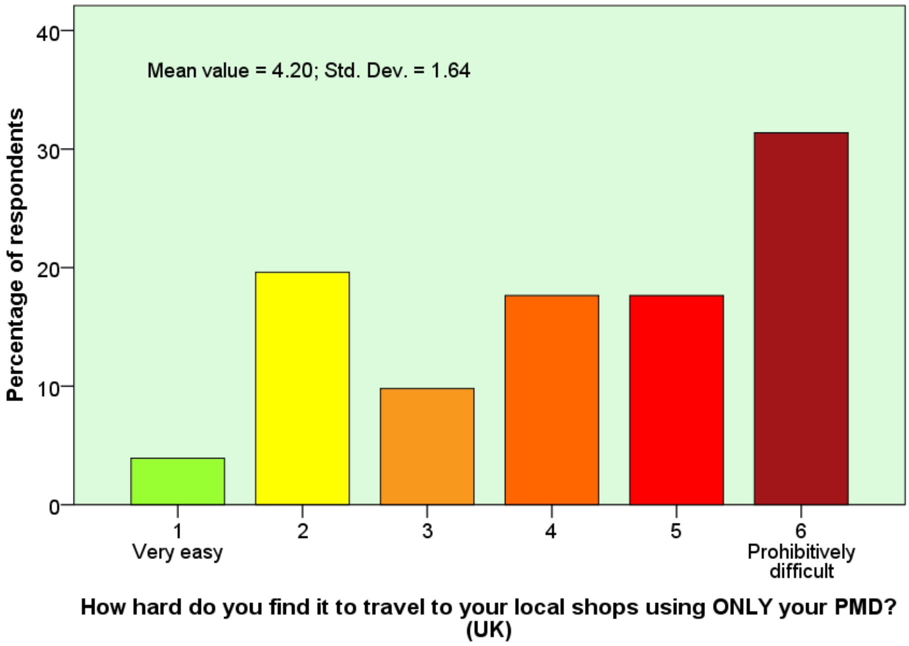

Chart 1: Difficulty in travelling to the local shopping area using only a PMA (UK)

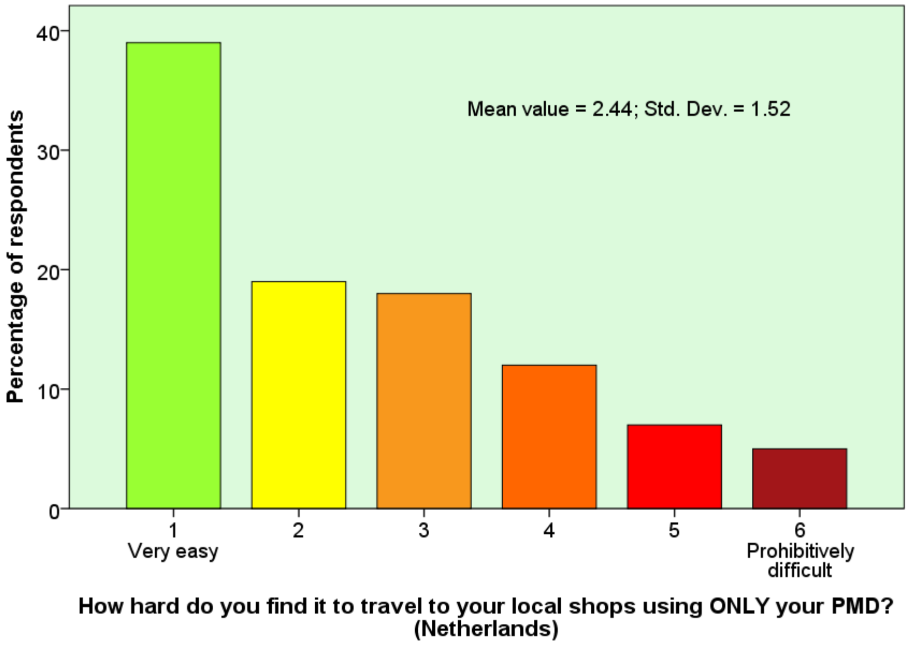

Chart 2: Difficulty in travelling to the local shopping area using only a PMA (the Netherlands)

People were then asked about difficulty in making a PMA-only trip to their favourite recreational area, again on a scale of 1 to 6. The mean score for the UK was 4.76, while it was 4.11 for Canada and 3.04 in the Netherlands, once again indicating the difficulty of using a PMA to get about in the UK, compared to the relative ease of using one to travel in the Netherlands.

Questions on whether it was necessary to have access to a car and access to good public transport were then asked, with three answer choices given: essential, somewhat necessary, or not necessary at all. Combining the totals for both questions (effectively asking the necessity to have access to some form of road-based motorised transport), the pattern was once again the same: considerably more people in the UK and Canada found these to be essential than in the Netherlands, whilst those saying that they were not necessary at all were more than four times as many in the Netherlands compared to the UK. This really cements the conclusion that PMA-only travel is far easier in the Netherlands than in the other study countries. One of the possible reasons for this is that the devices in the Netherlands were found to have higher top speeds than in the UK or Canada. However, anecdotal evidence from the literature, and from the author's own observed experiences on study tours in the Netherlands point towards a more powerful explanation: that bicycle infrastructure plays a significant role in overcoming the infrastructural barriers presented by poorly designed or maintained footways. Hence, several questions were asked in the questionnaire on the topic of bicycle infrastructure.

5.3 Understanding barriers

The analysis of how bicycle infrastructure compares to other types was started by asking PMA users to rate (on a scale of 1 to 6, with 6 being best) the provision and quality of different types of infrastructure and transport provision. These included public transport, community transport (Dial-a-ride), accessible taxis, blue-badge parking, bicycle infrastructure, footway quality, footway continuity, pedestrian facilities like crossings and dropped kerbs, and number of accessible businesses, toilets, and public buildings. The Dutch respondents gave higher scores than the British for every single measure; in particular, the average Dutch score for footway quality was much higher, at 3.67 vs 2.14 in the UK. In both countries, bicycle infrastructure was given a higher rating than any aspect of pedestrian infrastructure.

From the literature review, it was surmised that the most problematic or commonly-encountered barriers were likely to be poor footway surfaces, narrow/obstructed/crowded footways, and a lack of dropped kerbs. Respondents were provided a list of 19 potential barriers, and asked to tick the box for each barrier that they would be likely to encounter on a typical trip to the shops, park, or place of employment. The aforementioned barriers that were deduced to be the most commonly encountered effectively made up 4 of the top 5 most commonly encountered barriers, with the other being that distances were too great. The following table shows some of the most commonly encountered barriers (as well as a couple of the least encountered), and the percent of people who listed them in the UK and the Netherlands (Canada was excluded from the analysis due to a translation error).

Barrier	UK	Netherlands
Poor quality footways	**89%**	**39%**
Insuff./poorly placed dropped kerbs	**75%**	**43%**
Distance too great	**69%**	**51%**
Footway too narrow	**60%**	**18%**
Cars parking on footway	**56%**	**37%**
Footway obstructed (signs, bins, etc)	**44%**	**32%**
Would have to ride on road (intimidating)	**42%**	**23%**
Footpath is too crowded with people	**27%**	**12%**
Fear of footway cyclists	**15%**	**9%**
Fear of collision using cycle infrastructure	**10%**	**9%**

Table 2: Percent of respondents saying they would encounter each barrier on a common trip

As can be seen, poor footway quality and a lack of dropped kerbs were particularly common barriers in the UK, whilst a relatively small percentage of those in the Netherlands cited them; narrow footways were one thing that was much more commonly cited in the UK, whilst the most common barrier in the Netherlands was that the distance would be too great. It is worth noting though that some respondents in the Netherlands travelled from rural or edge-of-town areas using only their PMA.

Respondents were asked to make a choice on whether they would like to see improved bus and car transport and facilities (road infrastructure), or more pedestrianisation and wheelchair-friendly pedestrian facilities in their city. There was an overall desire in all three countries that leaned towards more pedestrian facilities, especially in the UK and the Netherlands, seeming further affirming the idea that PMA users do not want to be dependent upon road-based transport to move about.

5.4 Bicycle infrastructure as a mobility solution

Just over one-third of PMA users from the UK sample said that they had travelled on a cycle path before (despite in technically being illegal), while in the Netherlands, around 85-90% had. Dutch respondents were also asked what percentage of their trips incorporated the use of bicycle infrastructure, and 63% of respondents answered that about half or more of their trips involved it (including about 15% who said that “more than 90%” of their journeys involved its use). People were then asked to rate the experience of travelling on bicycle infrastructure compared to the footway. In both the

UK and the Netherlands (Canada excluded due to translation error), the large majority said the cycle infrastructure was much better, slightly better, or similar to, the footway. Almost no-one reported it being “much worse”, and less than 20% said that it was slightly worse than the footway. Therefore, it is evident that there is a general preference for using bicycle infrastructure for most people (for just under 40% of the Dutch, it provided a similar experience, although as discovered earlier, the Dutch rated their footways as less problematic than the British).

Participants in the UK and Canada provided some written comments on their experiences of using cycle paths, and the large majority of statements were positive, and often cited benefits like being smoother and more comfortable (and less painful) to travel on, being safer than the road, and being able to travel faster than on the (sometimes crowded or obstructed) footway. There were very few negative comments, and these mostly related to verbal abuse from cyclists (although some mentioned pedestrians being abusive if using the footway). Dutch respondents were also asked to comment, and they were also positive for the most part regarding the surface quality being better than the footway or the road; negative comments again mostly related to behaviour of cyclists, such as riding too many abreast or riding the wrong way on the path.

British and Canadian respondents were also shown a photo of a high-quality section of cycle path in the Netherlands, with adjoining wide footway. People were asked to indicate whether they would be more, or less likely to use the cycle path than the footway. 75% of those in the UK said they would be more likely to use the cycle path, and 89% in Canada indicated the same. Sharing their reasoning, positive comments mentioned smoother surface, lack of kerbs, feeling safer, and lack of obstacles or pedestrians. Concerns related to fear of collision with a cyclist.

Finally, respondents were asked whether they would like to have more cycle infrastructure or less bicycle infrastructure in their city. In the UK, over half of respondents seemed either unsure or not to have a strong opinion, while a quarter were strongly in favour of more. 88% of respondents in Canada indicated that they would like more, and 80% of those in the Netherlands said that they would like to have more.

6. CONCLUSIONS

It seems only right that, in an urban environment, any trip that can be made by car should also be able to be made by PMA, safely, comfortably, and directly; unfortunately, however, this does not appear to be the case in the UK at the present time. Despite the increasing number of PMA users in the UK and other developed countries due to the ageing of the population, the transport needs of these people are frequently ignored, with many planners and engineers seemingly being unaware of what these needs even are. While there are many intangible barriers to the use of PMAs such legislative barriers or those related to living arrangement, barriers such as low car ownership and not being able to depend upon public transport means that if one does not want to remain home-bound or reliant on others, making a PMA-only trip is essential. Unfortunately, the literature review revealed a host of barriers to using pedestrian infrastructure, especially relating to poor travel surfaces and obstructions to movement on the footway, as well as a lack of dropped kerbs. The findings from the questionnaire revealed that these barriers were indeed a very common in the UK, and that as a result, being able to access the shops or park using only a PMA was prohibitively difficult for many. Conversely, PMA users in the Netherlands reported fewer barriers, rated the quality of their footways and cycle paths more highly, and the majority said that making a PMA-only trip to the shops or park would be easy.

In both the UK and the Netherlands, the majority of PMA users reported a preference for using cycle infrastructure over footways, and cited the main benefits as being smooth surfaces, good width, a lack of kerbs, and the absence of obstructions, while speed, directness, and safety were also frequently mentioned. There was also a strong desire for construction of more cycle infrastructure in the Netherlands and Canada, although a proportion of those in the UK were unsure, perhaps due to a lack of experience using it.

Evidence has shown that those with mobility difficulties, which includes all PMA users, are more likely to be home-bound and therefore withdrawn from society, which has negative impacts on individual happiness and health, as well as negative economic impacts for the wider economy. As the population ages, the transport needs of the increasing number of people who rely on personal mobility aids needs to be addressed as a priority. Taking the UK's stopgap approach (providing low-floor buses and blue-badge parking spaces) will not suffice forever, and only continues to support a car-based society. PMA users often use their devices as both a substitute for walking and cycling, and in some cases, as an alternative to driving or public transport. Therefore, an approach is needed that results in improvements to pedestrian infrastructure, which may involve mandating revised minimum design standards by law. Additionally, the strong support and preference for bicycle infrastructure would also help to justify considerable additional investment in more cycle paths, as these will always provide the smoothest, fastest, and most direct solution for PMA-only travel. In short, bicycle infrastructure greatly facilitates travel for PMA users by overcoming the barriers that pedestrian infrastructure commonly presents, and in doing so, sets power wheelchair and mobility scooter users free from reliance on road-based transport for making all but the longest urban journeys.

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