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Development of an Instrument to assess Transport Ability for people with low vision and limited mobility

Natalie Chan

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Declaration

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

Natalie Chan

Abstract

This research project aims to develop an instrument that can measure the ability of people with low vision and/or mobility problems to use public transport. Focus groups were used to design a self-assessment instrument to help identify and measure existing problems with public transport navigation. Rasch analysis, an analytical technique used to convert ordinal difficulty ratings into interval measures, was used to validate the questionnaire. Difficulty ratings were calculated for each transport item and Transport Ability was calculated for each participant to develop a Transport Ability scale.

The first survey included 22 public transport items and was applied to 414 people with various combinations of visual ability and mobility problems. The second survey included a further 24 transport items related to accessible transport modes and was applied to a further 308 participants, who had a combination of different visual ability levels and mobility aid requirements. The second validated instrument was then applied to three different case studies to investigate whether Transport Ability and Life Space score, which measures the extent and frequency of travel, could help to assess the effectiveness of transport schemes and skills training.

The self-reported transport instrument developed in this study has demonstrated sufficient internal and construct validity to reliably measure the effect of Transport Ability for people with a combination of vision and mobility impairments. Principle Component Analysis of the residuals indicated that there were no other significant dimensions being measured.

Overall, people with low vision and mobility aid users were found to experience lower Transport Ability and Life Space scores. However, the combination of both mobility aid use and low vision was not found to have a compounding effect on Transport Ability. Application of the instrument to transport accessibility schemes indicates that Transport Ability can be used to measure the benefit of schemes to individuals.

Impact Statement

This study was the first to apply Rasch Analysis to develop a Transport Ability scale. Using a multidisciplinary approach has allowed this study to develop an interval scale to measure both Transport Ability and Item Difficulty, in order to investigate the ability of mobility and visually impaired people to use public transport, and how this affects the extent and frequency of travel, as measured by Life Space score.

Rasch analysis is relatively commonplace in the study of education and health, but there has been limited application of this analytical technique in transport studies in general, or in transport accessibility more specifically. This is the first transport accessibility study to use Rasch analysis as its primary analytical tool and has shown that it is a viable technique to use in this field.

The study evaluated changes in Transport Ability, at both an individual and aggregate level, and the instrument developed has the flexibility to be applied to a number of different transport schemes that aim to improve transport accessibility by either improving a person's ability to use transport, providing a mobility aid or making a transport task easier to perform. The measure has been validated against a scale that is currently used by a London Borough, denoted as Council A in this study, to measure mobility as a vital tool in its decisions to allocate valuable transport concessions.

The finding that different mobility aids and different accessibility schemes have different effects on Transport Ability could have implications for policy. It is possible that simpler and cheaper interventions can still provide many benefits relative to more expensive, labour intensive or hi-tech solutions. This focus on value for money in accessibility policy is only likely to grow in importance over time.

The fields of ophthalmology and transport have rarely been studied in combination in the past, however the multidisciplinary approach taken in this study has shown that the two fields must work in combination to ensure that the accessibility issues faced by people with low vision are robustly analysed. Doing so will allow ophthalmological expertise to inform transport design, helping the public realm to complement clinical intervention to the benefit of people with low vision.

This study adds to the growing body of research in mobility and low vision transport studies and has the potential to be one of the first steps of a wider project to develop and evaluation methodology for transport accessibility projects. Having demonstrated the viability of using Rasch analysis to measure accessibility benefits, future studies could build on this to convert the interval measures produced into tangible units, and particularly monetary values. This would allow the full benefits of each potential intervention to be weighed against cost, allowing the best value approach to be taken. It would also mean that the benefits and costs to mobility and visually impaired people of any changes to the transport system could be taken into account alongside the needs of other groups on a monetary equivalent basis.

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Special Thanks go to everyone in the Accessible Transport Department for helping me develop and validate my second transport instrument and for aiding with the data collection for both the ScootAbility and Disabled Transport Concession allocation case studies. I would also like to thank the Back-up Trust and everyone from the rehabilitation ward in Stanmore Hospital for giving me permission to apply my transport instrument to their Wheelchair Skills Training Sessions.

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List of Abbreviations

AMD	Age Related Macular Degeneration
DfT	Department for Transport
DIF	Differential Item Functioning
LSS	Life Space score
ODI	Office for Disability Issues
PAMELA	Pedestrian Environment Laboratory
TfL	Transport for London
UCL	University College London

Chapter 1 Introduction

1.1 Thesis Background

Transport is vital for accessing key activities. Indeed, it seems that "[a]ccessibility is a central requirement of society" (Tyler, 2002: xi). However, people whose mobility is impaired are placed at an ever-increasing disadvantage.

Transport accessibility and the ways in which we can evaluate it have gradually become more important in recent years due to the ageing population present in many developed countries worldwide. This places an increasing demand on transport infrastructure to be made more accessible. This is especially important as the ability of elderly and disabled people to access facilities and services dramatically increases their chances of having a good quality of life (Tyler, 2006).

However, as transport accessibility improvements can be costly and may only benefit a minority of the population, changes to transport infrastructure are often only in line with mandatory requirements. Statutory guidelines that state the minimum general requirements that make facilities and services accessible to all are outlined in the UK by the Equality Act (2010). This succeeds the regulatory guidelines placed in the Disability Discrimination Act (2005), which set basic guidelines for public transport accessibility. The Disabled Persons Transport Advisory Committee (DPTAC) was also established by the Transport Act 1985 as an independent body to advise government on the transport needs of disabled people, advocating the promotion of an accessible transport system in the advice given to government. In addition to this, the Rail Vehicle Accessibility Regulations (DfT, 2013) help transport service providers with accessible design.

It is important that accessible design focuses on the areas of public transport that need to be improved, in order to maximise user benefits. Consequently, if a new instrument was developed that was able to measure the difficulty of the task and the ability level required by an individual to complete various transport related tasks, this could be used to measure the change in difficulty of the transport scheme itself, whilst simultaneously measuring the change brought about on an individual level. This could eventually be used to help ensure that scarce government funds dedicated to transport accessibility improvements are spent in the most effective way. This research will focus on the beginning steps of this project; identifying a way to measure Transport Ability for those with visual and/or mobility impairments and developing an instrument that can capture this ability accurately.

This study focuses on analysing the ability to use public transport at an individual rather than an aggregate level because many aspects of accessibility are subjective and specific to the circumstances of individuals, given their unique set of capabilities, constraints and needs. Accessibility instruments are designed to measure the extent to which the transport network provides access to various opportunities in urban areas so that people can meet their daily needs (Brömmelstroet, 2016). Titheridge *et al.* (2010) argued that many of the most commonly used accessibility indicators relating to distance, time, transport transfers and cost between origins and destinations of various opportunities do not adequately measure older and disabled people's perception and experience of accessibility because they do not take into account the places that individuals can actually access. Instead such indicators tend to use aggregate measures, such as number of people living within a certain travel time of a place, or in some cases a subjective concept that a journey can be made "with reasonable ease", which will clearly vary between individuals. The conclusion drawn by Titheridge *et al.* (2010) was that "…a one-size-fits-all approach to developing indicators has led to a situation where what is measured is a far cry from what is experienced or what is important to many of those that the use of such indicators is supposed to help". This study will therefore attempt to develop an accessibility indicator that is based on the individual experience of accessibility.

1.2 Research Setting

According to the Office for Disability Issues (ODI) there are over eleven million people with a limiting long-term illness, impairment or disability in Great Britain (ODI, 2010). Among this population, the most commonly reported impairments are those that affect mobility, lifting or carrying. Statistics also show that the prevalence of disability rises with age; around 6 per cent of children are disabled, compared to 16 per cent of working age adults and 45 per cent of adults over the state pension age in Great Britain (ODI, 2010). The ODI also estimates that a fifth of disabled people report difficulties in accessing transport related to their impairment or disability (ODI, 2011). Additionally, in many countries where the older population is growing, it is predicted that the number of elderly passengers with age-related disabilities will increase.

As this project aims to develop an instrument that can be applied to people who have either or both of mobility and visual impairments, it is important that this study includes people who experience a wide variety of vision loss and who may experience a range of mobility problems. This study first focuses on developing an instrument to measure the effect of low vision and/or mobility problems on a person’s ability to use public transport. The visual conditions AMD and glaucoma were chosen for specific analysis because they are conditions that predominantly affect older people’s central and peripheral vision respectively, with varying severity (Quigley and Broman, 2006 and Bressler, 2004). As AMD and glaucoma are more prevalent among older people, this research focuses on elderly people, who may additionally have mobility problems or have limited mobility. This allows comparisons to be made between the two visual conditions. Consequently, this study includes the views of people who have age related Macular Degeneration (AMD), glaucoma, as well as people with limited and good vision, all of whom may or may not experience mobility problems.

AMD and glaucoma were selected because these are two of the most common causes of adult blind registration in many developed countries (Evans, 1996). According to Duffy (2015), AMD is characterised by loss of the central visual field, which results from degeneration of the fovea in the centre of the macula that provides the sharp detailed vision. Damage to the macula impairs the central, or "detail", vision that helps with essential everyday activities such as reading, watching television and face recognition (Bullimore *et al.* 1991, Fine *et al.*, 2000, Hassell *et al.*, 2006 and Bressler, 2004). Glaucoma is predominantly associated with loss of peripheral vision, also called a peripheral field defect. Moderate and severe cases of peripheral vision loss create the sensation of seeing through a narrow tube, a condition commonly referred to as ‘tunnel vision.’ Symptoms of peripheral vision loss also can include difficulty seeing in dim light and decreased ability to navigate while walking (Black and Wood, 2005, Black *et al*. 2011 and Ramulu *et al*. 2012).

Comparisons of the effect that these visual conditions have on the ability to use public transport may reveal which type of impairment has the bigger effect on public transport use. The prominence of AMD and glaucoma becomes a pressing issue when we consider that these low vision conditions are associated with older age, suggesting that the prevalence of these conditions is likely to increase over time with the onset of an ageing population, constituting a major public health burden, resulting in increased social isolation, depression and restriction of daily activities (Owen *et al.* 2003 and Quigley and Broman, 2006).

These problems are not aided by the geographical variations in the provision and accessibility of low vision services and as highlighted by Ryan and Culham (1999). The Department of Health (1998 and 2000) have introduced initiatives to tackle inequalities in social provision and access, but treatment and access may still vary geographically. Consequently, access to services and more specifically to transport is becoming essential for enabling fair and equal access to health care, and for reducing levels of social isolation.

This study is primarily based on London and its specific public transport facilities. London has an extensive and developed transport network which includes both private and public services. Journeys made by public transport systems account for 37% of London's journeys, while private services accounted for 36% of journeys (Transport for London, 2016). Public transport services are dominated by the executive agency for transport in London: Transport for London (TfL). TfL controls the majority of public transport, including the Underground (commonly referred to as the Tube), Buses, Tramlink, the Docklands Light Railway, London River Services and the London Overground. London also has extensive railway systems that are franchised to train operating companies by the Department for Transport (DfT) (Transport for London, 2016). Public transport and more specialised accessible transport modes are the focus of the transport instrument developed in this study due to the wide availability of these modes in London. This will enable the instrument developed in this study to be applied to accessibility schemes related to public transport or accessible transport modes and services offered in and around London. In this study overland railways will be referred to as ‘trains’, while the London Underground will be referred to as ‘the tube’. As this study only examines the use of public transport modes available in London, any findings may not be directly applicable to cities elsewhere in the UK. However, the density and availability of public transport in London make this a unique city to examine how low vision and mobility affect a person’s ability to use public transport.

1.3 Research Aim and Objectives

This research project aims to develop an instrument that can measure the ability of people with low vision and/or mobility problems to use public transport. This project will do this by investigating the ability levels required to use public transport and developing an instrument that can quantify the ability levels required to do specific everyday transport tasks, in order to investigate the ability levels of people with different mobility and visual capabilities.

The degree to which Transport Ability is related to the extent and frequency of travel, as measured by Life Space patterns (see section 2.3.4), will also be examined. This instrument will then be applied to various transport accessibility case studies to test whether it would be feasible to use this approach to evaluate transport accessibility schemes and projects.

Research objectives:

1. To develop and validate a new evaluation technique that can measure the ability to use transport reliably and consistently for people with low vision and/or mobility problems (Chapters Three, Four and Six)

2. To apply this technique to investigate the impact of low vision and/or mobility on Transport Ability and Life Space and the overall relationship between the Transport Ability and Life Space (Chapters Five and Seven)

- *It is predicted that people with more severe vision loss and/or limited mobility will experience lower levels of Transport Ability resulting in more restricted Life Space patterns*
- *It is additionally predicted that overall Transport Ability levels can be used as a predictor for Life Space with lower ability levels resulting in fewer journeys outside the home*

3. To measure Transport Ability levels in groups of people with different visual conditions and mobility related problems (Chapters Five and Seven)

- *It is predicted that mobility impairment will compound the negative impact that low vision has on Transport Ability*
- *It is hypothesised that AMD and glaucoma will have a similar effect on levels of Transport Ability and Life Space patterns, despite the two conditions having different effects on the visual field*
- *It is also hypothesised that different types and combinations of mobility aids (such as walking sticks and use of personal assistance) will have different effects on Transport Ability*

4. To examine whether Transport Ability and Life Space patterns can be used to evaluate existing transport accessibility projects and schemes (Chapters Eight, Nine and Ten)

- *It is hypothesised that the developed transport evaluation technique will make it possible to analyse the effect of transport training projects and schemes that make travelling or transport easier to access or use.*
- *It is also predicted that Transport Ability measures the same underlying trait as the tools used by councils to allocate transport concessions, such as Disabled Persons Freedom Passes, Blue Badges and Taxicards.*

1.4 Thesis Structure

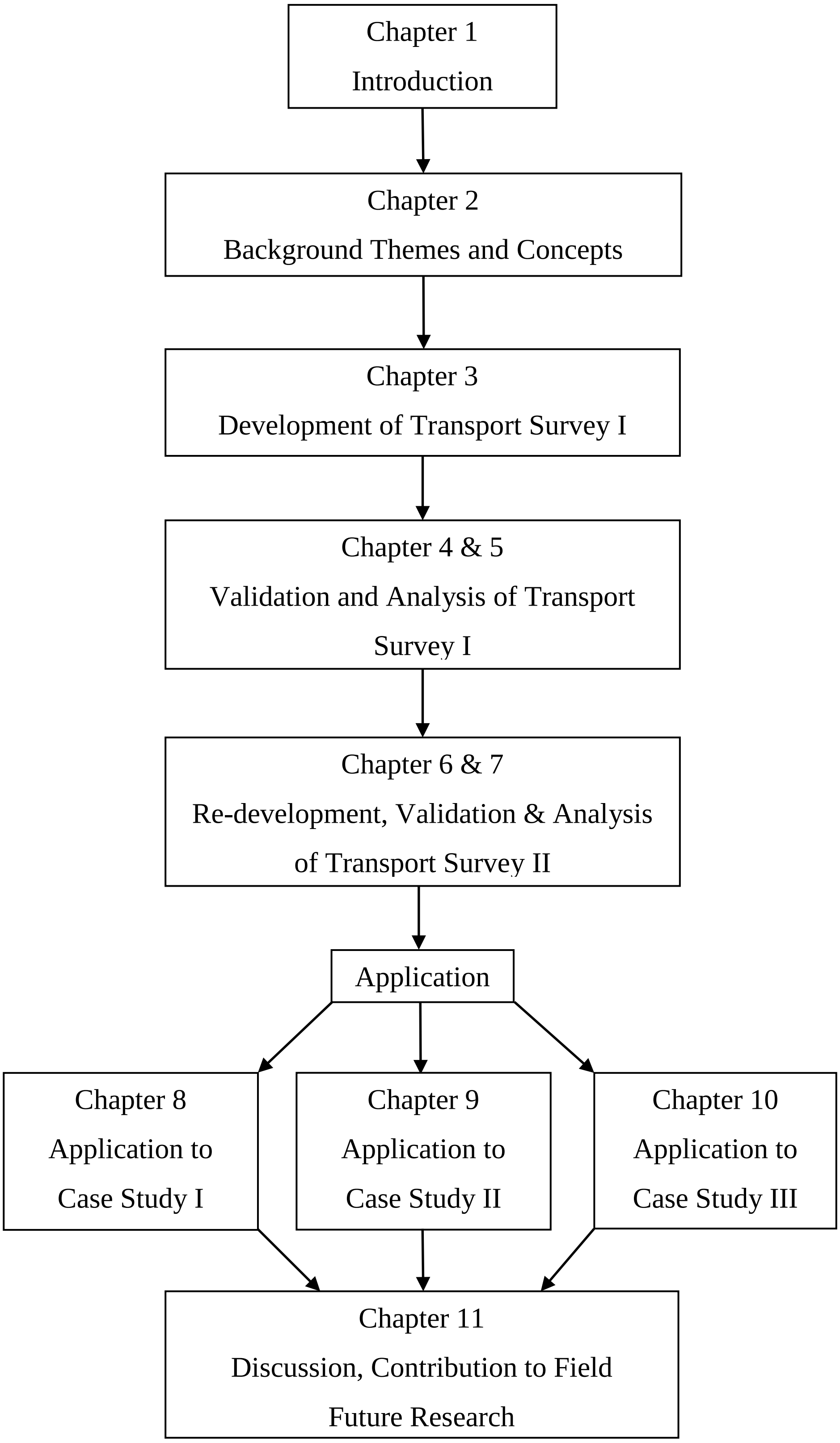

Figure 1.1 Structure of thesis

Chapter Two reviews relevant background themes, concepts and past research in order to identify research pertaining to the main issues of this study.

Chapter Three provides the background and process for how Transport Survey I was developed and carried out.

Chapter Four describes how Transport Survey I was validated using Rasch Analysis and how the participant data for Transport Survey I was cleaned.

Chapter Five describes how the results from Transport Survey I were analysed. Discussion of initial results will take a closer look at how individual characteristics affect Transport Ability and Life Space, and how Transport Ability levels affect overall Life Space patterns.

Chapter Six describes how Transport Survey I was re-developed and re-validated to form Transport Survey II.

Chapter Seven analyses the results from Transport Survey II presented in Chapter Six and compares the common transport item scores with Transport Survey I developed in Chapter Three and re-developed in Chapter Six.

Chapter Eight, Nine and Ten will discuss how Transport Survey II can be applied as part of a feasibility study, to assess existing transport accessibility schemes and scenarios. This will highlight the different ways in which this instrument can potentially be applied to assess the effectiveness of varying transport accessibility schemes.

Chapter Eight investigates the application of Transport Survey II to the ScootAbility Scheme operated by Camden Council.

Chapter Nine analyses the application of Transport Survey II to a wheelchair skills training scheme operated by the Back-Up Trust in Stanmore Hospital.

Chapter Ten compares the Transport Ability scale developed in this study with the Mobility Matrix Scheme, which is used to allocate Disabled Persons Freedom Passes, Blue Badges and Taxicards by Council A.

This will be followed by an overall discussion and summary in Chapter Eleven about how this research contributes to the transport accessibility research field, alongside suggestions for future research.

1.5 Discussion

Chapter One has outlined the background of this study regarding Transport Accessibility and the important role it plays in improving quality of life. The growing importance of understanding where transport accessibility improvements need to be focused and understanding how effective governmental schemes are regarding improved accessibility and mobility at both an aggregate and individual level helped to justify the research. The aims of the research project and research objectives are also presented, which are used to structure the data analysis within each chapter of the thesis.

Chapter 2 Background Themes and Concepts

2.1 Introduction

This chapter reviews relevant background themes, concepts and past research in order to identify research pertaining to the main issues of this study. These include studies within the field of transport accessibility (section 2.2), measuring mobility (section 2.3), visual impairment (section 2.4), transport accessibility evaluation techniques (section 2.5), patient based visual function assessment instruments (section 2.6) and studies that use the analytical technique of Rasch analysis (section 2.7). The electronic databases MEDLINE, Science Direct, and Google Scholar were searched for relevant articles relating to transport accessibility, mobility, low vision, AMD, glaucoma, vision and mobility instruments. Retrospective and prospective reference list searches were conducted for studies meeting eligibility criteria and relevant reviews.

2.2 Transport Accessibility

This section will provide an overview of transport accessibility and the importance of the whole journey chain, reviewing both guidelines published by government bodies and academic research.

Accessibility and mobility research have become an area of growing interest in recent years due to the aging of Western societies and the necessity to anticipate and plan for the needs of the growing elderly population (Paez *et al.* 2007). Mobility gives people the opportunity to participate in tasks and routines that provide people with valued roles. Fidler and Fidler (1978) and Llorens (1991) found that independent mobility promotes feelings of self-efficacy and competence. Various studies have found that people who are unable to move about freely as a result of physical limitations and people who cannot move freely due to limitations imposed on them by their surroundings have a lower quality of life (Breeze *et al.* 2005 and Gabriel and Bowling, 2004).

Sugiyama and Thompson (2007) state that better environments encourage people to perform outdoor activities as activity levels are affected by both personal and environmental characteristics. Out-of-home mobility is critical to numerous aspects of elderly people’s quality of life, since outdoor mobility is a prerequisite for partaking in social, commercial, and cultural activities (Mollenkopf *et al.* 2005). Mobility is therefore especially important when considering access to transport modes, meaning that many academics have focused research on pedestrian mobility and the walkability of environments. This access is often limited for older people and/or those with physical impairments that affect mobility, which will now be explored.

There have been a number of policy, guidance and research areas investigating the transport needs of older people and disabled users. It is widely recognised by many academics, including Tyler (2002), Church and Marston (2003), Metz (2003) and Casas (2007), that transport provides an essential link to friends, family and the wider community; a vital lifeline to maintaining independence. Lack of mobility can prevent older people from participating in social activities and lead to low morale, depression and loneliness, as well as restricting access to essential health care services, such as carers, social services and health agencies (Alsnih and Hensher, 2003, Lucas, 2012 and Shergold and Parkhurst, 2012).

In 2001 the UK Department for Transport (DfT) published ‘Older people: Their transport needs and requirements’ (DfT 2001). The report identified a number of factors that restricted the use of public transport by older people. One of the larger barriers to mobility was found to be physical difficulties associated with walking and accessing public transport. Limited access to transport information and a lack of awareness of special transport schemes such as Dial-A-Ride, a free door-to-door minibus service operated by TfL for disabled people unable to use public transport, and Shopmobility, a mobility scooter rental service, meant that those with the greatest need often failed to benefit from services that have been specifically implemented to help them. For those with more severe mobility impairments, community transport provided a valuable service. However, these were identified as having barriers of their own, such as long advance booking times, a restricted choice of destinations, limited operating hours and anxiety over completing the return trip. One of the most important recommendations was that transport planners and service providers should take a more holistic approach to address concerns associated with every element of the journey. Furthermore, when new or improved services are introduced, they should be given sufficient time to become established. Short-term pilots could be implemented to test new practices, which, if successful, should be used to implement longer-term projects.

The Disabled Persons Transport Advisory Committee (DPTAC) published a report in 2002, ‘Attitudes of Disabled People to Public Transport’ (DPTAC 2002), which included a large-scale survey of disabled people regarding their views on public transport matters. The survey covered approximately 1,000 disabled people living in urban and rural areas, whose disabilities included a variety of mobility, visual and hearing impairments and learning difficulties. The aim of the survey was to understand which transport modes were used by disabled people; determine the transport priorities of disabled people; assess how disabled people currently rate public transport provision; determine disabled peoples’ priorities for improving public transport and to determine the factors that deter disabled people from using public transport. The results showed that 52% of disabled people were frustrated that they could not make spontaneous journeys, and this percentage rose to 82% among wheelchair users. The same research also indicated that 23% of disabled people encountered problems traveling to visit friends and relatives, and 23% encountered problems traveling to work. The DfT published its draft Accessibility Action Plan in 2017 (DfT 2017). This set out measures to improve the physical accessibility of transport for disabled people; to provide better information for the disabled traveller; and to improve attitudes and behaviour towards disabled passengers.

Improving the accessibility of public transport would go some way towards meeting the needs of older and disabled users within mainstream transport. However, it is important to consider the accessibility of every step in the journey chain in order to make a journey seamless and there is a need to identify ways to overcome specific barriers in order to increase the accessibility of streets.

Litman (2003) identified a scale of accessibility that affects transport at four different levels: local, neighbourhood, regional and inter-regional. This was supported by Maynard (2009), "[f]or disabled and older people, the details of the interface are crucial, and that level of detail is not always considered in mainstream transport planning". Lavery *et al*. (1996) believed that travel for older people could only be increased through an interdisciplinary approach, linking 'friendly buses' with 'friendly streets'. The Employers' Forum on Disability (2008) identified that fear of not being able to complete journeys due to barriers experienced on journeys can result in disabled and older people experiencing fear of failure and lack of confidence when travelling. This in turn seriously impacts the journeys that they decide to make which affects their quality of life. It is therefore extremely important that accessibility research considers the entire journey chain and not just specific transport modes.

This section has outlined the importance of transport accessibility to enable everyone equal access to public transport, in order to improve personal mobility. The importance of addressing the whole journey chain has also been raised; which justifies the holistic approach addressed in this research, as every step in the journey chain is addressed.

2.3 Measuring Mobility

To understand more about how to measure mobility and improvements in mobility, a number of researchers have investigated a wide range of approaches. Section 2.3.1 will outline some of the tools and techniques that measure a person's mobility adopted by academics, including pedestrian shadowing, gait analysis and opportunity measures. Section 2.3.2 will cover software tools, while sections 2.3.3 and 2.3.4 respectively will give an overview of mobility questionnaires and the Life Space model that have been developed to measure mobility and access to opportunities and services.

2.3.1 Overview of Measuring Mobility

There are various techniques and instruments that have been used in clinical and accessibility studies to quantify a person's mobility by measuring everyday routines, task analysis and essential mobility tasks. Common methods for gathering information on human time–space patterns include the manual travel surveys and time–space diaries or interviews (Palmer *et al*. 2013). This method provides a systematic record of the way in which individuals occupy their time in space over a limited period, be it a few hours, a day, or a week (Anderson, 1971). While time–space diaries have been used to great effect by academics such as Doherty and Miller (2000) and Axhausen *et al.* (2002), they have several disadvantages as research tools. In particular, time–space diaries require participants to record in detail, their activities throughout the entire experiment (Thornton *et al.* 1997). Since participants often fail to record their actions faithfully, the data obtained are often of questionable credibility (Murakami and Wagner, 1999).

There have been some attempts to develop better approaches to recall the participant's activities with computerised and internet-based diaries (Doherty and Miller, 2000). However, as a result of these limitations, time–space diaries are generally used to collect data on time periods of up to 1 week. In addition, data regarding the pace of walking, number of stops, and exact locations of stops and places of activity are not generally recorded in travel diaries. These pieces of information are crucial for fully understanding mobility and are especially interesting when studying a population that might be experiencing physical difficulty when moving about, such as elderly people.

Basic tracking techniques include direct observations that focus on investigating and interpreting human mobility and behaviour. Participatory observation techniques involve the observer taking part in the participant's activities, in order to identify the main purposes influencing the subject's decisions. Similar to inquiry methods, participants are aware of the fact that they are being under observation and may tailor their behaviour to the researcher's expectations. In non-participatory, unobtrusive observations the researcher follows the subject at a distance, recording their movements by drawing a line corresponding to the subject's activities on a map of the investigation field. Resolving the problem of "observer effects", this method provides detailed information about the "natural" behaviour of pedestrians (Hill, 1984 and Keul and Kühberger, 1997). Yet, this technique is very time-consuming and labour intensive, and findings are limited to the visible activities of pedestrians.

Consequently, tools to describe older adult mobility, so as to better understand the influence of neighbourhood on their health and mobility, have been developed. 'Life Space' is a term frequently used by academics such as Baker *et al.* (2003), May *et al.* (1985) and Peel *et al.* (2005) to describe the extent and frequency of travel among older adults, and greater Life Space has been positively associated with reduced cognitive decline (Crowe *et al.* 2008) and reduced frailty (Xue *et al.* 2008). This self-reported measure describes the extent of recent travel using thresholds or zones such as: within the home, into the local neighbourhood, or beyond, to understand how frequently and far a person travels outside their home (see section 2.3.4 for more detail). Global Positioning Systems (GPS) technology has been applied to this Life Space measure means to calculate the geographic range of mobility and to detect outdoor physical activity (Kerr et al. 2012).

The development of sensors that capture movement information in real time and at detailed spatial and temporal scales (e.g. GPS trackers) has changed our ability to collect movement data (Kwan and Neutens 2014). GPS devices have given researchers the means to collect continuous and intensive time-space data for long periods of time. To represent daily mobility, neighbourhood studies of physical activity have used GPS-based "activity spaces" as an individual-based measure of spatial behaviour that focus on neighbourhood (out of home) behaviour, rather than mobility both within and beyond the home as measured by Life Space (Matthews and Yang, 2013 and McCormack *et al.* 2008). This has provided additional insight into the community factors and resources that shape neighbourhood activity. Hirsch *et al*. (2014) found that older adults deemed the most mobile for their age, had the largest activity spaces, after controlling for the walkability of their neighbourhoods, and whether or not they drove. This finding was supported by previous studies that found that an older adult's ability to drive will influence the size of their activity space (Shah *et al.* 2012 and Zeitler and Buys, 2014) and that the activity spaces of older adults are smaller those of younger adults, on average (Snih *et al.* 2012). However, limitations of GPS-based activity spaces are that they do not reflect the duration of time spent in any area or give insight into the locations individuals visit most frequently or how they travelled there (Hirsch *et al.* 2016). They also are not able to provide specific detail about how specific difficulties a person experiences that may affect their overall mobility.

Wearable sensors have been used to investigate aspects concerning detailed mobility. Tracking techniques undertaken in laboratory tests and assessments include gait analysis and the ability to transfer the body from one situation to another, as demonstrated by Wolfson *et al.* (1990) and Podsiadlo and Richardson (1991). Wearable sensors have the ability to measure mobility directly. Pedometers, foot-switches and heart rate measurements can measure a person's level of dynamic activity and energy expenditure, although they do not provide information on a person's static activities. Accelerometer and gyroscope-based tracking devices can be used to distinguish between individual static postures and dynamic activity (Mathie, 2004).

Most mobility, gait, and posture wearable applications are accelerometer and/or gyroscope based as these are low-cost, flexible, and accurate methods for the analysis of posture and movement, with applications in fall detection and gait analysis (Celler *et al.* 2001 and Mathie, 2001). Gait disorders are highly frequent in adults aged 65 years (Verghese *et al.* 2006). Bridenbaugh and Kressig (2010) analysed the gait and motor control required to walk and believed that older adults were less able to walk automatically due to the fact that they required more concentration and motor control when walking. Their study identified that early detection of gait disorders would reduce the risk of falling in elderly people. Herman *et al.* (2005) also identified that fear of falling resulted in changes in gait performance in elderly people, resulting in mild-to-moderate slowing, reduced mean stride length, and widening of the base of support.

Another measure that has been used to measure mobility is the 'Timed Up and Go' (TUG). This is a clinical test that has been extensively used to assess functional disability and mobility, mainly in frail older people (Lee *et al.* 2016, Benavent-Caballer *et al.* (2016) and Podsiadlo and Richardson (1991). These studies observed the time taken to stand up, walk 3 metres, turn, walk back to the chair and sit down again and the level of difficulty experienced by participants while doing so. Mobility measures such as these require no special equipment or training and could easily be included as part of a routine medical examination. However, the mobility measures produced by studies such as these are very specific and have limited applicability when measuring real world independence and mobility. Furthermore, Kubicki (2014) stated that gait speed tests should be preferred over the TUG, and that clinical measurements such as gait speed are more relevant when assessing functional capabilities.

Other academics have focussed on understanding the effect of training and interventions on a person's physical mobility. De Vries *et al*. (2012) conducted a meta-analysis to investigate the effect of physical exercise therapy on the mobility of physically disabled elderly patients; identifying that both short and longer-term intentions improved mobility, with higher intensity exercise therapy improving mobility more than low intensity exercise. However, De Vries *et al*. (2012) also found that a large number of studies in this area did not report sufficient data to be included in the meta-analysis and, furthermore, that there was a large variation in the measurement instruments used in the studies that were included, going on to advise that their results should be interpreted with caution.

Hardy (2004) proposed the use of the Occupational Performance Model (Australia) as a framework to examine the extent to which powered wheelchairs and mobility scooters allow disabled people to enhance their performance of tasks and routines in valued life roles. Hardy (2004) outlined how the framework can be used to ascertain whether an individual is able to utilise a powered wheelchair or scooter to fulfil their specific life role or roles. However, the model is a qualitative assessment tool that lacks any substantial quantitative measure of ability, so cannot easily be used to compare abilities between individuals.

Indeed, there are many different measures of accessibility that vary in terms of detail, parameters and perspectives, which have been addressed by studies such as Geurs and Eck (2001); Geurs and Wee (2004); Halden *et al*. (2005). Studies that attempt to measure accessibility often use the shortest route between the origin and destination of an individual journey. This is a technique has been adopted by academics using Geographical Information System (GIS) techniques to analyse spatial patterns, in order to calculate the shortest path between two points on a network (O'Sullivan *et al.* 2000 and Achuthan *et al*. 2007). However, as shown by Church and Marston (2003), some individuals may not be able to use the same path. Pavlovskaya (2006: 2016) claimed that GIS is neither quantitative nor qualitative but has the potential to represent and understand "complex relationships, non-quantifiable properties, unprivileged ontologies, and fluid human worlds". Tools commonly included in commercial GIS software offer interactive and rapid calculations on simple networks but are insufficient for a rich understanding of urban accessibility (e.g. inclusion of scheduling information or the monetary costs of journeys).

Improvements to these basic GIS functions have been presented in recent years; Liu and Zhu (2004) developed an accessibility toolkit for ArcView GIS, which measured accessibility by different modes and to various destinations; Lei and Church (2010) included walking times and transit frequencies in their assessment of accessibility; Benenson *et al*. (2010) introduced an ArcGIS-based toolkit to calculate service areas and travel times including transfers and timetable information for public transport; and Mavoa *et al*. (2012) calculated accessibility scores by public transport for 17 different destination types. In addition, more advanced analysis of accessibility using graph-theoretical approaches have been developed (Chen *et al.* 2014 and Curtis and Scheurer, 2010). These studies are especially useful for local authorities that are legally required to have accessibility strategies in local transport plans (DfT, 2006).

Other accessibility measurement methodologies include opportunity measures describing the level of accessibility to spatially distributed activities, such as the number of people within 30 minutes travel time of a destination, which are widely used in practice in the UK (DfT, 2004). The popularity of these types of measures may be because they can be implemented using GIS, allowing measures and results to be better visualised and hence more easily understood and interpreted by planners and policy makers. GIS tools have been developed by Mackett and Titheridge (2004) and Accession (see Brown and Wood, 2004), which is the software commissioned by the DfT to help planners to analyse accessibility.

Titheridge *et al*. (2010) compared accessibility as measured by planners with the experiences of older people and people with disabilities, as identified through interviews. Titheridge *et al*. (2010) suggested that these groups perceive and experience accessibility in a way that is not adequately captured by the indicators commonly used by transport planners and policy makers. The study highlighted the need to measure accessibility as it is actually experienced by individuals, as opposed to the aggregate indicators mentioned above, such as the number of people within 30 minutes travel time of a place (DfT, 2004), or benchmarks relating to the ability to make certain journeys “with reasonable ease” (Titheridge and Solomon, 2007).

2.3.2 Software Tools

In order to identify accessibility gaps and monitor progress towards closing these, various indicators of and targets for accessibility are used. The Department for Transport uses a range of indicators based on journey times by public transport (DfT, 2009). However, work carried out in the context of the AUNT-SUE (Accessibility and User Needs in Transport in Sustainable Urban Environments) project found that these indicators did not reflect the travel patterns of older people and those with disabilities, their perceptions, or their aspirations (Titheridge and Solomon, 2007). According to Titheridge *et al*. (2009), one way to assess whether a policy action is effective is to use benchmarks representing a ‘reasonable’ level of access.

AMELIA (A Methodology for Enhancing Life by Increasing Accessibility) is a software tool that examines the extent to which transport policies can improve social inclusion, as part of the aforementioned AUNT-SUE project. In contrast to other tools and methodologies that focus on the parts of the journey that are completed by public transport modes and private vehicles, this software takes account of the whole journey chain, using a more holistic approach. Specifically, the software allows analysis of the effect of removing barriers to improve pedestrian access, including details such as steps, slopes, access to individual buildings and obstructions on the pavement, in order to make street more accessible (Mackett *et al*. 2008a and Mackett *et al*. 2008b). This software has been applied to investigate the effect that the closure of services has on the wellbeing of elderly and disabled people relative to the general population (Mackett *et al*. 2012) and can also be used to compare the effect of different accessibility improvements, with regard to both the number of people who would benefit from the removal of a barrier and the cost of each policy (Mackett *et al.* 2010). This allows value for money comparisons to be made between policy options, which can help to decide expenditure priorities. However, this aggregate approach still relies on a number of assumptions about the capabilities of the affected population.

Titheridge *et al.* (2010) also highlighted the difficulties inherent in incorporating the experience of the individual into measures of accessibility, by looking at how the AMELIA tool (see Mackett *et al*. 2008a and Mackett *et al*. 2008b) attempts to incorporate the concept of making journeys with reasonable ease with data on the capabilities of individuals. Titheridge *et al.* (2010) described how the AMELIA tool treats barriers in absolute terms, in that they make areas permanently inaccessible, whereas in reality some barriers are transient and many others are an annoyance that can become easier to traverse as familiarity grows rather than an insurmountable obstacle.

Titheridge *et al.* (2010) concluded that an ideal methodology would be one that could model each and every person separately, taking into account an individual's capability at a particular moment in time. Whilst doing this is not possible in practice, any steps taken towards this ideal methodology would help to improve measures of accessibility. This justifies the approach adopted in this study to investigate whether a technique can be developed that enables individual capability levels to be addressed, based on the self-reported day-to-day difficulty experienced by those individuals. If an individual's ability level could be measured and compared with the ability level required to complete a specific transport related task, it may be possible to calculate the probability of a person completing a task. This could then be used to assess the effectiveness of transport interventions and improvements to make sure the correct accessibility issues are being addressed in the most effective way.

2.3.3 Mobility Questionnaires

Disability in older people can be assessed based on their ability to carry out the 'activities of daily living', which are the activities people need to do every day in order to live independently and be integrated with their environment (WHO, 2001).

To date, the measurement of disability has principally been built using 2 types of information: self-reported measurements and observation of performance. Both methods have their own merits and disadvantages.

Self-reported measurements of disability have a long history and wide application and have the benefit of being low-cost and easy to use (McDowell, 2006). However, self-reported measures can be either overestimated or underestimated as they are based on respondents' perceptions of what they can and cannot do. Furthermore, Daltroy *et al.* (1995) believe that results may be affected by other personal factors such as depression, language, education, and culture. Conversely, performance-based measurements test the actual, not perceived, ability of respondents and are sensitive to change. However, such measurements depend on the cooperation of respondents, may require special equipment and may need to be conducted by clinicians or other health professionals, making them more time and money intensive (Daltroy *et al.* 1995 and Reuben and Siu, 1990). Nevertheless, Rozzini *et al.* (1997) believed that performance-based measures could detect a functional limitation before it became measurable by self-reported questionnaires. Furthermore, a more recent systematic review completed by Coman and Richardson (2006) found moderate to large correlation coefficients between self-reported and performance-based measures when they assess the same area of disability. Consequently, measures reported in self-assessment questionnaires can produce meaningful results when investigating a specific physical function.

When focusing on activities and participation, Activites of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL) have been given widely used in self-assessment mobility questionnaires. This may be because academics such as Jette (2006) state that ADLs and IADLs are designed to assess the ability of a person to live independently. Graf (2008) identifies there to be over 200 questionnaires that measure physical function, including approximately 50 for assessing ADLs. Health practitioners or clinicians normally conduct these, but ADL and IADL questionnaires can also be self-assessed. Most self-assessed questionnaires used an ordinal 5-point scale, as used in the World Health Organisation Disability Assessment Schedule (WHODAS) (Üstün *et al.* 2010), Physical Self-Maintenance Scale (PSMS) (Lawton and Brody, 1969) and Pepper Assessment Tool for

Disability (PAT-D) (Donald, 1997).

Both ADLs and IADLs outline a specific list of essential daily tasks aimed at understanding individual mobility and ability levels, as supported by Granger and Gresham (1993) and Lawton *et al*. (1982). The International Classification of Functioning, Disability and Health (ICF) (WHO, 2001) established the difference between the ADL and IADL. ADLs are defined as those activities essential for an independent life such as bathing, dressing, toileting, transferring, continence, and feeding (Katz e*t al.* 1963). IADLs are more complex and require a higher level of personal autonomy and these include shopping, food preparation, housekeeping, laundry, medication administration, transportation and ability to handle finances (Lawton and Brody, 1969). These IADL-scores refer to tasks requiring enough capacity to make decisions about the tasks, as well as a greater interaction with the environment. Based on these differences, deficits in the IADL normally precede deficits in the ADL (Judge *et al*. 1996).

In addition to instruments that measure ADLs and IADLs, some scales have measured advanced ADLs (known as AADLs), including exercise, leisure activities, work, travel, hobbies, volunteering, or participation in religious or social activities. ADLs and IADLs are not only used to measure independent living with people with mobility impairments but have also been used to assess the effect of vision loss on everyday life. There have been many studies that have shown a relationship between vision loss and limited mobility, with an increase in difficulty in performing ADLs and IADLs shown by Brennan *et al*. (2005), Laitinen *et al*. (2007) and Portegijs *et al*. (2016). Hochberg *et al*. (2012) investigated the effect that visual acuity loss from AMD and peripheral vision loss from glaucoma would have on a person's ability to perform IADLs.

Mathew *et al.* (2011) and Hochberg *et al*. (2012) found that 39–45 percent of AMD patients required help with at least one activity of daily living. Cruess *et al.* (2007) and Lotery *et al.* (2007) suggested that between two and eight times as many AMD patients required assistance with activities of daily living compared with those without AMD. Mangione *et al.* (1999) found that the severity of AMD was associated with difficulty in completing ADLs, unless visual function was unaffected. People with severe AMD have been found to have particular difficulty in completing ADLs such as meal preparation, travelling, cleaning, grooming, shopping, going out, navigating steps and pavement curbs, noticing objects, hobbies, watching TV and reading (Hochberg *et al.* 2012, Hassell *et al.* 2006 and Backman and Williams, 2002). Ability to carry out activities requiring visual resolution, such as reading, can distinguish those who are capable of self-care only with those who are able to care for themselves and others. Similarly, Stevenson *et al.* (2004) found that ability to carry out household chores, such as preparing food, can distinguish those who are capable of self-care and those who are not.

Hochberg *et al*. (2012) identified that more severe visual acuity and visual field loss made IADL disability increasingly likely. The study found that AMD patients with more severe visual acuity loss and glaucoma patients with more severe peripheral vision loss experienced particular difficulty in the mobility related tasks. People with vision loss due to AMD found the reading related IADL tasks more difficult in in comparison to people with glaucoma-related vision loss. Hochberg *et al*. (2012) briefly looked at the effect of different kinds of vision loss on everyday tasks but did not investigate in detail the effect on wider accessibility or ability to use transport, both of which are important for a good quality of life.

The relationship between ADLs and IADLs has been researched and attempts to validate it have been made by academics such as Spector *et al*. (1987). However, the validity of using ADLs and IADLs was also questioned by Thomas *et al*. (1998), who stated that assumptions regarding ADL/IADL unidimensionality and hierarchy were not always valid, and that ADL and IADL items should be considered in combination with other models to capture a greater range of functional disability prevalence. Graf (2008) supported this, stating that many instruments lack information on reliability and validity and have not been formally tested, making comparison difficult. When investigating the validity of the psychometric properties of ADL and IADL questionnaires for dementia patients, Sikkes *et al*. (2011) found that improvements to the survey and more data were necessary in order to justify their use.

In addition to the validity of ADL and IADL instruments being questioned, these instruments do not take into account overall mobility or the frequency with which a person accesses areas within their home, local community and the surrounding area. If a person's weekly routine could be analysed, it would be possible to gauge how frequently and how often they travel in order to identify trends. This would help to understand how living with visual and/or mobility impairment may affect levels of independent mobility and travel. ADLs and IADLs will therefore not be used to measure mobility in this study.

2.3.4 Life Space Model

As previously discussed in section 2.3.1, another technique that measures mobility on an individual basis is the Life Space model. The Ageing Life-Space Assessment is an instrument used to measure how a person's mobility varies on a weekly basis, and how frequently they travel within their home and community (Peel *et al*. 2005). The study identified 6 concentric zones ranging from within the bedroom to beyond a person's home town or city, see Figure 3.2 in section 3.3.1, and participants were interviewed about how frequently they had been to each area in the past four weeks.

Peel *et al.* (2005) found that the Life Space measure was associated with physical capacity and well as other factors that may limit a person's mobility. This could be successfully used in combination with other tests and assessments in order to illustrate mobility patterns and deficits (Peel *et al*. 2005). This was supported by Barnes *et al.* (2007) who believed that the Life Space measure was a more comprehensive measure of mobility than other previously established measures; taking into account the broader dimensions of social integration and community participation. Consequently, the Life Space Assessment is seen as a reliable index to measure the extent and frequency of individual travel behaviour.

The first measurement of Life Space, the Life-Space Diary was conceived by May *et al.* (1985). Five separate concentric zones were identified: the bedroom, the surrounding habitual area, the garden, courtyard and surrounding grounds, the residential "block", and the area across a busy street. Participants recorded the number of times that they visited each area every day for a month. The value in the study by May *et al.* (1985) was that the data recorded showed what the participants actually did on a regular basis, as opposed to what they were capable of doing. This method of measuring a person's mobility also makes it easier to understand a person's mobility over a specific time period. This makes Life Space a particularly useful tool in understanding the effect of training, interventions and treatment on changing mobility levels, as mobility comparisons can be made before and after a treatment or intervention.

Baker *et al.* (2003) used the Life Space assessment to compare the validity and reliability of standardised approaches for assessing life space mobility and its ability to detect changes in life space over time in community-dwelling older adults. Baseline data collected during in-house interviews was compared to Life Space assessments made two weeks after the interview and again 6 months later. Correlations were found between the baseline Life Space and measures of physical and mental health (physical performance, activities of daily living, instrumental activities of daily living, a global measure of health (the short form-12 question survey), the Geriatric Depression Scale, and comorbidities), which established validity. Follow-up Life Space assessments established short-term test-retest reliability and the ability of the Life Space assessment to detect change. This study found that the Life Space assessment scoring method had the highest correlation with measures of physical performance and function. It also correlated with observed physical performance and self-reported function. Life Space scores were found to be stable over a two-week period but showed changes over a 6-month period. Life Space scores were also reported by respondents and were found to generally change by around 10% in 50% of the subjects, whereas their ADL and IADL scores remained relatively unchanged. This study therefore showed that Life Space scores were a way of measuring overall changes in mobility patterns that may not be picked up by other indicators.

Individuals with AMD have been found to travel less and be less likely to drive than those with other eye diseases (Popescu *et al.* 2011). Curriero *et al.* (2013) investigated travel patterns as part of real-world routines to determine whether decreased visual acuity from AMD and visual field loss from glaucoma are associated with restricted travel patterns in older adults. Curriero *et al*. measured the distance participants travelled outside their homes by tracking their location every 15 minutes between 7am and 11pm for 7 days using a tracking device. The study found that loss in visual acuity from AMD, but not loss in visual field from glaucoma, was associated with a reduction in travel to nearby locations. Being married or living with someone and younger age were also associated with more distant travel, while less-distant travel was noted for older individuals. Sengupta *et al.* (2015) also investigated excursions and time spent away from home among patients with late AMD. Patients with late AMD generally walked less due to lower visual acuity and contrast sensitivity. However, the time spent away from home on excursions did not differ between patients with AMD and a control group.

Curcio *et al.* (2013) found that Life Space scores were higher among people with better functional performance and those who reported better mobility. Low levels of education, insufficient income, depressive symptoms, and low scores of cognitive function were all significantly related to lower Life Space scores. The study also found that women were more likely to be restricted to their neighbourhood and had lower Life Space scores in comparison to men. Older age, being female, and having physical limitations have been associated with reduced Life Space, as was having had a stroke, high depressive symptoms, and being obese by Snih *et al.* (2012) and Byles *et al.* (2014). Curcio *et al*. (2013) therefore concluded that Life Space scores are a good measure of mobility that reflect the interplay of physical functioning with gender and the social and physical environment.

Portegijs *et al.* (2014) studied the seasonal variance in Life Space scores of community-dwelling older men and women aged 75 to 90 years in central Finland. Participants in this study were found to have a median life-space mobility score at baseline of 64. Participants that experienced a decline in health or mobility over the one-year study period demonstrated a significantly larger decrease in life-space mobility score than those reporting no or positive changes over the year. Snih *et al.* (2012), who studied factors associated with life-space mobility in Mexican Americans aged over 75 years of age, found their participants to have an average Life Space score of 41.5. Their study also found that older age, being female, limitations in Activities of Daily Living, stroke and high depressive symptoms were significantly associated with lower Life Space scores. Byles *et al*. (2014) also identified that higher education, better lower extremity function and muscle strength were associated higher Life Space scores. These studies illustrate that Life Space scores vary according to individual studies and participant samples. Physical factors such as geographic location, urban density, availability of public transport, weather and seasonal changes, in addition to personal factors such as mobility, age, gender, financial situation and level of education, may help to explain how Life Space scores will vary between different academic studies and participant study samples.

The Life Space model has also been used to by DeCarlo *et al*. (2003) to examine how driving related status affected the Life Space patterns of people with age-related maculopathy. Drivers reported driving an average of 4 days and 10 miles per week. Over 50% of drivers reported that because of their vision, they had difficulty with or did not drive at all in rain, at night, on freeways or interstate highways, in heavy traffic areas, or during rush hour. However, the study found that Life Space scores to be similar regardless of whether or not they drove, implying that non-drivers were able to compensate with other transport modes. This study showed that the Life Space model can be used as part of self-assessment instrument to help understand the relationship between individual ability levels and mobility patterns.

A number of academics, including Harada *et al.* (2010), James *et al.* (2011) and Crowe *et al.* (2008), have also Life Space scores to examine differences in life-space between individuals, rather than simply using the Life Space score attained. This shows that the Life Space model could be used by physical therapists as an outcome assessment of mobility, complementing traditional methods that measure impairments or functional limitations, helping to understand how patients are recovering from illnesses or operations during the rehabilitation process (Peel *et al.* 2005). If Life Space patterns were monitored on a regular basis, declines in Life Space patterns could show health professionals that something may be wrong with the patient, assuming that other changes to environment and transport options were controlled for. However, comparisons of absolute scores between individuals would be less useful depending on how similar their circumstances were, because the difficulty of travelling between the different zones may vary significantly depending on where a person lives. Nevertheless, changes in Life Space scores are a strong indication that person's transport behaviour has changed.

Although this study is not a longitudinal study, the Life Space assessment has been shown to be a simple but effective way of gauging the extent to which people travel on a regular basis. While Life Space scores may not be especially meaningful in absolute terms, they are a good indicator of real-world travel behaviour, so are a valuable crosscheck for a new measurement tool; unless a difference is found in both the new tool and Life Space score it will be difficult to definitively conclude that there is a significant impact on quality of life. This method for measuring mobility will therefore be adopted in this study in order to gauge how mobility levels vary between individual participants and over time.

2.3.5 Summary of Measuring Mobility

Various mobility measurement techniques have been covered in this section. While pedestrian shadowing and laboratory-based assessments can provide detailed and precise results, they are very labour intensive and do not necessarily replicate real life situations, as discussed in section 2.3.1. Furthermore, De Vries *et al.* (2012) found such large variation in the measurement instruments used in mobility studies that it prevented their meta-analysis from producing robust results. This suggests that there is no consensus within the field that any previously used instrument is demonstrably the most appropriate for measuring mobility.

Titheridge *et al.* (2010) argued that opportunity measures, such as the DfT's Accession tool and AMELIA (see section 2.3.2), which generally provide aggregate measures of the number of people notionally able to access a location within a certain timeframe, do not accurately measure accessibility as experienced by individuals. An ideal measurement tool, according to Titheridge *et al.* (2010), would model each person separately and account for their capability at that precise moment, which, while impossible in practice, is a useful benchmark to work towards.

The Activities of Daily Living instruments, discussed in section 2.3.3, are not a holistic approach to mobility, so are not suitable for this study, whilst the Life Space model, discussed in section 2.3.4, is shown to potentially be a useful tool against which to compare a new mobility measurement technique.

2.4 Visual Impairment

As this study aims to analyse the effect of both visual and mobility impairment, it is necessary to provide some context around specific visual conditions. In particular, how low vision affects general mobility levels, transport accessibility, and how visual ability can be measured. In section 2.4.1 an overview will be given of the most common types of visual impairment; section 2.4.2 will outline how visual impairment affects mobility; and section 2.4.3 will look at how this affects transport accessibility. In section 2.4.4 an overview is given of the various methods used to categorise visual impairment.

2.4.1 Overview to Vision Loss

When investigating the relationship between transport use and navigation for blind and low vision users it is important that a wide range of conditions that can lead to low vision are considered. Significant differences between different visual conditions and the loss in visual field experienced at an individual level mean that the effect of specific visual conditions should be investigated. There have been a number of studies that have addressed how tunnel vision, with reference to Retinitis Pigmentosa in particular, affects how people navigate and experience outdoor environments, such as Turano and Schuchard (1991) and Turano *et al*. (2002). However, visual conditions that are characterised by central field loss, such as Macular Degeneration, and the peripheral field loss associated with glaucoma have had slightly less attention within this research field. Consequently, this presents a research area that requires further development in order to better understand how vision loss associated with AMD and glaucoma affects navigation and mobility. The different characteristics of AMD and glaucoma make a useful comparison of the effect that loss of the central and peripheral visual field have on mobility, and in particular, ability to use transport.

AMD is a highly prevalent condition that causes loss of central vision (Berdeaux and Nordmann, 2005). Central visual field loss typically leads to problems with reading, watching television and face recognition (Bullimore *et al.* 1991, Fine *et al*., 2000, Hassell *et al.,* 2006 and Bressler, 2004). It is the most common cause of blindness in developed countries and is labelled a 'priority eye disease' by the WHO (Lamoureux *et al.* 2008). In the UK, an incidence of 71,000 new cases of late AMD per year has been estimated (Owen *et al.* 2012), and both the incidence and prevalence of AMD are set to rise as the population ages. Wong *et al.* (2014) estimate the projected number of people with AMD in 2020 to be 196 million globally, increasing to 288 million in 2040.

Glaucoma is another leading cause of visual loss in older adults that affects visual field, reducing peripheral vision (Ramrattan *et al.* 2001 and Hochberg *et al.*, 2012). This loss of peripheral vision has been shown by academics to affect mobility more significantly than reading related tasks that require central vision, in contrast to AMD (see section 2.4.2 below). According to Quigley and Broman (2006), glaucoma is the second leading cause of blindness worldwide, disproportionately affecting women and Asian people. It is estimated that by 2020, 80 million people will have Open Angle Glaucoma (OAG) and Angle Closure Glaucoma (ACG), and of these, 74% will have OAG. Tham *et al.* (2014) estimate that bilateral blindness will be present in 6 million people with OAG and 5 million people with ACG in 2020, and the number of people with glaucoma worldwide is forecast to increase to 112 million in 2040.

There is a significant amount of research by academics into new treatments and genetic risk factors for AMD and glaucoma, such as Kolko (2015), Jung *et al.* (2014) and Garway-Heath (2013). However, the effect of vision loss related to AMD and glaucoma on mobility has had less attention. This has led to some academics believing that clinicians do not fully understand the impact of the vision loss on mobility, particularly vision loss related to AMD (Stein *et al.*, 2003 and Stein 2004). This is especially pressing given the rapid ageing of the population worldwide, as the numbers of individuals affected by glaucoma and AMD are projected to rise significantly by 2020 (Friedman *et al.*, 2004 and Quigley and Broman, 2006). There is therefore a need to understand how function and quality of life are affected by these conditions, so that the correct issues are tackled (Hochberg *et al*. 2012).

A number of studies have also looked at AMD and its limiting effect on quality of life, level of independence and social interaction (Klein *et al*. 1998, West *et al*. 1997 and Slakter, 2005). The relationship between AMD and depression has also been covered in a number of studies including Williams *et al*. (1998), Rovner *et al*. (2002) and Rovner *et al*. (2014) to name a few. There have been a number of publications investigating quality of life for people with glaucoma, with a total of 660 papers related to the topic published in 2009 alone as demonstrated by Glen *et al.* (2011). The recent increase in studies using self-reported questionnaires may be because they provide valuable insight into the patient's personal experiences and point of view outside the clinic, allowing questionnaires to gain information that it is difficult to capture during the limited time constraints of clinical appointments (Glen *et al.* 2011). However, performance-based studies specifically of people with glaucoma seem to be rare. The small number of mobility related papers focusing on people with glaucoma is surprising considering the large number of papers published relating to quality of life. This may be a missed opportunity as performance-based tasks may capture unconscious difficulties that individuals fail to report in questionnaires due to the asymptomatic nature of glaucoma in the early stages of the disease (Rozzini *et al*. 1997).

2.4.2 Visual Impairment and Mobility

There is a large body of academic work that has used a range of techniques to analyse how visually impaired people perceive space. Examples include spatial cognitive mapping, orientation and mobility skills in Kitchen and Jacobson (1997) and Lahav and Mioduser (2000). Additionally, there is a wealth of literature focusing on the walkability of pedestrian environments for both visually and non-visually impaired people, such as Molen *et al*. (1981) and Kelly *et al*. (2011). These predominantly involve testing various methodologies in real life such as on-street surveys, pedestrian shadowing and pedestrian mapping.

A number of academics have attempted to understand the relationship between central vision loss associated with AMD and mobility issues. Kuyk and Elliot (1998) attempted to recreate 'real world' navigational courses by scattering the courses with obstacles for participants to navigate around in order to try and replicate everyday situations. This study concluded that visual field and contrast sensitivity were the best indicators for predicting the time taken to complete the course and the number of times contact was made with the obstacles. Brown *et al*. (1986) used indoor obstacle courses to examine the effects of mobility on participants with AMD, findings that suggested that visual acuity and central visual field accounted for 86% of the variance in mobility in AMD participants (Brown *et al*. 1986). Other early research investigated relative luminance levels and differing complexity levels of specific mobility courses. Wilcox and Burdett (1989) used a simple mobility course design to test relative luminance levels on AMD participants. The study found that under high illumination levels participants with AMD had no more difficulty with mobility than people of a similar age with good vision. Kuyk and Elliot (1998) found that AMD patients performed worse on an obstacle course in dim lighting compared to well-lit conditions. Subjects with AMD walked faster on simpler mobility courses than on more complex ones.

However, limiting methodologies and variables measured during these early experiments limit the reliability of these studies. For instance, Kuyk and Elliot (1998) did not measure visual acuity or contrast perception. Similarly, Brown *et al.* (1986) and Wilcox and Burdett (1989) did not assess many vision and perceptual functions when examining the mobility of AMD participants. Studies such as Hassan *et al.* (2002) attempted to improve methodological techniques and sampling strategies to review past conclusions identified by previous academics researching within the field of navigation and visual field loss. As a result, they found that the height of the obstacle and illumination levels did not affect the likelihood of people with AMD making contact with obstacles on the course, in contrast to studies by Wilcox and Burdett (1989) who found different results under different illumination environments. They also found that only 29%-35% of the variance of the mobility of AMD participants can be accounted for by visual field and contrast sensitivity measures, instead concluding that as the size of the binocular central scotoma increases, mobility performance decreases.

Spaulding *et al*. (1994) found that people with AMD walked slowly and cautiously during light and dark adaptation, while fully sighted people only behaved in this way during dark adaptation, indicating that those with good vision respond during dark adaptation as though their vision were impaired. People with AMD walk more cautiously, make more gait modifications while walking on altered surfaces (Spaulding *et al*. 1994). Alexander *et al.* (2014) also found people with AMD experienced difficulty with stepping on low contrast targets and found kerb navigation particularly challenging in dim lighting and during dark adaptation.

Hassell *et al*. (2006) identified mobility problems as a significant concern for people with various different severities of AMD. Peripheral vision was identified to be sufficient to be able to identify obstacles, however a lack of confidence experienced by participants was found to limit their overall mobility. This study recommended that training in orientation and mobility would be beneficial to rehabilitation programmes for people with AMD. This was built upon by Hooper *et al*. (2008) who identified an unmet need in determining the correct types of orientation, mobility programs and visual devices required to help people with AMD.

Subhi and Sørensen (2016) investigated physical activity patterns in Danish patients with early and late AMD. They found that patients with late AMD may still be physically active and that the degree of visual impairment plays a significant role in determining the type of physical activity in which the patient engages. The intensities of some physical activities (working up a sweat and climbing many steps) were correlated with visual acuity but being physically active or walking regularly were not correlated. Patients with late AMD with tended to engage in controlled activities that do not to the necessarily require a sharp central vision such as gardening or walking. Neither early nor late AMD were associated with a lower level of physical activity. The findings of this study also correlated with similar observations seen in patients with AMD in other populations. Loprinzi *et al*. (2015) investigated daily movement patterns and intensity of activity levels in patients with early and late AMD compared with healthy control individuals. Patients with late AMD were significantly less physically active and engaged in less moderate-to-vigorous physical activity, which was explained by a lower visual acuity.

Nguyen *et al.* (2015) found that patients with AMD spend less time on moderate-to-vigorous physical activity than control groups due to an increased fear of falling, a finding that Van Landingham *et al.* (2014) also supported. Popescu *et al*. (2011) investigated mobility limitations in patients with late AMD and found that these patients had poor balance, an increased frequency of falls within the past year and lower Life Space scores. Willis *et al*. (2013) compared balance measures with visual impairment and found that reduced visual inputs may weaken the vestibule-ocular system that maintains balance.

The relationship between glaucoma and mobility related tasks have also been addressed by a number of academics. Ramulu *et al*. (2012) found that patients with glaucoma walk more slowly than people the same age who do not have glaucoma. Black and Wood (2005) found that people with glaucoma to bump into objects more frequently, while Ivers *et al.* (1998) found a relationship between vision loss and an increased risk of falling. Glaucoma has been found to be associated with higher rates of injurious falls and fractures (Black *et al*. 2011). Ramulu *et al*. (2012) investigated the relationship between the fear of falling and visual field loss due to glaucoma. This study identified a greater fear of falling in participants with severe visual field loss than among those whose vision loss was less severe.

Wood *et al*. (2011) explored the specific relationship between AMD, fall risk and other injuries and visual risk factors. Amongst older adults with AMD, increased visual impairment and reduced contrast sensitivity were found to increase the frequencies of falls and other injuries. Szabo *et al*. (2008) specifically identified older women with AMD to have impaired balance, slow visual reaction times, and poor vision, which resulted in a significantly greater risk of falling than population norms. These findings have important implications for the assessment of visually impaired older adults. However, these studies do not identify or examine the specific mobility issues that are experienced by people with AMD and glaucoma. Additionally, these studies do not investigate the effect of mobility in real life environments.

Developments in technology have allowed navigation techniques to be closely examined. Improvements in eye tracking and video analysis technologies have enabled better understanding of how gaze and observation vary as everyday tasks are performed. Turano *et al.* (2002) found that participants with central field loss navigate using the expected position of features and the general direction and location of their target. When comparing the navigational behaviour of a central field loss participant with a participant with good vision they found a wide range in the degree of similarity between the two subjects, depending on the severity of the vision loss. This showed that visual field loss, navigation and gaze tendencies were closely related.

These findings are also consistent with the small number of performance-based research projects specifically designed to measure mobility in glaucoma patients. Reduced mobility in patients with advanced glaucoma is expected due to their reduced peripheral vision identified through visual field tests (Lovie-Kitchin *et al.* 1990 and Crabb *et al.* 2013). However, the effects of early stage glaucoma on mobility are largely unaddressed. Turano *et al.* (1999) found that glaucoma was associated with decreased mobility performance, with patients with glaucoma found to be 10% slower in completing an established travel path in comparison to the good vision group. Additionally, the number of people who experienced bumps, stumbles or orientation problems was almost twice as high in the glaucoma group compared to the good vision group.

Research from the Salisbury Eye Evaluation Project, which investigated the relationship between visual field loss and mobility within a population-based sample of older adults, also supported this finding (Turano *et al.* 2004 and Friedman *et al.* 2007). Visual field loss was found to be closely correlated with a decline in mobility performance, leading to an increase in the number of collisions with obstacles and a decrease in walking speed, even after adjusting for use of a mobility aid (Friedman *et al.* 2007). A glaucoma study by Noe *et al.* (2003) also identified that participants’ mobility was especially affected when moving independently outside their home. This warrants further specific research to investigate the impact of central and peripheral field loss on of everyday mobility related tasks in outdoor environments.

The association of visual field loss with mobility performance in older adults is growing and a small number of academics have started to investigate this relationship more closely. However, these studies do little to try to understand how mobility related problems are experienced in transport environments for people with AMD and glaucoma. This issue is becoming more pressing due to the growing prevalence of macular conditions among the aging populations in most developed nations. This constitutes a major public health burden and may result in increased social isolation, depression and restriction of daily activities.

2.4.3 Visual Impairment and Transport

Transport accessibility among people with low vision is a growing field of study. This was supported by Montarzino *et al.* (2007) who believed that mobility plays a vital role in the quality of life of visually impaired people, with a lack of mobility usually leading to a lack of self-sufficiency, recreational activities and employment. Indeed, there are many studies that have been commissioned by low vision charities in order to improve knowledge of how low vision users use public transport. These primarily focus on how transport systems can be improved in order to allow fair and equal access and improved quality of life for visually impaired people.

Pavey *et al.* (2009) looked at travel, transport and mobility issues of people in the UK who are blind and partially sighted as part of a study commission by the Royal National Institute for the Blind (RNIB). This study aimed to gain a clear understanding of the opinions and individual circumstances of registered blind and visually impaired people in the UK, relating to travel, transport and mobility. The study highlighted that people who are less mobile, who are often older or have additional disabilities, find it especially difficult to travel outside of the home.

Montarzino *et al*. (2007) also focused on understanding the factors behind the restricted levels of mobility within a range of transport modes and environments. The study revealed that the main contributory factors to the mobility of visually impaired elderly people included factors such as: age, with lower mobility levels found in those over 77 years old; the level of vision in the better eye; and the feeling of personal safety. This group tended to use fewer transport services and did not see them as being valuable or useful. It is therefore important that individual needs and difficulties are addressed in order to allow people with reduced mobility to use public transport. Consequently, there has been a drive in academic research to investigate the barriers to transport and how changes to infrastructure can be made in order to enable a greater amount of independent living among visually impaired people.

Marston and Golledge (2003) identified five types of spatial information points that are difficult for visually impaired people to identify in unfamiliar areas. These included directional cues and identification of locations, self-orientation and position, spatial information and an understanding of the model of the space. Marston and Church (2005) addressed how walking environments could be improved for low vision transport users to navigate successfully. This paper concentrated on the time taken to complete simulated transport transfers between modes. They found that more complicated tasks where the position of objects could not be predicted, such as inconsistently placed amenities, crossing a street and finding unmarked doors, were difficult and time consuming. However, more simple tasks such as crossing a smaller road or walking down the street were relatively easy to achieve. The study concluded that the careful placement of additional cues in order to specify direction and providing auditory signage may help eliminate navigational problems. Uniform positioning of facilities and services also may help address personal orientation around street environments especially when in unfamiliar locations.

The impact of mobility and public transport on visually impaired people has been addressed by some academics. Cook *et al.* (1997) addressed how colour and contrast can be best implemented within urban design to help people with a range of different visual abilities to navigate. Golledge and Marston (1999) found that some of the most difficult transport problems faced by visually impaired people include identifying the locations of bus stops, boarding areas, station amenities and facilities such as ticket offices, in addition to the correct identification of specific bus numbers, train destination boards and modal interchange points.

Montarzino *et al*. (2007) specifically investigated the personal, environmental, and transportation factors that have an impact on visually impaired people's mobility and independence. The built environment and transport systems, such as controlled road crossings and the location of bus stops, play an important role in determining the travel and behaviour of visually impaired people. However, Montarzino *et al*. (2007) also identified a personal factor, involving a combination of age and vision in the better eye, that best explained the travel behaviour patterns of visually impaired people.

2.4.4 Categorising Visual Impairment

Vision tests administered by trained technicians can measure visual acuity, contrast sensitivity, glare sensitivity, stereo acuity and visual fields (Rubin *et al*. 1997). However, getting accurate visual acuity information for self-assessment questionnaires is challenging. Meadows (2011) argued that important information about a person may be missed if a person's visual ability is measured by visual acuity alone, as psychological status, physical health, social relationships and the surrounding environments also influence a person.

A number of patient reported outcome measures have been developed and used to investigate the effect of AMD on patient-reported general vision function. These include the Visual Functioning index, VFI (Bernth-Petersen, 1981), Activities of Daily Vision Scale, ADVS (Mangione *et al.* 1992), Visual Function Index-14, VF-14 (Steinberg *et al*. 1994), Visual Function and Quality of Life, VF&QOL (Fletcher *et al*. 1997), Quality of Life and Visual Function, QOLVFQ (Carta *et al.* 1998), Visual Disability Assessment, VDA (Pesudovs and Coster, 1998), Cataract Symptom Scale, CSScale (Crabtree *et al.* 1999), Impact of Cataract Surgery, ICS (Monestam and Wachtmeister, 1999), Houston Vision Assessment Test, HVAT (Prager *et al.* 2000) and the National Eye Institute-Visual Function Questionnaire, NEI-VFQ (Mangione *et al.* 2001).

As will be discussed in more detail in section 2.6, these instruments ask patients to rate the impact their vision has on completing specific daily tasks. The NEI-VFQ is a widely used patient reported outcome measure in AMD (Mangione *et al.* 2001 and Mitchell and Bradley, 2006). Average scores are reported to be poorer among people with AMD compared to those without and, unsurprisingly, worse among those with more severe disease (Clemons *et al*. 2003 and Lamoureux *et al*. 2011). However, as discussed in more detail in section 2.6, in order to measure visual function ability from patient responses to items on a visual function questionnaire accurately, an explicitly defined statistical item response model such as the Rasch model should be applied (Massof and Rubin, 2001 and Hambleton and Cook, 1997). A simpler instrument is therefore required to assign an approximate vision level to each participant that can be included in a self –assessment questionnaire.

The visual analogue scale is a psychometric response scale, which can be used in questionnaires to measure characteristics or attitudes that cannot be directly measured. According to Dauphin *et al. (*1999), it has often been used in epidemiologic and clinical research to measure the intensity or frequency of various symptoms. When responding to a visual analogue scale item, respondents specify their level of agreement to a statement by indicating a position along a continuous line between two end-points. Studies such as Gould *et al.* (2001) have used the visual analogue scale to measure the amount of pain that a patient feels, ranging across a continuum from none to an extreme amount of pain. However, there is little evidence to suggest that this scale can effectively be applied in questionnaires to measure visual ability.

Grundy *et al*. (1999) used a Vision Level scale between 1-10 to measure the visual ability levels of participants, with Level 1 representing the worst vision and Level 10 being the best vision. Each Vision Level was associated with an everyday recognition task, with the worst levels of vision being classified by: ‘Cannot tell by the light where the windows are’; ‘Cannot see shapes of furniture in a room’; ‘Cannot recognise a friend if close to his/her face’ and the better levels of vision being classified by: ‘Has difficulty recognising a friend across the road’, ‘Has difficulty reading ordinary newspaper print’; and ‘full visual ability’. Participants were asked to read down the list and mark the Vision Level ability that best described the limit of their vision when using their usual vision aids. A visual ability score could then be allocated to each participant through a self-assessment survey. As this technique could be easily and implemented in a paper based self-assessed questionnaire, this methodology was therefore included in the overall study questionnaire. This would allow an approximate vision level to be assigned to each participant, based on everyday activities, and would not require each participant to be examined individually.

Dalke and Conduit (2010) used groups of people across the visual ability range of V1 to V10 to validate a prototype measurement tool and contrast guide that could be used in the design, manufacture and planning of products and buildings. Groups of 10 people in each vision level category were used to test their prototype measurement tool. This allowed them to ensure that they were testing their prototype measurement tool across a wide range of people with different visual abilities.

A similar technique was also used by Douglas *et al*. (2006) in their study, which surveyed 1000 visually impaired people aged 18 and over about the changing needs of visually impaired people. The survey used six questions to score the functional level of participant's vision on a seven-point scale (0-6) as used in the 1991 RNIB Adult Needs Survey (Bruce *et al.* 1991). Participants were asked six questions regarding how much they could see. These categories included: No light perception; Can tell by the light where the windows are; Can see the shapes of furniture in a room; Can recognise a friend if close to their face; Can recognise a friend at arm's length away; Can recognise a friend across a room; and Can recognise a friend across a road. Douglas *et al*. (2006) also found that self-reported levels of vision correlated with registration status. As would be expected, partially sighted people were more likely to be able to see well enough to recognise a friend across a road (functional vision score 6) than people who were registered blind (16% and 2% respectively).

2.4.5 Summary of Visual Impairment

In section 2.4.1 the different effects of AMD and glaucoma related visual impairment were described, with the former affecting the central field and the latter affecting peripheral vision. While numerous studies were shown to have studied the effect that these conditions have on quality of life, there is relatively little research on their impact on mobility or transport use.

Section 2.4.2 showed that previous studies of visual impairment and mobility have focused on the ability to traverse obstacles, and the risk or fear of falling, but there has been limited research relating to travel in real world transport environments. Visual field loss generally has been found to reduce mobility, but there is little research on whether loss of central or peripheral vision has a greater effect.

Transport accessibility was shown in section 2.4.3 to be key to independent living among visually impaired people, with lower mobility and lower use of public transport found by Montarzino *et al*. (2007) to be correlated with both low vision and age. Marston and Golledge (2003) and Marston and Church (2005) found that travel in unfamiliar areas was particularly difficult for visually impaired people, whereas more simple tasks were easy to achieve, and that locating certain facilities proved especially hard, highlighting how the individual experience and the whole journey chain must be taken into account when assessing accessibility.

Various methods of categorising visual impairment were summarised in section 2.4.4. Clinical measurements of visual acuity would require each participant to be examined individually. However, as the study questionnaire is a self-reported postal questionnaire, the assessment used to measure a person's approximate vision level must be simple to understand and administer on paper, but accurate enough to reliably determine visual ability. A Vision Level scale of the type developed by Grundy *et al*. (1999) was shown to be an appropriate technique for this study and has been successfully employed by other studies, such as Dalke and Conduit (2010).

2.5 Transport Accessibility Evaluation Techniques

Having outlined the main issues surrounding transport accessibility in section 2.2 and summarised current research around measuring mobility and categorising visual impairment in sections 2.3 and 2.4 respectively, it is necessary to look at the ways in which measures to improve accessibility for mobility and visually impaired people are traditionally evaluated.

This section will give an overview of two prominent techniques used to evaluate improvements to transport accessibility. Section 2.5.1 will summarise the current research around applying the economic tool of cost benefit analysis to accessibility projects, whilst section 2.5.2 will cover the capability approach, which attempts to measure changes to quality of life.

2.5.1 Cost Benefit Analysis

The importance of transport accessibility evaluation techniques has been increasing in recent years, exacerbated by the ageing populations found in many developed countries today. However, as there is intense competition for the limited public funding available for transport infrastructure, it is important that both current and future transport accessibility projects are properly evaluated to ensure that investment is directed towards the schemes that provide the best value for money. An example of evaluation of different projects using a unilateral index is cost benefit analysis, in which benefits are converted into monetary values, allowing different types of benefit and cost to be compared.

While transport projects are generally evaluated using cost benefit analysis, accessibility transport projects cannot be evaluated in the same way. Reduced travel times are measured as the main benefits of transport projects, which can be converted into monetary values using established estimates of the value of time, but benefits cannot be measured in the same way for accessibility projects (Metz, 2008). The AMELIA tool, discussed in section 2.3.2, can be used to compare the number of beneficiaries from a policy with the cost of the policy (Mackett *et al.* 2010), but is not capable of precisely quantifying the benefits brought in monetary terms.

The difficulties in converting the benefits of accessibility interventions to monetary values are because the benefits of accessible transport schemes are mainly social, as found by Lucas *et al.* (2009). As indicated by Suzuki *et al.* (2007) and Maynard (2009), transport improvements may not only benefit those with limited mobility, so it is important that all benefits, including those to visually impaired people, are captured. Having access to transport enables people to have better access to employment and services and gives people the ability to socialise and integrate with society. However, it is difficult to measure these intangible benefits.

When considering transport accessibility evaluation techniques, it is important to consider how important a transport facility is and how important it is for an individual to complete a task. This viewpoint contradicts the set guidelines produced by the Department for Transport (DfT, 2005) and evaluation tools that are used to identify barriers within street and transport environments (TRL, 2006). This is because it is necessary to identify and quantify the benefits of transport accessibility with regards to cost. Additionally, it could be argued that infrastructure and transport improvements should be completed with respect to the importance they are given by those who are meant to benefit from the scheme. This neglected question within accessible transport evaluation was raised by a study by University College London that investigated the acceptable level of barriers within street environments, which had previously been neglected in previous studies (Thoreau and Tyler, 2008). By investigating how a barrier or environmental condition contributes to the completion of a transport related task it would be possible to investigate the importance of weightings of barriers and conditions within transport environments. Consequently, the evaluation of mobility and transport accessibility tasks needs further investigation.

Additionally, traditional transport cost benefit analysis addresses large scale projects and aggregate data analysis instead of looking at the ability levels of individuals, the disadvantages of which are discussed in section 1.1. The potential drawback to this utilitarian approach is that a small benefit to a large number of generally more able people may be valued more highly than a significant improvement in accessibility for a small number of people, who currently have little to no access to the facilities in question. Consequently, traditional transport evaluation techniques are not suitable for evaluating transport accessibility projects.

2.5.2 The Capability Approach

The capability approach has increasingly been used as a framework within the transport discipline to measure the quality of life of individuals. This aims to capture the effect of transport policies on an individual basis. The capability approach addresses aspects of a person's abilities that allow them to participate in society. Although Nussbaum (2000) developed a list of functions, the capability approach is a broad enough concept for it to be necessary to develop new models during the operational process. This is illustrated by a study developed by Inoi and Nitta (2005) who evaluated local bus networks using this methodology. In this study the list of functions was based in terms of the International Classification of Functioning, Disability and Health (WHO, 2001), and gave a weight to each function based on a survey. However, as this study did not base utility values on existing established utilities, values cannot be compared with those outside of the study. The capability approach is increasingly being used in health economics, in the allocation of resources for health-related interventions. Furthermore, Coast *et al.* (2008) and Cookson (2005) have attempted to integrate the capability approach with general wellbeing in addition to health.

Cepolina and Tyler (2004) proposed a new framework for the evaluation of transport, which takes into account the capability of individuals in addition to activity and environmental requirements. Each person has an individual set of capabilities, which means that different people interact differently with environments. Jenson *et al.* (2002) developed a model to assess public bus environments, taking into account the functional capability of people and the physical environment taking a new approach by using predetermined scores. However, this study is also limited as it is unclear how these scores were determined and how it could be applicable in other contexts. Nevertheless, the capabilities approach appears to be the most appropriate framework to use to analyse transport accessibility.

2.5.3 Summary of Transport Accessibility Evaluation Techniques

Cost benefit analysis is the most common tool used to evaluate transport schemes, but, as discussed in section 2.5.1, is not well suited to assessing transport accessibility because it generally uses travel time savings, converted into monetary values, to measure the benefits that accrue to individuals. The benefits of transport accessibility schemes tend to primarily be easier participation in society for specific groups, alongside a host of other intangible benefits, which cannot easily be converted into monetary values in the way that cost benefit analysis requires. In addition to this issue, cost benefit analysis is generally used at an aggregate level, rather than taking individual experiences in to account, so is not suitable for use in this study.

The capability approach, discussed in section 2.5.2, can be used in transport studies as a framework with which to measure changes in quality of life for individuals based on their ability relative to the ability required by the transport environment. This framework is more appropriate for this study than cost benefit analysis, so will inform the approach taken.

2.6 Patient Based Visual Function Assessment Instruments

In order for visual impairment to be incorporated into the development of a new instrument to measure Transport Ability from the perspective of the individual, it is necessary to find a simple way to measure visual function that relates to the way that individuals experience vision loss and how it affects their day-to-day life. This section will therefore give an overview of self-reporting visual function questionnaires.

As mentioned in section 2.4.4, more than twenty self-reported visual function questionnaires have been developed over the last 30 years. This could be justified by an increased emphasis on practical applications in ophthalmology, leading to health care insurers and research funding agencies to developing and using their own visual function questionnaires (Massof and Rubin, 2001). Clinicians also perceive measures such as visual acuity to not fully explain specific aspects of visual function from a patient's perspective (Massof and Rubin, 2001). These include Visual Activities Questionnaires, Activities of Daily Vision Scale and the National Eye Institute Visual Function Questionnaire (Szlyk *et al*. 1990, Sloane *et al*. 1992, Mangione *et al*. 1992, Frost *et al*. 1998 and Gothwal *et al.* 2009). According to Meadows (2011), patient reported outcomes assess different aspects that are influenced by a person's health, measuring the impact of their condition on their ability to function on an everyday basis.

The developers of visual function questionnaires typically divide the items into several different subscales, with the average of the ordinal patient ratings across items for each subscale and/or for the total instrument being used as the overall patient score (Massof and Rubin, 2001). These instruments typically include items relating to specific everyday activities, which participants are asked to rate on a numeric scale, between 1 and 5. These questions were typically rated according to difficulty (with 0 = no difficulty at all to 5 = extreme difficulty), frequency (0 = not at all to 5 = all the time), severity (1 = none to 5 = very severe), and global ratings (1= very good to 4 = poor). The number of categories with ‘difficulty’ questions ranged from three to five. These comprised a simple question format (e.g. “do you have difficulty recognising people’s faces because of trouble with your eyesight?” These varied in length with QOLVFQ (Carta *et al.* 1998) only consisting of 3 questions to the NEI-VFQ (Mangione *et al.* 2001), which consisted of 39 questions.

In some cases, these instruments are scored by taking an average of the subscales to generate a total score for the instrument (Balkrishnan *et al*. 2003) or overall score (Labiris *et al.* 2008). However, unless participant responses can be transformed to an interval scale, psychometric visual function assessment instruments provide little more than descriptive explanations, rather than measurements (Massof and Rubin, 2001). This is because clinicians require measurement tools to measure the clinical state of their patients. According to Mallinson (2007), essential measurement features include unidimensionality, hierarchical order and equal interval scaling. In the case of optometrists, unidimensionality is important so that measuring instruments capture a single construct such as intraocular pressure; hierarchical order is required, so that measuring instruments are arranged in order from less to more consistently across patients; and equal intervals are useful so that steps on a measuring instrument are the same size at all points on the instrument. These features are essential so that measurement tools can make meaningful comparisons, to compare between patients and to make comparisons over time. For such comparisons to be meaningful, the measuring instruments optometrist use must demonstrate the essential features of measurement. Traditionally, Likert-type items are summed to produce a total score and traditional evaluations of test functioning, such as Cronbach’s alpha, make the underlying assumption that all items are of equal difficulty (Massof, 2002 and Garamendi *et al.* 2006). These methodologies can therefore be misleading, particularly when some items are easier to complete than others, making it particularly crucial for us to understand how individual people responded to individual items (Merbitz, 1989). Results from these instruments therefore cannot be interpreted in terms of a functional ability variable.

In order to measure visual function ability from patient responses to items on a visual function questionnaire accurately, Massof and Rubin (2001) stated that an explicitly defined statistical item response model such as the Rasch model should be applied, as previously done by Hambleton and Cook (1997). Rasch analysis of item responses in self-assessment questionnaires allow the development of a valid interval visual function scales to be estimated for patients with visual impairments (Mallinson, 2007).

In summary, self-reported questionnaires are a well-established technique within the study of visual impairment. However, in order for the ordinal scores give more meaningful results, an item response model, such as the Rasch model, must be applied. Rasch analysis can be used to validate new functional assessment instruments in order to provide meaningful results.

2.7 Rasch Analysis

This section gives an overview of Rasch analysis, with section 2.7.1 summarising some relevant studies that utilise the technique and section 2.7.2 justifying why it is more appropriate to use in this study than the available alternatives.

Rasch Analysis is an analytical technique used to convert ordinal difficulty ratings into interval measures by converting scores into logits (Turano *et al.* 1998). Initially developed by George Rasch (1980), the Rasch model is now recognised as an appropriate methodology in health and ophthalmology studies for the development of new questionnaires, revising of existing questionnaires and test equating. Pallant and Tennant (2006) stated that Rasch analysis addresses important methodological characteristics associated with scale development and construct validation, as well as providing a transformation of the ordinal raw scores to a linear interval scale permitting the use of parametric statistical techniques. Rasch analysis also calculates item difficulty in relation to person difficulty and assesses the scale validity, in particular the item and person fit to the overall construct (Pesudovs *et al.* 2003). Whilst there are numerous questionnaires dedicated to measuring visual ability, their scores cannot be simply compared directly to one another. Rasch Analysis allows scores from different questionnaires to be compared as they all measure the same underlying trait, allowing them to be modelled on the same latent variable (Pesudovs, 2006).

There are several different circumstances in which Rasch analysis is an appropriate analytical method to use. These include patient-reported outcomes for clinical trials and questionnaire items where total scores are provided, the development of new scales, reviewing the psychometric properties of existing scales and when examining hypothesis about the dimensional structure of ordinal scales (Tennant and Conaghan, 2007). Rasch analysis was seen as the most appropriate analytical technique for this study as it involves developing a new transport difficulty questionnaire and scale, in which items are set to fit the model expectations.

Rasch analysis is completed in this study by analysing the relative Transport Ability (Rasch score) and item difficulty (Rasch Measure) using a computer program called Winsteps, as in Linacre (2007). Item difficulty estimates and Transport Ability levels are expressed in values, referred to as logits, which can range from negative infinity to positive infinity. The logit scale is an interval scale in which all logits are of the same size. Each item and person is located along the logit scale according to its estimated value. Higher values are located at the top of the scale and lower values are located at the bottom of the scale (Fox and Bond, 2007). The size of the difference between Transport Ability and item difficulty is central to the Rasch model: the larger the Transport Ability level is compared to the item difficulty the larger the probability of a successful response to the transport item. Thus, the probability of a person finding a task easy to complete is large for persons that are much more able than the difficulty of the item, whereas the probability is small for persons for which the reverse is true.

The value of a linear scale is that valuable comparisons can be made that reflect differences in patient ability over time, or before and after an intervention. In this case, the difficulty of a specific transport task and can also be measured allowing us to see the benefit of interventions, in particular how much easier a task is to complete.

2.7.1 Existing Studies using Rasch Analysis

Rasch analysis has been used in many ophthalmological studies as a way to measure the outcome of interventions such as cataract surgery or blind rehabilitation as shown by studies by Pesudovs *et al.* (2003), Kuyk *et al.* (2004) and Gothwal *et al*. (2009). Rasch analysis has also been used in the modification of existing scales or the development of new scales in areas such as rehabilitation medicine (Hart and Wright, 2002), gerontology (Jette *et al*. 2002) and overall health related quality of life (Prieto *et al*. 2003 and Vijaya *et al.* 2009).

Rasch analysis is also being increasingly applied to understand the effect of visual impairment and specific eye conditions aspects on mobility. The self-assessment questionnaire developed by Turano *et al.* (1998), where independent mobility was assessed for persons with Retinitis Pigmentosa, was adjudged to be the most relevant instrument to this study. It was used to determine whether patient-based assessment is valid for measuring perceived visual ability for independent mobility in patients with Retinitis Pigmentosa. The questionnaire asked subjects to rate on a scale of 1 to 5 how difficult they would find 35 different hypothetical situations if they had no assistance. Each task described a different mobility situation (e.g. moving about in the home, moving around in social gatherings, walking at night). The interval scale developed through Rasch analysis was used to compare the perceived difficulty of items and the perceived ability of individuals. Walking at night was found to be the most difficult task as it required the most visual ability. Moving about in the home was identified to be the least difficult task, requiring a lower level of visual ability. The study also established that the person measure calculated through Rasch Analysis could be used to discriminate between patients who limited their travel and/or had a fear of falling, from those who did not, significant at the 2% level (Turano *et al.* 1998).

Rating categories could relate to the level of difficulty, frequency of problems, level of disability or level of agreement with a statement. Lamoureux *et al.* (2006) used Rasch analysis to measure the impact of vision impairment on restriction of participation in daily activities relating to mobility, the household, personal care, consumer and social interactions, leisure, work and emotional reaction to vision loss. The self or interview administered 32 item Impact of Vision Impairment scale (IVI) questionnaire was based on a five-category Likert scale: ranging from (0) *not at all* and (5) *can't do because of eyesight.* Participants were asked if their vision impacted on items such as; Reading a street sign; Getting outdoors; Travelling or using transport; and going downs steps, stairs or curbs. These studies by Turano *et al.* (1998) and Lamoureux et al. (2006) show how Rasch analysis has been used to examine the impact of vision on general accessibility and transport related tasks.

Other studies that briefly touch on mobility related issues include Weih *et al.* (2002) and Gothwal *et al*. (2009). These instruments incorporated a few transport and mobility related items when using Rasch analysis to analyse mobility. The list of items in their questionnaire included: the perceived difficulty of using stairs; stepping off kerbs within street environments; the ability to read signs across the street; and the ability to use public transport in a general sense. These focus on a narrow range of mobility problems primarily on the walkability of street environments. Nevertheless, the fact that a mobility related self-assessment questionnaire had already been successfully validated and used through using Rasch analysis, shows that a modified transport related questionnaire could also be developed. The public transport focused self-assessment questionnaire developed in this thesis will therefore be the first study that uses Rasch analysis to investigate the relationship between vision and/or mobility problems when using public transport.

A few studies have been completed on other transport modes, such as driving. Massof *et al.* (2007) investigated self-perceived driving ability to examine if the difficulty of driving increased with the magnitude of visual impairment. In the study 21 different driving related tasks were ranked on a scale between one and five and visual acuity and visual contrast were accurately measured in order to investigate the relationship between visual ability and perceived difficulty in driving. Massof *et al*. (2007) identified the most difficult driving tasks to be navigating in parking ramps, parking in correct spaces, seeing lane markings and reading signs. Despite that fact this this study focuses on driving instead of public transport modes, this has shown that Rasch analysis can be used to construct and validate survey instruments. This approach shows that the interval scale developed through using the Rasch model can be used to identify benefits from particular interventions or scheme improvements.

It is important to consider the rating scale used in patient reported outcome instruments as any loss of measurement quality would degrade the quality of clinical studies. Some researchers argue that more reliable and precise measurement can be obtained with more response categories (more than seven) (Preston and Colman, 2000). Whereas others such as favour a small number of response categories based on the theory that fewer response options offer minimum respondent confusion and reduce respondent burden (Viswanathan *et al.*1996).

Khadka *et al.* (2012) used Rasch analysis to explore the characteristics of rating scales and developed guidelines for formulating rating scales. Seventeen existing patient reported outcome instruments designed to measure vision-related quality of life dimensions were mailed for self-administration, in sets of 10, to patients who were on a waiting list for cataract extraction. Khadka *et al*. (2012) found that patient reported outcome instruments with a simple and uniform question format, comprising four or five labelled categories, were most likely to be functional and often demonstrate characteristics such as hierarchal ordering (indicating categories are distinct from each other and follow a logical transition from lower to higher value), even utilisation of categories and a good range coverage of the latent trait being measured (indicating that the rating scale was able to measure a wide range of item difficulty and participant ability levels).

Khadka *et al.* (2012) used these findings to develop evidence-based guidelines for rating scale design, which included a maximum of five categories for most ratings (e.g. difficulty, frequency, severity), use of short non-overlapping category descriptors, use of non-overlapping categories and use of a simple question format with the same response category format for all questions in a domain, as far as possible. These guidelines were followed in the development of the self-assessment instrument in this study to examine if low vision and limited mobility affect the ability of a person to use public transport.

2.7.2 Alternative Methodologies and Justification

An alternative methodology that performs analysis similar to that of Rasch Analysis is Classical Test theory. Classical Test theory is similar to Rasch analysis in that it is used to predict outcomes of psychological testing such as the difficulty of items or the ability of individuals; aiming to understand and improve the reliability of psychological tests. Classical Test Theory was developed by Spearman (1904), who argued for the decomposition of an observed score into a true score and an error and estimated the reliability of observed scores. The premise was that items can be summed (without weighting or standardization) to produce a total score (Lord and Novick, 1968). Limitations of Classical Test Theory are that participants and test characteristics cannot be separated as each can only be interpreted in the context of the other. Additionally, it cannot make predictions of how well an individual or even a group of participants might do on a test item (Hambleton *et al*. 1991). By contrast, Rasch Analysis is able to predict the probability of a person with a particular ability level being able to perform tasks with a certain difficulty level.

The validity of scores that are calculated through questionnaires has always been difficult to justify. As previously explained in section 2.6, if ordinal response scores are simply added up, as in Likert scores, with items given equal rating, it is difficult to justify the accuracy of the scores and conclusions that are made (Likert, 1932). However, Rasch analysis, assumes that different items within a questionnaire vary in difficulty, calculating item difficulty in relation to Transport Ability and weighting overall scores accordingly. Rasch analysis is also useful in the development of scales as scores are linear, allowing the easy comparison of measures before and after interventions. Additionally, a necessary strength of Rasch analysis is that it is able to investigate instrument validity; fitting items to the overall construct to allow direct comparison between the perceived difficulties of each item to the ability of individual patients.

2.7.3 Summary of Rasch analysis

The major advantage that Rasch analysis has over other techniques is that it allows ordinal responses, such as self-reported ratings given as questionnaire answers, to be converted into logits, which are interval measures. As discussed in sections 2.7 and 2.7.1, Rasch analysis is an established technique in health and ophthalmology studies but has yet to be widely applied to transport studies.

Nevertheless, as discussed in section 2.7.1, there are a small number of studies, such as Turano *et al.* (1998), that have used Rasch analysis in a transport context, demonstrating that this is a feasible approach to use in this field. The most prominent alternative technique, Classical Test theory, is very limited compared to Rasch analysis so is not an appropriate approach to use in this study.

2.8 Summary

A research gap has been identified through investigation of existing studies and methodologies within the transport study fields involving mobility, low vision and current transport accessibility evaluation techniques. This research gap is within the field of transport accessibility, where there is an identifiable need to develop an accessibility indicator that is based on the capability of individuals, and that takes into account the views and experiences of older people and people with vision and/or mobility related problems. Closer analysis of background themes and concepts has also identified a methodological technique, Rasch analysis, that can be applied within a transport context to develop a tool that can be used to measure a person's ability. Additionally, a number of other important characteristics have also been identified, through close analysis of research studies within the field of transport accessibility, mobility, visual impairment, transport accessibility evaluation techniques, patient based visual function assessment instruments and studies that use Rasch analysis.

To enable fair and equal access to public transport, it is essential that Transport Accessibility takes a holistic approach with every part of the journey chain taken into account, as identified in section 2.2. Using public transport in a complex task and the inability of a person to complete one part of the journey chain will prevent the entire journey from being completed.

Analysis of the field of mobility in section 2.3 identified a number of techniques that have been used to measure pedestrian mobility in real and laboratory environments, which were each found to have a number of limitations. However, the approach that was found to encapsulate a holistic approach and found to be most applicable to this study was the Life Space model. This will therefore be used alongside the instrument developed in this study, in order to compare the frequency and the extent of each participant's travel with their ability to use transport and self-assessed vision level.

Various methods of categorising visual impairment were summarised in section 2.4, which each have many advantages and disadvantages. Clinical measurements of visual acuity were found to be time consuming and labour intensive, but self-reported measures have to be simple to understand and administer, but accurate enough to reliably determine visual ability. A Vision Level scale of the type developed by Grundy *et al*. (1999) was identified to be the most appropriate technique for this study and has been successfully employed by other studies, such as Dalke and Conduit (2010).

Analysis of visual impairment studies in section 2.4 also revealed that visual field loss has generally been found to reduce mobility, but there is little research on whether loss of central or peripheral vision has a greater effect. Also, relatively little research has been completed that compares the impact of AMD and glaucoma on mobility or transport use. This study will therefore initially focus the development of the transport instrument to help understand the impact that AMD and glaucoma has on the ability to use public transport; contributing to the field of central and peripheral field loss and navigation.

The capability approach was identified in section 2.5 to be the most appropriate approach to evaluating transport accessibility for this study. The benefits of transport accessibility schemes tend to primarily be that the barriers to participation in society are reduced for specific groups, alongside a host of other intangible benefits that cannot easily be converted into monetary values in the way that traditional cost benefit analysis would require. In addition to this issue, cost benefit analysis is generally used at an aggregate level, rather than taking individual experiences in to account, so is not suitable for use in this study. In contrast, the capability approach can be applied within the field of transport studies as a framework with which to measure changes in quality of life for individuals based on their ability relative to the ability required by the transport environment.

Self-reported questionnaires are identified as being a well-established technique within the study of visual impairment in section 2.6. However, when developing new functional assessment instruments, it is important to consider how measurements will be validated in order to provide meaningful results. For the ordinal scores generated by self–assessment questionnaires to be give more meaningful results than a simple ranking, an item response model, such as the Rasch model, must be applied.

Rasch analysis appears to be the most appropriate analytical technique for this study as it involves developing a new transport difficulty questionnaire and scale in which items are set to fit the model expectations. As summarised in section 2.7, the production of a linear logit scale through Rasch analysis will enable valuable comparisons to be made that reflect differences in patient ability over time, or before and after an intervention. In this case, Rasch analysis will allow the difficulty of a specific transport task to be measured; allowing the benefit of interventions to be measured, in particular how much easier a task is to complete. The public transport focused self-assessment questionnaire developed in this thesis will be the first study that uses Rasch analysis to investigate the relationship between vision and/or mobility problems with the difficulty of tasks required to use public transport.

This research project will now focus on the development an instrument that can measure the ability of people with low vision and/or mobility problems to use public transport on both a disaggregate and aggregate basis. If an individual's ability level could be measured and compared with the ability level required to complete a specific transport related task, it may be possible to calculate the probability of a person completing a task. This could then be used to assess the effectiveness of transport interventions and improvements to make sure the correct accessibility issues are being addressed in the most effective way.

Chapter 3 Development of Transport Survey I

3.1 Introduction

Self-assessment instruments have increasingly been used to develop vision related questionnaires, in order to capture specific aspects of visual function from a patient's perspective, as described in section 2.7. Therefore, a self-assessment instrument that could be administered on a large scale was thought to be the most effective way of reaching a large audience about specific transport related problems. This would allow investigation into whether an underlying latent trait of Transport Ability exists, and a better understanding of how to measure such a trait among a group of people with a range of low vision and/or mobility problems.

One of the benefits of using a self-assessment tool is that the data is provided by the individual participants themselves, meaning that differences in ability between individuals can be measured based on their personal day-to-day experience and opinion, rather than by assessment by another person. Furthermore, it is possible to go beyond aggregate analyses to drill down to the level of the individual in order to examine which individuals are most affected by specific accessibility interventions and why. This allows equity to be taken into consideration, so that barriers to accessibility that have a large effect on a small number of people can be highlighted.

The transport related tasks that would need to be completed in order to successfully complete various forms of whole journey chain when using public transport were examined in this study, reflecting the holistic approach recommended by the DfT, as discussed in section 2.2. The aim was to understand the relative difficulty of these transport related tasks, as experienced by people with the central vision loss associated with AMD and peripheral vision loss associated with glaucoma. As previously discussed in section 2.4, because AMD and glaucoma predominantly affect older people with varying severity (Quigley and Broman, 2006 and Bressler, 2004), this research focuses on elderly people and mobility aid users. Mobility issues are also investigated alongside vision related problems in order to gauge how using a mobility aid affects a person's Transport Ability. This will help to understand whether mobility and vision can be measured in the same way;

contributing to research relating to how people with low vision and/or mobility problems travel within transport environments.

The goal of the self-assessment instrument is to determine the perceived level for independent mobility within a group of subjects with varying severity levels of visual and mobility impairment. In addition to Transport Ability ratings, the questionnaire also recorded personal characteristics for each participant, including age, gender, whether they live alone, visual ability, visual condition, number and type of mobility aids used and their Life Space patterns. As discussed in section 2.3.4, Life Space patterns are used to assess how a person's mobility varies on a weekly basis and how far and how frequently they travel within and outside their home and neighbourhood (Peel *et al*. 2005). The Life Space score calculated for each participant in the study will allow investigation of the extent to which each characteristic influences individual travel behaviour, helping to understand how living with visual and/or mobility impairment affects independent mobility and travel.

As described in section 2.6, in order to measure visual ability from responses to items on a visual function questionnaire accurately, statistical item response models such as the Rasch model should be applied (Massof and Rubin, 2001). This will allow participant responses to be transformed into an interval scale in order to produce validated measurements that can provide meaningful results. This chapter will now discuss how the transport instrument was developed and validated using Rasch Analysis.

3.2 Methodology for the Development of Survey I

This study underwent and successfully passed the research ethics procedure of the Department of Civil, Environmental and Geomatic Engineering, University College London. Figure 3.1 summarises the main stages in the development of the survey instrument.

The objective of using the instrument was to investigate the transport related problems that exist for people with low vision and/or limited mobility. The survey developed was loosely based on a patient assessment questionnaire developed by Turano *et al.* (1998) and Lamoureux *et al.* (2006) who both developed self/interview assessed questionnaires to investigate the impact of low vision on mobility. As explained in section 2.7.1, these studies were adjudged to have the most relevant instrument to this research. The questionnaire used by Turano *et al.* (1998) asked participants to rate on a scale of 1 to 5 how difficult they would find 35 different hypothetical situations if they had no assistance. Each task described a different mobility situation (e.g., moving about in the home, moving around in social gatherings, walking at night). Whereas Lamoureux *et al.* (2006) measured the impact of vision impairment on restriction of participation in daily activities relating to mobility; household; personal care; consumer and social interactions; and leisure and work and emotional reaction to vision loss. The style of the questions used in these studies were adopted but tailored to a transport related context. These were based on results from focus groups conducted in the second stage of the study, as shown in Figure 3.1. The whole public transport journey chain was also taken into account in the development of the transport items for Survey I, the importance of which was previously discussed in section 2.3.

In order to organise a number of focus groups with people who had AMD, area leaders who organised monthly coffee mornings for the Macular Society in different parts of London were contacted and gave permission for this study to be discussed at a series of meetings across London. Informal focus groups were held during these coffee mornings that took place in local community centres in Richmond, Enfield, Croydon, Camden and West Hampstead. Members of the AMD society who wished to take part in these focus groups spoke about the challenges they experienced when using public transport. Approximately 5-6 people took part in each of the 5 focus group sessions, most of whom were women above the age of 60. During these sessions participants deliberated about the aspects of public transports that they found most challenging and difficult, and discussed particular difficulties experienced with specific transport modes and navigation more generally. These informal discussions highlighted that individuals used a range of public transport modes, but some experienced more difficulty than others depending on the severity of their AMD and level of mobility. It was therefore concluded that the study questionnaire should include a range of different London transport modes and include questions about all parts of the journey chain, in order to understand the full effect that AMD and mobility limitations had on the ability to use public transport.

The subsequent pilot survey consisted of 4 sections: Part 1 asked participants to rate on a scale of 1 (“no difficulty”) to 5 (“extreme difficulty”) the level of difficulty they experienced in specific transport related tasks; Part 2 asked a series of multiple-choice and open-ended questions on transport; Part 3 comprised the Life Space questionnaire, described in section 3.3.1, used to identify how far afield a person reported that they travelled in an average 7-day period, and part 4 of the questionnaire was used to ask personal information, such as age, type of AMD and whether they lived alone. The pilot questionnaire was sent to participants who attended the Macular Society coffee mornings in order to make sure that the survey was easily understood and addressed the full range of transport modes. After reviewing the results of the 50 participants who returned the pilot study, over half of the participants had commented in the comments section that they particularly found travelling at night and in large crowds intimidating and difficult. These tasks were not previously included in the questionnaire, so questions were therefore added into part 1 of the questionnaire, so as to include some general navigational related questions that affected an individual’s ability to use public transport. The instrument was then ready to be applied to a larger sample.

The third stage was to recruit participants to take part in the study to test the developed instrument. The questionnaire was also sent out by the Macular Society to 1000 of their London-based members. The survey was administered by post, although the Macular Society also conducted some interviews by phone if contacted by individuals wishing to take part. The aim of this was to capture people who have low vision and/or mobility problems, who may or may not attend local support group centres. This was seen as a way to include people who were active but also those who felt less comfortable travelling outside the home. Participants were also recruited through an advertisement in the Glaucoma Association newsletter, in addition to being conducted at a Community Centre in Borough A and with participants over the age of 65 on the PAMELA (Pedestrian Accessibility Mobility Environment Laboratory) University College London research facility participant list.

The returned survey data was then analysed using Rasch analysis in Winsteps (version 3.75.1) in order to validate the questionnaire, as shown in stage 4 of Figure 3.1. Regression analysis was then carried out to help explain the variance in Transport Ability and Life Space score, as well as examining how Life Space patterns varied with Transport Ability levels.

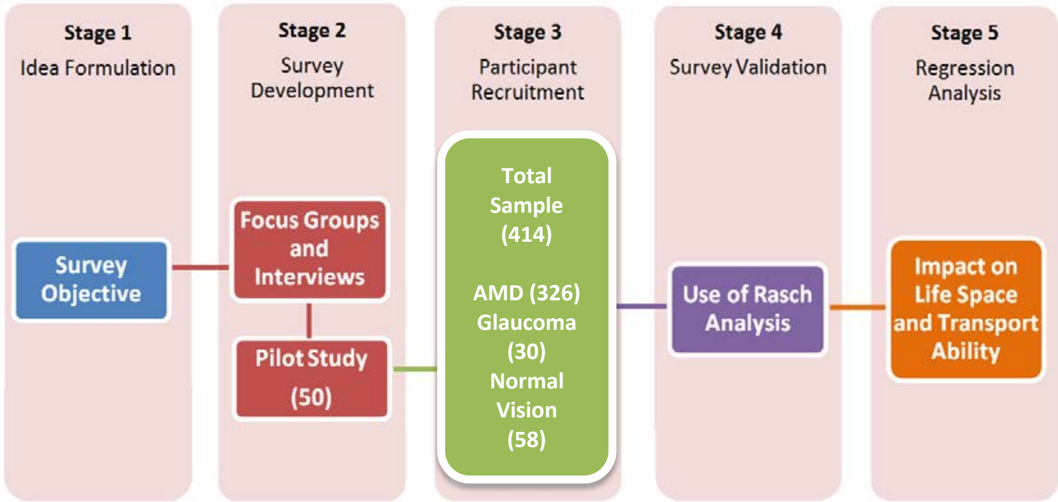

Figure 3.1 Main stages in the development of Survey I

3.3 Structure of Questionnaire

The developed questionnaire was structured into four different parts as shown below. A copy of this questionnaire can be found in the Appendix 1.

- Part 1 participants were asked to rate on a scale of 1 (“no difficulty”) to 5 (“extreme difficulty”) the level of difficulty they experienced in each of the 25 transport and navigational related tasks when they did not have an accompanying person or mobility aid to assist them.
- Part 2 participants were asked to answer a series of multiple-choice and open-ended questions on transport.
- Part 3 comprised the Life Space questionnaire, described in section 3.3.1, which was used to identify how far afield a person reported that they travelled in an average 7-day period.
- Part 4 of the questionnaire was used to ask personal information such as age, type of AMD and whether they live alone. Information about their vision

was also collected through the use of visual ability statement categories as applied by Grundy *et al*. (1999), as described in section 3.3.2.

3.3.1 Life Space Questionnaire

As discussed in section 2.3.4, in order to gauge the extent to which people travel, a Life Space questionnaire formed part of the self-assessment instrument. The Life Space questionnaire used in this study was taken from a Life Space instrument developed by Peel *et al.* (2005). Six separate concentric zones were identified, as shown in Figure 3.2, and participants were asked to estimate the number of times that they visited each zone during an average week.

A Life Space score was generated for each participant by assigning a value to each of the 6 different levels (0-5) and then summing the scores. The level scores were obtained by multiplying the level number (0-5) by a value for independence (2 = no assistance, 1.5 = use of equipment only, 1 = use of another person and/or equipment) times a value for frequency of movement (1 = less than once a week, 2 = 1–3 times each week, 3 = 4–6 times each week, and 4 = daily). The Life Space scores ranged from 0 (bed-bound) to 120 (travelled out of town every day without assistance). The sum of these scores produced an overall Life Space score for each participant. The more frequently and further afield a person is able to travel, the higher their Life Space score.

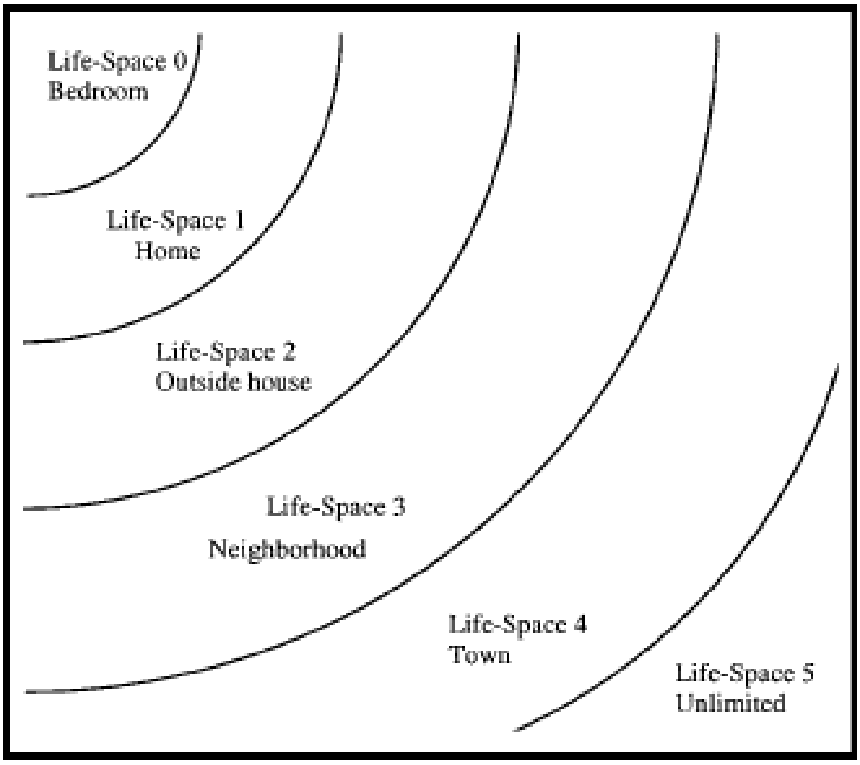

Figure 3.2 Conceptual levels in a Life Space Model (Peel *et al*. 2005)

The below equation summarises how Life Space scores were calculated for each individual in this study.

$$\textbf{LSS} = \textbf{Level} \times \textbf{Independence} \times \textbf{Frequency}$$

Where:	Level =	0-5	(see Figure 3.2 above)
	Independence =	1	(use of another person or equipment)
		1.5	(use of equipment only) or
		2	(no assistance)
	Frequency of movement =	1	(less than once a week),
		2	(1–3 times each week),
		3	(4–6 times each week), and
		4	(daily)

3.3.2 Measuring Visual Acuity

As discussed in section 2.4.4, the vision level table used in Grundy *et al*. (1999) was adjudged to be the best way for participants to assess their visual ability level alongside the self-assessment instrument developed in this study.

Table 3.1 denotes the visual ability categories as used by Grundy *et al*. (1999) to allow an approximate visual ability level for each participant to be recorded. Participants were asked to read down the list and mark the Vision Level that best described the limit of their vision when using their usual vision aids. An approximate visual ability score could then be allocated to each participant in order to assess how Transport Ability varies with Vision Level (V Level) and whether this affected the extent and frequency of their travel (Life Space score).

Table 3.1 Vision Level table (Grundy *et al*. 1999)

V Level	**Vision**
V1	Cannot tell by the light where the windows are
V2	Cannot see the shapes of furniture in a room
V3	Cannot recognise a friend if close to his/her face
V4	Cannot recognise a friend who is at arm's length away
V5	Cannot read a newspaper headline
V6	Cannot read a large print book
V7	Cannot recognise a friend across a room
V8	Has difficulty recognising a friend across the road
V9	Has difficulty reading ordinary newspaper print
V10	Full vision ability

3.4 Summary

This chapter has summarised the main stages in the development of the Transport Survey I, a copy of which is provided in Appendix I. Transport Survey I has contributed towards the first research objective; to develop a new evaluation technique that can measure the ability to use transport reliably and consistently for people with low vision and/or mobility problems.

As previously discussed in section 3.2 of this chapter, the style of the questions used in Turano *et al.*'s (1998) study were adopted but tailored to a transport related context. These were based on results from focus groups conducted in the second stage of the development of Transport Survey I. The whole public transport journey chain was also taken into account in the development of the transport items for Survey I.

This chapter has introduced the concepts of Visual Ability and Life Space that will help measure a person's self-assessed level of vision and extent of travel outside their home. Along with other characteristic data collected in the survey instrument such as age, gender and whether or not a person lives alone, these variables will be used to analyse and validate a person's Transport Ability level for people with low vision and/or mobility problems. The following chapter will now investigate whether an underlying latent trait of Transport Ability exists, in order to validate Survey I using Rasch analysis. This will help to achieve the first study research objective for Transport Survey I; to develop and validate a new evaluation technique that can measure the ability to use transport reliably and consistently for people with low vision and/or mobility problems.

Chapter 4 Validation of Transport Survey I

4.1 Introduction

Transport Survey I developed in Chapter Three can now be validated using Rasch analysis using Winsteps version 3.75.1. The survey data was manually entered into a Microsoft Excel 2010 spreadsheet for checking and cleaning before being exported to Winsteps to conduct Rasch analysis. The Winsteps outputs were then exported to both Excel and JMP version 12 for further analysis and the creation of summary charts and tables. As illustrated by Fox and Bond (2007) the main validation stages include (i) Category Performance, summarised in section 4.2.1; (ii) Fit of the model, covered in section 4.2.2; (iii) Item-person match, shown in section 4.3.2; (iv) Differential Item Functioning (DIF), described in section 4.3.3 and (v) Multidimensionality investigation, outlined in section 4.3.4, as well as an analysis of the correlation between Transport Ability and various participant characteristics to determine construct validity and to ensure logical results and conclusions.

4.2 Validation Stages

4.2.1 Category Performance

According to Tennant and Conaghan (2007), it is important to examine the category structure of the questionnaire data to examine whether responses to items are consistent with the metric estimate of the underlying construct, which is indicated by an ordered set of response thresholds for each of the items.

Figure 4.1 shows the category probability curves produced by Winsteps to illustrate the construct validity of the data. The Transport Ability measure relative to the item difficulty is represented by the x-axis, the probability of a person giving a particular difficulty rating is represented by the y-axis and each curve represents one of the 5 response categories. Each of the peaks in the graph indicates the probability of a person giving a particular rating at differing difficulty levels relative to the item difficulty. For example, in Figure 4.1 the pink line shows that a person with zero difference between their Transport Ability measure and the Item Difficulty, shown as 0 on the x-axis, has a more than 0.5 probability of giving that item a rating of 3, whilst the blue and black lines respectively show that the probability of a 4 or 2 rating being given is around 0.2. The probability of a 5 or 1 rating, as shown by the red and green lines respectively, is close to zero.

The overall category performance for the main dataset of this study is relatively strong. The curves form a series of distinct peaks and each of the curves are in ascending order along the latent variable, meaning that each category is most likely to be chosen in ascending order as item difficulty increases relative to Transport Ability. The crossover points between each category are also at roughly two logit intervals, showing that each of the categories 2, 3 and 4 are the most likely response for similar spreads of ability relative to item difficulty. For example, the green line shows that easier items, where Transport Ability exceeds item difficulty by three or more logits, are most likely to be given a score of 1, whereas the red line shows that where item difficulty exceeds Transport Ability by three or more logits, these items are most likely to be given a difficulty rating of 5. This indicates that each difficulty rating is incremental and is able to measure the differing abilities of the participants. Hence, the responses given by each participant for each of the transport related task are consistent with the underlying construct.

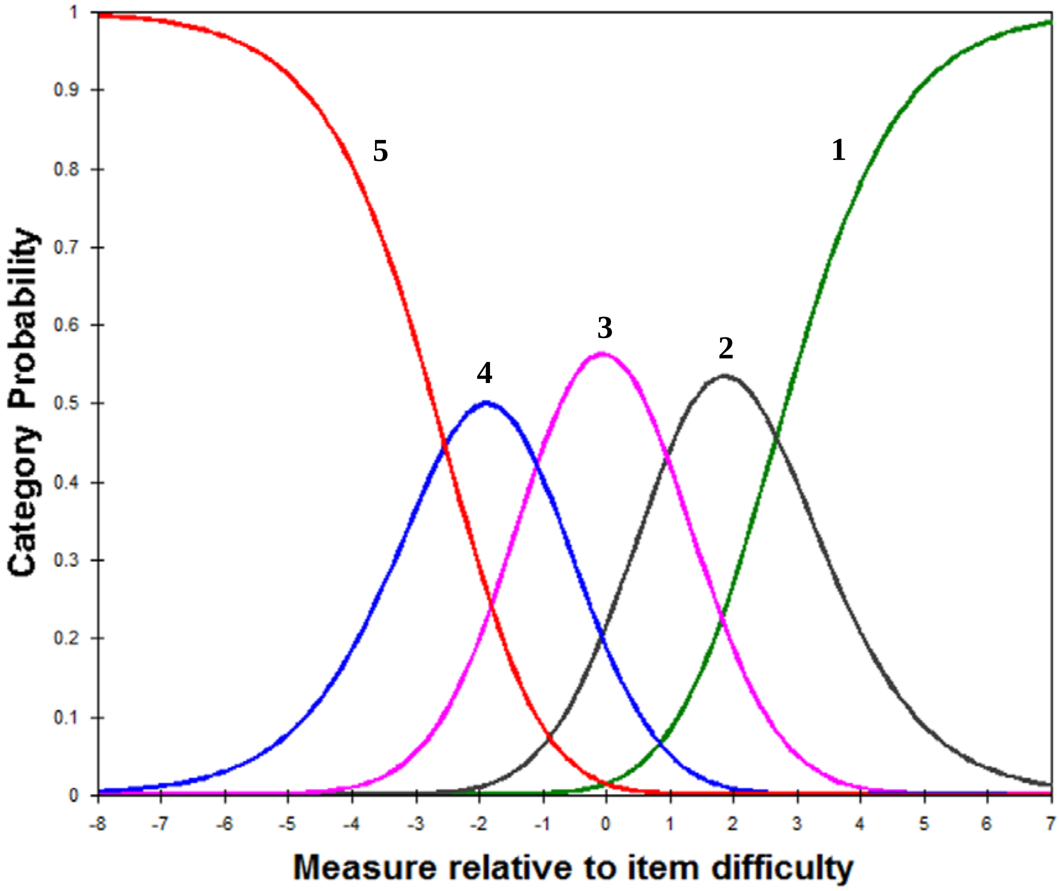

Figure 4.1 Category Probability Curve for responses to Survey I

The person and item measures have equal status in the Rasch model and the difference between the person and item measures can be described as the 'functional reserve' (Stelmack *et al*. 2006). The functional reserve can be defined in this study as the difference between the Transport Ability possessed by a participant the level of Transport Ability required to perform each Transport Item (Massof, 1995 and 1998). Therefore, if a person finds a task easy to perform, it is more than likely that their Transport Ability level will exceed the necessary level required to perform that transport related task. If a person's Transport Ability level is similar to the level required to perform the transport task, their functional reserve is limited as they will find it more difficult to perform that particular transport related task. Likewise, if their Transport Ability level is lower than that required by the item, their functional reserve will be negative and the participant would be expected to be more likely to report a high level of difficulty in performing the task.

4.2.2 Fit of the Model

Person and item separation and reliability scores are used to determine how well an instrument is able to discriminate between different ability levels of individuals and different item difficulties. Low person separation of <2 or person reliability <0.8 would imply that the instrument may not be sensitive enough to distinguish between people with higher and lower abilities (Bond and Fox 2007). In the first instance, when all 414 persons and 25 items were included in the model it had a person separation score of 3.44, with a person reliability score of 0.92, so had sufficient items of various levels of difficulty to discriminate between different ability levels well.

Low item separation of <3 or item reliability <0.9 would imply that the person sample was not large enough to confirm the item difficulty hierarchy of the instrument (Bond and Fox 2007). The model had an item separation score of 10.12, with an item reliability score of 0.99, so had a sufficient number of people of varying ability levels to confirm the construct validity of the instrument.

However, among the 414 people there were 21 who responded N/A to every item, 10 who answered 1 for every item and 13 who answered 5 to every item. Those who only responded ‘N/A’ provided no useful data so could not be included in the dataset. The people who gave all 1s and the people who gave all 5s were also excluded from the dataset as they found every item respectively too easy or too difficult, meaning that their abilities would all take the maximum or minimum value and due to ceiling and floor effects their responses provide no useful information on the relative difficulty of each item.

Furthermore, the 30 people with glaucoma were also excluded because this sample size was too small to provide comparisons with people with either AMD or neither condition that were statistically significant. This meant that altogether 74 people had been removed from the dataset because they answered N/A, 1 or 5 for all items or had glaucoma, leaving a person sample of 340. Person separation and reliability had increased to 3.72 and 0.93 respectively, while item separation fell slightly to 8.20 and reliability remained 0.99.

Upon running the model using the remaining 340 responses, the fit statistics revealed a number of unexpected responses, denoted by infit and outfit. The infit and outfit statistics produced in Winsteps identify the most misfitting data in the model. Infit indicates the difference between observed and expected responses for items that have a difficulty level near the person's ability level, whereas outfit uses the differences for all items, without taking into account how far away the item difficulty is from the person's ability (Tennant and Conaghan, 2007). In this sense, the infit is a weighted statistic as more significance is placed on items close to the participant's ability level. In this study, participants who had a large infit or outfit statistic may have under or overestimated their navigational ability in comparison to their individual level of vision or may have even misunderstood the rating scale.

The 340-person infit and outfit z-statistics were plotted as shown in Figure 4.2, and the responses given by the participants outside of the acceptable range of +2 -2 denoted by the red box were removed, paying more attention to infit than outfit and more attention to positive misfit rather than negative misfit.

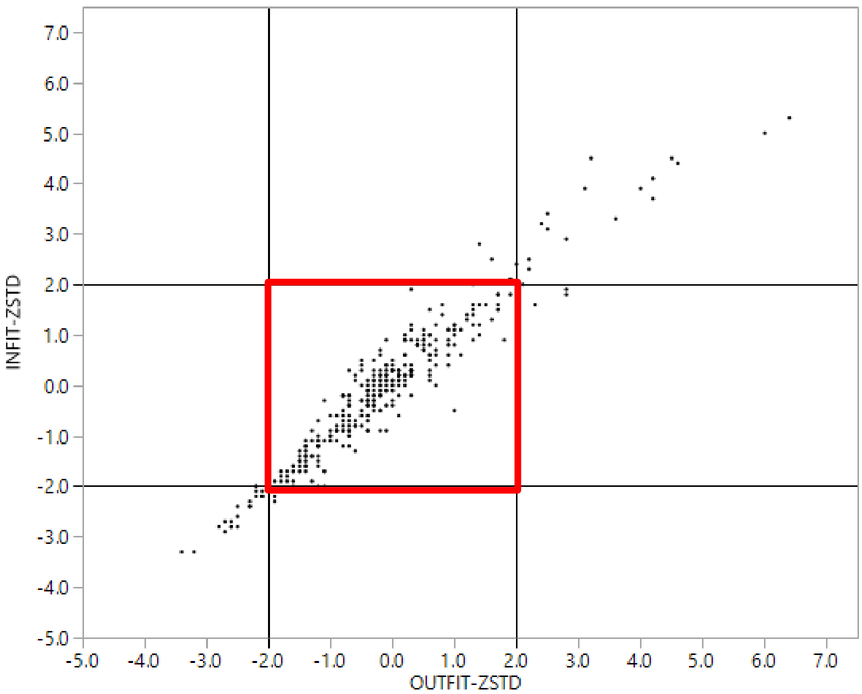

Figure 4.2 **Infit and outfit z-statistics of 340 participant dataset**

In total 44 people were removed from the dataset; 21 with infit greater than 2 and 23 with infit less than -2. Figure 4.3 illustrates the infit and outfit z-statistics for the remaining 296 participants, showing fewer outliers. Removing these misfitting individuals increased person separation and reliability to 3.98 and 0.94 respectively, while item separation and reliability were virtually unchanged at 8.18 and 0.99.

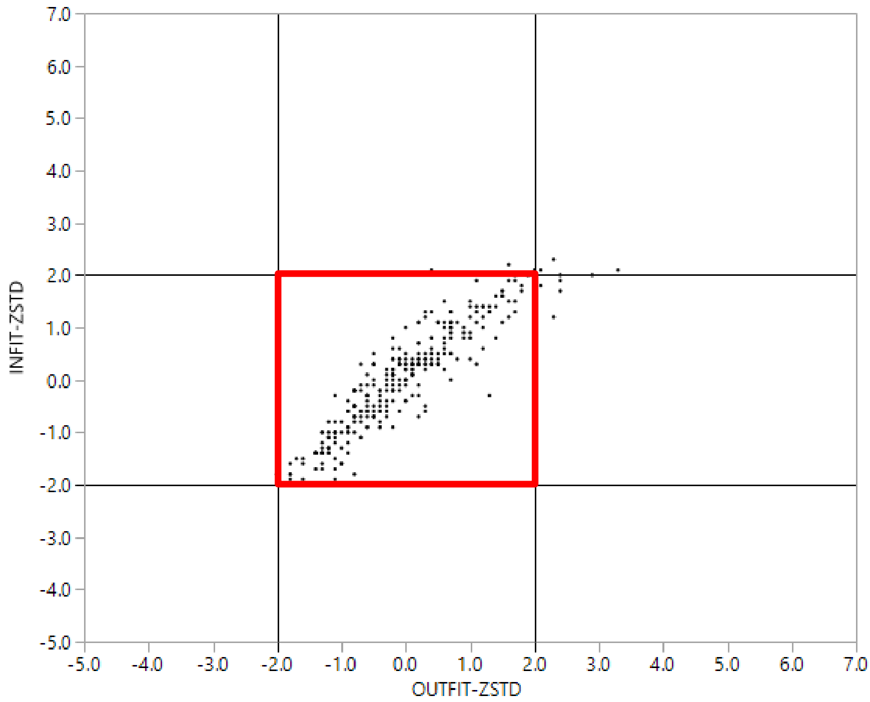

Figure 4.3 Infit and outfit z-statistics of cleaned 296 participant dataset

After cleaning the misfitting individuals from the dataset, there were still six participants with infit greater than 2 and a further six with outfit greater than 2. The raw responses of these 12 individuals were inspected but, while there were one or two surprising responses for each person, there did not appear to be a compelling reason to exclude these people from the dataset.

The relative infit and outfit z-statistics for each of the 25 transport items included in this study were plotted as shown in Figure 4.4. The red box denotes the acceptable boundary for misfitting items, set within a range of +2 and -2.

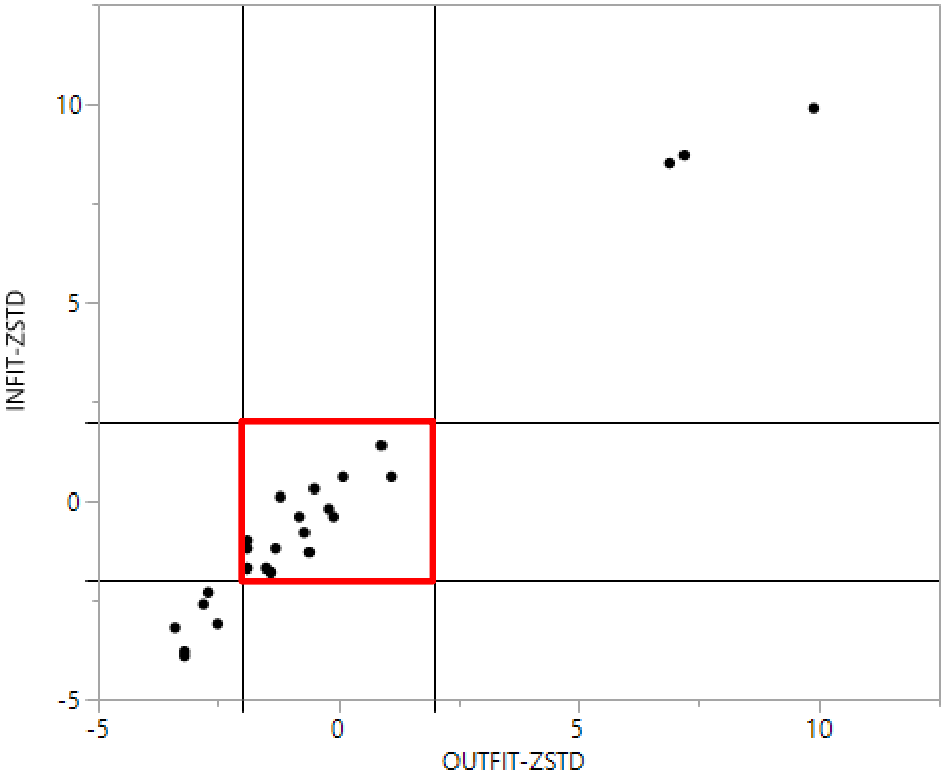

Figure 4.4 **Transport item infit and outfit z-statistics for all 25 items**

There were 3 clear outliers to the top right of the graph, which indicated that these transport items might not fit the Rasch model and should not be included in the study. These were ‘Reading Tube arrival boards’, ‘Reading Train arrival boards’ and ‘Reading bus numbers’. These tasks seemed to be specifically measuring ability to read from a distance, so it was reasonable to conclude that the challenge they present is qualitatively different to that presented by the other tasks, meaning that they were not measuring the same underlying latent trait of Transport Ability. ‘Reading bus numbers’ was the biggest outlier, so was removed first and the model refitted. Unsurprisingly ‘Reading Tube arrival boards’ and ‘Reading Train arrival boards’ remained significant outliers, so each of these were also removed one at a time, as summarised in Table 4.1.

Removing these items increased person separation to 4.10 and item separation to 8.75. Person and item reliability remained 0.94 and 0.99 respectively. The model was refitted again, with the misfit of the remaining 22 items shown in Figure 4.5, in order to analyse whether removing these items significantly improved the fit of the data to the Rasch model.

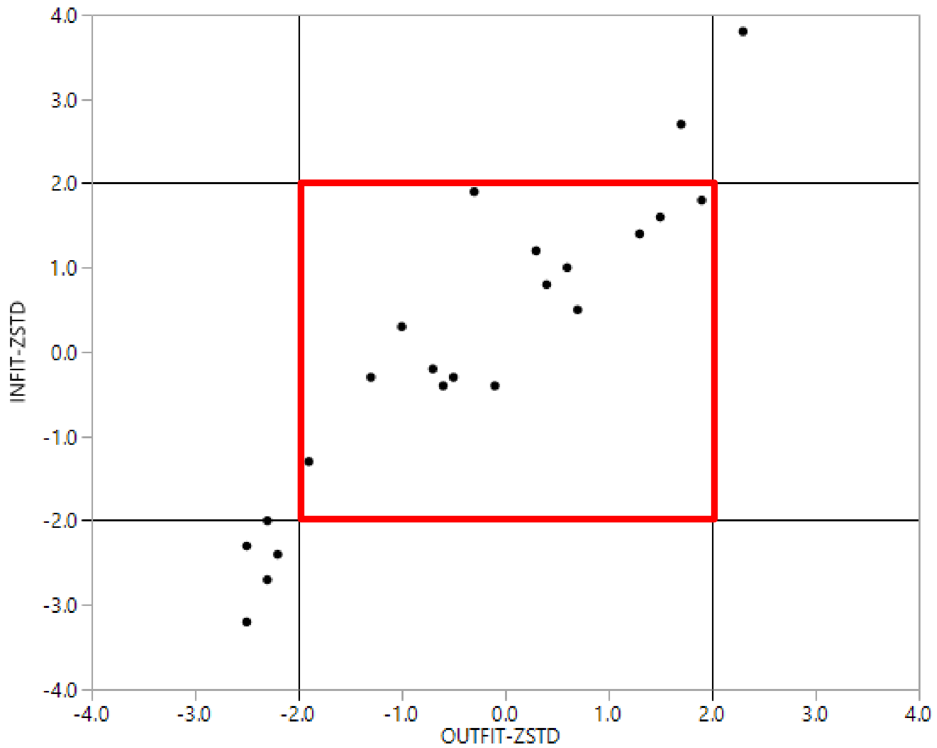

Figure 4.5 Item infit and outfit z-statistics for 22 items

Figure 4.5 shows that 7 of the remaining 22 items lay outside of the ideal -2 to +2 range for infit or outfit. However, this didn't necessarily make these items candidates for removal because Linacre (2002) showed that as sample size increases the number of degrees of freedom also increase, which inflates misfit z-statistics. Linacre suggested that to counter this mean-square statistics should be used instead, with a range of 0.5 to 1.5 seen as an acceptable fit because mean-square statistics below this range suggest that responses to the item are too predictable to be useful, whereas above this range the noise in the responses tends to drown out any useful information. Pesudovs *et al.* (2007) suggest using 0.7 to 1.3 as a guide, while also advising that this range be widened as sample size increases. The plot of the infit and outfit mean-square statistics for the remaining 22 items is shown in Figure 4.6, with the acceptable ranges suggested by both Linacre and Pesudovs indicated. All 22 points lie within Linacre's suggested range of 0.5 to 1.5 for both infit and outfit. As a result, no further items were excluded on the basis of misfit.

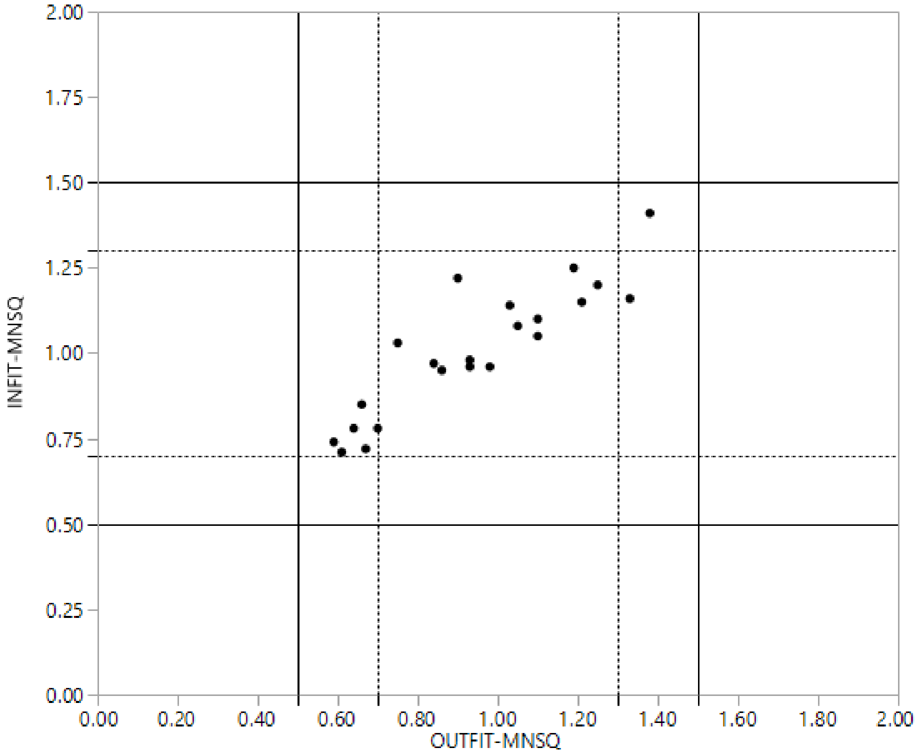

Figure 4.6 **22 item infit and outfit mean-square statistics**

In addition to misfit, Pesudovs *et al.* (2007) suggest that items should be removed if they have significant missing data (>50%) or are subject to floor or ceiling effects, whereby more than half of responses are in an end category, in this instance 1 or 5. While none of the remaining 22 items were missing more than half of responses, there were five items subject to a floor effect more than half of respondents gave a rating of 5, which were 'travelling to the bus stop', 'travelling to the Tube station', 'travelling in familiar areas', 'boarding the Tube' and 'travelling to the train station'. As a majority of respondents rated these items as the lowest difficulty, these items are of limited use in attempting to differentiate between differing Transport Ability levels. These items were removed one at a time, in order of the proportion of responses in the end category, with the person and item reliability and separation scores recalculated after each item was removed, as shown in Table 4.1.

In order to improve the efficiency of the instrument, items that were potentially redundant due to similarity to other items were identified by measuring inter-item correlation between each of the remaining 17 items. Jones *et al.* (2009) suggest that an inter-item correlation great than 0.7 indicates that the correlated items are sufficiently similar to render one of them redundant. Seven pairs of items were correlated to this extent, suggesting that seven items could be removed to improve the efficiency of the instrument.

In each correlated pair of items, the item with fewer responses was removed in order to maximise the number of person responses utilised, with the items with a higher correlation removed first. The items removed were ‘alighting the train’, ‘stairs in a Tube station’, ‘escalator in a tube station’, ‘alighting the bus’, ‘manoeuvring on the Tube’, ‘navigating in a Tube station’, and ‘escalator in a train station’. The items were removed on by one, with the person and item separation and reliability calculated after the removal of each item, as summarised in Table 4.1. Following the removal of the correlated items person separation and reliability fell to 3.22 and 0.91 respectively, while item separation and reliability were 10.00 and 0.99. As person separation and reliability were still greater than 2 and 0.8 respectively, despite the removal of 15 items, this showed that the 10 remaining items had sufficiently varied levels of difficulty to discriminate between different Transport Ability levels.

Table 4.1 Summary of items removed

Item removed	**Reason**	**Person separation**	**Person Reliability**	**Item separation**	**Item reliability**
Initial scores after person removal		3.98	0.94	8.18	0.99
Reading bus numbers	Misfit	4.05	0.94	8.50	0.99
Reading Train arrival boards	Misfit	4.07	0.94	8.56	0.99
Reading Tube arrival boards	Misfit	4.10	0.94	8.75	0.99
Travel to bus stop	Floor effect	4.83	0.94	8.25	0.99
Travel to Tube station	Floor effect	4.00	0.94	8.20	0.99
Travelling in familiar areas	Floor effect	3.86	0.94	7.63	0.98

Boarding Tube	Floor effect	3.80	0.94	7.69	0.98
Travelling to train station	Floor effect	3.76	0.93	7.60	0.98
Alighting train	Correlated with boarding train	3.73	0.93	7.83	0.98
Stairs in a Tube station	Correlated with stairs in a train station	3.65	0.93	8.02	0.98
Escalator in a Tube station	Correlated with escalators in a train station	3.61	0.93	8.39	0.99
Alighting bus	Correlated with boarding bus	3.43	0.92	8.66	0.99
Manoeuvring on Tube	Correlated with manoeuvring on train	3.34	0.92	8.88	0.99
Navigating in Tube station	Correlated with navigating in train station	3.27	0.91	9.38	0.99
Escalator in a train station	Correlated with stairs in a train station	3.22	0.91	10.00	0.99

Following the item reduction process, 13 participants were found to have rated the remaining 10 items as either all 1 or all 5. These people were therefore removed from the sample, leaving 283 participants in total.

4.3 Overall Instrument Reliability

The overall reliability of the instrument was analysed to make sure that it was consistently measuring the construct of Transport Ability, meaning that two different people of similar ability would give approximately the same Transport Ability ratings for each item, producing results consistent with the rest of the questionnaire and showing that the instrument was internally consistent. According to Massof and Rubin (2001), Cronbach's Alpha is the best methodology to validate this approach.

Table 4.2 Cronbach's Alpha reliability statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
0.89	0.89	10

Split half reliability splits the data randomly into two sets of data, producing a score for each participant based on each half of the scale. If the scale is very reliable, the participants' total score from the items in one half of the data should be very similar to that produced by the other half of the data. However, as the data could be split in many ways, Cronbach's Alpha (α) is equivalent to a correlation coefficient for all possible split half reliabilities of the items used in the study, with an alpha closer to 1 suggesting better reliability. However, scores that are close to 1 are suggestive of redundancy, meaning that some items could be removed without significantly reducing the measurement accuracy of the instrument.

According to Cortina (1993), the Cronbach's Alpha score represents reliability and unidimensionality of the scale, and a score of above 0.8 is considered strong. For this instrument, the Cronbach's Alpha measure for the Transport Ability scale was 0.89 as shown in Table 4.2, showing that the instrument was reliable without being so high as to suggest significant redundancy among the items.

4.3.1 Transport Item Difficulty

The remaining 10 items are shown in Table 4.3, ranked by their difficulty. The Rasch measure item difficulty indicates the relative difficulty of each of the tasks; the larger the measure, the more difficult the item. The list makes logical sense, as the higher difficulty items are intuitively more challenging than the lower difficulty items because they involve a greater amount of uncertainty, more challenging obstacles or less space in which to manoeuvre. It is also clear that the scope for redundancy among the items has been reduced by the removal of correlated items, as most activity types are listed only once, with the exception of boarding and manoeuvring on buses and trains, which may be qualitatively different enough from each other to be distinctly different transport tasks.

Table 4.3 Summary of 10 remaining items used for final instrument

Ranking	Item number	Item	Item difficulty
1	4	Travelling at night	2.37
2	2	Unfamiliar areas	1.36
3	21	Stairs (Train Station)	0.6
4	3	Crowded situations	0.5
5	23	Boarding (Train)	-0.17
6	19	Navigation (Train Station)	-0.55
7	17	Alighting (Tube)	-0.79
8	8	Manoeuvring (Bus)	-1.07
9	24	Manoeuvring (Train)	-1.12
10	7	Boarding (Bus)	-1.13

4.3.2 Item Person Map

The item person map in Figure 4.7 shows the range of participants' abilities in relation to the difficulty level of each of the transport related tasks. The most able people and hardest tasks have positive measures and are shown at the top, while the least able people and easiest tasks have negative measures and are shown at the bottom.

```
           Person - MAP - Item
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                     |
            XXX      |
  5                 T+
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           XXXX      |
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          XXXXX      |
  4         XXX      +
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          XXXXX      |  2 - Unfamiliar areas
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           XXXX     M|  13 - Stairs (Train Station)
                        3 - Crowded situations
      XXXXXXXXX      |
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       XXXXXXXX      |  14 - Boarding (Train)
        XXXXXXX      |
          XXXXX      |  11 - Navigation (Train Station)
  XXXXXXXXXXXXX      |  24 - Alighting (Tube)
 -1  XXXXXXXXXX      +  8 - Manoeuvring (Bus)
       XXXXXXXX      |S 15 - Manoeuvring (Train)
                        7 - Boarding (Bus)
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Figure 4.7 **Item Person Map**

The spread of the items in the item person map indicates that their relative difficulty levels are sufficient to differentiate between more and less able participants. However, the fact that the participants are more spread out than the transport difficulty items shows that Survey I could be better at discriminating between people near either end of the scale. Consequently, the distribution of transport related items on the right-hand side, when compared to the person measures on the left indicate that the self-assessment instrument could be improved by adding both easier and more difficult items.

As indicated by the red box on Figure 4.7, the individual means of both the person and item measures were both relatively close, with a difference of 0.67 logits, indicating that the items fit the range of individual abilities fairly well. Perfect targeting of items to the abilities of the study sample would result in zero difference between mean Transport Ability and item difficulty. Khadka *et al.* (2014) suggest that a difference in item and person means that is greater than 1 logit suggests mistargeting, whilst smaller differences indicate acceptable targeting. This indicates that the instrument was fairly successful in investigating a wide range of individual navigational abilities within different transport environments.

4.3.3 Differential Item Functioning (DIF)

An important stage of questionnaire validation involves examining whether differential item functioning (DIF) exists within the model. DIF measures whether specific questionnaire items are answered differently according to person characteristics (such as age or gender) that are unrelated to the underlying variable being measured. Examining DIF in health-related quality of life has become increasingly important, especially when developing a new scale or when applying to different disease groups (Lai *et al*. 2005).

DIF analysis was completed in Winsteps by creating dummy variables for each category, as summarised in Table 4.4. This was simply done for gender, whether a person lives alone, mobility and visual condition, but required a separation point to be defined for low vision and age. For gender females were assigned 0 and males were assigned 1; for ‘live alone’ 0 represented people who do not live alone and 1 represented people who do live alone; for mobility aid use, people who do not use a mobility aid were assigned 0 and those who do use a mobility aid were assigned 1. Similarly, people with AMD were assigned 1 and those who did not have AMD were assigned 0.

Table 4.4 Number of people assigned each to each dummy variable category

Variable	0	1
Gender (Male = 1)	201	82
Live alone (Yes = 1)	136	147
AMD (Yes = 1)	51	232
Low vision (V7 or below = 1)	148	135
Age (81 or above = 1)	138	145

In order to determine how the vision category should be split, the vision categories of V1-V10 were plotted with Transport Ability in order to investigate whether there was a natural separation point at which Transport Ability significantly improved with better vision. The graph in Figure 4.8 shows average Transport Ability and the standard error around that average by Vision Level. The wide standard error bars for V1 and V2 are due to the small number of people in those categories, while the above V7 Transport Ability improves markedly in comparison with the lower visual ability levels. The Least Squared Means Tukey test category test in Table 4.5 also supports this finding with vision levels V1-V7 identified as a distinctly different category from vision levels V8-V10. The dummy variable for Low Vision therefore assigned V1-V7 a value of 1 and V8-V10 a value of 0.

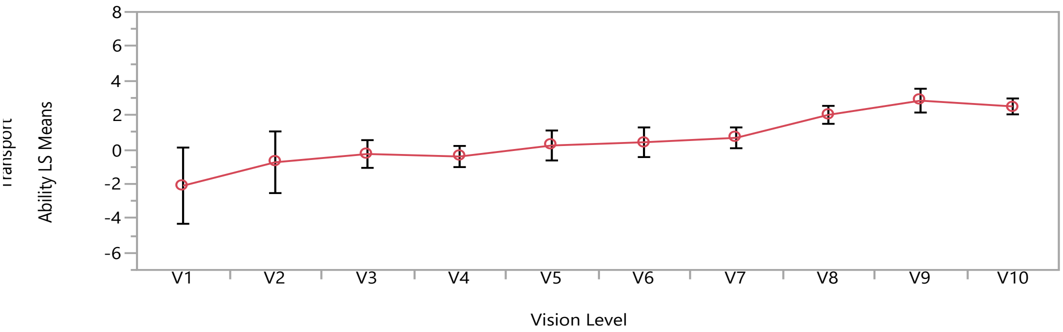

Figure 4.8 Least Squared Means Plot for Transport Ability by Vision Level

Table 4.5 Least Squared Means Tukey category differences

Level	Category*			Least Sq Mean
V1	C			-2.10
V2	C	B		-0.74
V4	C			-0.40
V3	C			-0.26
V5	C			0.24
V6	C			0.42
V7	C			0.68
V8		B	A	2.02
V9			A	2.84
V10			A	2.51

*Levels without a letter category in common are significantly different.

For age a cut-off point was chosen at 81 as this was the median age in the sample, thus creating two similarly sized subgroups; people aged 80 years or younger were assigned 0 and people aged 81 or over were assigned 1.

The dummy variables for gender, living alone, AMD status, low vision and age were used to calculate DIF scores in Winsteps, as shown in Figure 4.9 to Figure 4.13 respectively, to review whether there was any item bias within the dataset due to personal characteristics. The DIF sizes plotted in each of these figures show the size in logits of the item DIF for each group relative to the overall difficulty of each item. DIF scores with differences greater than 1.0 are a concern as this highlights the existance of bias within the transport tasks examined and suggests that another latent variable other than Transport Ability may be present.

However, as none of the personal characteristics examined in this study items had a difference greater than one for any of the items, this shows that responses to Survey I do not vary significantly depending on these personal or habitual characteristics independently of Transport Ability. Rasch analysis has therefore shown that only one latent variable is present throughout the data. This helps support the hypothesis that a latent variable, termed Transport Ability, is consistently being measured by Survey I in this study.

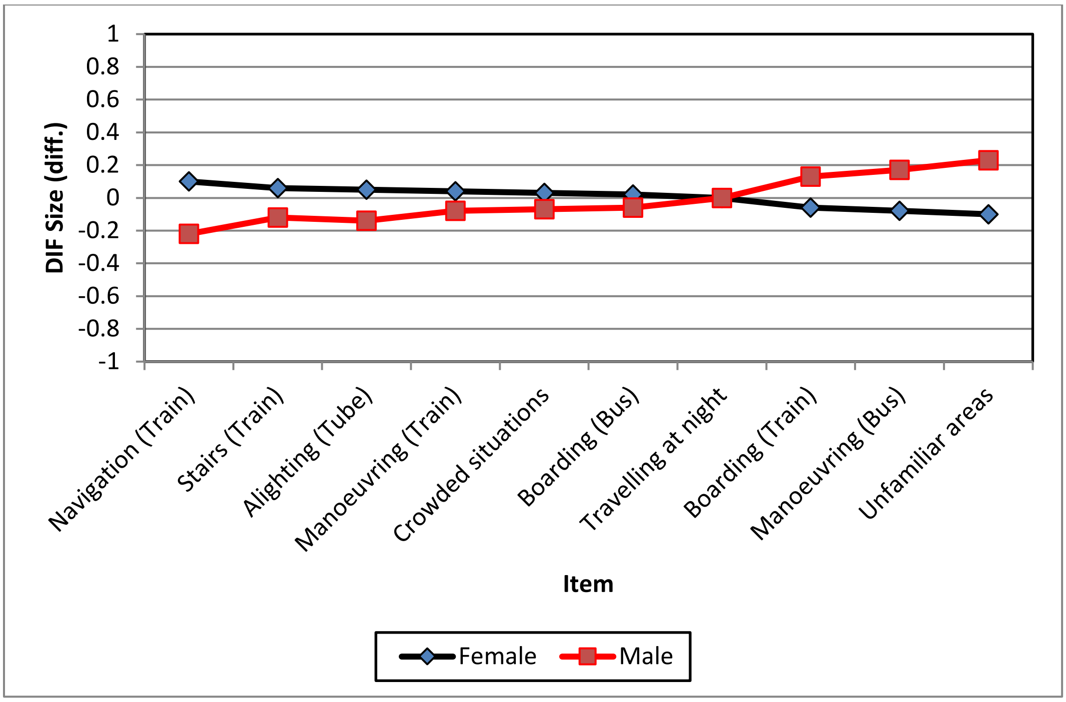

Figure 4.9 DIF plot for Gender

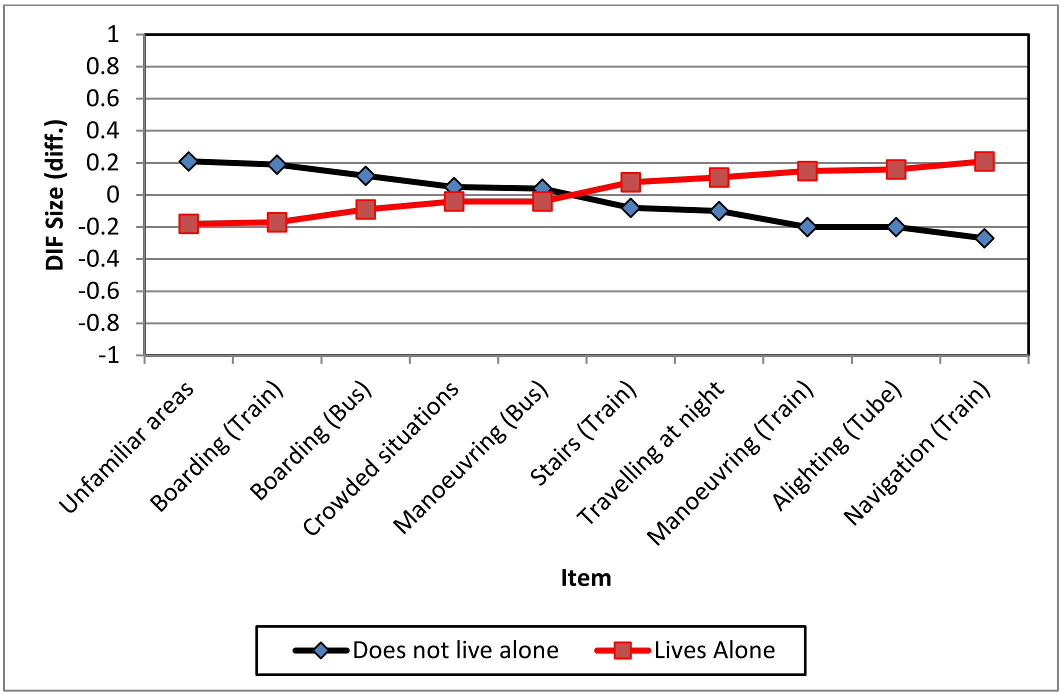

Figure 4.10 DIF Plot for Lives Alone

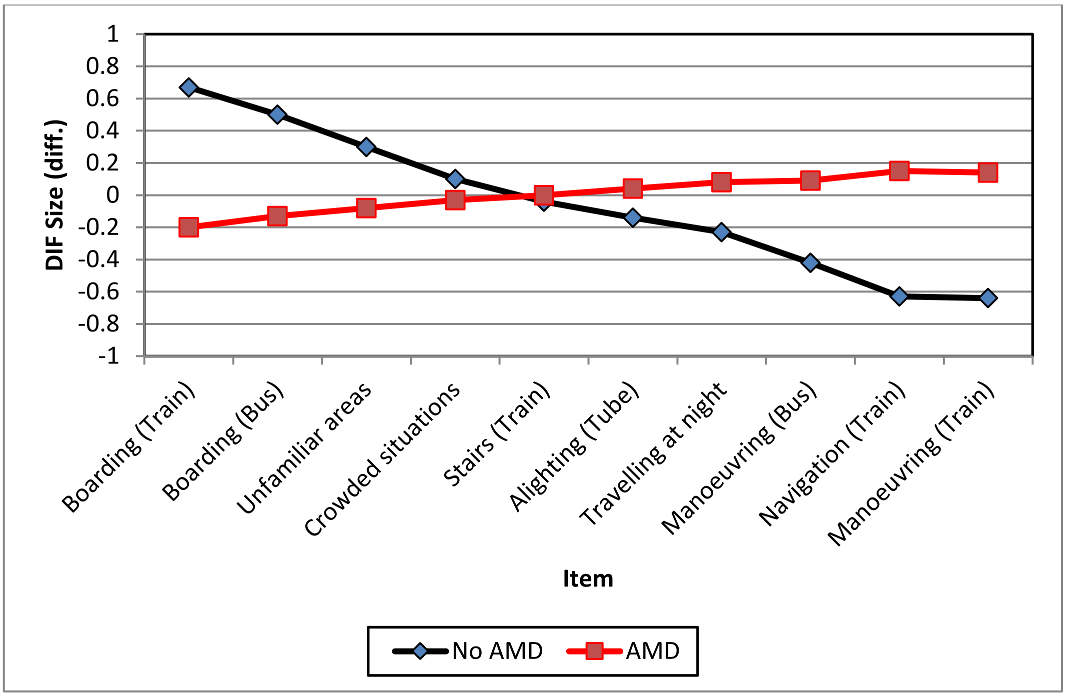

Figure 4.11 DIF Plot for AMD

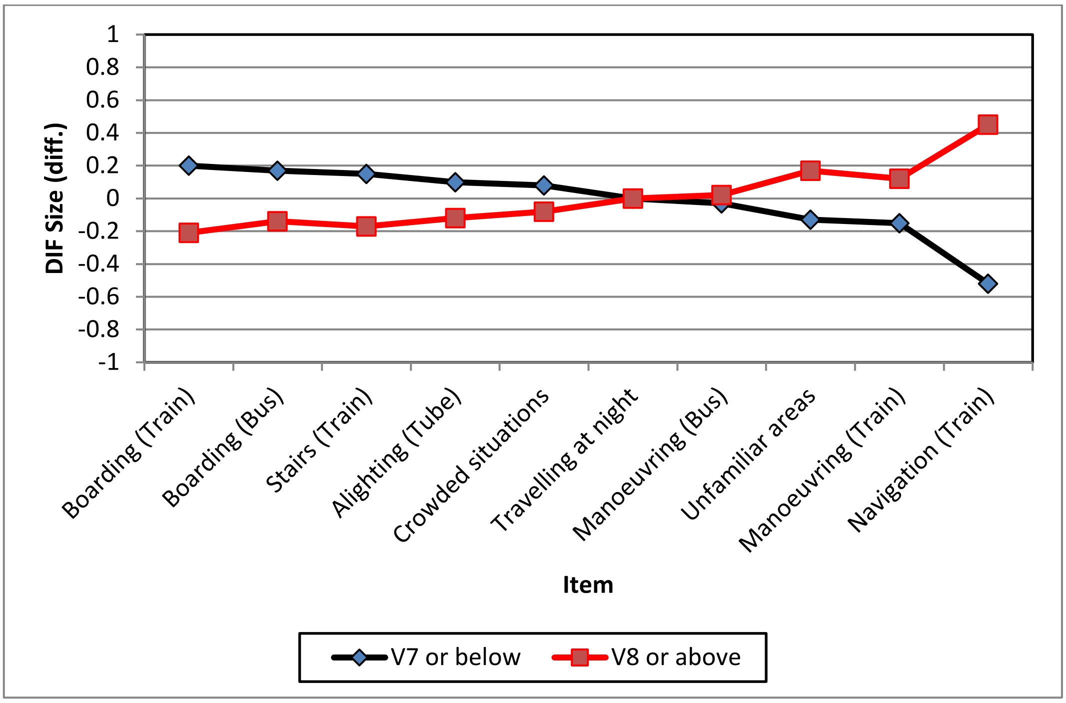

Figure 4.12 DIF Plot for Low Vision

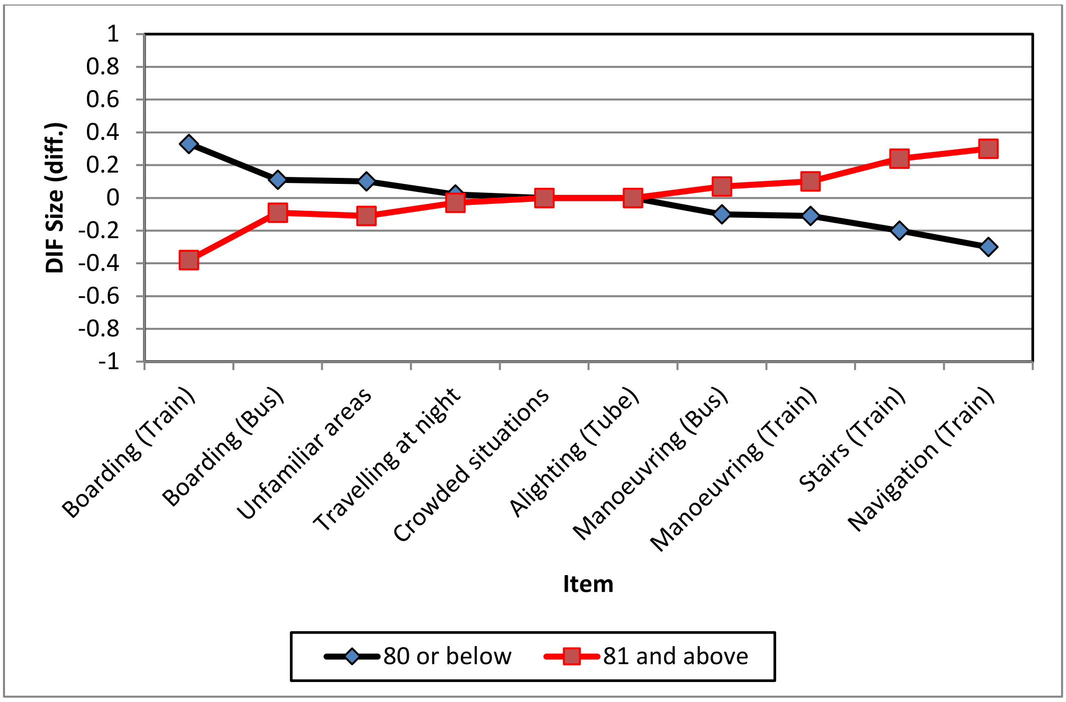

Figure 4.13 DIF Plot for Age

4.3.4 Multidimensionality

Principle component analysis investigation was carried out in order to test whether Survey I was measuring a latent variable relating to a single dimension for Transport Ability.

The residual contrast plot shown in Figure 4.14 shows the proportion of the raw variance in Transport Ability in total (T), explained by measures (M), persons (P) or items (I), or unexplained (U). The numbers 1 to 5 then show the proportion of variance explained by the first to fifth contrasts, which are the five most significant alternative dimensions to the Rasch measure.

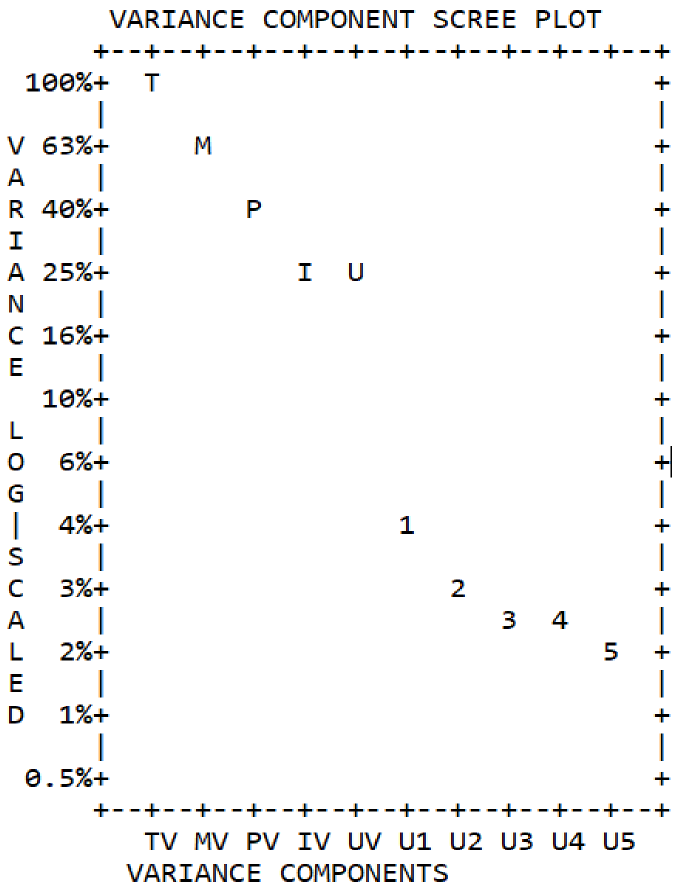

Figure 4.14 Residual Contrast Plot

Table 4.6 shows that the 10 items used in the Rasch analysis instrument explain 27.4% of the total variance in Transport Ability, compared to 4.1% explained by the first contrast. This means that the most significant alternative dimension to the Rasch dimension has a much smaller effect than the Rasch dimension, which has almost seven times more explanatory power than the first contrast.

Table 4.6 Explained and unexplained variance in observations

	Empirical			Modelled
	Eigenvalue	%	%	%
Total raw variance in observations	39.2	100.0%		100.0%
Raw variance explained by measures	27.5	70.2%		70.9%
Raw variance explained by persons	16.8	42.8%		43.2%
Raw Variance explained by items	10.7	27.4%		27.7%
Raw unexplained variance (total)	11.7	29.8%	100.0%	29.1%
Unexplained variance in 1st contrast	1.6	4.1%	13.7%	
Unexplained variance in 2nd contrast	1.1	2.8%	9.5%	
Unexplained variance in 3rd contrast	0.9	2.3%	7.6%	
Unexplained variance in 4th contrast	0.8	2.1%	7.2%	
Unexplained variance in 5th contrast	0.7	1.9%	6.4%	

4.3.5 Overview of Transport Ability, mobility aid use and vision

In order to demonstrate construct validity, which shows that the overall results are logical, and to understand how Transport Ability varies with mobility aid use and vision level, the relationship between these variables was investigated, as shown in Figure 4.15 and Figure 4.16.

As shown in Figure 4.15, the relationship between Transport Ability and Vision Level is in the hypothesised direction, with higher vision levels associated with higher Transport Ability. Vision Level is measured on an ordinal scale, meaning that the differences between each Vision Level do not necessarily represent the same difference in visual ability.

In Figure 4.15, mobility aid users represented by the blue line, showing that the need for a mobility aid reduces Transport Ability at all Vision Levels. The effect of Mobility Aid use appears to increase as Vision Level increases, although this may be partly due to the small number of people with Vision Levels of V1 and V2. This relationship will be further explored in Chapter Five.

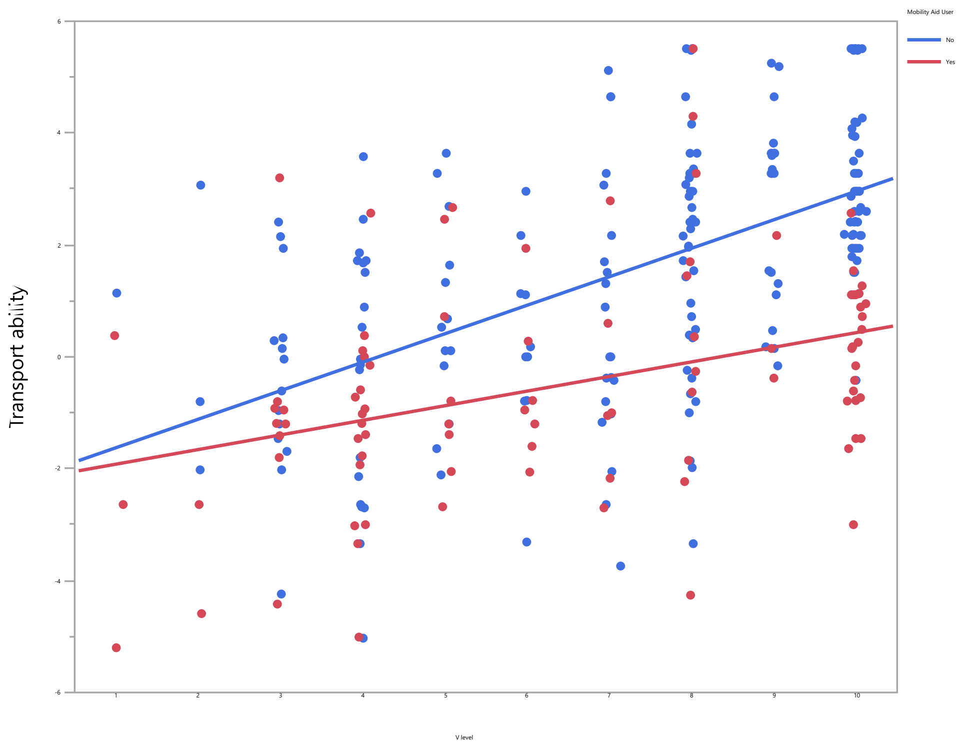

Figure 4.15 Transport Ability and Vision Level by mobility aid use

Figure 4.16 shows the relationship between the binary Low Vision (V Level 1-7) and Good Vision (V Level 8-10) categories and Transport Ability using a boxplot. The line at the centre of the box shows the median Transport Ability of the group, with the box above and below this line extending to the third and first quartiles respectively, thus the box shows the interquartile range (IQR). The 'whiskers' above and below the box show the maximum and minimum values, omitting outliers defined as values lying more than three IQRs above the third or below the first quartile.

The boxes show that among people with good vision, mobility aid use is correlated with lower Transport Ability as the median score is much lower for mobility aid users than non-users and the IQRs do not overlap. The distribution of mobility aid users and non-users appears to be very similar. Among low vision participants the median Transport Ability is also lower for mobility aid users than non-users but to a smaller extent, and there is significant overlap of the IQRs of the two groups. Low vision mobility aid users show a similar spread to the two good vision groups, but the non-users with low vision are noticeably more spread than the other three groups. Comparing mobility aid users with good vision with non-users with low vision suggests minimal difference in the median Transport Ability in the two groups, but a larger spread among the latter.

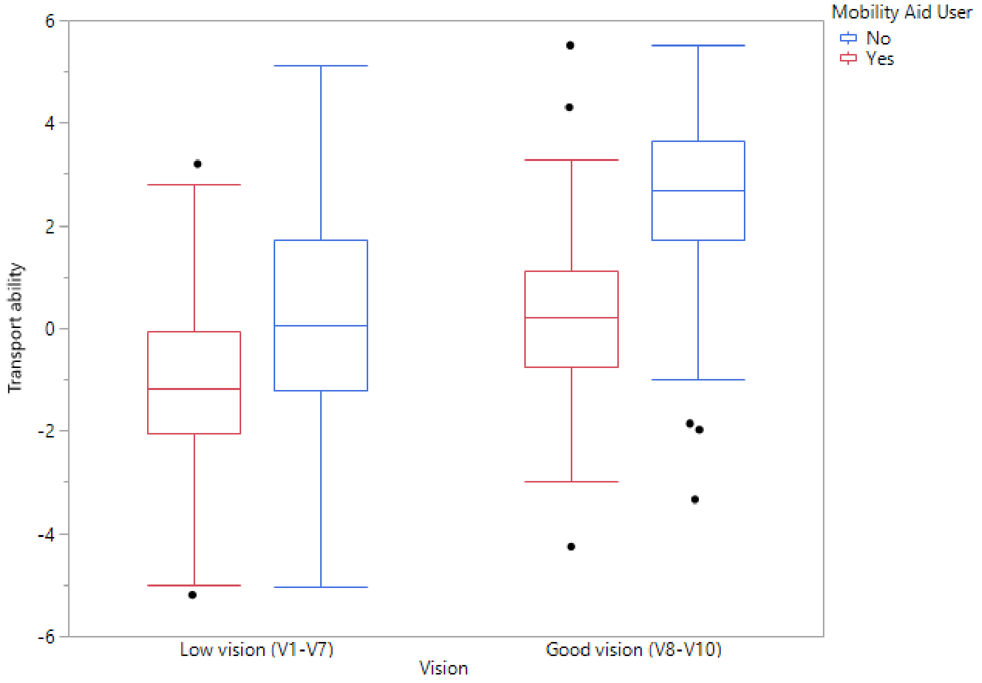

Figure 4.16 Transport Ability and Vision Level by mobility aid Use

4.4 Discussion

This chapter has shown the validation process for the Survey I, developed in Chapter Three. The validation techniques undertaken through the Rasch analysis process have indicated that Survey I sufficiently tested a range of ability levels, is unidimensional, not biased towards participants with certain personal or habitual characteristics and has shown to produce logical results. The process also supports the hypothesis that a common latent trait is present within low vision and mobility groups, termed Transport Ability, which has shown to be measured consistently by Survey I. Furthermore, the fact that the data sample of 283 people with a mixture of low vision and good vision, who may or may not experience mobility problems fits the Rasch model well, shows that individual ability levels are estimated well by the Rasch model. By using the Rasch scores and Rasch measures allocated to each participant and transport item by the Rasch model, it is possible to measure each person and item on a Transport Ability scale constructed by the Rasch model. This will be explored in more detail in the Chapter Five.

The range in vision levels and visual conditions, in addition to people’s individual mobility limitations, verified that Survey I was able to assess their Transport Ability level, not only for people with varying vision levels and/or mobility aid use, but also people with and without AMD, or no visual or mobility impairment. This meant that Transport Ability could be compared between groups.

The relationship overview in section 4.3.5 in this chapter has also demonstrated that the initial findings in this study are logical; demonstrating the hypothesised relationship between mobility, vision and Transport Ability, with lower visual ability associated with lower Transport Ability and mobility aid use compounding this effect. The following chapter will now explore this in more depth.

Chapter 5 Analysis of Transport Survey I

5.1 Introduction

The validation process using Rasch Analysis, in section 4.2 in the previous chapter, has demonstrated that Survey I was unidimensional, not significantly biased by personal or habitual characteristics and produces logical results. This chapter will now explore the common latent trait identified in this study as being exhibited by people with low vision and/or limited mobility, termed ‘Transport Ability’, which is measured consistently in this data.

In Chapter One it was hypothesised that lower visual ability levels are associated with lower Transport Ability and additionally that use of one or more mobility aids would reduce Transport Ability. This will now be investigated in more depth to explore these initial findings and to understand how the extent and frequency of travel outside a person’s home (Life Space patterns) vary with Vision Level and mobility aid use. The effects of AMD on Transport Ability will also be analysed. Additionally, the relationship between Transport Ability and Life Space will be explored in order to test whether Transport Ability can be used as a predictor for overall Life Space patterns, which was also hypothesised in Chapter One.

5.2 Methodology of Univariate and Multiple Regression Analysis

Univariate and multiple regression analysis was completed in JMP (version 12) in order to explore factors that have an impact on the ability to use transport (Transport Ability) and to investigate the impact of Transport Ability has on Life Space patterns.

For this study, it was decided to split the variables into three different groups; outcomes (Transport Ability and Life Space score), predictors (visual ability, mobility aid use, AMD condition) and confounders (age, gender and whether a person lives alone). This was done by firstly investigating the individual relationship between each confounder and predictor and Transport Ability and Life

Space score in turn using univariate regression analysis. Multiple regression analysis was then used to investigate the combined effect of the significant predicting variables on Transport Ability and Life Space score, whilst controlling for significant confounding effects. Interactions between Transport Ability and Life Space score were investigated in order to gauge how Life Space patterns interact with Transport Ability and whether Transport Ability can be used as a predictor for Life Space score.

5.3 The Participant Characteristics

Table 5.1 summarises the participants' characteristics related to mobility impairment, visual impairment, Transport Ability, Life Space and possible confounders of the relationships between these variables.

The response to the survey was fairly successful, with 414 participants taking part in the study. The participants reported various combinations of AMD, glaucoma and good vision, and/or mobility problems, defined by whether or not they required a mobility aid. As described in Chapter Four, participants who responded to too few items, who gave only 1 or 5 for every item or displayed significant misfit were excluded from the final sample, as were 30 people who reporting having glaucoma, leaving 283 participants in total. The characteristics of the participants in this sample are summarised in Table 5.1.

Table 5.1 shows that the median age in the sample was 81, with most participants being in their 70s and 80s. The median Vision Level was V8, which is explored further in Table 5.2. The median Transport Ability was 1.0, meaning that on average participants' Transport Ability was one logit higher than the Item Difficulty of items in Instrument I. Statistical tests showed that the hypothesis that the Transport Ability data is normally distributed cannot be rejected at the 5% level, although the p-value for the Shapiro-Wilk W test was 0.07, so was approaching the threshold value of 0.05. However, the same test showed that the hypothesis that Life Space score was normally distributed can be rejected at the 5% level.

Table 5.1 Summary of Survey I remaining participant characteristics

Sample size	283				
	Mean	**Median**	**Range**	**Interquartile range**	**Standard deviation**
Age	79.2	81	46 to 94	74 to 87	9.6
Vision Level	7.0	8	1 to 10	5 to 10	2.6
Transport Ability	0.9	1.0	-5.2 to 5.5	0.8 to 2.7	2.4
Life Space score	50.6	51	9 to 102	31 to 68	23.0
	Males	**% Males**	**Females**	**% Females**	
Gender	82	29%	201	81%	
	Yes	**Yes %**	**No**	**No %**	
Live alone	147	52%	136	48%	
Mobility Aid User	92	33%	191	67%	
AMD	232	82%	51	18%	
Low vision (V1-V7)	135	48%	148	52%	

In the general population around 1 in 8 people aged over 80 have AMD severe enough to cause serious visual loss and approximately twice as many women over the age of 75 have AMD compared with men of the same age (Smith *et al.* 1997 and Smith *et al.* 2001). This may partly explain why the sample was disproportionately female. The sample was fairly evenly split between people who live alone and with others, while less than one third used one or more mobility aids. More than 80% of the sample had AMD, as the Macular Society mailing list was to recruit participants.

Table 5.2 summarises the participants' Vision Levels. Very few participants reported having a Vision Level below V3, whereas more than half reported a Vision Level of V8 or better, including more than a quarter of the sample who reported having full visual ability. All 51 people who reported that they do not have AMD also reported having V10, full visual ability. For analysis purposes participants with reported V Levels of 7 or below have been grouped together as the 'low vision' group, while those reporting V8 and above are grouped together as the ‘good vision’ group, as described in section 4.3.5 in the previous chapter.

Table 5.2 Summary of participant Vision Levels

Vision level	V Level	Number	%
I cannot tell by the light where the windows are	1	4	1%
I cannot see the shapes of furniture in a room	2	5	2%
I cannot recognise a friend if close to his/her face	3	23	8%
I cannot recognise a friend who is at arm’s length away	4	38	13%
I cannot read a newspaper headline	5	21	7%
I cannot read a large print book	6	17	6%
I cannot recognise a friend across a room	7	27	10%
I have difficulty recognising a friend across the road	8	51	18%
I have difficulty reading ordinary newspaper print	9	23	8%
I have full visual ability	10	74	26%

Table 5.3 summarises mobility aid use and vision within the Survey I sample. Of the 283 participants, more than two-thirds did not use a mobility aid, 14% used only one walking stick, 12% used personal assistance and the remaining 6% used a variety of other mobility aids or combinations of aids. It is notable that while among no mobility aid and one walking stick users there are slightly more people with good vision, people with low vision predominate among personal assistance users. This may be because people with low vision and mobility problems prefer personal assistance to other aids, or even that assistance is more likely to be offered to people with both mobility and visual impairments than people with a mobility impairment but relatively good vision.

Due to the small numbers of participants using mobility aids other than one walking stick or personal assistance, these 18 mobility aid users were grouped together into an ‘other mobility aid’ category. Due to the range of mobility aids used by members of this group it was not expected that the results produced by studying this group as a collective would be useful, but that grouping them together would prevent them from distorting the results produced by analysing users of no mobility aid, one walking stick and personal assistance.

Table 5.3 Summary of participant mobility aid use and Visual Ability

Mobility aid used	Low Vision (V1-V7)	Good Vision (V8-V10)	Total	%
None	82	109	191	67.5%
One Walking Stick	15	24	39	13.8%
Personal Assistance	26	9	35	12.4%
Zimmer frame	2	4	6	2.1%
Wheelchair	3	1	4	1.4%
Two Walking Sticks	3	0	3	1.1%
Scooter	1	1	2	0.7%
Walking Stick & Personal Assistance	2	0	2	0.7%
Walking Stick & Zimmer frame	1	0	1	0.4%
Total	135	148	283	100.0%

Table 5.4 illustrates the characteristics of participants with low vision, of V1 to V7, compared to participants with good vision, of V8 or above. Participants with good vision were in the majority among those under 80, while the reverse was true of those aged 81 or over, as vision tends to deteriorate with age. There was a relatively even spread of low vision and good vision among males and females, those who live alone and with others, and among users of different mobility aid types or none. More people with AMD had low vision than good vision, although more than a third of all participants had AMD but not low vision, while every participant without AMD had good vision.

Table 5.4 Summary of interaction between vision and other characteristics

	Low vision	% of total	Good vision	% of total
Aged 80 or under	56	20%	93	33%
Aged 81 or over	79	28%	55	19%
Lives alone	75	27%	72	25%
Does not live alone	60	21%	76	27%
Female	96	34%	105	37%
Male	39	14%	43	15%
Has AMD	135	48%	97	34%
No visual condition	0	0%	51	18%
No mobility aid	82	29%	109	39%
One Walking Stick	15	5%	24	8%
Personal assistance	26	9%	9	3%
Other mobility aid	12	4%	6	2%
Overall	135	48%	148	52%

Table 5.5 illustrates the characteristics of participants with AMD compared to participants with no vision condition. Participants with AMD made up the greater proportion of those aged over 80, who do not live alone, and females. The majority of participants with AMD did not use a mobility aid but were more likely to use personal assistance than a walking stick if they did, in contrast to participants with no vision condition among whom only one participant reported using personal assistance, compared to 16 who reported using one walking stick.

Table 5.5 Summary of interaction between AMD condition and other characteristics

	Has AMD	% of total	No vision condition	% of total
Aged 80 or under	103	36%	35	12%
Aged 81 or over	129	46%	16	6%
Lives alone	107	38%	29	10%
Does not live alone	125	44%	22	8%
Female	169	60%	32	11%
Male	63	22%	19	7%
No mobility aid	161	57%	30	11%
One Walking Stick	23	8%	16	6%
Personal Assistance	34	12%	1	0%
Other mobility aid	14	5%	4	1%
Overall	232	82%	51	18%

Table 5.6 summarises the characteristics of males and females to allow comparison. This shows a fairly similar gender split of around 40% males among the over and under 80-year olds, but that twice as many males lived alone than with others, in contrast to females, who were almost 50% more likely to live with others than alone. The spread of mobility aid use was not materially different between the genders.

Table 5.6 Summary of interaction between gender and other characteristics

	Male	% of total	Female	% of total
Aged 80 or under	38	13%	100	35%
Aged 81 or over	44	16%	101	36%
Lives alone	55	19%	81	29%
Does not live alone	27	10%	120	42%
No mobility aid	54	19%	137	48%
One Walking Stick	13	5%	26	9%
Personal assistance	10	4%	25	9%
Other mobility aid	5	2%	13	5%
Overall	82	29%	201	71%

Table 5.7 shows the characteristics of those aged 80 and under compared to the over 80s. The older age group was more likely to live alone, whilst the younger group was more likely to live with others, possibly reflecting the increased likelihood of having lost a partner and no longer having children living at home among the older group. Unsurprisingly mobility aid use was higher among the older group, but notably there was a bigger difference in the use of personal assistance between the groups than the use of one walking stick.

Table 5.7 Summary of interaction between age and other characteristics

	Aged 80 or under	% of total	Aged 81 or over	% of total
Lives alone	50	18%	97	34%
Does not live alone	88	31%	48	17%
No mobility aid	113	40%	78	28%
One Walking Stick	15	5%	24	8%
Personal assistance	8	3%	27	10%
Other mobility aid	2	1%	16	6%
Overall	138	49%	145	51%

Table 5.8 shows that while there is an even split between people who live alone and with others among other mobility aid types and no mobility aid, one walking stick is more than twice as common a mobility aid among people who live alone than with others. Perhaps surprisingly, a similar number of people who live alone use personal assistance as who live with others. While it may be the case that living with others means that personal assistance is more readily available, this suggests that living alone was not a barrier to receiving personal assistance. Conversely, living with others may not necessarily mean that personal assistance can be provided if they are, for instance, a partner who is physically unable to provide such assistance. It may be the case that a greater number of participants who live alone would use personal assistance if it were available, and even among those who used personal assistance the availability of this assistance among those who live alone may be more restricted than among those who live with others.

Table 5.8 Summary of interaction between living alone and mobility aid use

	Lives alone	% of total	Does not live alone	% of total
No mobility aid	94	33%	97	34%
One Walking Stick	27	10%	12	4%
Personal assistance	17	6%	18	6%
Other mobility aid	9	3%	9	3%
Overall	147	52%	136	48%

5.4 Transport Ability Univariate Regression Analysis

The next stage is to test the hypothesis that the effect of vision loss on Transport Ability is compounded mobility impairment, signified by the use of one or more mobility aids.

In order to address how each of the confounders and predictors affect Transport Ability, it was first necessary to investigate the relationship between Transport Ability and each of these variables individually. The effect of age, gender, living alone, low vision, mobility aid use and Age-related Macular Degeneration (AMD) on Transport Ability were measured by conducting univariate regression analyses with each in turn as the independent variable and Transport Ability as the dependent variable. Age was used as a continuous variable in the analysis, whereas dummy variables were used to analyse the other variables.

Figure 5.1 shows that the relationship between Transport Ability and age was in the predicted direction, with Transport Ability decreasing with age. Transport Ability is estimated to decrease by -0.07 logits for every year of age. However, the R squared value was fairly low at 0.09, suggesting that while age does influence Transport Ability, only 9% of the variation in Transport Ability can be explained by age alone.

Parameter Estimates for Age

RSquared	0.09
Estimate	-0.07
Prob > [t]	<.0001

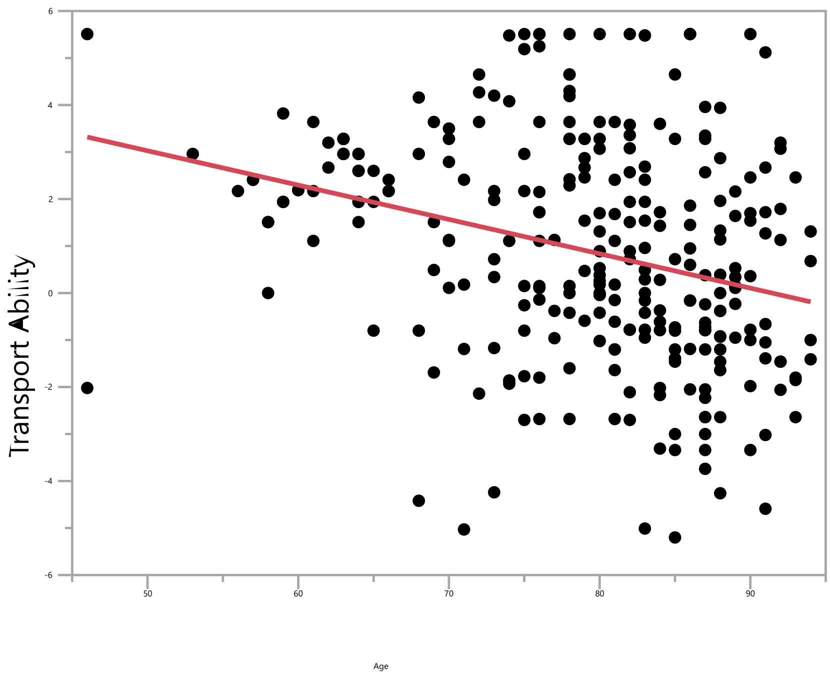

Figure 5.1 Scatterplot of Transport Ability against Age

Dummy variables represent the two states of a binary variable with the values 0 and 1, meaning that the estimated coefficient of a dummy variable gives the effect on the dependent variable of the state assigned 1 by the dummy variable relative to the state assigned 0. Table 5.9 summarises the dummy variables used to represent the remaining confounders and predictors, describing the states assigned 1 and 0 for each variable, the number of people assigned each state and the results of the univariate regression of the variable against Transport Ability.

Gender was not found to have a statistically significant effect on Transport Ability, as while the regression coefficient suggests that being male reduces Transport Ability by 0.07 logits, the high p-value shows that there is an 83% chance that the effect is actually zero. The effect of living alone, however, was found to be significantly correlated with an average reduction in Transport Ability of 0.76 logits. However, the R squared value for living alone was very small at 0.03, suggesting that it only explains 3% of the variation in Transport Ability.

Low vision was found to significantly reduce Transport Ability by 2.28 logits, explaining almost a quarter of the variation in Transport Ability. Similarly, mobility aid use was found to reduce Transport Ability by 2.05, explaining 16% of the variation in Transport Ability. While the coefficient on the AMD dummy variable hints that having AMD may be associated with lower Transport Ability, the p-value shows that this effect did not quite pass the 5% threshold for statistical significance.

Table 5.9 Summary of dummy variables used for univariate regression against Transport Ability

Variable	Assigned 1 if:	Number assigned 1	Assigned 0 if:	Number assigned 0	Intercept	Co-efficient	P value	R squared
Gender	Male	82	Female	201	0.91	-0.07	0.83	0.0002
Live Alone	Live alone	147	Live with others	136	1.29	-0.76	0.01	0.03
Low Vision	V Level 7 or below	135	V Level 8 or above	148	1.98	-2.28	<.0001	0.23
Mobility Aid Use	Use 1 or more mobility aids	93	Use no mobility aids	190	1.57	-2.05	<.0001	0.16
AMD	Has AMD	232	Does not have AMD	51	1.41	-0.63	0.09	0.01

In summary, univariate regression analysis showed that neither gender nor AMD status have an effect on Transport Ability that is significant at the 5% level. Age, living alone, low vision and mobility aid use all individually had a statistically significant impact on Transport Ability, which will be investigated further using multiple regression analysis in the next section.

5.5 Transport Ability Multiple Regression Analysis

The variables that were found by univariate regression to be significantly correlated with Transport Ability were all used in a multiple regression with Transport Ability as the dependent variable. This resulted in a regression equation of the form:

Transport Ability = Age + Live Alone + Low Vision + Mobility Aid Use

Table 5.10 shows the parameter estimate and p-value produced for each independent variable, and the R squared value for the model. As shown by the R squared value of 0.36 in Table 5.10, 36% of the variance in Transport Ability can be explained by the independent variables. Low Vison and Mobility Aid Use had a statistically significant effect on Transport Ability, whilst neither Age nor Live Alone had an effect significant at the 5% level. Low Vision, defined as having Vision Level of 7 or below, was associated with a 2.00 logit reduction in Transport Ability on average, illustrating that people with impaired vision experience greater difficulty when using public transport compared to people with relatively good vision. Mobility Aid Use was associated with a reduction in Transport Ability of 1.68 logits on average.

Table 5.10 Relationship between Transport Ability and significant variables from univariate regression

Term	Estimate	Prob>[t]
Intercept	3.28	0.001
Age	-0.01	0.16
Live Alone	-0.42	0.13
Low Vision	-2.00	<.0001
Mobility Aid Use	-1.68	<.0001

R Squared = 0.36

An interaction term for Low Vision and Mobility Aid Use, the two variables found to be statistically significant, was added to the equation. An interaction term is the product of the two interacting variables, meaning that it takes the value 1 only when both variables take the value 1. This resulted in a regression equation of the form:

Transport Ability = Age + Live Alone + Low Vision + Mobility Aid Use + Low Vision*Mobility Aid Use

Table 5.11 summarises the results of this multiple regression. While parameter estimate on the interaction term indicates that the combined effect of low vision and mobility aid use is a smaller reduction in Transport Ability than the sum of the two individual effects, it is not significant at the 5% level. Nonetheless, the p-value of-0.08 is approaching significance, so is perhaps worthy of further investigation.

Table 5.11 Relationship between Transport Ability and significant variables from univariate regression, including interaction term

Term	Estimate	Prob>[t]
Intercept	3.34	<.0001
Age	-0.01	0.57
Live Alone	-0.35	0.15
Low Vision	-2.30	<.0001
Mobility Aid Use	-2.15	<.0001
Low Vision *Mobility Aid Use	0.89	0.08

R Squared = 0.36

In the final regression, summarised in Table 5.12, the mobility aid use dummy variable was replaced by three different dummy variables for type of mobility aid: one walking stick, personal assistance and other mobility aid. This gave a regression equation of the form:

Transport Ability = Age + Live Alone + Low Vision + One Walking Stick + Personal Assistance + Other Mobility Aid

The other mobility aid category comprised users of mobility aids other than one walking stick and personal assistance. The parameter estimate for each of these dummy variables shows the effect that use of each mobility aid type has on Transport Ability relative to not using mobility aids.

All three mobility aid dummy variables were found to be significant at the 5% level, with one walking stick and other mobility aid both being correlated with a 1.9 logit reduction in Transport Ability, while personal assistance was correlated with a smaller reduction of 1.2 logits. This may suggest that personal assistance is a more effective aid than using one walking stick.

Neither age nor living alone were found to have an effect on Transport Ability significant at the 5% level, although the latter was approaching significance with a p-value of 0.08. Low vision was found to have the biggest impact on Transport

Ability of any of the independent variables, being correlated with a 2.1 logit reduction. This is slightly bigger than the impact of using one walking stick or other mobility aid, suggesting that visual ability is a bigger factor than mobility aid use in determining a person's ability to use transport.

Table 5.12 Relationship between Transport Ability and significant variables from univariate regression, with separate mobility aid dummy variables

Term	Estimate	Prob>[t]
Intercept	3.29	.002
Age	-0.01	0.55
Live Alone	-0.42	0.08
Low Vision	-2.05	<.0001
One Walking Stick	-1.89	<.0001
Personal Assistance	-1.21	.001
Other Mobility Aid	-1.88	.0002

R Squared = 0.36

In a further model, interaction terms were introduced between low vision and each of the mobility aid variables but were not found to be statistically significant. This indicates that the combined effect of low vision and mobility aid use is no different to the sum of the individual effects, irrespective of the type of mobility aid used.

5.6 Discussion of Transport Ability

The univariate regression results, summarised in section 5.4, showed that neither gender nor AMD had a significant impact on Transport Ability, while all of the other variables did have a significant effect. There is no compelling reason why Transport Ability should differ among males and females, so the lack of significance of this variable is unsurprising. However, the fact that AMD was only approaching significance at the 5% level is surprising given that low vision is highly significant, correlated with a reduction in Transport Ability of 2.3 logits. This suggests that AMD not only had no significant correlation with Transport Ability but was not strongly correlated with low vision either. As Table 5.4 showed, 97 of the 232 participants with AMD had good vision, defined as V8 or above. As every participant with low vision also had AMD, this shows that it was low vision as a result of AMD that affected Transport Ability, rather than AMD in itself.

In the final multiple regression, summarised in Table 5.12, neither age nor living alone were found to have a significant effect on Transport Ability at the 5% level, despite having done so in the univariate regression analysis. This suggests that neither variable had a significant impact on Transport Ability, other than being correlated with other variables, such as low vision and mobility aid use, that do have a significant impact.

Low vision, use of one walking stick, personal assistance and any other mobility aid were all found to significantly reduce Transport Ability. This is in line with the hypothesis, set out in section 1.3, that impaired vision and reduced mobility will result in lower levels of Transport Ability.

Use of other mobility aids covers such a variety of aids that it is difficult to draw any conclusions about its significance as a variable beyond the fact that users of other mobility aids tend to have lower Transport Ability relative to non-users of mobility aids. Notably low vision and use of one walking stick both had a similar impact, reducing Transport Ability by around 2 logits.

The smaller reduction in Transport Ability attributed to use of personal assistance, 1.2 logits when compared to 1.9 logits for use of one walking stick, suggests that personal assistance is a more useful aid than a walking stick, in line with the hypothesis that different types of mobility aid will have different effects on Transport Ability. This is logical in that assistance from another person provides much more adaptable help than the support of a walking stick, meaning that that more challenging transport items can be traversed. Personal assistance potentially also has an emotional and psychological benefit that allows harder items to be attempted, because reassurance can be provided and there is the knowledge that help is at hand should anything go wrong.

The fact that the effect of the interaction terms between low vision and mobility aid use were not found to have an impact on Transport Ability significant at the 5% level shows that having low vision and using a mobility aid in combination has the same effect on Transport Ability as the sum of the individual effects. This suggests that low vision reduced Transport Ability to a similar extent irrespective of which mobility aid is used or whether a mobility aid is used at all. There is therefore no evidence to support the hypothesis that mobility aid use has a compounding effect on low vision. Neither is there evidence that mobility aid use lessens the negative impact of low vision, as none of the interaction terms for low vision and each of the three mobility aid groups were found to be significant, when it may have been expected that, for example, personal assistance would have a side effect of lessening the impact of low vision on Transport Ability.

5.7 Life Space score and Transport Ability

Figure 5.2 shows a plot of Life Space score against Transport Ability. There is a significant positive correlation, with a one logit change in Transport Ability correlated with a change in Life Space score of 5.45. The R squared value shows that Transport Ability explains 32% of the variation in Life Space score. This is evidence to support the hypothesis, set out in section 1.3, that Transport Ability can be used as a predictor for Life Space, with lower ability resulting in fewer journeys outside of the home.

Parameter Estimates for Life Space score

RSquared	0.32
Estimate	5.45
Prob > [t]	<.0001

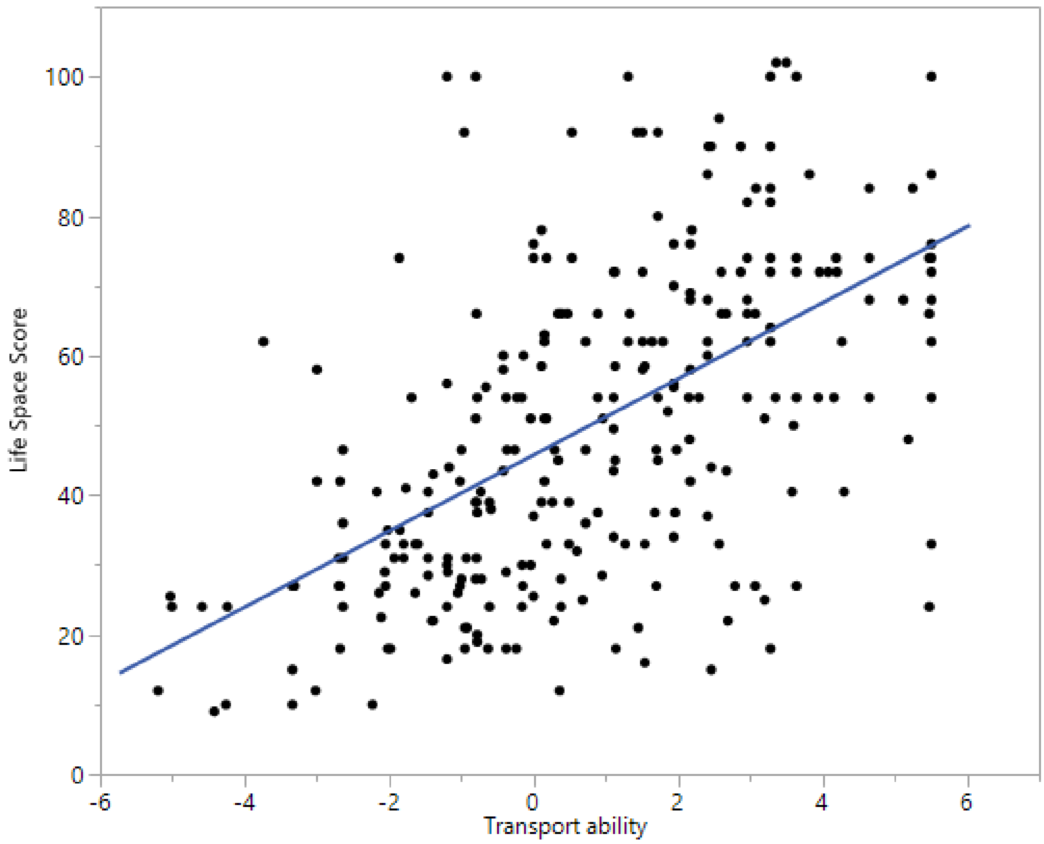

Figure 5.2 Scatterplot of Transport Ability against Life Space score

As mobility aid use is both part of the calculation of Life Space score and highly correlated with Transport Ability, it is unsurprising that there is strong correlation between the two. As discussed in section 3.3.1, Life Space score is a measure of how often a person travels to areas within and outside the home and whether mobility aids or assistance were used to do so, all of which are likely to be determined by a wide range of factors beyond just the ability to use transport. Therefore, it may be possible to use the data collected on other participant characteristics to explain some of the remaining 68% of variation in Life Space score not explained by Transport Ability.

5.8 Life Space Score Univariate Regression Analysis

Univariate regression analysis was used to examine the relationship between Life Space score and age, gender, living alone, low vision and Age-related Macular Degeneration (AMD). Mobility aid use is integral to the calculation of Life Space score, so cannot be used as an independent variable in relation to Life Space score.

Figure 5.3 shows that Life Space score was found to significantly decrease with age by one point for every year of age. The R squared value was 0.17, suggesting that 17% of the variation in Life Space score can be explained by age alone.

Parameter Estimates for Age

RSquared	0.17
Estimate	-0.99
Prob > [t]	<.0001

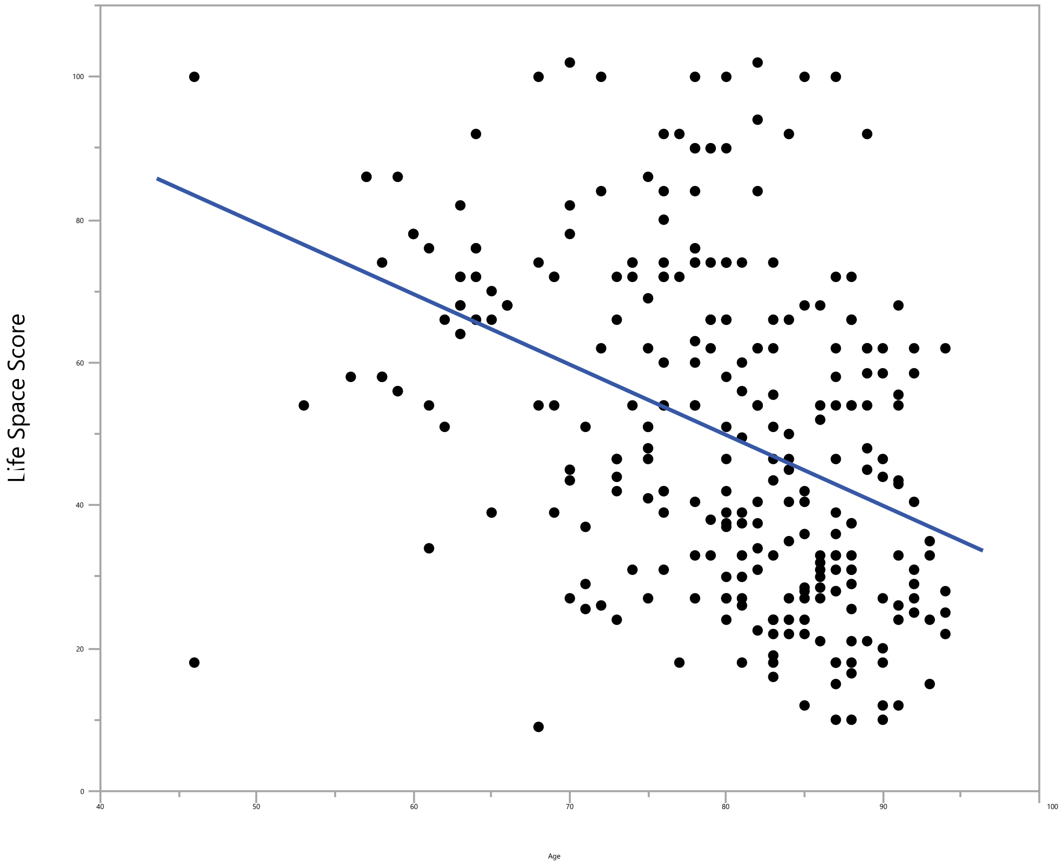

Figure 5.3 **Scatterplot of Life Space score against Age**

Table 5.13 summarises the effect on Life Space score of the remaining variables. Neither gender, living alone or AMD were found to have a statistically significant effect on Life Space score.

Table 5.13 Summary of dummy variables used for univariate regression against Life Space score

Variable	Assigned 1 if:	Number assigned 1	Assigned 0 if:	Number assigned 0	Intercept	Co-efficient	P value	R squared
Gender	Male	82	Female	201	50.1	1.99	0.51	0.002
Live Alone	Live alone	147	Live with others	136	52.7	-4.02	0.14	0.008
Low Vision	V Level 7 or below	135	V Level 8 or above	148	59.14	-17.81	<.0001	0.24
AMD	Has AMD	232	Does not have AMD	51	55.7	-6.19	0.08	0.01

Low vision was found to have a significant effect on Life Space score, with a V Level of 7 or below correlated with a reduction in Life Space score of 17.8 points. The R squared value of 0.24 suggests that low vision can explain 24% of the variation in Life Space score. As with Transport Ability, the effect of AMD on Life Space score was only approaching significance at the 5% level.

5.9 Life Space Score Multiple Regression Analysis

Transport Ability, age and low vision were the only variables found to be significantly correlated with Life Space score by univariate regression. These three variables were added to a multiple regression with Life Space score as the dependent variable. This resulted in a regression equation of the form:

Life Space score = Transport Ability + Age + Low Vision

Table 5.14 shows the parameter estimate and p-value produced for each independent variable, and the R squared value for the model. As shown by the R squared value of 0.39 in Table 5.14, 39% of the variance in Life Space score can be explained by the independent variables. Transport Ability and age had a statistically significant effect on Transport Ability, while low vision was only approaching significance at the 5% level.

A one logit change in Transport Ability was found to be correlated with a change in Life Space score of 4.3 points on average, illustrating that there is a strong correlation between the ease of using transport and the extent and frequency of travel. A one-year increase in age was associated with a reduction in Life Space score of 0.6 points on average, suggesting that old age causes a reduction in Life Space score that is separate to the effect that age has on Transport Ability.

As the effect of low vision on Life Space score was not found to be significant at the 5% level, this suggests that the only influence low vision has on the extent and frequency of travel is through its effect on Transport Ability.

Table 5.14 Relationship between Life Space score and significant variables from univariate regression

Term	Estimate	Prob>[t]
Intercept	96.38	<.0001
Transport Ability	4.32	<.0001
Age	-0.60	<.0001
Low Vision	-4.29	0.09

R Squared = 0.39

5.10 Discussion of Life Space score

The univariate regression results, summarised in section 5.8, showed that none of gender, living alone or AMD had a significant impact on Life Space score, while Transport Ability, age and low vision did have a significant effect. As AMD was not found to significantly affect Transport Ability, it is unsurprising that it did not significantly affect Life Space score either.

Gender has been found to have an influence on Life Space score in other studies, for example by Curcio (2013), because gender roles can determine the extent and frequency of travel because certain trip types, such as those related to work and shopping, are more often undertaken by one gender than the other. However, the insignificance of gender in this sample suggests that this effect is not present, perhaps because the age of most sample participants means that there is no longer a need to travel for employment or look after children at home, both of which would probably introduce a bias toward higher scores among males and lower scores among females.

Living with other people might be expected to increase Life Space score if it provides motivation for travel outside of the home to accompany cohabitees on their trips. However, it is also possible that living with others would remove the motivation to travel outside of the home for entertainment or companionship, as well as reducing the need to make shopping strips as cohabitees may be able to make these trips instead. As living alone was not found to be significant this suggests that neither effect was dominant enough to significantly affect the extent and frequency of travel.

Multiple regression analysis showed that while Transport Ability, age and low vision were all significant in univariate regression, low vision was no longer significant at the 5% level in multiple regression. This suggests that low vision only affects Life Space score through the impact it has on Transport Ability. There was no strong evidence that low vision was affecting the extent and frequency of participants' travel for reasons distinct from Transport Ability, such as psychological reasons related to confidence.

Age was the only variable other than Transport Ability found to have a significant effect on Life Space score in multiple regression, suggesting that it affects the extent and frequency of travel in a way distinct from its impact on Transport Ability. This is notable because multiple regression found no evidence that age had significant impact on Transport Ability, suggesting that age does not affect Transport Ability but does affect Life Space score. This may be because, irrespective of their ability to use transport, older people have fewer reasons to travel outside of the home. This could be explained by the fact that the likelihood of being retired increases with age, reducing the number of work-related trips made. It is also possible that another variable that affects the extent and frequency of travel but not Transport Ability varies with age. An example of this could be overall health, which may have little impact on a participant's general ability to complete specific transport tasks but poor health may significantly restrict the extent and frequency of travel.

Overall, Transport Ability and age were found to be good predictors of Life Space score, explaining almost 40% of the variation in Life Space score in multiple regression. However, there are clearly still a significant number of other factors that significantly affect Life Space score, meaning that there is scope for further research in this area. Furthermore, while age was found to have a significant negative correlation with Life Space score there is a strong possibility that age is functioning as a proxy variable because it is correlated with a number of other variables that impact Life Space score, such as employment status and health. Further research is necessary to determine which age-correlated variables have a significant impact on Life Space score.

5.11 Summary

In this chapter it has been shown in Table 5.10 that the primary determinants of Transport Ability among the participants of Survey I were low vision and mobility aid use. As hypothesised in section 1.3, more severe vision loss and limited mobility were associated with lower Transport Ability. However, Table 5.11 shows that there was a lack of evidence to support the hypothesis that low vision and mobility aid use have a compounding effect on Transport Ability. Due to the small number of participants with glaucoma in the sample it was not possible to test the hypothesis that AMD and glaucoma have a similar effect on Transport Ability and Life Space score.

Further analysis that split mobility aid by type, summarised in Table 5.12, showed that of the two most popular types of mobility aid, one walking stick was associated with a lower Transport Ability than personal assistance and both types of aid were correlated with a significantly lower Transport Ability relative to no mobility aid. This was a logical result because it showed people with lower transport mobility are more likely to use a mobility aid and a more basic aid, in the form of a walking stick, does less to enhance Transport Ability than the more comprehensive support provided by personal assistance. However, low vision was not found to compound the effect on Transport Ability of either one walking stick or personal assistance, which is perhaps surprising given than personal assistance in particular might be expected to mitigate the impact of low vision.

Life Space score was found to be significantly correlated with Transport Ability and age. This suggests that, as hypothesised in section 1.3, a greater ability to use transport is associated with more frequent travel over greater distances, but also that age affects travel patterns in a separate mechanism to its effect on Transport Ability. It is possible that the significant effect of age arises because age is correlated with variables such as employment status and health. A possible avenue for further research may therefore be whether controlling for employment status, health and other variables potentially correlated with age results in the effect age on Life Space score becoming statistically insignificant.

Chapter 6 Development and Validation of Transport Survey II

6.1 Introduction

Survey I, developed in Chapter Three and validated in Chapter Four of this study, analysed the effect of low vision and reduced mobility on Transport Ability and Life Space patterns using a list of transport items that were identified as difficult by people with limited vision and/or mobility. Chapters Three and Four have therefore shown that it is possible to develop and validate an instrument that can successfully measure Transport Ability for people with impaired vision and/or mobility. It would therefore be interesting to analyse whether Survey I could be extended and developed to include specialised transport modes that are frequently used by people with reduced mobility but were not previously included in the questionnaire. This is a logical development for the survey, especially as it aims to focus on measuring Transport Ability among people with limited mobility and/or low vision. This chapter will also compare the transport item scores generated by Instrument I and the redeveloped transport instrument, Instrument II, in order to measure the extent to which they differ, if at all, given the different sample groups.

6.2 Methodology for the Development of Survey II

Figure 6.1 summarises the main stages in the development of Survey II.

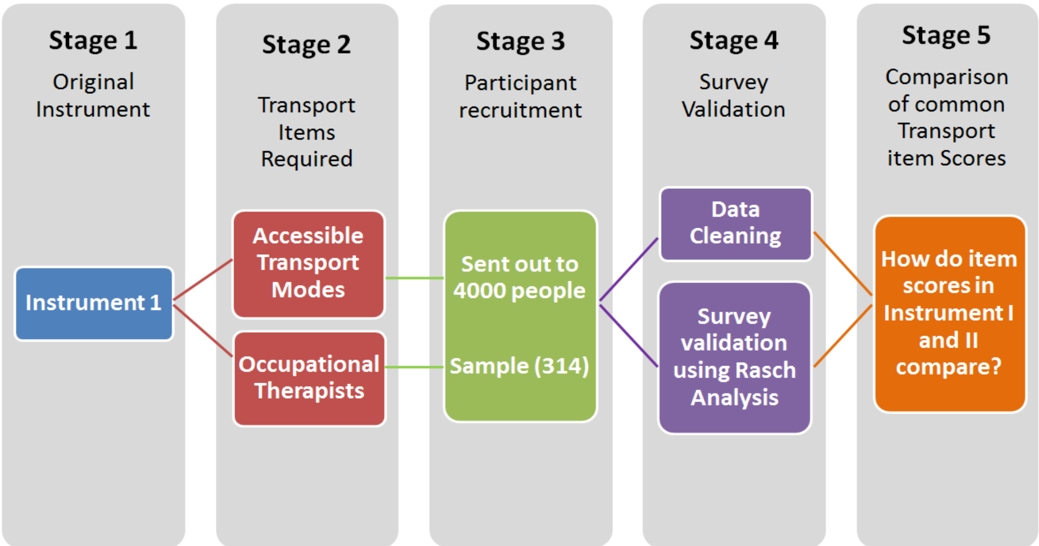

Figure 6.1 **Main stages in the development of Survey II**

The objective of Survey II remained the same as Survey I, developed in Chapter Three of this study, which was to investigate the Transport Ability and Life Space patterns for people with low vision and/or limited mobility. This was therefore the starting point in the redevelopment of the instrument as shown in Stage 1 in Figure 6.1.

The second stage comprised two workshops that were conducted with occupational therapists from Council A, the local authority governing a densely populated inner London borough, to discuss the ways in which Survey II could be developed to further analyse the effect of Transport Ability among people with reduced mobility. The first session was used to discuss the purpose of the survey and the possible accessible transport modes operated by Council A, commonly used by people with low vision and/or limited mobility living in the London borough, that could be included. The specialised accessible transport modes that were added to Survey I to broaden the questionnaire include scooters, taxis and minicabs, day care centre buses and the buddying walking system. The second workshop involved people who operate each of the specific accessible transport modes, in addition to the occupational therapists, to breakdown the individual steps for each transport mode that people find most difficult when using each specific specialised accessible transport mode. The redeveloped Survey II aimed to give a more accurate representation about how these services improve the ability to use transport for people with reduced mobility compared to public transport modes.

The third stage was to send out the redeveloped survey, in order to validate the redeveloped instrument. The questionnaire was sent out by Council A, to the home addresses of 4000 people who were on record with the council as having impaired mobility or vision and who had previously applied for one or more of the three transport concessions available through Council A; Disabled Persons Freedom Pass, Taxicard or Blue Badge. These concessions are described in more detail in section 10.1. This may have excluded some people who had moved to a different address after submitting their application for a transport concession. No other exclusion criteria were applied. Out of the total 4000 surveys that were sent, 314 responses were returned for analysis.

As this instrument was applied to a different sample group from the original transport instrument and included an extended number of transport modes, the data validation steps undertaken as part of Rasch Analysis, as described in section 4.2, would need to be repeated. The returned survey data was then analysed by Rasch analysis in Winsteps (version 3.75.1) in order to validate the questionnaire, as shown in Stage 4 of Figure 6.1.

The transport item scores generated by Instrument I and Instrument II were compared in order to measure the extent to which they differed given the different sample groups, as shown in Stage 5 of Figure 6.1. The structure of the questionnaire remained the same as the original instrument, as shown in section 3.3, with the only major change being the addition of the extra accessible transport modes in section 2. A copy of Survey II can be seen in Appendix II.

The following chapter will now discuss the validation stages for the redeveloped instrument, which includes the specialised transport modes as well as the original public transport modes investigated in Survey I. To summarise, these main validation steps included: (i) Category performance; (ii) Fit of the model; (iii) Item-person match; (iv) Differential Item Functioning (DIF) and (v) Multidimensionality investigation. In addition to this the correlations between Transport Ability and various participant characteristics are analysed to determine construct validity and overall transport item difficulty, and a validation test is conducted to ensure logical results and conclusions.

6.3 Validation Stages

6.3.1 Category Performance

As explained in section 4.2, it is important to examine the category structure of the questionnaire data, so as to determine whether the responses to the items are consistent with the underlying construct, indicated by an ordered set of response thresholds for each of the items.

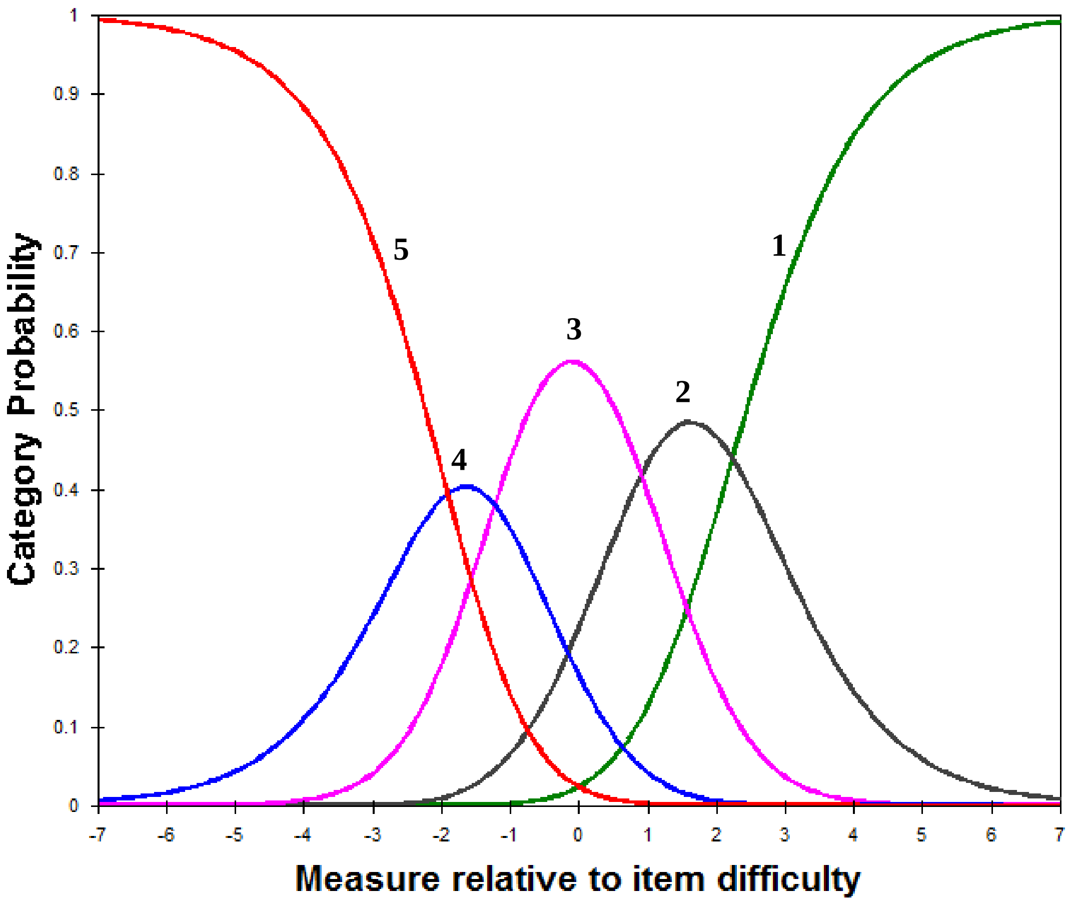

Figure 6.2 **Category Probability Curve for Survey II**

The category probability curve illustrated in Figure 6.2 indicates that the overall category performance for the main dataset of this study was relatively strong. The curves form a series of distinct peaks and each of the curves are in ascending order, increasing with the latent variable, measured on the x-axis. With the exception of category 4, crossover points between each variable are also at roughly the same intervals, showing that the category performance for each item is fairly strong. The crossovers denoting where category 4 is the most likely category are closer together than categories 2 or 3, suggesting that category 4 could be removed with limited detriment to category performance. However, as category 4 is still the most likely response for a certain range of Transport Ability relative to item difficulty, albeit small, it has not been removed. As previously explained in section 4.2.1, this indicates that each difficulty rating is incremental and is able to measure the differing abilities of the participants. Hence, the responses given by each participant for each of the transport related tasks in the redeveloped transport survey are consistent with the underlying construct.

6.3.2 Fit of the Model

Fit statistics showed that the overall data reliability of the model was good, with a person separation score of 3.61 and person reliability score of 0.93, and an item separation score of 5.38 and item reliability score of 0.97. These scores showed that the overall fit of the data to the model was good, meaning that the instrument was sensitive enough to consistently distinguish high and low performers and the item difficulty hierarchy. As explained in section 4.2.2, low person separation of <2 implies that the instrument may not be sensitive enough to distinguish between high and low performers. For items, low separation of <3 implies that the person sample is not large enough to confirm the item difficulty hierarchy of the instrument. However, the person separation score of 3.61 and item separation score of 5.38, revealed that the instrument was sensitive enough to distinguish between high and low performers and that the sample was large enough to confirm the item difficulty hierarchy of the instrument. Similarly, as explained in section 4.2.2, high person and item reliability scores of >0.9 reflect the ability variance of the participants and item difficulty variance, the length of the rating scale and the number of categories per item. The high person and item reliability scores of 0.93 and 0.97 reflected the wide range of person measures at different ability levels and that appropriate difficulty levels were present in the instrument to measure this.

However, there were six participants who responded to each item with the same answer of either 1 or 5, signifying that they found every item either too easy or too difficult. Due to ceiling and floor effects these participants responses would provide no useful information about the difficulty of items, so they were therefore excluded, leaving a person sample of 308 participants.

Fit statistics for the redeveloped transport survey were analysed to highlight any unexpected participant responses, denoted by the infit and outfit. The infit and outfit statistics produced in Winsteps identify the most misfitting data in the model. As explained in section 4.2.2, infit indicates the difference between observed and expected responses for items that have a difficulty level near the person's ability level, whereas outfit uses the differences for all items, without taking into account how far away the item difficulty is from the person's ability (Tennant and

Conaghan, 2007). In this sense, the infit is a weighted statistic as more significance is placed on items close to the participant's ability level. In this study, participants who had a large infit or outfit statistic may have under or overestimated their navigational ability in comparison to their individual level of vision or may have even misunderstood the rating scale.

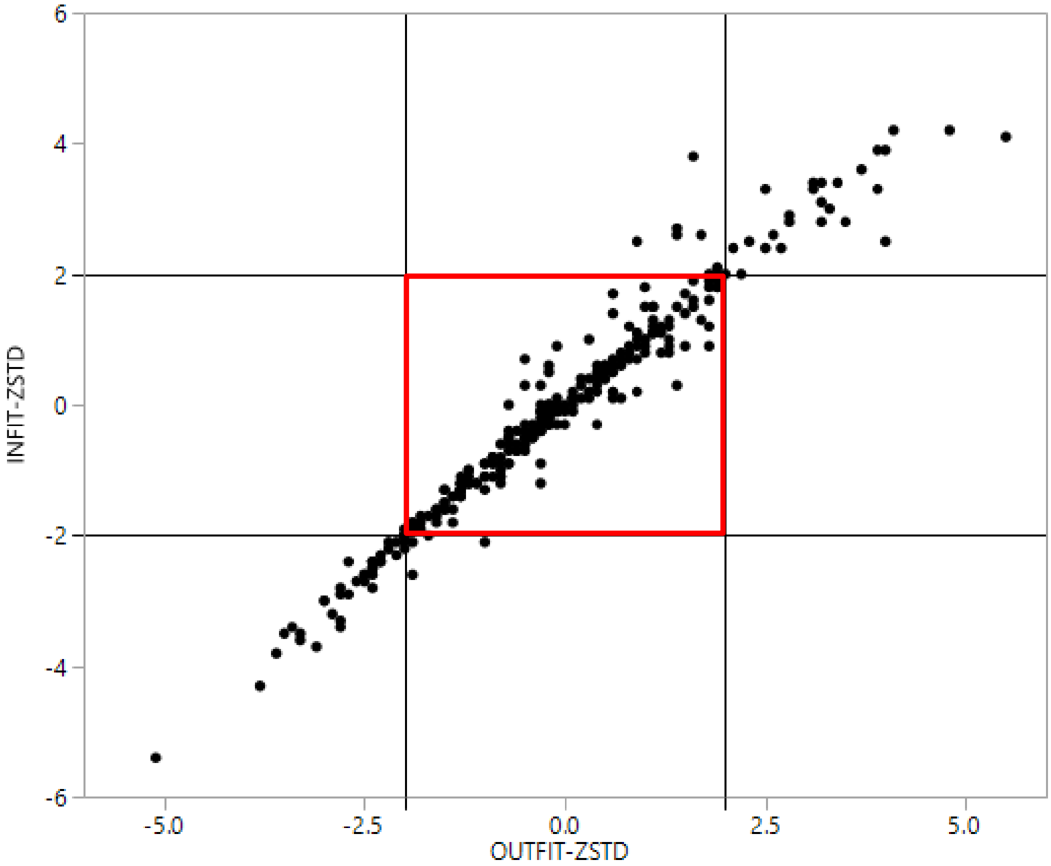

Figure 6.3 Infit and outfit z-statistics of Survey II participant dataset

The participant infit and outfit z-statistics for this study were plotted as shown in Figure 6.3 with the red box indicating the acceptable range of ±2 for participant responses. There were 29 participants with infit greater than 2 and 43 with infit less than -2. These participants were removed from the sample and the infit and outfit was recalculated for the remaining 236 participants, as shown in Figure 6.4. Removing these misfitting individuals increased person separation to 3.71, while person reliability was unchanged at 0.93. Item separation and reliability fell to 4.78 and 0.96 respectively.

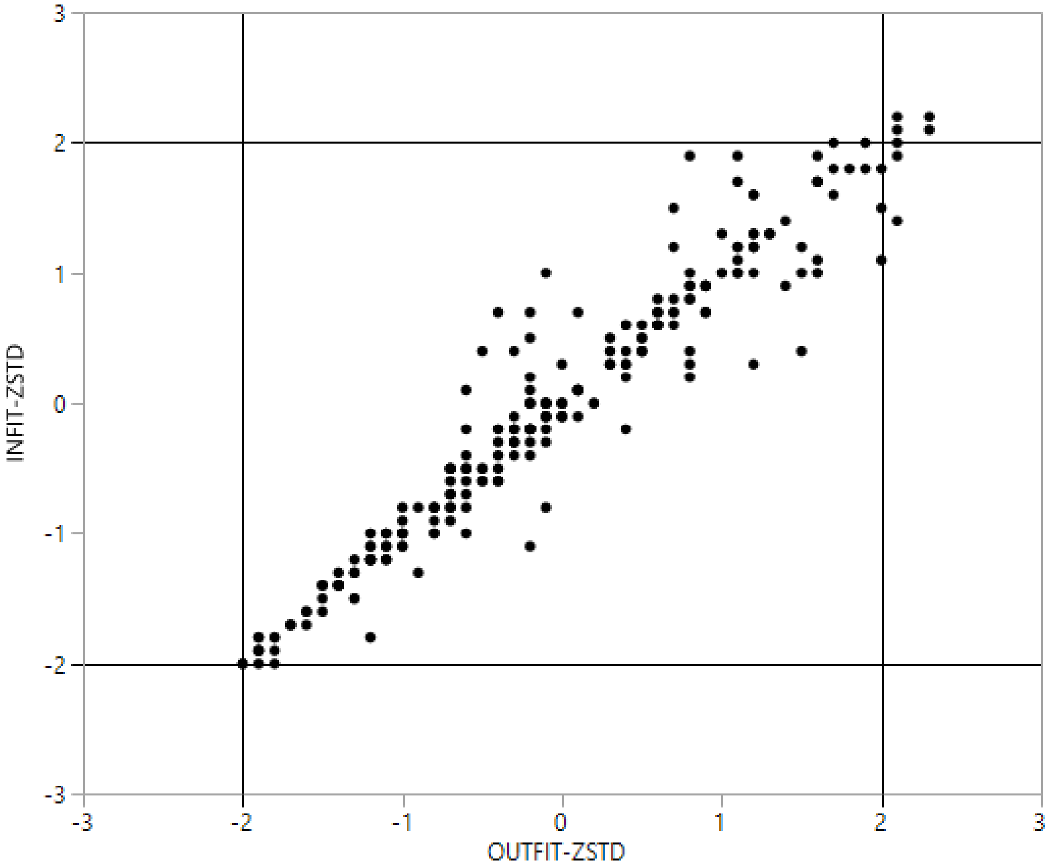

Figure 6.4 Infit and outfit z-statistics of Survey II cleaned 236 participant dataset

As Figure 6.4 shows, there were four participants with infit greater than 2. The responses of these participants were examined, but no compelling reason was found to exclude these participants from the sample.

Pesudovs *et al.* (2007) suggested that items where more than half of responses are missing data should be removed in order to optimise instrument efficiency. Inspection of the item responses showed that 32 of the items, including all of the additional items relating to specialised transport modes, had response rates below 50%. These items were removed, leaving 17 remaining items. After removing these items, person separation and reliability fell to 2.82 and 0.89 respectively, while item reliability and separation rose to 11.73 and 0.99 respectively.

The infit and outfit z-statistics for the remaining 17 items are plotted in Figure 6.5. The red box denotes the acceptable boundary for misfitting items, set within a range of +2 and -2. There were two clear outliers in the top-right of the graph; ‘Reading Bus numbers’ and ‘Reading Tube arrival boards’. This was similar to Figure 4.4 in section 4.2.2, in which the biggest outliers related to reading because the skill being measured was qualitatively different to the mobility skills involved in completing the other items. ‘Reading Train arrival boards’ was also an outlier in Figure 4.4, but is not included in Figure 6.5 because it was previously removed due to its low response rate.

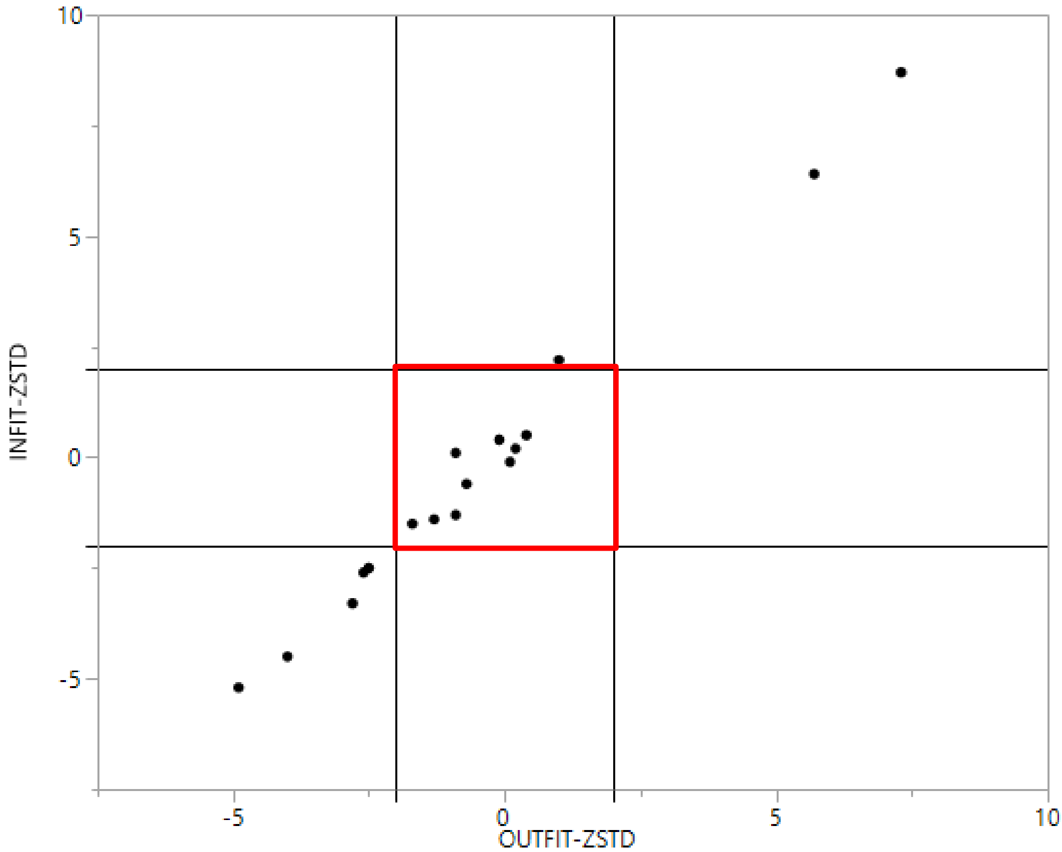

Figure 6.5 Transport item infit and outfit z-statistics for 17 Items

The largest outlier, ‘Reading bus numbers’, was removed and the infit and outfit z-statistics recalculated for the remaining 16 items, as shown in Figure 6.6. As summarised in Table 6.15, person separation increased very slightly to 2.84 and item separation fell slightly to 11.61, while both person and item reliability remained unchanged at 0.89 and 0.99 respectively.

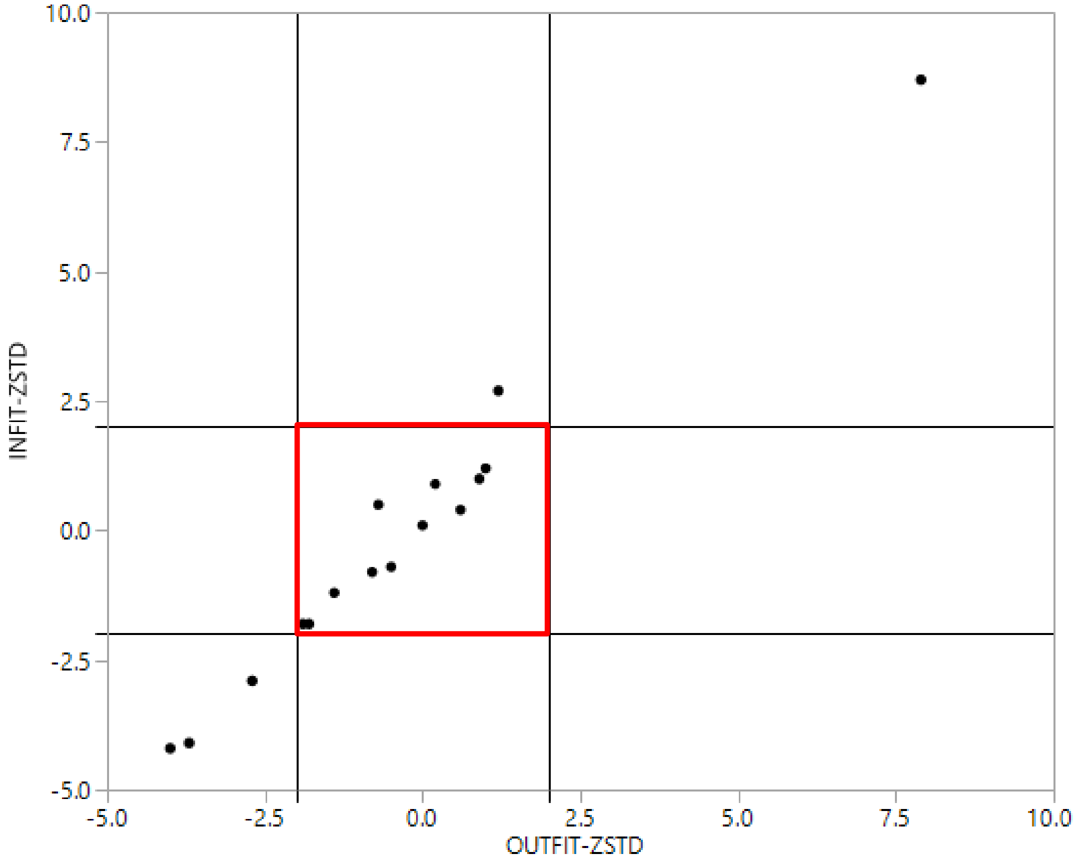

Figure 6.6 Transport item infit and outfit z-statistics for 16 Items

As Figure 6.6 shows, 'Reading Tube arrival boards' was still a significant outlier. this item was also removed and the model refitted. The infit and outfit z-statistics for the remaining 15 items are shown plotted in Figure 6.7. Removing this outlier increased both person and item separation to 2.92 and 12.14 respectively, while person and item reliability remained unchanged at 0.89 and 0.99 respectively, as summarised in Table 6.15.

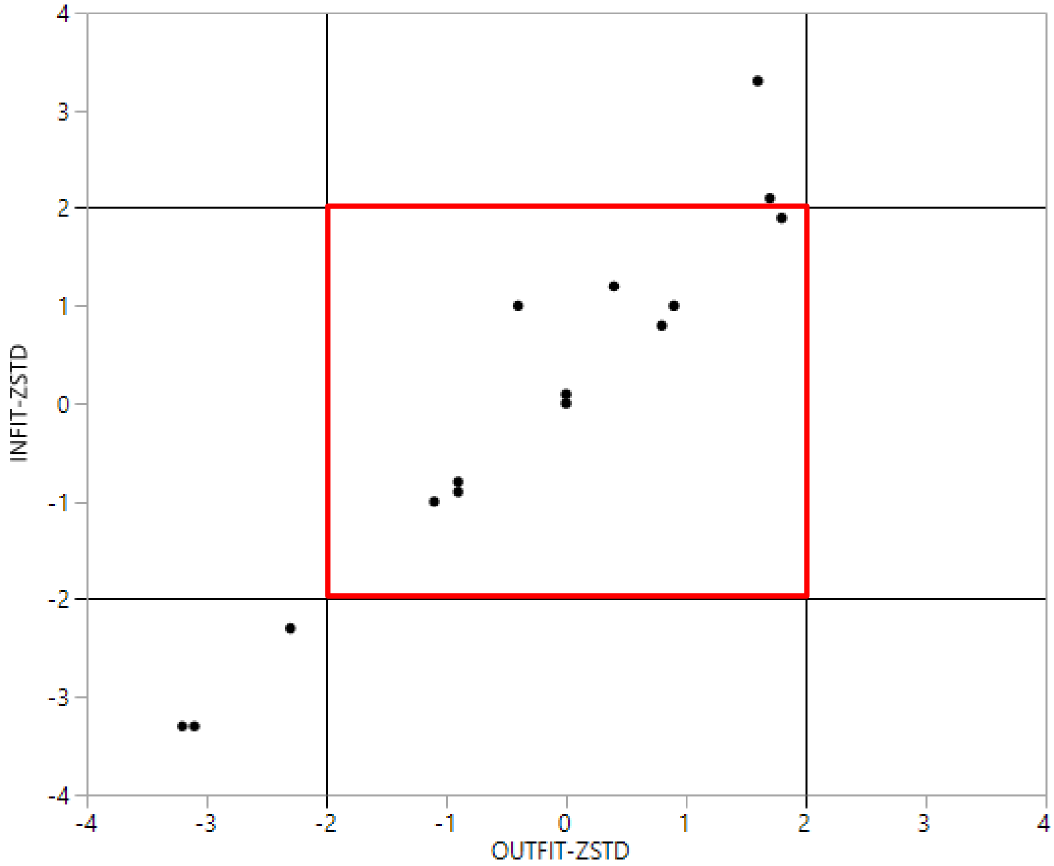

Figure 6.7 Transport item infit and outfit z-statistics for 15 Items

While Figure 6.7 shows that there were still some of the remaining 15 items with infit z-statistics outside of the range -2 to +2, they were not necessarily candidates for removal because misfit z-statistics are inflated by large sample sizes, as described by Linacre (2002) and discussed in section 4.2.2.

Figure 6.8 instead shows the mean-square statistics for the 15 items, as recommended by both Linacre and Pesudovs *et al.* (2007) for large sample sizes. All of the items were within the 0.5 to 1.5 range suggested by Linacre and all items except one were within the 0.7 to 1.3 range suggested by Pesudovs *et al.* Therefore, no further items were excluded on the basis of misfit.

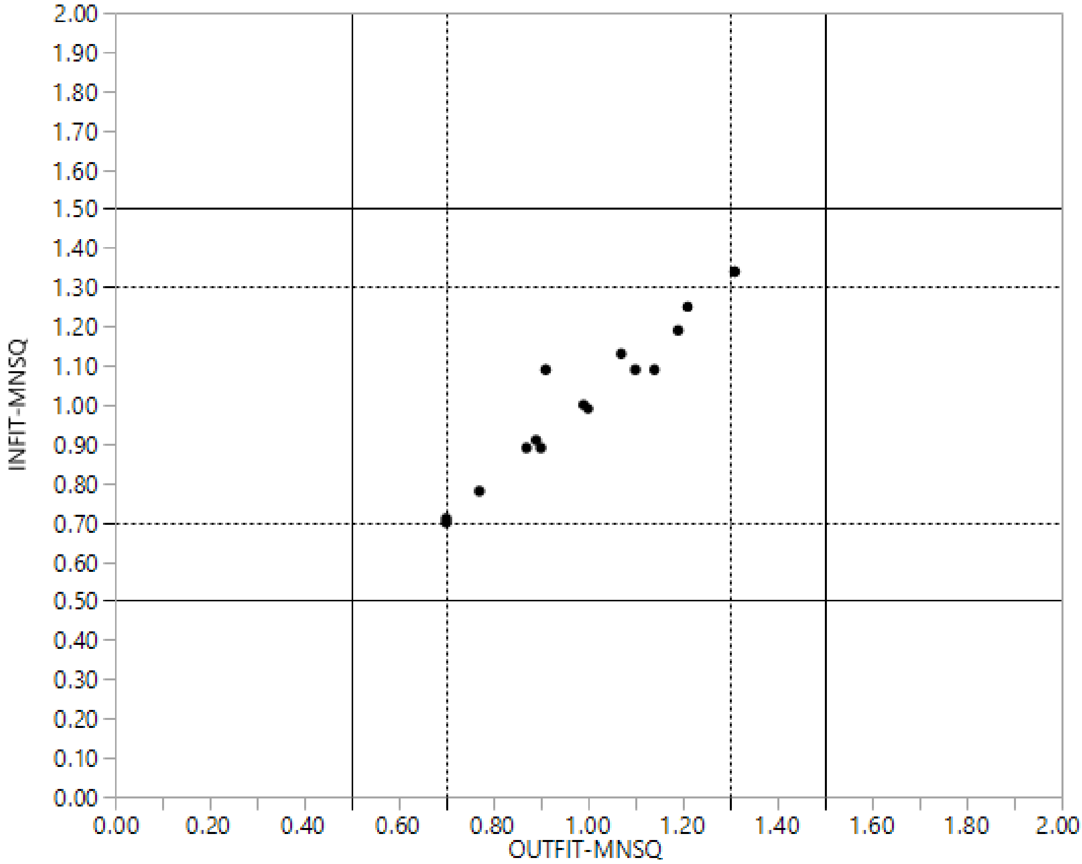

Figure 6.8 Transport item infit and outfit mean-square for 15 Items

In order to improve the efficiency of the instrument and reduce redundancy among the items, the inter-item correlation between each pair of items was calculated and where the correlation was greater than 0.7 one of the items was removed, as recommended by Jones *et al.* (2009) and discussed in section 4.2.2. As in Chapter Four, the item with the fewer responses of the correlated items was removed, with the highest correlations removed first. As summarised in Table 6.15, the model was refitted and the person and item separation and reliability were recalculated after each item was removed. Three items were found to be sufficiently correlated with other items so as to be redundant and were therefore removed. These were ‘Manoeuvring on the Tube’, ‘Boarding the Tube’ and ‘Alighting the bus’.

Table 6.15 Summary of items removed

Item(s) removed	**Reason**	**Person separation**	**Person Reliability**	**Item separation**	**Item reliability**
Initial scores after person removal		3.71	0.93	4.78	0.96
32 items	Response rate < 50%	2.82	0.89	11.73	0.99
Reading bus numbers	Misfit	2.84	0.89	11.61	0.99
Reading Tube arrival boards	Misfit	2.92	0.89	12.14	0.99
Manoeuvring on Tube	Correlated with boarding and alighting Tube	2.85	0.89	12.65	0.99
Boarding Tube	Correlated with alighting Tube	2.79	0.89	13.19	0.99
Alighting Bus	Correlated with boarding bus	2.59	0.87	13.59	0.99

After the three correlated items were removed the person separation was 2.59, while person reliability was 0.87. These were greater than 2 and 0.8 respectively, meaning that the remaining 12 items in the instrument were sufficient to distinguish between people with higher and lower abilities. Similarly, the item separation of 13.59 and item reliability of 0.99 were higher than 3 and 0.9 respectively, meaning that the person sample was sufficient to confirm the item difficulty hierarchy of the instrument. Following the removal of 37 items, a further 5 participants were removed from the sample because their responses to the 12 remaining items were all either 1 or 5, meaning that they were subject to ceiling or floor effects, as described earlier in this section. The person final person sampled therefore comprised 231 participants.

6.4 Overall Instrument Reliability

The overall reliability of the instrument was analysed to make sure that it was consistently measuring the construct of Transport Ability, as discussed in section 4.3.

Table 6.16 Cronbach's Alpha reliability statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	No. of Items
0.90	0.90	12

According to Cortina (1993), Cronbach's Alpha represents reliability and unidimensionality of the scale, and a score of above 0.8 is considered strong. For this instrument, Cronbach's Alpha for the Transport Ability scale was 0.9, as shown in Table 6.16, showing that the scale was reliable without being so high as to suggest significant redundancy among the items.

6.4.1 Transport Item Difficulty

The remaining 12 items are shown in Table 6.17, ranked by their difficulty. The Rasch measure item difficulty indicates the relative difficulty of each of the tasks; the larger the measure, the more difficult the item. The list makes logical sense, as the higher difficulty items are intuitively more challenging than the lower difficulty items because they involve a greater amount of uncertainty, more challenging obstacles or less space in which to manoeuvre. It is also clear that the scope for redundancy among the items has been reduced by the removal of correlated items, as most activity types are listed only once, with the exception of travelling to the bus stop and to the Tube station. As participants are likely to live much closer to a bus stop than a Tube station, the distance required to travel to the bus stop is likely to be much shorter than to the Tube station, meaning that it is not redundant to have both items in the instrument as they are potentially two distinct tasks.

Table 6.17 Summary of 12 remaining items used for final instrument

Ranking	Item number	Item	Item difficulty
1	4	Travelling at night	1.97
2	13	Stairs (Tube Station)	1.95
3	3	Crowded situations	1.86
4	2	Unfamiliar areas	1.63
5	12	Escalator (Tube Station)	0.24
6	11	Navigation (Tube Station)	-0.03
7	8	Manoeuvring (Bus)	-0.09
8	17	Alighting (Tube)	-0.26
9	7	Boarding (Bus)	-0.70
10	10	To Tube Station	-1.67
11	5	To Bus Stop	-2.29
12	1	Familiar areas	-2.60

6.4.2 Item Person Map

As explained in section 4.3.2, the item person map indicates the range of participants' abilities in relation to the difficulty level of each of the transport related tasks. The more able people and most difficult tasks are at the top, while the least able people and easiest tasks are at the bottom. The spread of the items in the Item Person Map in Figure 6.9 indicates that the spread of difficulties is sufficient to differentiate between more and less able participants. However, there are some gaps in item difficulty where it would help to better discriminate between participants if there were items with an item difficulty somewhere between two other items, such as between 'Unfamiliar areas' and 'Escalators in Tube stations' or between 'Boarding the Bus' and Travelling to the Tube station'.

The mean Transport Ability was -0.95, compared to the mean item difficulty that is set at zero by definition, as indicated by the red box in Figure 6.9 . This indicates that the targeting of items to participants could be improved by adding easier items, thus bringing the mean item difficulty closer to the mean Transport Ability. Nonetheless, the difference is still slightly less than the one logit threshold identified by Khadka *et al.* (2014) as the limit below which targeting is considered to be acceptable.

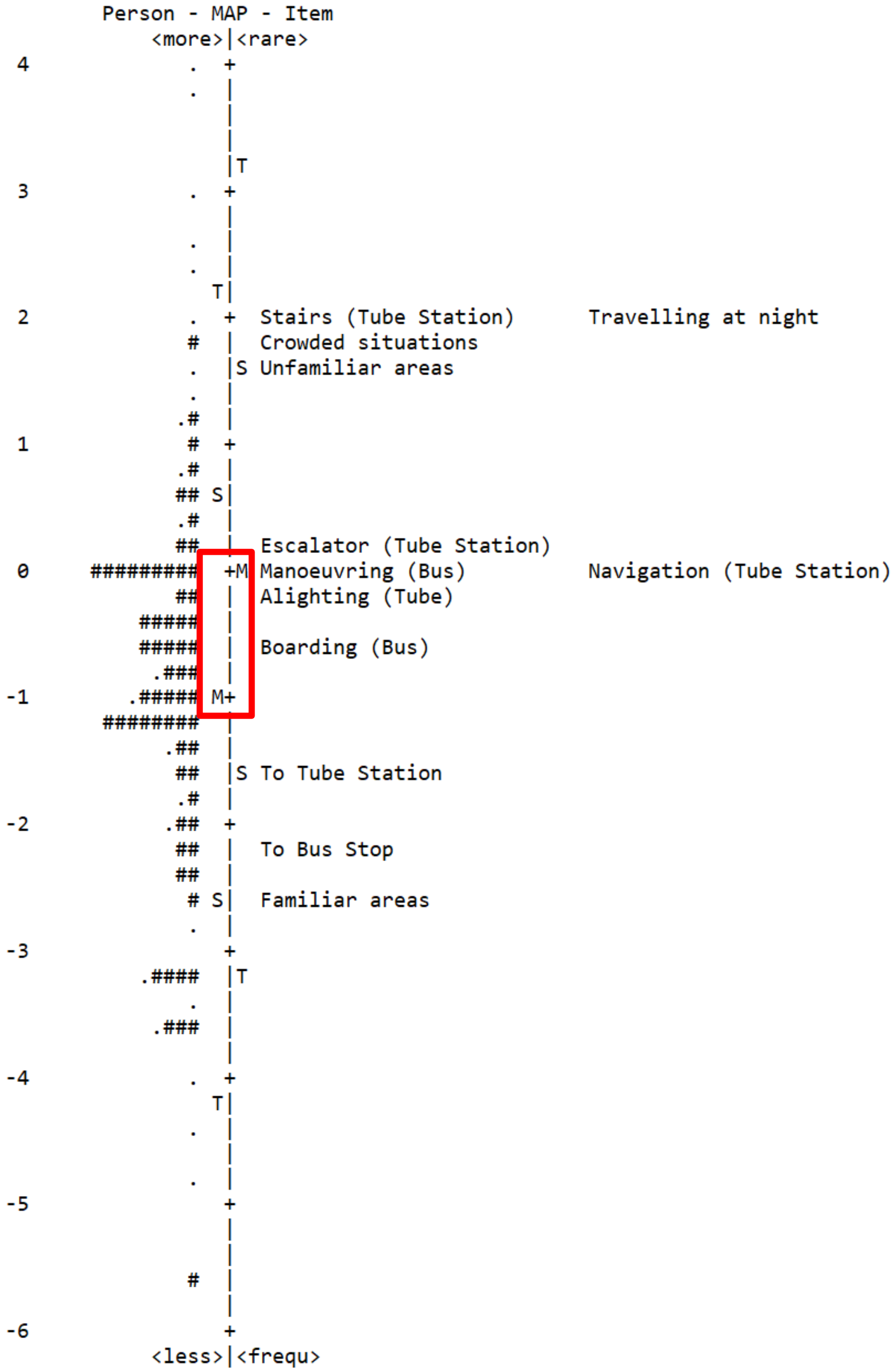

Figure 6.9 **Item Person Map**

6.4.3 Differential Item Functioning (DIF)

As explained in section 4.3.3, an important stage of questionnaire validation involves examining whether differential item functioning exists within the model. DIF measures whether specific questionnaire items are answered differently according to person characteristics (such as age or gender) that are unrelated to the underlying variable being measured. Examining DIF in health-related quality of life has become increasingly important, especially when developing a new scale or when applying to different disease groups (Lai *et al*. 2005).

DIF analysis was completed in Winsteps by creating dummy variables for age, gender, living alone and mobility aid use. For gender females were assigned 0 and males were assigned 1; for 'live-alone' 0 represented people who do not live alone and 1 represented people who do live alone; and for mobility aid use, people who do not use one or more mobility aids were assigned 0 and those who do use a mobility aid were assigned 1. In contrast to Survey I, none of the participants had AMD or glaucoma, so it was not necessary to create dummy variables for visual condition.

As in section 4.3.3, the Least Squared Means Tukey category test was used to separate the Vision Level categories into binary form, as shown in Table 6.15 and Figure 6.10. Compared to Table 4.5, it was less obvious where the cut-off point between good vision and low vision ought to be in Table 6.18, as V8 was not clearly significantly different from V7 in the same way. However, because there was still a suggestion that V8 to V10 were in a different category to V1 to V7, and for consistency with Survey I, V7 was again chosen as the cut-off. Consequently, for the Low Vision dummy variable, vision categories V1 to V7 were represented by 1 and V8 to V10 were represented by 0. Figure 6.10 also seems to suggest a separation point between V7 and V8, while very few participants had vision below V5, meaning that the standard errors for these categories were large.

Table 6.18 Least Squared Means Tukey category differences

Level	Category*			Least Sq Mean
V1	C			-4.26
V2	C	B		-4.36
V4		B		-2.79
V3	C	B		-2.48
V5	C	B		-0.48
V6	C	B		-0.42
V7	C	B		-0.34
V8	C	B	A	0.27
V9	C		A	0.41
V10			A	0.72

*Levels without a letter category in common are significantly different.

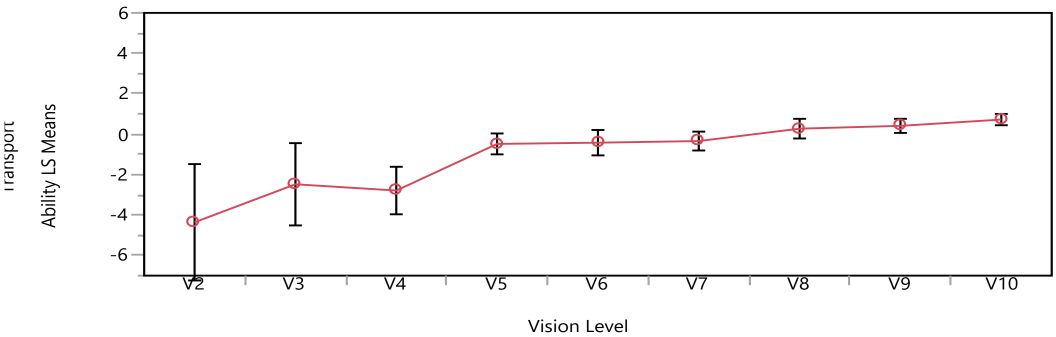

Figure 6.10 Least Square Means plot for Transport Ability and Vision Level

For age a cut-off point was chosen at 54 as this is the median age in the sample, thus creating two similarly sized subgroups; people aged 53 years or younger were assigned 0 and people aged 54 or over were assigned 1.

Table 6.19 Number of people assigned each to each dummy variable category

Variable	0	1
Gender (Male = 1)	129	102
Live alone (Yes = 1)	135	96
Low vision (V7 or below = 1)	153	78
Age (54 or above = 1)	100	131

DIF scores were calculated in Winsteps to review whether there was any item bias within the dataset due to personal characteristics. The DIF sizes plotted in each of these figures show the size in logits of the item DIF for each group relative to the overall difficulty of each item. DIF scores with differences greater than 1.0 are a concern as this highlights the existance of bias within the transport tasks examinined in the self-assessment instrument. None of the personal characteristics examined in this study items had a difference greater than 1.0. This shows that responses to Survey II do not vary significantly depending on certain personal or habitual characteristics, independently of Transport Ability.

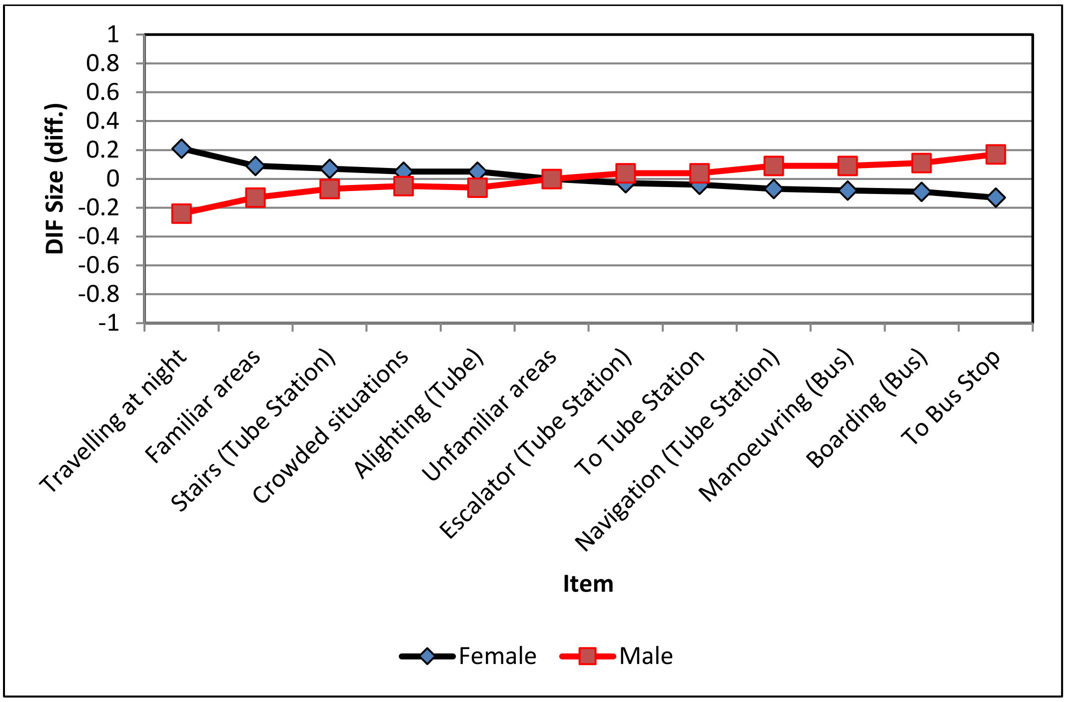

Figure 6.11 DIF plot for Gender

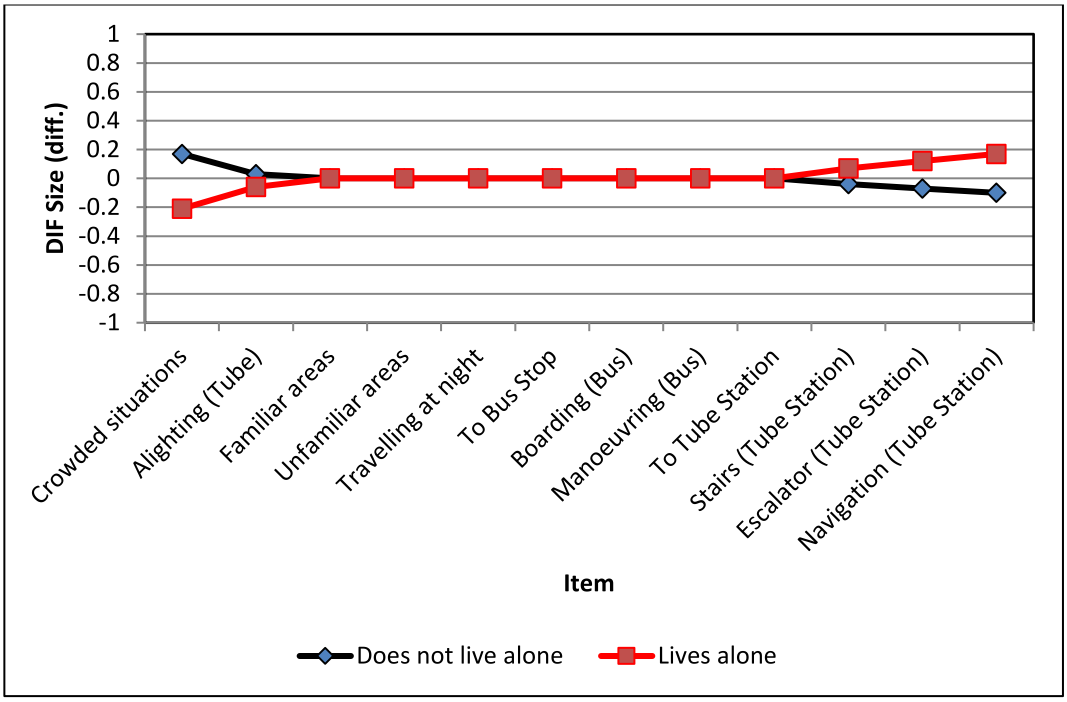

Figure 6.12 **DIF Plot for Lives Alone**

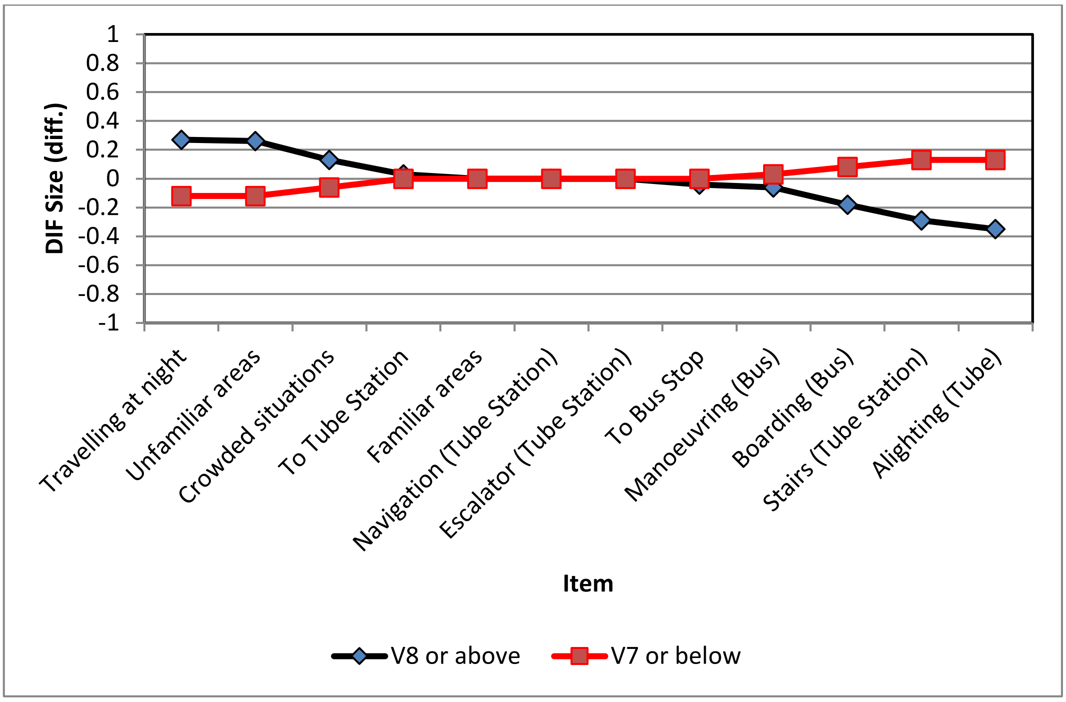

Figure 6.13 **DIF Plot for Low Vision**

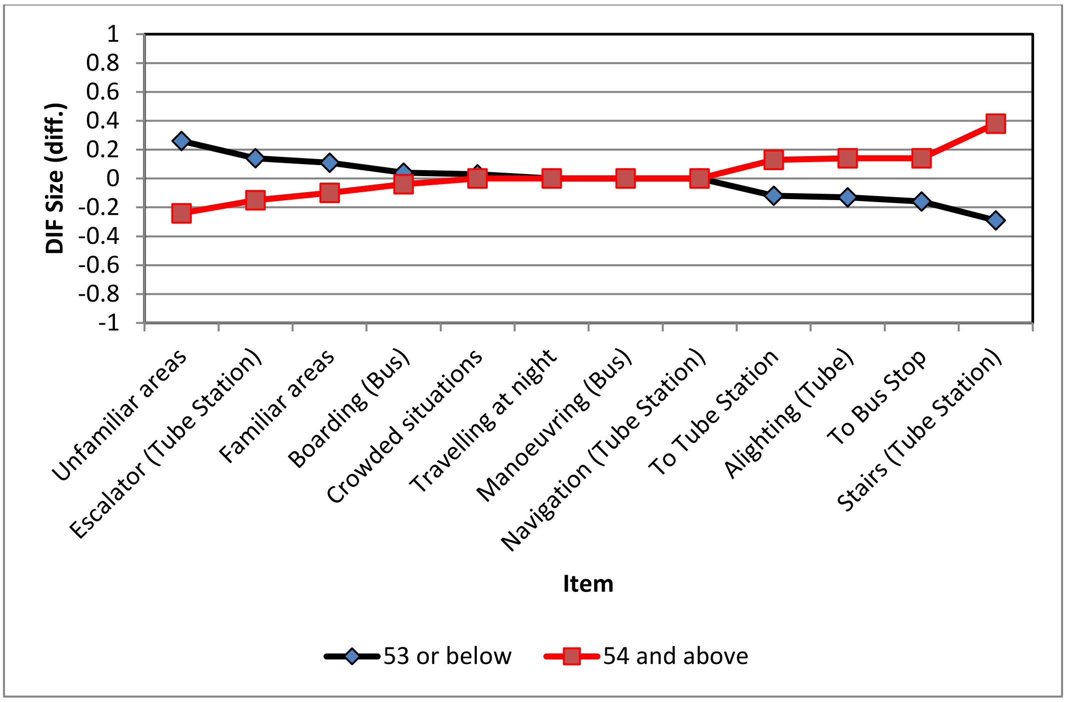

Figure 6.14 DIF Plot for Age

6.4.4 Multidimensionality

In the same process as that shown in section 4.3.4, principle component analysis was carried out in order to test whether Survey II was measuring a latent variable relating to a single psychometric dimension for ‘Transport Ability’.

The residual contrast plot shown in Figure 6.15 shows the proportion of the raw variance in Transport Ability in total (T), explained by measures (M), persons (P) or items (I), or unexplained (U). The numbers 1 to 5 then show the proportion of variance explained by the first to fifth contrasts, which are the five most significant alternative dimensions to the Rasch measure.

```
       VARIANCE COMPONENT SCREE PLOT
      +--+--+--+--+--+--+--+--+--+--+--+
  100%+  T                             +
      |                                |
V  63%+     M                          +
A     |                                |
R  40%+           I                    +
I     |                                |
A  25%+        P     U                 +
N     |                                |
C  16%+                                +
E     |                                |
   10%+                                +
L     |                                |
O   6%+                                +
G     |                 1  2           |
|   4%+                                +
S     |                       3        |
C   3%+                          4  5  +
A     |                                |
L   2%+                                +
E     |                                |
D   1%+                                +
      |                                |
  0.5%+                                +
      +--+--+--+--+--+--+--+--+--+--+--+
         TV MV PV IV UV U1 U2 U3 U4 U5
        VARIANCE COMPONENTS
```

Figure 6.15 Residual Contrast Plot

Table 6.20 shows that the 12 items used in the Rasch analysis instrument explain 41.2% of the total variance in Transport Ability, compared to 5.7% explained by the first contrast. This means that the most significant alternative dimension to the Rasch dimension has a much smaller effect than the Rasch dimension, which has more than seven times the explanatory power of the first contrast.

Table 6.20 Explained and unexplained variance in observations

	Empirical			Modelled
	Eigenvalue	%	%	%
Total raw variance in observations	766.0	100.0%		100.0%
Raw variance explained by measures	535.0	69.8%		69.6%
Raw variance explained by persons	219.2	28.6%		28.5%
Raw Variance explained by items	315.8	41.2%		41.1%
Raw unexplained variance (total)	231.0	30.2%	100.0%	30.4%
Unexplained variance in 1st contrast	43.3	5.7%	18.8%	
Unexplained variance in 2nd contrast	39.7	5.2%	17.2%	
Unexplained variance in 3rd contrast	27.2	3.6%	11.8%	
Unexplained variance in 4th contrast	20.8	2.7%	9.0%	
Unexplained variance in 5th contrast	19.5	2.5%	8.4%	

6.4.5 Overview of Transport Ability, mobility aid use and vision

In order to demonstrate construct validity, which shows that the overall results are logical, and to understand how Transport Ability varies with mobility aid use and vision level, the relationship between these variables was investigated, as shown in Figure 6.16.

Figure 6.16 shows the relationship between the binary Low Visual Ability (V Level 1-7) and Better Vison (V Level 8-10) categories and Transport Ability using a boxplot. The line at the centre of the box shows the median Transport Ability of the group, with the box above and below this line extending to the third and first quartiles respectively, thus the box shows the interquartile range (IQR). The 'whiskers' above and below the box show the maximum and minimum values, omitting outliers defined as values lying more than three IQRs above the third or below the first quartile.

The boxes show that participants with good vision who do not use a mobility aid generally had a higher Transport Ability than participants who had low vision and/or used a mobility aid, as the median score was much higher for non-users of mobility aid users with good vision than for the other three groups and the IQRs did not overlap, the same as the pattern seen in section 4.3.5.

Median Transport Ability was similar for the other three groups; mobility aid users with low vision, mobility aid users with good vision and non-users of mobility aids with low vision. Nevertheless, the distributions of the other three groups suggest a similar pattern to that seen in section 4.3.5, with participants who both used a mobility aid and had low vision generally having lower Transport Ability than either of the other two groups. However, as shown in Table 6.21 and will be explored in more detail in Chapter Seven, the relatively small number or participants who did not use a mobility aid means that these results are only indicative.

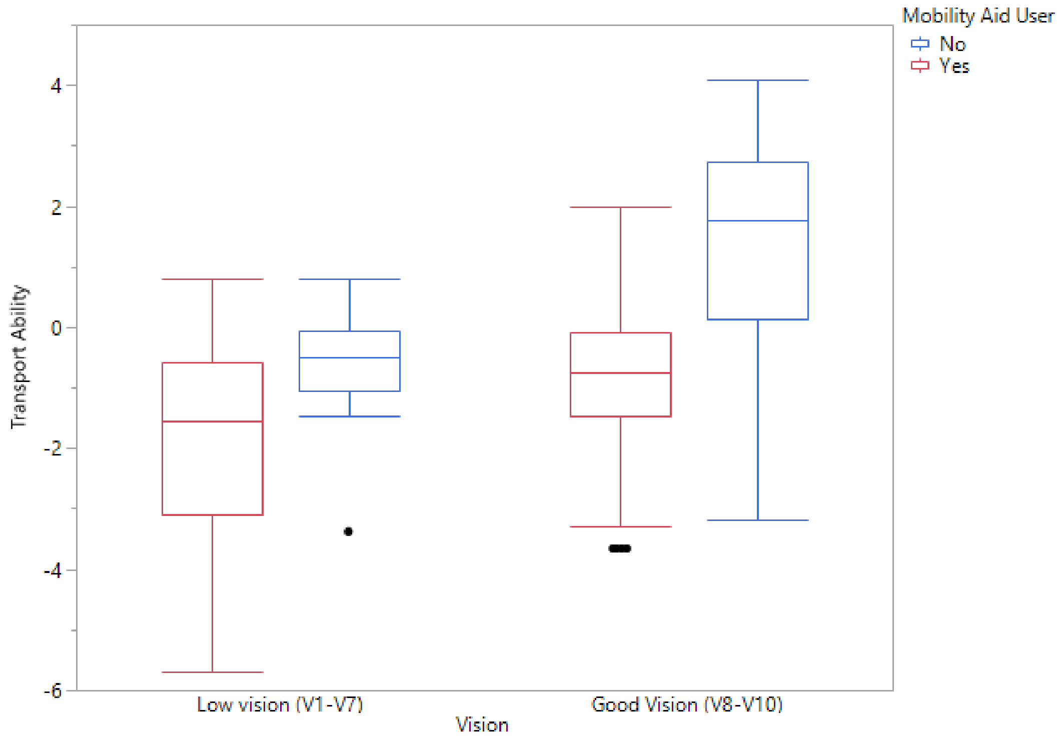

Figure 6.16 Transport Ability and Vision Level by mobility aid use

Table 6.21 Crosstab of Low Vision and mobility aid use

	Mobility aid user	
	No	Yes
Low Vision	18	135
Good Vision	14	64

6.5 Comparison of Common Transport Items

To help further validate the transport items addressed in this study, the difficulty scores for the common transport items between Instrument I and II were compared. There were eight common transport items between Instrument I and Instrument II, as shown in Table 6.22. Although they were presented as separate items, ‘Stairs in a Train station’ was found to be highly correlated with ‘Stairs in a Tube station’, as was ‘Navigating in a Train station’ with ‘Navigating in a Tube station’, as shown in Table 4.1 in section 4.2.2. These two pairs of items are therefore being treated as common items between Instrument I and Instrument II. With the exception of

'Travelling at night', all of the common items were rated as more difficult by Instrument II than Instrument I.

Table 6.22 Difficulty ratings of common items

Item number	Item	Instrument I Item difficulty	Instrument II Item difficulty	Difference
4	Travelling at night	2.37	1.97	-0.40
2	Unfamiliar areas	1.36	1.63	0.27
3	Crowded situations	0.50	1.86	1.36
17	Alighting (Tube)	-0.79	-0.26	0.53
8	Manoeuvring (Bus)	-1.07	-0.09	0.98
7	Boarding (Bus)	-1.13	-0.70	0.43
21/13	Stairs (Train/Tube Station)	0.60	1.95	1.35
19/11	Navigation (Train/Tube Station)	-0.55	-0.03	0.52

A bivariate analysis of the eight common item responses from Instrument I and Instrument II, was conducted with the results shown in Figure 6.17.

The x-axis represents the score from the original data from Instrument I and the y-axis represents the score from Instrument II. Each data point in the scatterplot represents a transport item common to both instruments. The solid red line is the best-fit line, showing an estimate of relationship between the common item difficulty measure for the two instruments with an intercept of 0.7 and a slope of 0.8.

The slope is not close to being parallel to the identity line, suggesting that the two tests do not discriminate between items in a consistent way. This could be because 'Travelling at night' is an outlier that, unlike the other common items, was given a lower item difficulty by Instrument II than Instrument I. This could be because participants in Survey I have a higher incidence of low vision and a lower incidence of mobility aid use than participants in Survey II, as shown in Table 7.9 in Chapter Seven. Therefore, it is logical that participants in Survey I would find travel in low light situations more difficult than participants in Survey I, whereas the reverse would be expected of other tasks where vision was less important.

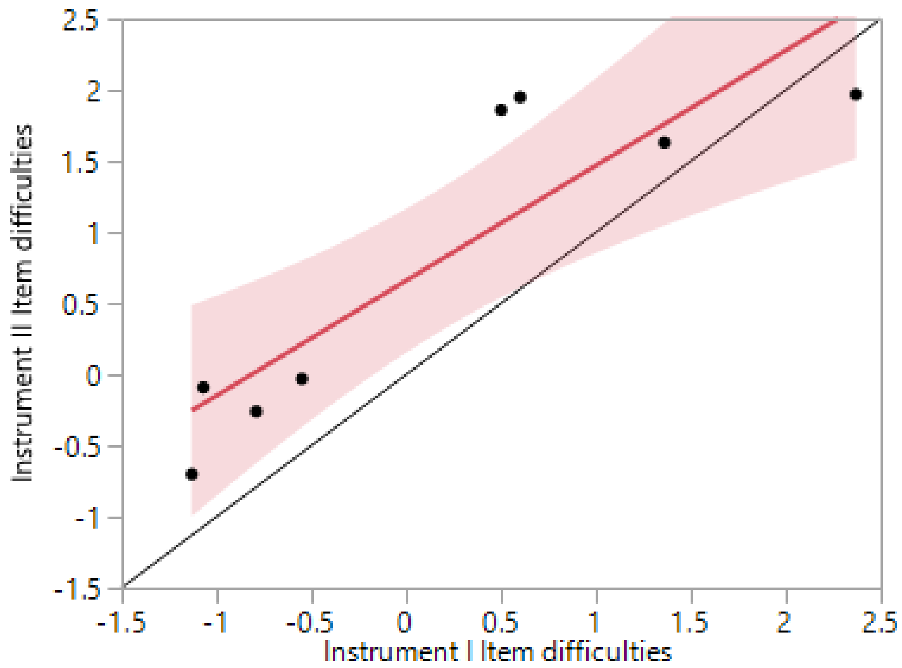

Figure 6.17 **Comparison of eight common item difficulties**

Linear Fit
Instrument II Item Difficulty = 0.66 + 0.81*Instrument I Item Difficulty

Summary of Fit
RSquare 0.78

The bivariate analysis was repeated for the remaining seven common items with 'Travelling at night' omitted, as shown in Figure 6.18. The slope was close to 1, meaning that the two tests discriminate between these seven common items based on their difficulty in a consistent way. The intercept was 0.8, meaning that there was a 0.8 logit shift in item difficulty scores between the instruments. This was because each test has its zero-difficulty point set at the mean difficulty of all items in the test, but only the common items are being compared. These seven common items had an average difficulty of -0.2 in Instrument I and 0.6 on Instrument II.

The shaded area shows the 95% confidence interval of the best-fit line. As all the data points lie within the 95% confidence interval of the best fit line, this suggests that there is a strong and predictable relationship between the results for the difficulty ratings for the common transport items for the two instruments. In order to further analyse the similarity of the common transport item difficulty ratings of the two instruments, Bland Altman analysis was also performed.

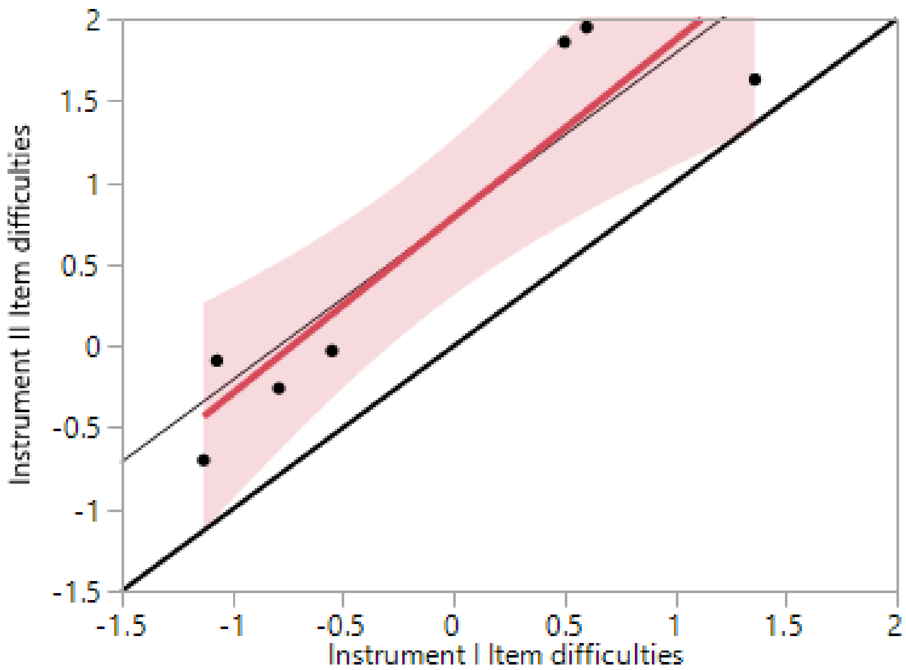

Figure 6.18 Comparison of seven common Item difficulties

Linear Fit
Instrument II Item Difficulty = 0.79 + 1.08*Instrument I Item Difficulty

Summary of Fit
RSquare 0.85

6.5.1 Bland Altman Analysis

The primary application of the analysis developed by Altman and Bland (1983) is to compare the results of two clinical measurements that measure the same response, usually from the same sample group. It can also be used to measure the extent to which new and existing measurement techniques or methods give the same outcome, which again usually involves applying the different techniques to the same sample group. In this study the participant samples were different and the instruments, although developed using the same method, were not the same. Bland-Altman analysis will therefore measure differences introduced by both the difference in measurement instrument and in the sample groups used.

Bland Altman plots allow the investigation of bias and to identify possible outliers. The mean difference is the estimated bias, and the standard deviation of the differences measures the random fluctuations around this mean. It is common to compute 95% limits of agreement for each comparison (average difference ± 1.96 standard deviation of the difference), which show how far apart the common item measures of the two instruments' measurements.

Figure 6.19 is a Bland Altman graph comparing the seven common item measures from Instruments I and II, excluding 'Traveling at night'. As illustrated by the black dashed line, the mean difference in scores is 0.79 logits, while a standard deviation of 0.45 means that the lines that represent ±2 standard deviations of the mean are at 0.1 and -1.7 logits. All of the data points lie within ±2 standard deviations of the mean. This suggests that on average the difficulty rating for each transport item was 0.8 logits greater in Instrument II compared to Instrument I. Furthermore, the majority of data points were within one standard deviation of the mean, with the remainder much closer to one standard deviation from the mean than two. The difference in item measure scores is also scattered fairly consistently around the mean across the range of average item measures. This suggests that both surveys are measuring the same latent trait, as might be expected given that the items are the same, and that the difference in difficulty ratings between the two instruments is consistent across items. For example, if Instrument I gave a transport item a difficulty rating of 0, on average Instrument II would give the same transport item a difficulty rating of 0.8 logits, with a 95% confidence interval that the rating will be between -0.1 and 1.7.

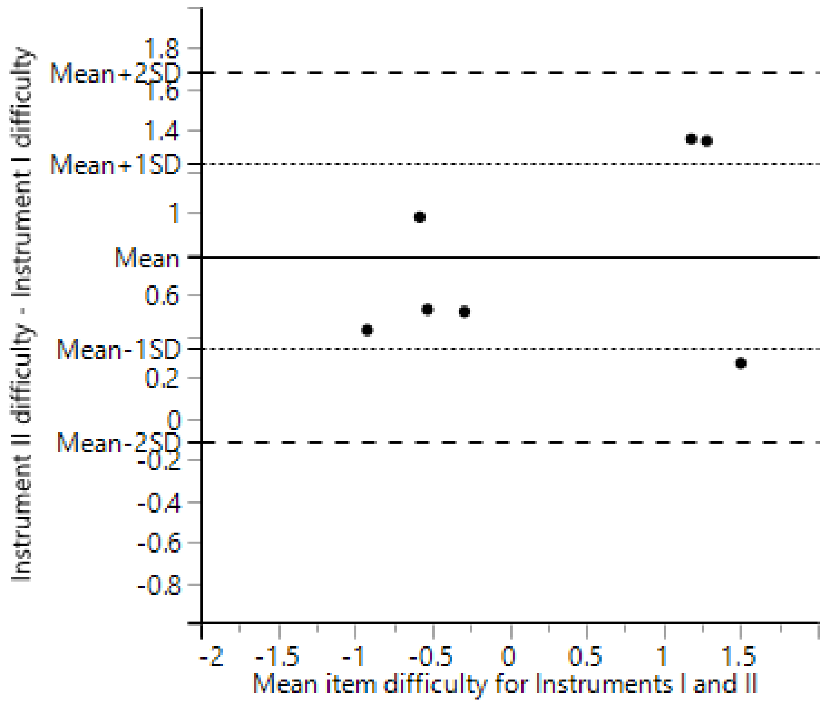

Figure 6.19 Bland Altman plot comparing difficulties of items common to Instruments I and II

6.6 Overall Discussion

This chapter has reviewed the main stages in the application of Survey II in order to develop Instrument II. It has been demonstrated that it is possible to develop and validate a new self-assessment instrument that is able to measure Transport Ability for people with limited mobility and varying levels of visual impairment.

The validation techniques undertaken through the Rasch analysis process have indicated that the questionnaire has sufficiently tested a range of ability levels, is unidimensional, is not biased with regards to participants with certain personal or habitual characteristics and has shown to produce logical results. The process also provides further evidence to support the hypothesis that Transport Ability is a latent trait present within low vision and mobility impaired groups that has been consistently measured by both instruments.

Furthermore, the bivariate analysis of the transport difficulty scores for the seven common transport items in Instruments I and II developed in this study indicate that there is a strong and predictable relationship between the difficulty ratings for the common transport items for the two instruments. This helps to validate the difficulty measures given to each item through Rasch analysis. This finding was further supported by the Bland Altman graph in Figure 6.19, which identified that the differences in item difficulty between the two surveys for each common transport item were scattered fairly consistently around the mean across the range of item difficulties. This suggests that both instruments measured the same latent trait and that the difference in difficulty ratings between items was similar in the two surveys.

The fact that it has been possible to validate a further sample of 231 people, who use a range of different mobility aids and have varying degrees of visual ability levels, through Rasch analysis further confirms that individual ability levels are estimated well by the Rasch model. By using the Rasch scores allocated to each participant and Rasch measures allocated to each transport item by the Rasch model, it is possible to measure Transport Ability for a further group of people. This will be explored in more detail in the following chapter, with a particular focus on the effect of the number and the type of mobility aids required has on levels on Transport Ability.

Chapter 7 Validation of Instrument II

7.1 Introduction

In order to understand how Transport Ability varies with mobility aid use in the Survey II dataset, the relationship between Transport Ability, the type of mobility aid used and visual ability are investigated in this chapter. This will also help to demonstrate construct validity; ensuring that the overall results are logical and examining the effect of mobility more specifically.

This chapter further addresses the hypothesis that mobility impairment and visual impairment reduce a person’s overall Transport Ability and Life Space patterns, with different mobility aid types having a varying effect on Transport Ability and lower Transport Ability reducing overall Life Space patterns. It was also predicted that mobility impairment has a compounding effect on low vision, further reducing overall Transport Ability and Life Space patterns.

7.2 Participant Characteristics

As outlined in Section 6.2, Survey II was sent out by Council A to the home addresses of 4,000 people who were on record as having impaired mobility or vision who had previously applied for a transport concession, such as a Disabled Persons Freedom Pass, Taxicard or Blue Badge. There were 314 responses in total and, as described in section 6.3.2, participants who responded to too few items, who gave only 1 or 5 for every item or displayed significant misfit were excluded from the final sample, leaving 231 participants in total being used to calibrate Instrument II, who had a combination of different visual ability levels and mobility aid use, although none of the participants had AMD. The characteristics of the participants in this sample are summarised in Table 7.1.

Table 7.1 Summary of Survey II remaining participant characteristics

Sample size	231				
	Mean	**Median**	**Range**	**Interquartile range**	**Standard deviation**
Age	53.8	54	22 to 93	48 to 60	10.4
Vision Level	8.2	9	2 to 10	7 to 10	1.8
Transport Ability	-0.93	-0.77	-5.7 to 4.1	-1.8 to -0.1	1.6
Life Space score	40.4	38	7 to 104	28 to 46.5	17.7
	Males	**% Males**	**Females**	**% Females**	
Gender	102	44%	129	56%	
	Yes	**Yes %**	**No**	**No %**	
Live alone	96	42%	135	58%	
Mobility Aid User	205	89%	26	11%	
Low vision (V1-V7)	78	34%	153	66%	

Table 7.1 shows that the median age in the sample was 54, with most participants being in their late 40s and 50s, as shown by the interquartile range. The median Vision Level was V9, which is explored further in Table 7.2. The median Transport Ability was -0.9, meaning that on average the difficulty of the items in Instrument II was 0.9 logits higher than participants' Transport Ability, and statistical tests showed that the hypothesis that the Transport Ability data is normally distributed cannot be rejected at the 5% level, although the p-value for the Shapiro-Wilk W test was 0.10, so was approaching the threshold of 0.05. However, the same test showed that the hypothesis that Life Space score was normally distributed can be rejected at the 5% level.

The sample had a small majority of females and people who did not live alone. The vast majority of participants used one or more mobility aids, which was to be expected as participants recruited from a contact list of people registered with Council A as being in receipt of a transport concession administered by the council, or otherwise having shared their contact details with the council due to their vision or mobility impaired status.

Table 7.2 summarises the participants' Vision Levels. Very few participants reported having a Vision Level below V5, whereas more than half reported a Vision Level of V9 or better, including almost a third of the sample who reported having full visual ability. For analysis purposes participants with reported V Levels of 7 or below have been grouped together as the 'low vision' group, while those reporting V8 and above are grouped together as the 'good vision' group, as described previously in sections 4.3.5 and 6.4.3. Around two thirds of participants reported good vision, while a third reported low vision. Due to an error, the administered visual ability questionnaire was unclear about whether reported visual ability should relate to vision with or without participants' usual visual aids. This may mean that some participants reported their vision level without their visual aid and would have reported a higher vision level when using their usual visual aid. This may have resulted in some participants reporting an erroneously low vision level and the proportion of participants with low vision to be overestimated.

Table 7.2 Summary of participant Vision Levels

Vision level	V Level	Number	%
I cannot tell by the light where the windows are	1	0	0%
I cannot see the shapes of furniture in a room	2	1	0%
I cannot recognise a friend if close to his/her face	3	0	0%
I cannot recognise a friend who is at arm's length away	4	4	2%
I cannot read a newspaper headline	5	24	10%
I cannot read a large print book	6	16	7%
I cannot recognise a friend across a room	7	33	14%
I have difficulty recognising a friend across the road	8	26	11%
I have difficulty reading ordinary newspaper print	9	56	24%
I have full visual ability	10	71	31%

Table 7.3 summarises mobility aid use and vision within the Survey II sample. Of the 231 participants, 11% did not use a mobility aid, 55% used one walking stick, 22% used personal assistance and the remaining 12% used a variety of other mobility aids or combinations of aids. It is notable that while among one walking stick and personal assistance users there were approximately twice as many participants with good vision as low vision, low vision and good vision are equally

common among participants who do not use a mobility aid. This may be because very few people with good vision who do not use a mobility aid were on the contact list used by Council A.

As in section 5.3, the 28 participants who used mobility aids other than one walking stick or personal assistance were grouped together into an 'other mobility aid' category due to the small sample sizes that used each individual type of mobility aid.

Table 7.3 Summary of Participant Mobility Aid use and Visual Ability

Mobility aid used	Low Vision (V1-V7)	Good Vision (V8-V10)	Total	%
One walking stick	43	84	127	55.0%
Personal assistance	15	35	50	21.7%
None	13	13	26	11.3%
One walking stick and personal assistance	4	4	8	3.5%
Two walking sticks	0	7	7	3.0%
Wheelchair	0	4	4	1.7%
Scooter	0	2	2	0.9%
Walking stick and wheelchair	1	1	2	0.9%
Leg brace	0	1	1	0.4%
Walking stick and Zimmer frame	1	0	1	0.4%
Walking stick, Zimmer frame and wheelchair	0	1	1	0.4%
Wheelchair and personal assistance	1	0	1	0.4%
Zimmer frame	0	1	1	0.4%
Total	78	153	231	100.0%

Table 7.4 illustrates the characteristics of participants with low vision, of V1 to V7, compared to participants with good vision, of V8 or above. While participants with good vision are in the majority among those under 54, and the reverse is true of those aged 54 or over, the differences were very small and a significant majority had good vision in both age groups. For people who live alone and with others, males and females, and users of each type of mobility aid, good vision was much

more common than low vision. Only among non-users of mobility aids was there an even split of participants with low vision and good vision.

Table 7.4 Summary of interaction between vision and other characteristics

	Low vision	% of total	Good vision	% of total
Aged 53 or under	34	15%	80	35%
Aged 54 or over	44	19%	73	32%
Lives alone	30	13%	66	29%
Does not live alone	48	21%	87	38%
Female	45	19%	84	36%
Male	33	14%	69	30%
No mobility aid	13	6%	13	6%
One Walking Stick	43	19%	84	36%
Personal assistance	15	6%	35	15%
Other mobility aid	7	3%	21	9%
Overall	78	34%	153	66%

Table 7.5 summarises the characteristics of males and females to allow comparison. This shows that males were slightly more likely to be in the older age group, while females were slightly more likely to be in the younger group. While both genders were more likely to live alone than with others, the difference was much bigger amongst males than females. The spread of mobility aid use was similar in both genders, although of not using a mobility aid was slightly more common among males than females.

Table 7.5 Summary of interaction between gender and other characteristics

	Male	% of total	Female	% of total
Aged 53 or under	45	19%	69	30%
Aged 54 or over	57	25%	60	26%
Lives alone	64	28%	71	31%
Does not live alone	38	16%	58	25%
No mobility aid	16	7%	10	4%
One walking stick	53	23%	74	32%
Personal assistance	21	9%	29	13%
Other mobility aid	12	5%	16	7%
Overall	102	44%	129	56%

Table 7.6 shows the characteristics of participants aged 53 and under compared to those aged 54 and over. The older age group was slightly less likely to live alone than the younger, this is perhaps surprising as among participants in Survey I the older group was more likely to live alone, possibly due the increased likelihood of having lost a partner and children having left the family home. However, as the median age of Survey II participants was more than 25 years younger than Survey I participants, the effect of partner loss among the older group may be smaller, and one might speculate that a proportion of the younger age group live alone because they have yet to move in with a partner or are divorced. Overall mobility aid use was similar in the older and younger age groups, although use of one walking stick was slightly more popular among the older group than the younger group with the reverse true of personal assistance. This is especially notable because the younger group were more likely to live alone, so use of personal assistance might be expected to be less common than in the older group, for whom assistance from cohabitees would be more readily available. This may suggest that the younger participants were generally less mobile and therefore more likely to take advantage of personal assistance where available.

Table 7.6 Summary of interaction between age and other characteristics

	Aged 53 or under	% of total	Aged 54 or over	% of total
Lives alone	50	22%	46	20%
Does not live alone	64	28%	71	31%
No mobility aid	14	6%	12	5%
One Walking Stick	57	25%	70	30%
Personal assistance	30	13%	20	9%
Other mobility aid	13	6%	15	6%
Overall	114	49%	117	51%

Table 7.7 shows that there was a fairly even split between people who live alone and with others among each mobility aid type and no mobility aid. Perhaps surprisingly, a larger proportion of participants who live alone used personal assistance as who live with others. While it may be the case that living with others meant that personal assistance was more readily available, this suggests that living alone was not a barrier to receiving personal assistance. Conversely, living with

others may not necessarily mean that personal assistance can be provided if the cohabitee is, for instance, a partner who is physically unable to provide such assistance. It may be the case that a greater number of participants who live alone would use personal assistance if it were available, and even among those who used personal assistance the availability of this assistance among those who live alone may be more restricted than among those who live with others.

Table 7.7 Summary of interaction between living alone and mobility aid use

	Lives alone	% of total	Does not live alone	% of total
No mobility aid	10	4%	16	7%
One Walking Stick	50	22%	77	33%
Personal Assistance	25	11%	25	11%
Other mobility aid	11	5%	17	7%
Overall	96	42%	135	58%

7.3 Comparison of Participant Characteristics with Survey I

Table 7.8 and Table 7.9, compare the characteristics of the participants in Survey I, as summarised in section 5.3, and Survey II. Compared to the sample for Survey II the sample group for Survey I were more than 25 years older on average, with a similar spread of ages around the mean. It was to be expected that the sample used for Survey I would be biased towards older participants because the majority of these participants were recruited from London-based members of the Macular Society, meaning that they were likely to have AMD and, therefore, be older.

Vision Level was lower on average among Survey I participants than Survey II participants, with a mean V Level of 7 among the former group and 8 among the latter. The higher standard deviation and interquartile range for V Level in Survey I compared to Survey II shows that there was a greater spread of Vision Levels among Survey I participants, with the majority of participants in Survey II having good vision and relatively few having low vision, defined as V7 or below. As with the age difference, this was likely to be the result of the involvement of the Macular Society in recruitment for Survey I, which also explains why the vast majority of

Survey I participants had AMD while none of the Survey II participants reported having AMD.

Average Transport Ability in Survey I, as measured by Instrument I, was 0.9, meaning that on average the Transport Ability participants in Survey I was 0.9 logits higher than the average difficulty of the items used for Instrument I, which is by definition set at zero. By contrast, average Transport Ability in Survey II was -0.9, as measured by Instrument II, showing that the average difficulty of the items used for Instrument II was 0.9 logits higher than the average Transport Ability of the participants. In section 6.5 analysis of seven common items showed that item difficulty measured by Instrument II was approximately 0.8 logits higher than in Instrument II. This meant that the 1.8 logit difference in average Transport Ability between the two surveys became a difference of 1.0 logits after adjusting for the difference in measurement between the two instruments.

The participants in Survey II were therefore found to have Transport Ability that was on average one logit lower than participants in Survey I. This was consistent with the higher rate of mobility aid use among Survey II participants, with 89% of participants using mobility aids compared to 33% in Survey I, which was the result of recruitment from a Council A contact list of residents who had applied for a transport concession. The spread of Transport Abilities was larger in Survey I than Survey II, with both the standard deviation and interquartile range roughly 50% larger in Survey I than Survey II. Comparing Life Space score between the two surveys shows similar results to Transport Ability, with higher but more spread scores among Survey I participants than Survey II participants.

Table 7.8 Comparison of participant characteristics in the two survey samples (Continuous variables)

	Survey I participants					Survey II participants				
Sample size	283					231				
	Mean	**Median**	**Range**	**IQR**	**Std. Dev**	**Mean**	**Median**	**Range**	**IQR**	**Std. Dev**
Age	79.2	81	46 to 94	74 to 87	9.6	53.8	54	22 to 93	48 to 60	10.4
Vision Level	7.0	8	1 to 10	5 to 10	2.6	8.2	9	2 to 10	7 to 10	1.8
Transport Ability	0.9	1.0	-5.2 to 5.5	0.8 to 2.7	2.4	-0.9	-0.8	-5.7 to 4.1	-1.8 to -0.1	1.6
Life Space score	50.6	51	9 to 102	31 to 68	23	40.4	38	7 to 104	28 to 46.5	17.7

Table 7.9 Comparison of participant characteristics in the two survey samples (Binary variables)

	Survey I Participants				Survey II Participants			
	Males	**% Males**	**Females**	**% Females**	**Males**	**% Males**	**Females**	**% Females**
Gender	82	29%	201	81%	102	44%	129	56%
	Yes	**Yes %**	**No**	**No %**	**Yes**	**Yes %**	**No**	**No %**
Live alone	147	52%	136	48%	96	42%	135	58%
Mobility Aid User	92	33%	191	68%	205	89%	26	11%
Low vision (V1-V7)	135	48%	148	52%	78	34%	153	66%
AMD	232	82%	51	18%	0	0%	231	100%

Among Survey II participants there were slightly more females than males, compared to a significant majority of females in Survey I, and slightly more people who lived alone, whereas similar numbers of Survey I participants lived alone as with others. As discussed in section 5.3, the disproportionate number of females in Survey I may be linked to the higher incidence of AMD among females than males.

7.4 Transport Ability Univariate Regression Analysis

In order to address how each of the confounding and predicting variables affected Transport Ability, it was first necessary to investigate the relationship between Transport Ability and each of these variables individually. The effect of age, gender, living alone, low vision and mobility aid use on Transport Ability were measured by conducting univariate regression analyses with each in turn as the independent variable and Transport Ability as the dependent variable. Age was used as a continuous variable in the analysis, whereas dummy variables were used to analyse the other variables.

Figure 7.1 shows that the relationship between Transport Ability and age was in the predicted direction, with Transport Ability decreasing by 0.02 logits with each year of age. However, this relationship was only approaching significance at the 5% level and the R squared value was very low at 0.01, suggesting that while there is a suggestion that age influenced Transport Ability, only 1% of the variation in Transport Ability can be explained by age alone.

Parameter Estimates for Age

RSquared	0.01
Estimate	-0.02
Prob > [t]	0.06

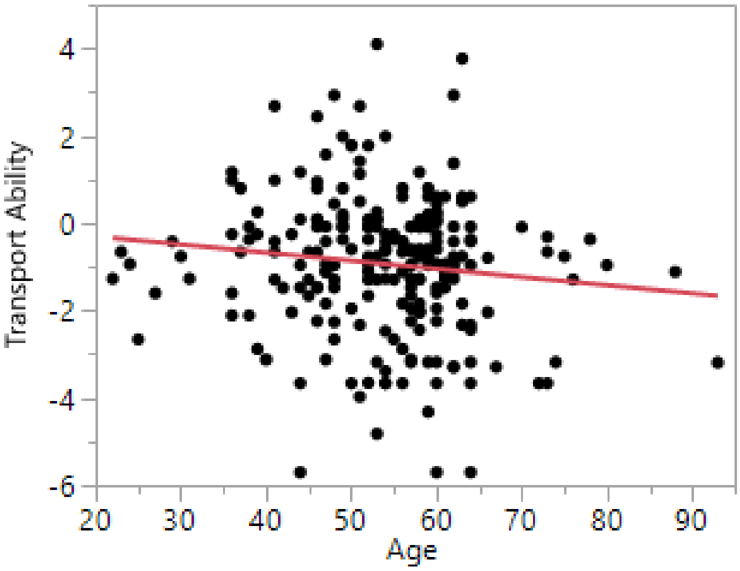

Figure 7.1 **Scatterplot of Transport Ability against Age**

Table 7.10 summarises the dummy variables used to represent the remaining confounders and predictors and the results of the univariate regression of the variable against Transport Ability. These variables are the same as those described in section 5.3, although the AMD variable was not applicable to Survey II as none of the participants had AMD.

Neither gender nor living alone were found to have a statistically significant effect on Transport Ability. Low vision was found to significantly reduce Transport Ability by 1.1 logits, with the R squared value showing that it explained 10% of the variation in Transport Ability. Similarly, mobility aid use was found to reduce Transport Ability by 1.6 logits, explaining 13% of the variation in Transport Ability.

Table 7.10 Summary of dummy variables used for univariate regression against Transport Ability

Variable	**Assigned 1 if:**	**Number assigned 1**	**Assigned 0 if:**	**Number assigned 0**	**Intercept**	**Co-efficient**	**P value**	**R squared**
Gender	Male	102	Female	129	-1.01	0.19	0.37	0.003
Live Alone	Live alone	96	Live with others	135	-0.96	0.07	0.76	0.0004
Low Vision	V Level 7 or below	78	V Level 8 or above	153	-0.57	-1.08	<.0001	0.10
Mobility Aid Use	Use 1 or more mobility aids	205	Use no mobility aids	26	0.47	-1.63	<.0001	0.13

In summary, univariate regression analysis showed that neither age, gender nor living alone had an effect on Transport Ability that was significant at the 5% level. Low vision and mobility aid use both individually had a statistically significant impact on Transport Ability, which will be investigated further using multiple regression analysis in the next section.

7.5 Transport Ability Multiple Regression Analysis

The two variables that were found by univariate regression to be significantly correlated with Transport Ability, low vision and mobility aid use, were used in a multiple regression with Transport Ability as the dependent variable. This resulted in a regression equation of the form:

Transport Ability = Low Vision + Mobility Aid Use

Table 7.11 shows the parameter estimate and p-value produced for each independent variable, and the R squared value for the model.

Table 7.11 Relationship between Transport Ability and significant variables from univariate regression

Term	Estimate	Prob>[t]
Intercept	0.99	0.0002
Low Vision	-1.18	<.0001
Mobility Aid Use	-1.77	<.0001

R Squared = 0.25

As shown by the R squared value of 0.25 in Table 7.11, 25% of the variance in Transport Ability can be explained by the independent variables. Both Low Vison and Mobility Aid Use had a statistically significant effect on Transport Ability. Low Vision, defined as having Vision Level of 7 or below, was associated with a 1.2 logit reduction in Transport Ability on average, illustrating that people with impaired vision experience greater difficulty when using public transport compared to people with relatively good vision. Mobility Aid Use was associated with a larger reduction in Transport Ability of 1.8 logits on average.

An interaction term for Low Vision and Mobility Aid Use was added to the equation, which resulted in a regression equation of the form:

Transport Ability = Low Vision + Mobility Aid Use + Low Vision*Mobility Aid Use

Table 7.12 summarises the results of this multiple regression.

Table 7.12 Relationship between Transport Ability and significant variables from univariate regression, including interaction term

Term	Estimate	Prob>[t]
Intercept	1.36	<.0001
Low Vision	-2.02	<.0001
Mobility Aid Use	-2.18	<.0001
Low Vision *Mobility Aid Use	0.98	0.07

R Squared = 0.26

While parameter estimate on the interaction term indicates that the combined effect of low vision and mobility aid use is a smaller reduction in Transport Ability than the sum of the two individual effects, it is not significant at the 5% level. Nonetheless, the p value of 0.07 is approaching significance.

Table 7.13 summarises the results of a further multiple regression in which the mobility aid use dummy variable was replaced by three different dummy variables for type of mobility aid: one walking stick, personal assistance and other mobility aid. This gave a regression equation of the form:

Transport Ability = Low Vision + One Walking Stick + Personal Assistance + Other Mobility Aid

The other mobility aid category comprised users of mobility aids other than one walking stick and personal assistance. The parameter estimate for each of these dummy variables shows the effect that use of that mobility aid has on Transport Ability relative to not using a mobility aid.

Table 7.13 Relationship between Transport Ability and significant variables from univariate regression, with separate mobility aid dummy variables

Term	Estimate	Prob>[t]
Intercept	1.16	<.0001
Low Vision	-1.28	<.0001
One Walking Stick	-1.66	<.0001
Personal Assistance	-1.80	<.0001
Other Mobility Aid	-2.98	<.0001

R Squared = 0.31

All three mobility aid dummy variables were found to be statistically significant, with one walking stick and personal assistance having a similar effect, being correlated with a 1.7 and 1.8 logit reduction in Transport Ability, respectively. Other mobility aid was correlated with a much larger reduction of 3.0 logits. This suggests that users of personal assistance had a similar level of Transport Ability to users of one walking stick, while users of other mobility aids had a much lower Transport Ability. The use of each category of mobility aid was correlated with a larger reduction in Transport Ability than low vision, suggesting that mobility aid use hinders the ability to use transport to a greater extent than low vision.

In a final model, summarised in Table 7.14, interaction terms were introduced between low vision and each of the mobility aid variables, which resulted in a model of the form:

Transport Ability = Low Vision + One Walking Stick + Personal Assistance + Other Mobility Aid + Low Vision*One Walking Stick + Low Vision*Personal Assistance + Low Vision*Other Mobility Aid

Table 7.14 Relationship between Transport Ability and significant variables from univariate regression, with separate mobility aid dummy variables and interaction terms

Term	Estimate	Prob>[t]
Intercept	2.19	<.0001
Low Vision	-3.33	<.0001
One Walking Stick	-2.84	<.0001
Personal Assistance	-2.93	<.0001
Other Mobility Aid	-3.88	<.0001
Low Vision*One Walking Stick	2.49	<.0001
Low Vision*Personal Assistance	2.39	0.0003
Low Vision*Other Mobility Aid	1.55	0.04

R Squared = 0.37

All three mobility aid dummy variables and low vision were found to remain statistically significant, while all three interaction terms between low vision and mobility aid type were also significant at the 5% level. Low vision was found to have a slightly bigger negative impact on Transport Ability than use of either one walking stick or personal assistance, both of which were correlated with a reduction in Transport Ability of just under three logits.

All three of the interaction terms had positive coefficients, suggesting that the effect of using each type of mobility aid in addition to having low vision was less than the sum of the two individual effects. Notably, the magnitude of each of the interaction term coefficients was smaller than the corresponding coefficient for use of that mobility aid type alone or low vision alone. This meant that having low vision and using a mobility aid was estimated to be associated with Transport Ability lower than having either low vision or using each type of mobility aid alone, but greater than the sum of the effects of low vision or mobility aid use individually. This meant that for people with low vision, the negative effect of mobility aid use on Transport Ability was smaller than for people with good vision, and similarly among mobility aid users the negative impact of low vision on Transport Ability was smaller than among non-users of mobility aids.

The coefficient on the interaction term between low vision and one walking stick was similar in size to the coefficient on the interaction term between low vision and personal assistance. As this was also true of the coefficients for use of each of these mobility aids alone, this suggests that users of one walking stick and personal assistance had similar Transport Ability to each other both among participants with good vision and among participants with low vision. For example, a walking stick user with good vision would be predicted to have Transport Ability of -0.65 logits (2.19-2.84), compared to -0.74 (2.19-2.93) logits for a personal assistance user with good vision. A walking stick user with low vision would be predicted to have Transport Ability of -1.49 logits (2.19-3.33-2.84+2.49), which is reasonably close to the prediction for a personal assistance user with low vision, which is -1.68 (2.19-3.33-2.93+2.39).

7.6 Discussion of Transport Ability

The univariate regression results, summarised in section 7.4, showed that neither age, gender nor living alone had a significant impact on Transport Ability, while low vision and mobility aid use did have a significant effect. The significantly younger average age of participants in Survey II relative to Survey I may explain why age was significant in the univariate regression for the latter but not the former. There is no compelling reason why Transport Ability should differ among males and females, or people who live alone as opposed to with others.

In the final multiple regression, summarised in Table 7.14 and shown for comparison in Table 7.15, low vision, use of one walking stick, personal assistance and any other mobility aid were all found to significantly reduce Transport Ability. This was in line with the hypothesis, set out in section 1.3, that impaired vision and reduced mobility will result in lower levels of Transport Ability. As in the final regression for Survey I, summarised in Table 5.12 and shown for comparison in Table 7.15, the negative effect of low vision on Transport Ability was larger than the effect of using either one walking stick or personal assistance. As discussed in section 5.6, the diversity of mobility aid types in the other mobility aid category made it difficult to draw any useful conclusions from its coefficient, other than that using other mobility aids was correlated with lower Transport Ability than use of one walking stick or personal assistance, in line with the hypothesis that different types of mobility aid will have different effects on Transport Ability.

Table 7.15 allows comparison of the regression coefficients for the final regression for Survey I and Survey II, showing that for all of the common terms, the coefficient was lower in Survey II than Survey I. This shows that the participants in Survey II rated the tasks included in Instrument II as more difficult than the Survey I participants rated the tasks included in Instrument I.

Table 7.15 Comparison of final regression coefficients for Survey I and Survey II

Significant Terms	Survey I final regression coefficient	Survey II final regression coefficient	Difference
Intercept	3.29	2.19	1.10
Low Vision	-2.05	-3.33	1.28
One Walking Stick	-1.89	-2.84	0.95
Personal Assistance	-1.21	-2.93	1.72
Other Mobility Aid	-1.88	-3.88	2.00
Low Vision*One Walking Stick		2.49	
Low Vision*Personal Assistance		2.39	
Low Vision*Other Mobility Aid		1.55	

The negative effect of low vision on Transport Ability was larger among Survey II participants than Survey I participants, despite low vision being more prevalent and more severe among Survey I participants. This could be linked to the older age of Survey I participants, which may mean that they had been living with low vision for much longer and had been better able to develop coping strategies over time than the younger participants in Survey II.

The similar reduction in Transport Ability attributed to use of personal assistance and one walking stick, suggested that personal assistance provided the same benefit as a walking stick to Survey II participants, in contrast to Survey I participants among whom personal assistance was associated with higher Transport Ability than one walking stick. For Survey I participants it was suggested that personal assistance was a bigger help because not only was it more adaptable than a walking stick, it potentially also has an emotional and psychological benefit that allows harder items to be attempted, because reassurance can be provided and there is the knowledge that help is at hand should anything go wrong. It may be that among the younger participants in Survey II the emotional and psychological benefits of personal assistance have a smaller effect on Transport Ability than among the older participants in Survey I, meaning that personal assistance served little other purpose than to provide the functional support that a walking stick can also provide.

The fact that among Survey II participants the effect of the interaction terms between low vision and mobility aid use were all found to have a positive impact on Transport Ability showed that having low vision and using a mobility aid in combination had a smaller effect on Transport Ability than the sum of their individual effects. Low vision reduced Transport Ability to a greater extent among non-users of mobility aids than mobility aid users. This evidence runs against the hypothesis that mobility aid use has a compounding effect on low vision, suggesting that in fact the use of any type of mobility aid lessened the impact of low vision on Transport Ability. A possible explanation for this result could be that mobility aid use was beneficial to participants who also had low vision because the mobility aid could be used to help with issues caused by low vision. For example, a walking stick could provide some of the benefits of a cane for the visually impaired as well as physical support, while personal assistance could provide guidance in low light situations as well as help with mobility.

It is notable that the interaction terms between low vision and use of each type of mobility aid were not significant among Survey I participants but were significant among Survey II participants, suggesting that the combination of low vision and mobility aid use lessened the negative impact on Transport Ability among the latter but not the former. This could be linked to the older age of Survey I participants compared to Survey II participants, which may have allowed time to develop strategies to cope with low vision that the younger group has not yet had. This may mean that members of the younger group with low vision benefit from also using a mobility aid because they lack other strategies to cope with low vision, whereas members of the older group with low vision have generally developed these strategies and, therefore, benefit less from also having a mobility aid.

7.7 Life Space score and Transport Ability

Figure 7.2 shows a plot of Life Space score against Transport Ability. There is a significant positive correlation, with a one logit change in Transport Ability correlated with a change in Life Space score of 6.64. The R squared value shows that Transport Ability explains 36% of the variation in Life Space score. This is evidence to support the hypothesis, set out in section 1.3, that Transport Ability can be used as a predictor for Life Space, with lower ability resulting in fewer journeys outside of the home.

Parameter Estimates for Life Space score

RSquared	0.36
Estimate	6.64
Prob > [t]	<.0001

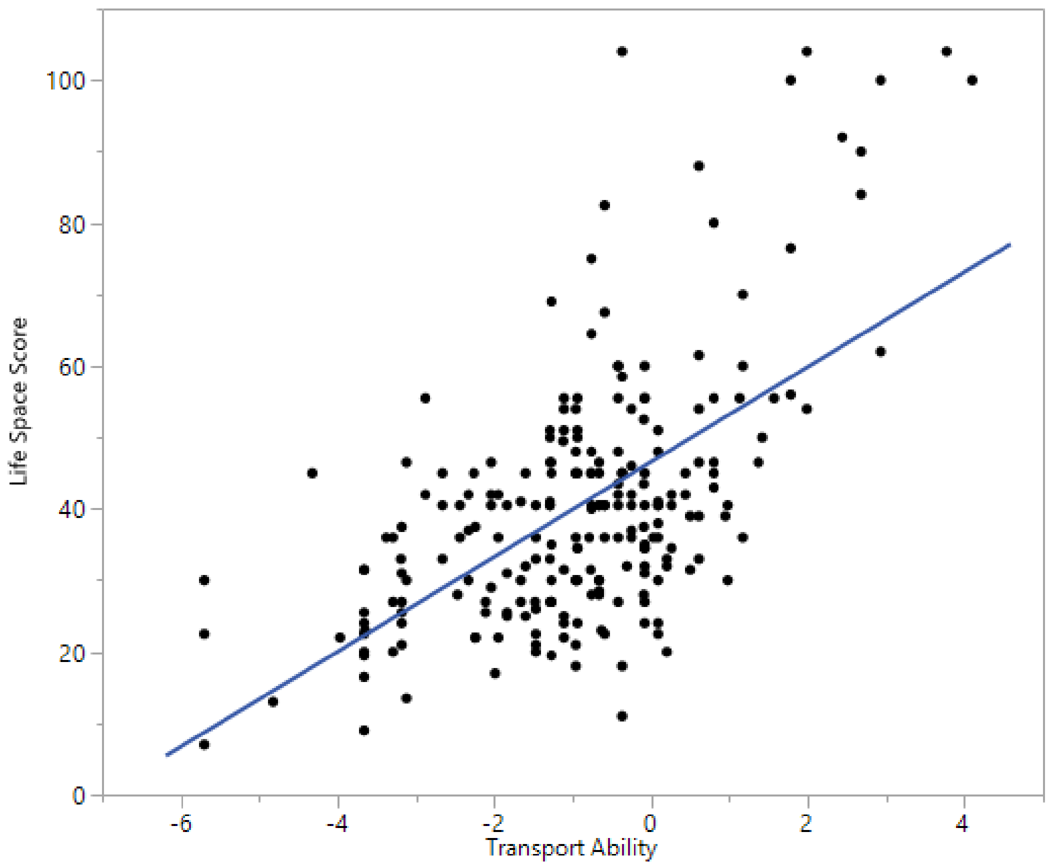

Figure 7.2 Scatterplot of Transport Ability against Life Space score

As mobility aid use is both part of the calculation of Life Space score and highly correlated with Transport Ability, it is unsurprising that there is strong correlation between the two. As discussed in section 3.3.1, Life Space score is a measure of how often a person travels to areas within and outside the home and whether mobility aids or assistance were used to do so, all of which are likely to be determined by a wide range of factors beyond just the ability to use transport. Therefore, it may be possible to use the data collected on other participant characteristics to explain some of the remaining 64% of variation in Life Space score not explained by Transport Ability.

7.8 Life Space Score Univariate Regression Analysis

Univariate regression analysis was used to examine the relationship between Life Space score and age, gender, living alone and low vision. Mobility aid use is integral to the calculation of Life Space score, so could not be used as an independent variable in relation to Life Space score.

Figure 7.3 shows that Life Space score was not found to significantly vary with age. This may be because the majority of participants were below 65, so still of working age. Among those in employment travel to work would vary little with age, reducing the potential for correlation between age and Life Space score.

Parameter Estimates for Age

RSquared	0.01
Estimate	-0.02
Prob > [t]	0.06

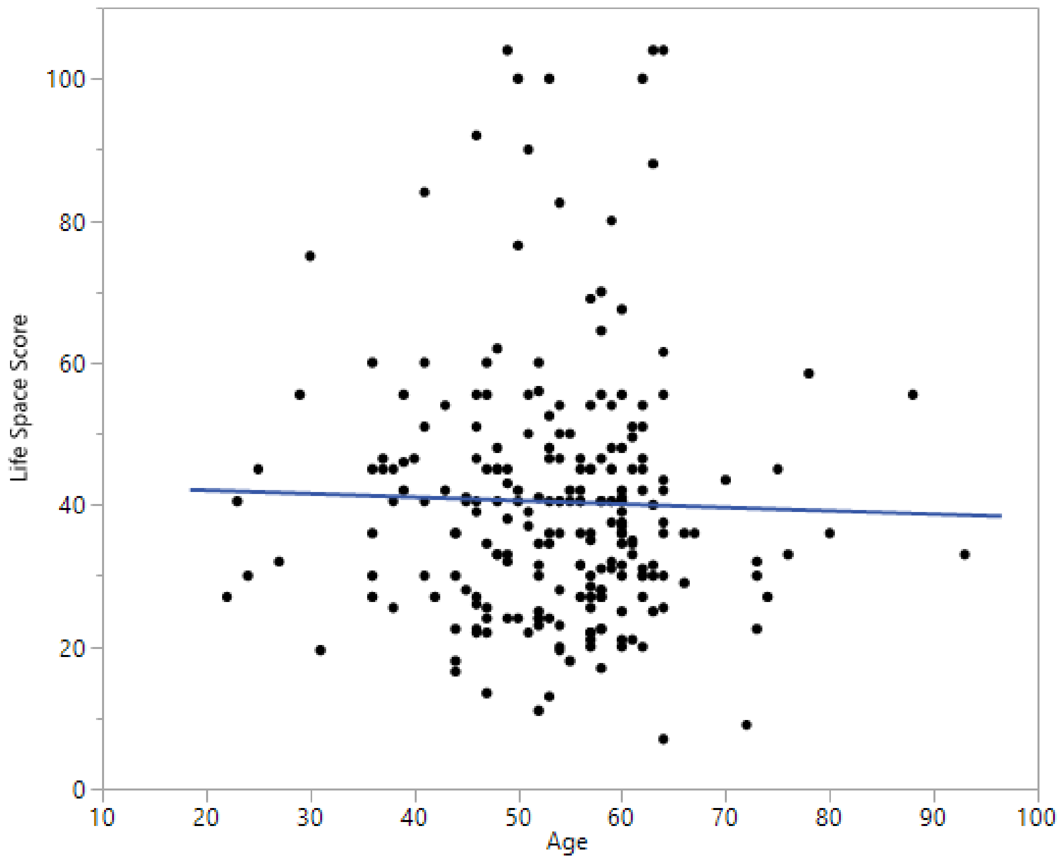

Figure 7.3 Scatterplot of Life Space score against Age

Table 7.16 summarises the effect on Life Space score of the remaining variables. Neither gender nor living alone were found to have a statistically significant effect on Life Space score.

Table 7.16 Summary of dummy variables used for univariate regression against Life Space score

Variable	Assigned 1 if:	Number assigned 1	Assigned 0 if:	Number assigned 0	Intercept	Co-efficient	P value	R squared
Gender	Male	102	Female	129	38.4	4.34	0.07	0.01
Live Alone	Live alone	96	Live with others	135	41.4	-2.45	0.14	0.008
Low Vision	V Level 7 or below	78	V Level 8 or above	153	42.6	-6.51	<.0001	0.03

Low vision was found to have a significant effect on Life Space score, with a V Level of 7 or below correlated with a reduction in Life Space score of 16.5 points. The R Squared value of 0.03 suggests that low vision only explains 3% of the variation in Life Space score. The effect of gender on Life Space score was approaching significance at the 5% level, despite not being close to significance in the univariate analysis with Transport Ability as the independent variable, summarised in section 7.4. This may be linked to the majority of participants being of working age, meaning that as males are more likely to be in full time work than females, males are likely to have a higher Life Space score than females due to work related travel. Nevertheless, this effect was not strong enough to be significant at the 5% level.

7.9 Life Space Score Multiple Regression Analysis

Transport Ability and low vision were the only variables found to be significantly correlated with Life Space score by univariate regression. These two variables were added to a multiple regression with Life Space score as the dependent variable. This resulted in a regression equation of the form:

Life Space score = Transport Ability + Low Vision

Table 7.17 shows the parameter estimate and p-value produced for each independent variable, and the R squared value for the model.

Table 7.17 Relationship between Life Space score and significant variables from univariate regression

Term	Estimate	Prob>[t]
Intercept	46.4	<.0001
Transport Ability	6.71	<.0001
Low Vision	-0.7	0.74

R Squared = 0.36

As shown by the R squared value of 0.36 in Table 7.17, 36% of the variance in Life Space score can be explained by the independent variables. Transport Ability had a statistically significant effect on Transport Ability, while low vision was not found to have an effect significant at the 5% level. A one logit change in Transport Ability was found to be correlated with a change in Life Space score of 6.7 points on average, illustrating that there was a strong correlation between the ease of using transport and the extent and frequency of travel.

This result shows that Transport Ability was the only one of the variables analysed that had a significant effect on Life Space score, whereas low vision was not found to affect Life Space score directly but only through its effect on Transport Ability. This suggests that there is no evidence among Survey II participants that that low vision had an effect on confidence or psychology that leads to a reduction in the extent and frequency of travel beyond the effect that low vision has on Transport Ability. This may be because Survey II participants were mostly of working age, meaning that it was possible that having to travel for work gave the participants little choice but to overcome any confidence or psychology related issues. However, low vision was not found to directly affect Life Space score among Survey I participants either, as summarised in section 5.9, which may suggest that confidence and psychology effects of low vision are either rare or must be overcome through necessity, whether for travel related to work or for other reasons.

7.10 Discussion of Life Space Score

The univariate regression results, summarised in section 7.8, showed that none of gender, living alone or age had a significant impact on Life Space score, while Transport Ability and low vision did have a significant effect. As none of these were found to significantly affect Transport Ability, it is unsurprising that they did not significantly affect Life Space score either.

Gender has been found to have an influence on Life Space score in other studies, for example by Curcio (2013), because gender roles can determine the extent and frequency of travel because certain trip types, such as those related to work and shopping, are more often undertaken by one gender than the other. As discussed in section 7.8, gender may have been approaching significance for these reasons, but the effect was not strong enough to be significant at the 5% level.

Living with other people might be expected to increase Life Space score if it provides motivation for travel outside of the home to accompany cohabitees on their trips. However, it is also possible that living with others would remove the motivation to travel outside of the home for entertainment or companionship, as well as reducing the need to make shopping strips as cohabitees may be able to make these trips instead. As living alone was not found to be significant this suggests that neither effect was dominant enough to significantly affect the extent and frequency of travel.

The multiple regression analysis showed that while Transport Ability and low vision were both significant in univariate regression, low vision was no longer significant at the 5% level in multiple regression. This suggests that low vision only affects Life Space score through the impact it has on Transport Ability. There was no strong evidence that low vision was affecting the extent and frequency of participants' travel for reasons distinct from Transport Ability, such as psychological reasons related to confidence or mental health.

Age was not found to have a significant effect on Life Space score in multiple regression, unlike among Survey I participants. This could be explained by the fact that most participants were too young for retirement, so the there was no observation of a reduction in journeys associated with hitting retirement age. Overall health was also unlikely to vary significantly with age among the Survey II participants, who were mostly in their 40s and 50s.

Overall, Transport Ability was found to be a good predictor of Life Space score, explaining almost 40% of the variation in Life Space score. However, there are clearly still a significant number of other factors that significantly affect Life Space score, meaning that there is scope for further research in this area.

7.11 Summary

In this chapter it has been shown in Table 7.11 that the primary determinants of Transport Ability among the participants of Survey II were low vision and mobility aid use. As hypothesised in section 1.3, more severe vision loss and limited mobility was associated with lower Transport Ability.

Further analysis that split mobility aid by type, summarised in Table 7.14, showed that of the two most popular types of mobility aid, use of one walking stick and personal assistance were correlated with a similar reduction in Transport Ability relative to not using a mobility aid. This contrasted with Survey I, where use of personal assistance was found to be associated with a smaller reduction in Transport Ability than use of one walking stick. Furthermore, low vision was not found to compound the negative effect on Transport Ability of use of any type of mobility aid, but to reduce the impact compared to the sum of the individual impacts. Users of personal assistance were found to have a similar Transport Ability to users of one walking stick both with and without low vision.

Life Space score was only found to be significantly correlated with Transport Ability in a multiple regression. This suggests that, as hypothesised in section 1.3, a greater ability to use transport is associated with more frequent travel over greater distances.

Chapter 8 Case Study I: ScootAbility

8.1 Introduction

This chapter will examine whether Transport Ability and Life Space score can be used to evaluate existing transport accessibility projects and schemes. It was hypothesised that the transport evaluation technique developed in the previous chapters will make it possible to analyse the effect of transport training projects and schemes on a person’s skill set and/or their ability to access and use transport. In order to examine the feasibility of this, Survey II was applied to Case Study I: The ScootAbility Scheme, which was jointly developed by Council A and a neighbouring borough and which will be discussed in this chapter.

It was predicted that both ScootAbility and Case Study II, the wheelchair skills training scheme, which will be covered in Chapter Nine, would increase a person’s Transport Ability and therefore their Life Space score, giving people the confidence and ability to travel further afield and more frequently than they did previously. However, the schemes aim to increase a person’s mobility in different ways, with wheelchair skills training aiming to increase a person’s physical ability in contrast to the ScootAbility scheme which aims to provide a mobility aid.

8.1 Anchoring scores

As only eight people took part in the ScootAbility scheme analysed in Case Study I, the datasets for these case studies were not large enough to be validated using the Rasch analysis process demonstrated in Chapters Four and Six. In this case the methodology that was deemed best to analyse this data was to anchor the pre- and post-scheme person and item measures to those generated by Instrument II. As the person and item scores from Instrument II, developed in Chapter Six, were already validated, this allowed effective analysis of the small datasets of both Case Studies I and II by anchoring the generated person and item scores to the comparable Instrument II dataset.

The questions asked to each participant in Case Study I and II were the same as those that participants were asked in Survey II, asking how difficult they found a certain transport task to perform. However, only the responses to the 12 items used in Instrument II were used in the calculation of each participant's Transport Ability before and after his or her participation in the ScootAbility scheme. In total 16 sets of responses to the 12 items were run through Winsteps, one before and one after joining the Scootability scheme for each participant, but this time the item difficulties from Instrument II were used rather than new item difficulties being calculated based on participant responses. Each participant therefore had two Transport Abilities, one from before and one from six months after joining the Scootability scheme. The change in Transport Ability, was therefore the difference between these scores.

8.2 Background to ScootAbility Scheme

The ScootAbility scheme is operated by Council A and gives residents with mobility problems the option to use a mobility scooter or powered wheelchair to increase their independence. Residents of Council A and a neighbouring borough who would like to use the ScootAbility scheme are able to apply to the scheme if they are over the age of 16. This scheme gives successful applicants the ability to borrow a mobility scooter or powered wheelchair for up to seven days at a time, free of charge. There is no formal limit to the frequency with which members of the scheme can borrow a scooter or wheelchair and during the period studied vehicle availability was sufficient that none of the participants had had a request to borrow a vehicle declined, with all participants reporting using the vehicles on an almost daily basis.

People who apply to their council to be part of the ScootAbility scheme are visited by an occupational therapist in their home to conduct a mobility assessment. This allows the council to verify whether the applicant qualifies for the scheme, have the appropriate ability levels to operate a mobility scooter or powered wheelchair safely, and are able to securely store and charge the mobility scooter or powered wheelchair in their home.

Successful applicants are given one-to-one training in how to operate and use the vehicle safely. Participants in the scheme are then able to book the use of a mobility scooter or powered wheelchair by phone or online, which is then delivered to and collected from their home by the council. Day hire is available to applicants who do not have a safe place to store or charge their mobility scooter or powered wheelchair, however these applicants were not included in this case study.

The range of mobility scooters and power wheelchairs available for hire through this scheme include the Auriga, Gogo, INV Pronto M61, Pride celebrity X4, Quingo and Quantum (Council A, 2015). Figure 8.1 illustrates a Pride celebrity X4 mobility scooter, which is one of the vehicles available for hire on the ScootAbility scheme.

Figure 8.1 Pride celebrity mobility Scooter (Council A, 2015)

8.3 Methodology for Case Study I

In order to investigate how participants' Transport Ability and Life Space scores changed whilst being on the ScootAbility scheme, Transport Ability and Life Space scores were measured during their application interview and again six months after they joined the scheme.

Participants were asked to complete Survey II, developed in Chapter Six, during their ScootAbility assessment with an occupational therapist, and were informed that this questionnaire was not part of the assessment, so that they knew that this was a separate study and would not be used to assess their eligibility for the scheme.

Despite this assurance, participants may still have exaggerated their difficulty with the items in the questionnaire in order to minimise any perceived risk of having their eligibility for the scheme removed. Participants were then contacted by Council A six months after they had been on the scheme to complete the same questionnaire again.

8.4 Results for Case Study I

Table 8.1 summarises the characteristics of the participants in the ScootAbility case study, along with their Transport Ability and Life Space score before joining the scheme and after 6 months of membership. The mean age of all the participants who took part in Council A's large-scale survey was 65 years, five of the eight participants were female and all but one participant lived alone. Furthermore, all participants in the ScootAbility study needed the use of one or more mobility aids and/or required personal assistance, and every participant reported V Level 10, full vision. The mean increase in Transport Ability six months after joining the scheme was 1.6 logits, as measured using Instrument II, while the mean increase in Life Space score was 25 points. This suggests that scheme membership had a positive impact on both the ability to travel and the extent and frequency of travel.

Table 8.1 Characteristics of ScootAbility participants

Person No.	Gender	Age	Live Alone	Trans-port Ability before	Trans-port Ability after	Change	Life Space score before	Life Space score after	Change
1	Male	77	Yes	-1.17	-0.14	1.03	45.0	75.0	30.0
2	Female	51	Yes	-1.97	0.13	2.10	52.0	67.5	15.5
3	Female	48	No	-3.25	1.72	4.97	30.0	61.5	31.5
4	Female	69	Yes	-2.09	-1.61	0.48	31.5	58.5	27.0
5	Female	76	Yes	-1.14	-0.13	1.01	33.0	55.5	22.5
6	Male	51	Yes	-0.96	1.00	1.96	28.5	55.5	27.0
7	Male	75	Yes	-0.31	0.55	0.86	40.5	61.5	21.0
8	Female	71	Yes	0.13	0.72	0.59	45.0	69.0	24.0
Mean		65		-1.35	0.28	1.63	38.2	63.0	25.5
Median		70		-1.16	0.34	1.02	36.8	61.5	24.8
SD		12		1.00	0.92	1.47	8.1	6.5	5.19

Table 8.2, summarises the changes in questionnaire responses among Scootability participants. These are the raw Likert scores, meaning that while the units are not meaningful, the changes in scores can be used to gauge trends. The clear trends are that the frequency of black cab use dropped to zero for all participants, so no ratings

were given, and that the difficulty of travelling on trains, tubes and buses remained virtually the same. None of the group reported using scooters before joining the scheme, so no change in difficulty can be measured, but the low difficulty ratings given for all five scooter-related items show that there were no parts of the process of using the vehicles provide by the scheme that presented a significant barrier to travel.

The biggest improvements were to travelling in unfamiliar areas, crowded situations and at night. These had previously been reported as having the maximum difficulty rating of 5 for almost all respondents but are now rated as between 3 and 4 on average. While they were still reported as being among the harder tasks on the list, they had become easier relative to other tasks.

There were modest reductions in the difficulty of dealing with specific obstacles, such as travelling on pavements and traversing kerbs. The fact that the more general barriers related to unfamiliarity and unpredictable situations saw the greatest improvement may suggest that Scootability had a significant impact in improving the confidence of participants.

However, it may have been the case that the participants' confidence when travelling in uncertain situations improved because they were being encouraged to try a new scheme and having an interest shown in their transport difficulty. Controlling for this effect would, however, be far from straightforward.

None of the reported changes in difficulty relating to using minicabs, carer transport or buddying and walking were captured by Instrument II, as these items were not included in the instrument. The only items included in Instrument II that showed a significant change in reported difficulty related to general public transport.

Table 8.2 Summary of changes in questionnaire responses among ScootAbility participants

Transport type	Task	ScootAbility			
		Mean difficulty before	Mean difficulty after	Difference	Part of Instrument II
Scooter	Access to scooter	n/a	1.3	n/a	
	Getting on scooter	n/a	2.1	n/a	
	Moving on a scooter	n/a	1.3	n/a	
	Charging a scooter	n/a	1.5	n/a	
	Using a scooter	n/a	1.6	n/a	
Black cab	Booking a taxi	2.0	n/a	n/a	
	Boarding a taxi	3.5	n/a	n/a	
	Moving inside a taxi	3.0	n/a	n/a	
	Getting out of a taxi	3.5	n/a	n/a	
MiniCab	Finding a minicab	2.7	3.0	0.3	
	Getting in a minicab	3.2	3.0	-0.2	
	Moving inside a minicab	2.8	2.5	-0.3	
	Getting off a minicab	3.3	3.0	-0.3	
Carer transport	Organising carer transport	1.7	2.0	0.3	
	Getting in the vehicle	2.7	2.5	-0.2	
	Moving inside the vehicle	3.0	2.5	-0.5	
	Getting off the vehicle	3.0	2.5	-0.5	
Buddying /walking	Organising	2.7	2.8	0.1	
	Kerbs	4.0	3.4	-0.6	
	Crossing the road	2.8	3.0	0.3	
	Travelling on pavements	4.0	3.2	-0.8	
General Public Transport	Familiar areas	2.4	1.3	-1.1	Yes
	Unfamiliar areas	4.9	3.6	-1.3	Yes
	Crowded situations	4.5	3.1	-1.4	Yes
	Travelling at night	5.0	3.8	-1.2	Yes
London Bus	Getting to station/stop	2.3	2.4	0.1	Yes
	Boarding the bus	2.7	2.6	-0.1	Yes
	Manoeuvring on the bus	2.5	2.6	0.1	Yes
	Alighting the bus	2.7	2.6	-0.1	
Tube	To station/stop	3.0	3.0	0.0	Yes
	Navigation in station	3.0	3.0	0.0	Yes
	Escalator	3.0	3.0	0.0	Yes
	Stairs	5.0	5.0	0.0	Yes
	Boarding	3.0	3.0	0.0	
	Manoeuvring	3.0	3.0	0.0	
	Alighting	3.0	3.0	0.0	Yes

Train	To station/stop	2.5	2.5	0.0	
	Navigation in station	3.5	3.5	0.0	
	Escalator	3.0	3.0	0.0	
	Stairs	4.5	4.5	0.0	
	Boarding	3.5	3.5	0.0	
	Manoeuvring	3.0	3.0	0.0	
	Alighting	3.5	3.5	0.0	

8.4.1 Change in Transport Ability

Figure 8.2 summarises the change in Transport Ability that was experienced by each participant after taking part in the ScootAbility scheme for six months, with Transport Ability before joining the scheme shown on the x-axis and six months after joining shown on the y-axis. The diagonal line is the identity line x=y, which represents no change. As all participants are above this line, every participant experienced a positive change in Transport Ability. There is one clear outlier, who experienced an extremely large change in Transport Ability, increasing 5 logits, with a change in Transport Ability from -3.3 to 1.7, going from the participant with the worst Transport Ability to the participant with the best. This may be because this person did not understand the scoring system the first time they completed the questionnaire or possibly had a significant improvement in their health or other circumstances that was outside of the factors considered in this study. It was not possible to contact the participant after the event to check whether there was an explanation for this change. The participant was the youngest in the sample and the only one who did not live alone, so was qualitatively different enough from the other participants to justify exclusion from the subsequent analysis of Transport Ability. The majority of the remaining participants experienced an increase in Transport Ability of between 0.5 and 2 logits.

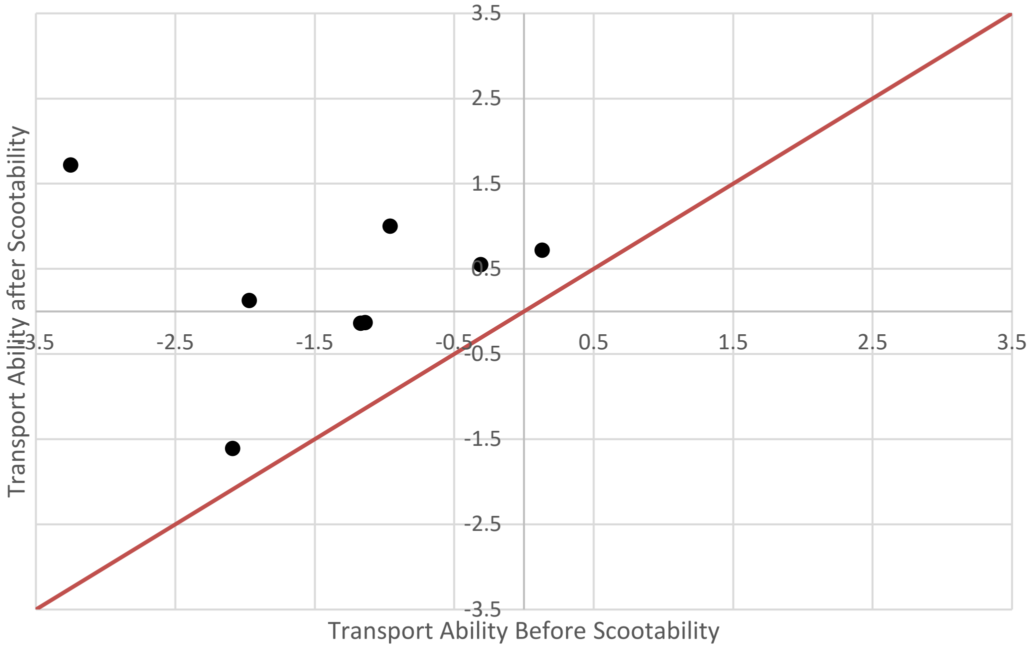

Figure 8.2 Relationship between Transport Ability before and after ScootAbility

Figure 8.3 shows the Transport Ability level of each of the remaining seven participants before taking part in the ScootAbility scheme, shown on the x-axis, in comparison to the change in Transport Ability after taking part in the ScootAbility scheme, shown on the y-axis. The effect of Transport Ability before training on the improvement in ability after the training is shown in Table 8.3 not to be significant at the 5% level. This suggests that initial Transport Ability did not affect the increase in Transport Ability due to the scheme, meaning that high and low ability participants alike received a similar benefit from joining the scheme. As the items included in Instrument II that exhibited the greatest change related to public transport in general and not specific tasks, this may suggest that the improvement in Transport Ability related to an increase in confidence rather than a reduction in the difficulty of traversing specific obstacles.

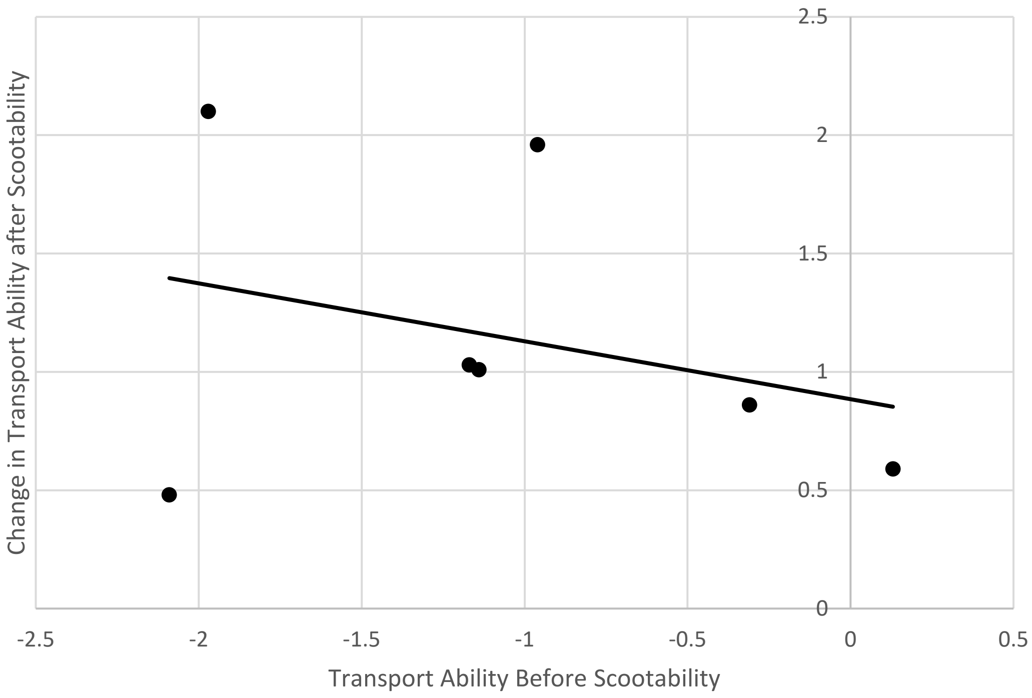

Figure 8.3 **Relationship between Transport Ability before ScootAbility and change in Transport Ability**

R Squared 0.10

Table 8.3 **Parameter estimates for relationship between Transport Ability before ScootAbility and change in Transport Ability**

Term	Estimate	Prob>|t|
Intercept	0.88	0.10
Transport Ability Before	-0.24	0.50

8.4.2 Change in Life Space score

Figure 8.4 shows the change in Life Space score that was experienced by each participant after they took part in the ScootAbility scheme for six months, with Life Space score before joining the scheme shown on the x-axis and six months after joining shown on the y-axis. Again, the diagonal line is the identity line where x=y, which represents no change. As all participants are above this line every participant experienced a positive change in Life Space score; travelling further and more frequently. While the outlier from the analysis of Transport Ability in section 8.4.1 also had the largest increase in Life Space score of 31.5 points, this was not significantly out of line with the increases observed among other participants, meaning that there was insufficient justification to exclude the data point from the Life Space score analysis.

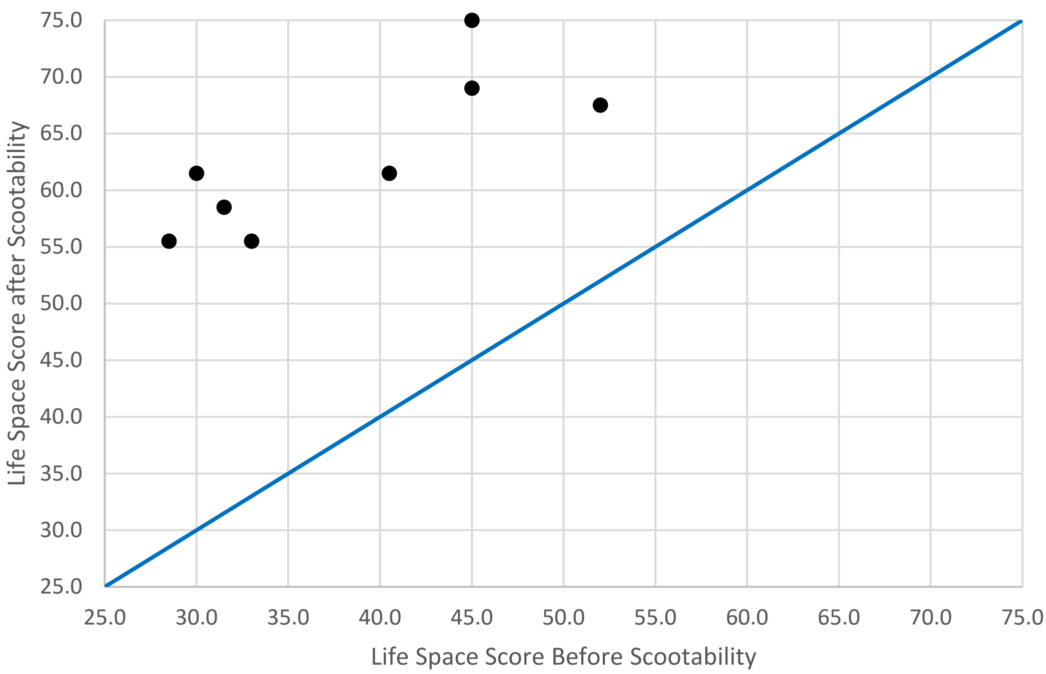

Figure 8.4 Relationship between Life Space score before and after ScootAbility

The graph in Figure 8.5 shows the Life Space score for each participant before taking part in the ScootAbility scheme in comparison to the change in Life Space score after taking part in the scheme. The average increase in Life Space score was 24.8. However, while there is a suggestion that a higher Life Space score before joining the scheme was correlated with a smaller improvement, Table 8.4 shows that the effect is not significant at the 5% level. As with Transport Ability, this suggests that the Scootability scheme delivered similar benefits to all participants irrespective of initial Life Space score. This suggests that even if the improvements in Transport Ability were related to confidence, membership of the Scootability scheme has generated a real increase in the extent and frequency of travel among participants.

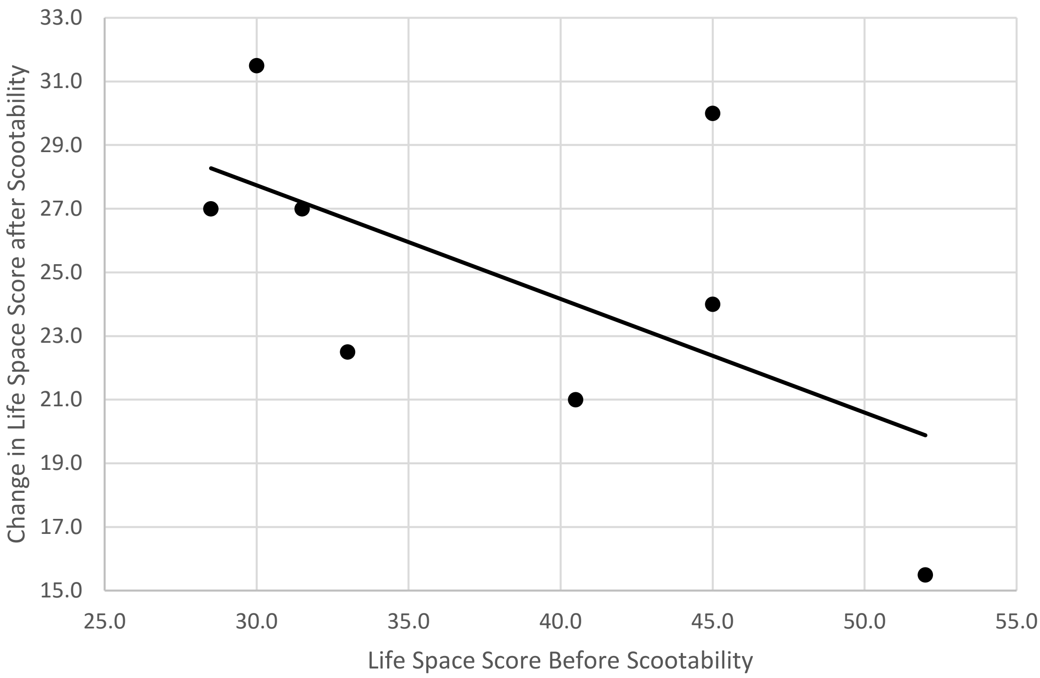

Figure 8.5 **Relationship between the difference in Life Space and initial Life Space score before the ScootAbility Scheme**

R Squared 0.35

Table 8.4 **Parameter estimates for relationship between Life Space score before ScootAbility and change in Life Space score**

Term	**Estimate**	**Prob>|t|**
Intercept	38.45	0.003
Life Space Before	-0.36	0.12

8.4.3 Relationship between the Change in Life Space score and Transport Ability

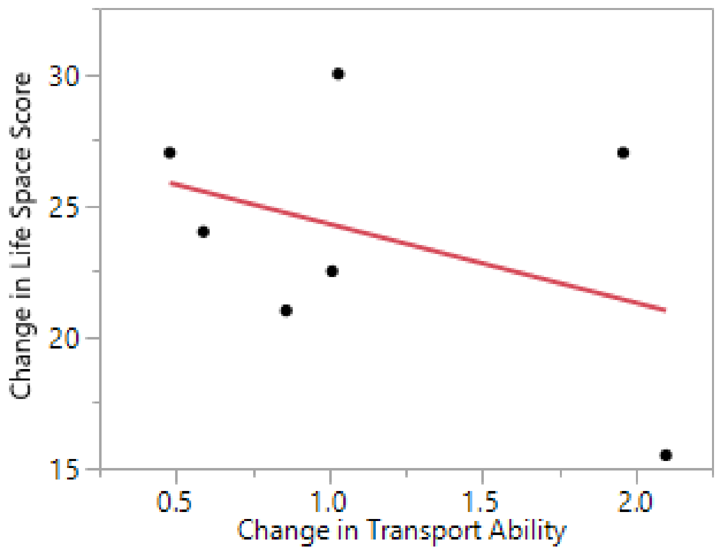

Figure 8.6 Changes in Transport Ability and Life Space score

RSquared 0.16

Table 8.5 Parameter estimates for relationship between change in Transport Ability and change in Life Space score

Term	Estimate	Prob>|t|
Intercept	27.29	0.001
Change in Transport Ability	-2.99	0.38

Figure 8.6 illustrates the change in Transport Ability and Life Space score that each participant, with the exception of the outlier identified in section 8.4.1, experienced after being on the ScootAbility scheme for 6 months, with the change in Transport Ability on the x-axis and the change in Life Space score on the y-axis. Table 8.5 shows that the relationship was not statistically significant at the 5% level. This shows that while both Transport Ability and Life Space score improved for all participants, a greater improvement in Transport Ability did not necessarily lead to a greater improvement in Life Space score. This suggests that there were a much wider range of determinants of Life Space score than Transport Ability alone.

8.4.4 Matched Pair Analysis for Transport Ability and Life Space score

In Figure 8.7, the y-axis shows the difference in Transport Ability for each of the seven participants, excluding the outlier, before and after taking part in the ScootAbility scheme and the x-axis shows the mean of the pre- and post-scheme Transport Ability for each person. The vertical bold red line is the mean of each participant's mean Transport Ability before and after joining the Scootability scheme. The horizontal bold red line is the mean difference in Transport Ability before and after joining the Scootability scheme and the dashed red lines are the 95% confidence interval for this mean. As all points are above zero, this shows that all participants experienced an increase in Transport Ability after taking part in the ScootAbility scheme, with an average increase of 1.2 logits, significant at the 5% level.

One logit measures the increase in Transport Ability or decrease in item difficulty required to increase the probability of a successful outcome by a factor of e or 2.718, the base of the natural logarithm, therefore the average increase in Transport Ability was by a factor of 1.2e. The key benefit of measuring ability and difficulty in logits is that the scale is additive, meaning that, for example, the difference between a score of 0 and 1 is the same as the difference between 1 and 2. However, the value of the logits calculated depends entirely on the specific distribution of responses, so cannot easily be used to make comparisons between experiments.

Table 8.6 Summary table for Matched Pair Analysis for change in Transport Ability

Transport Ability After	0.07
Transport Ability Before	-1.07
Mean Difference	1.15
Std Error	0.24
Upper 95%	1.74
Lower 95%	0.24
Correlation	0.71
Prob > |t|	0.003

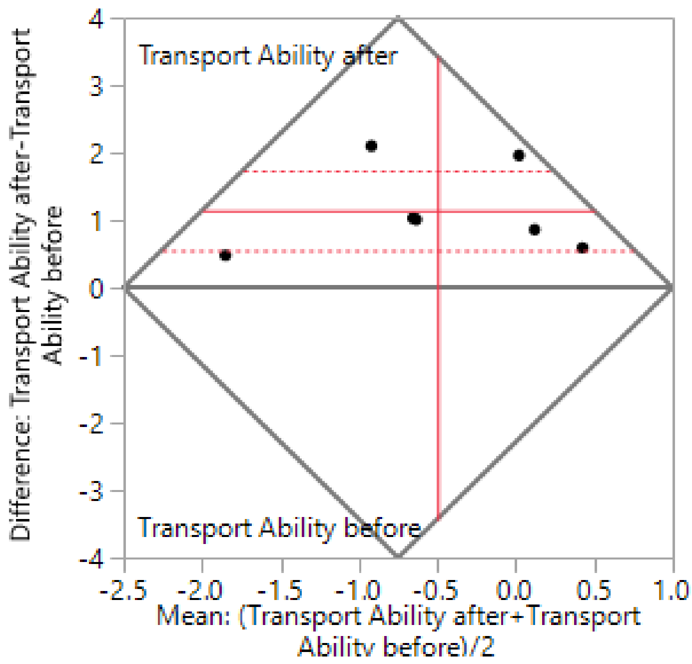

Figure 8.7 **Matched Pair Analysis for the Change in Transport Ability before and after joining the ScootAbility scheme**

The y-axis in Figure 8.8 represents the difference in Life Space score for each participant before and after taking part in the ScootAbility scheme and the x-axis is the mean of the before and after Life Space scores for each person. The bold red line represents the mean difference in Life Space score and the average pre- and post-scheme Life Space score. As all points are above 0, this shows that every participants' Life Space score improved after taking part in the ScootAbility scheme by an average of 24.8.

Table 8.7 **Summary table for Matched Pair Analysis for change in Life Space score**

Life Space After	63.00
Life Space Before	38.19
Mean Difference	24.81
Std Error	1.83
Upper 95%	29.15
Lower 95%	20.47
Correlation	0.80
Prob > |t|	<.0001

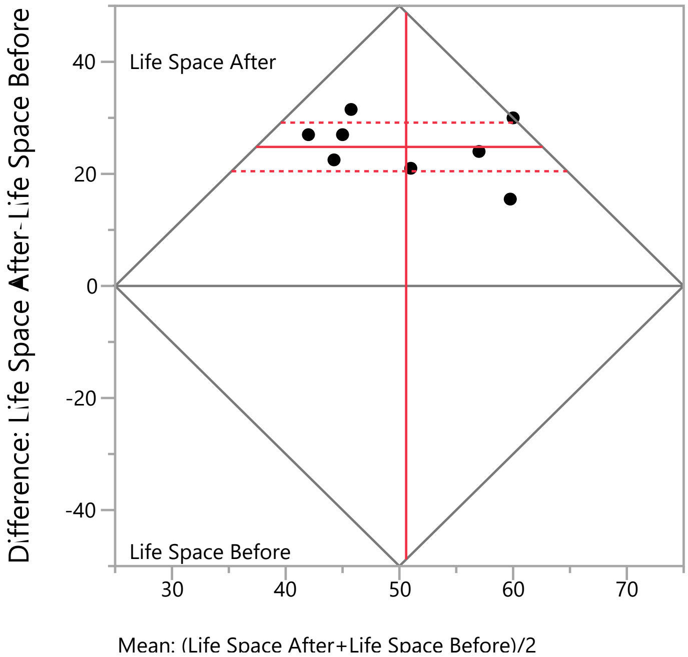

Figure 8.8 **Matched Pair Analysis for the change in Transport Ability before and after joining the ScootAbility scheme**

Table 8.8 shows that the increases in the median scores for both Transport Ability and Life Space score were statistically significant at the 5% level, as the p-values of 0.008 were below the threshold value of 0.05 meaning that the hypothesis that the samples had the same distribution before and after participants joined the Scootability scheme could be rejected. The Wilcoxon signed rank test is used as the distribution does not approximate a normal distribution and the two measurements are not independent of each other. The test is a non-parametric test based on the ranking of individuals, so is independent of the statistic being measured.

Table 8.8 **Wilcoxon Signed Rank test results**

	Transport Ability After-Transport Ability Before	**Life Space After-Life Space Before**
Test Statistic S	14.0	18.0
Prob>|S|	0.02	0.008

8.5 Discussion

This chapter addressed the research question of whether Transport Ability and Life Space scores could be used to evaluate an accessibility intervention, in this case the ScootAbility scheme. For Case Study I, it was hypothesised that Instrument II could be used to analyse the effectiveness of Council A’s ScootAbility transport scheme, which aims to make travelling and transport easier to use. To investigate this, Instrument II was applied to the sample group of 8 people shortly before and six months after they had joined the ScootAbility scheme. It was predicted that joining the ScootAbility scheme would lead to an increase in both Transport Ability and Life Space score among participants, giving them the ability to travel further afield and more frequently than they did previously.

The analysis illustrated that the participants who took part in the ScootAbility case study experienced increases in both Transport Ability and overall Life Space score, illustrating that the scheme was associated with a reduction in the reported difficulty of transport and an increase in the distance and frequency of travel. The majority of the participants who took part in the ScootAbility scheme experienced an improvement in Transport Ability of between 0.5 and 2.0 logits and an improvement in Life Space score of between 15 and 30 points after they were given access to mobility scooters.

In section 8.4.1 it was shown that, after excluding an outlier, there was no significant relationship between initial Transport Ability and change in ability. It may have been expected that participants with lower initial ability would have more scope to improve their ability that participants with higher initial ability, and that joining the Scootability scheme would result in participants’ Transport Abilities becoming more uniform. However, this was not shown to be the case, suggesting that Scootability has the potential to provide transport benefits to people with a range of initial abilities. This may be partly explained by the items used in Instrument II, among which the only significant changes that were observed related to public transport in general rather than specific tasks, meaning that the change measured was possibly related to confidence. Participants with higher initial ability may therefore have had scope to report lower difficulties on these items due to a general increase in confidence that would not have been reported for a specific transport task, which would need to have demonstrated a real reduction in the difficulty in traversing the obstacle to receive a lower difficulty rating. It was also possible that being studied biased the participants' responses and made them feel obliged to report an improvement. This could be resolved in future research by recruiting a larger sample that included participants who did not join the scheme for use as a control group.

Table 8.2 showed that the biggest reductions in item difficulty ratings were seen in more general tasks relating to travelling at night or in places that were unfamiliar or crowded, which are unpredictable, risky and possibly stressful situations. The results suggest that the scheme did not necessarily make many specific tasks significantly easier, as there was little change in the difficulty of tasks relating to public transport modes, although there was a reduction in some ratings relating to carer transport, kerbs and pavements. Instead the primary benefits of the scheme may arise because these powered wheelchairs and scooters may make participants feel less vulnerable and reduce the problem of physical tiredness when travelling outside the home. There was therefore likely to be a reduction in the perception of risk associated with unpredictable situations, such as the risk of getting stranded in an unfamiliar area, the risk of getting injured in a crowded situation or the road safety risk when travelling at night.

There are a plethora of personal internal factors and external physical factors that may have influenced the perceived mobility levels reported by each participant at the time when they completed the questionnaire. Everyone experiences both good and bad days and personal factors such as mood, confidence level and wellbeing to name a few, will all effect how a person responds to a self-assessed questionnaire. Additionally, not everyone has the same social and work activities and needs on a week on week basis, showing how this can cause a difference in self-reported Life Space score. Other external factors such as weather also contribute significantly to whether or not a person chooses to go outside their home and the frequency with which they do so. These personal and physical factors are only a few of many variables which all contribute to how a person responds to either the questionnaire developed in this study or the actual transport or mobility scheme being assessed.

These all limit the effectiveness of the study and the reliability that only the ScootAbility scheme in isolation was being evaluated.

Chapter 9 Case Study II: Wheelchair Skills Training

9.1 Introduction

This chapter will address the research question in order to examine whether Transport Ability and Life Space score can be used to evaluate existing transport accessibility projects and schemes. It was hypothesised that the developed transport evaluation technique will make it possible to analyse the effect of transport training projects and schemes that make travelling or transport easier to access or use or develop the skillset of the person. In order to examine the feasibility of this, the evaluation tool developed in this study was applied to Case Study II - Wheelchair Skills Training, which will be discussed in this chapter.

It was predicted that wheelchair skills training would lead to an increase Transport Ability and, therefore, an increase in Life Space score, giving people the confidence and ability to travel further afield and more frequently than they did previously. However, the wheelchair skills training and Scootability schemes aim to increase a person's mobility in different ways, with wheelchair skills training aiming to increase a person's physical ability in contrast to the ScootAbility scheme, which aims to increase mobility by providing access to a mobility aid.

9.2 Anchoring scores

As only 15 people took part in the wheelchair skills training scheme in Case Study II, the dataset was not large enough to be validated using the Rasch analysis technique as demonstrated in Chapters Four and Six. In this case the methodology that was deemed best to analyse this data was to anchor the pre- and post-training person and item measures to those generated by Instrument II. As the person and item scores in the results from Instrument II, developed in Chapter Six, were already validated, this allowed the small datasets in both case studies to be anchored to the person and item scores generated by the application of Survey II.

9.3 Background to Wheelchair Skills Training

Wheelchair skills training sessions provided by the Back-Up Trust are held at Stanmore Orthopaedic Hospital every two months and aim to help both in-patients and out-patients with spinal injuries to gain new skills to help them to lead independent lives. Skilled trainers and volunteers who had themselves experienced spinal injuries teach new skills and techniques to people who had recently become wheelchair users, with the aim of helping them to use their wheelchairs more effectively in everyday life. The objective is to make everyday tasks easier, such as getting on the bus, going to the local shops, or safely carrying a cup of tea from one room to another. These sessions are also an opportunity to meet other people going through the same life-changing events, as well as to learn from other people's experiences. All the wheelchair skills trainers have a spinal cord injury and can draw from their own experiences to find the best way to teach new skills and techniques.

9.4 Methodology for Case Study II

The wheelchair skills training sessions given at Stanmore Orthopaedic hospital are tailored specifically to each group for both manual and power wheelchairs. This case study focused on the wheelchair skills exercises given to manual wheelchair users during their first training sessions at Stanmore Orthopaedic hospital, which involved two one-hour training sessions that were one week apart. All participants were given the transport questionnaire by the trainers and asked to complete it ahead of their first training session. They were also asked to fill out the same questionnaire again one week after their wheelchair skills training sessions had finished and return these by post. This was so that it would be possible to gauge their Transport Ability before the training session in order to see how the skills they learnt in their first session changed their ability to use transport and their Life Space patterns overall.

A typical session at the hospital covered pushing technique, getting over obstacles, tackling kerbs and thresholds, back-wheel balancing and may also cover steps and transfers if time and equipment allows. The manual wheelchair training session first started with the two trainers teaching basic wheel pushing techniques; making the participants hold a teacup in each so that they could learn how to propel themselves using one hand at a time. This would allow the participants to hold something whilst still being mobile.

The next stage of the wheelchair training exercises aimed to teach the participants how to travel over obstacles. To initiate this, a small piece of rope was place on the floor as shown in Figure 9.1, and the trainers taught each person how to lift up the front of their wheelchair slightly so that they could get the front wheels of their chair over the obstacle in order to push themselves over it. After this basic manoeuvre was practised, participants were ready to practise on some more advanced obstacles that they would face on an everyday basis.

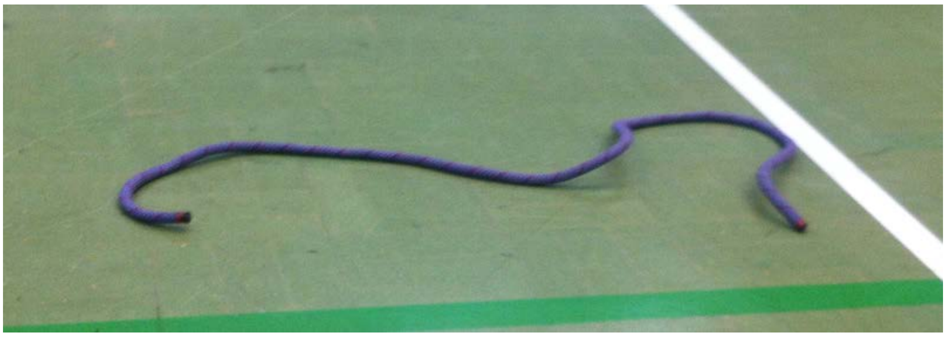

Figure 9.1 First stage in obstacle training

In order to teach manual wheelchair users how to travel on surfaces where there is a slight change in level, a series of wooden blocks were placed on the floor in order of step height. The small step change shown by the obstacle in Figure 9.2 was comparable to a dropped kerb in height. This helped participants develop the skills they learnt in the rope exercise, using the same technique in a more advanced setting. Once participants were able to perform this task, they were asked to practise on the more advanced step change, as shown in Figure 9.3, which is comparable to a small kerb or doorframe. Participants who successfully managed to learn how to travel up and down the change in level obstacles were then encouraged to travel up and down on a kerb mock-up, as shown in Figure 9.4.

Figure 9.2 Change in level training

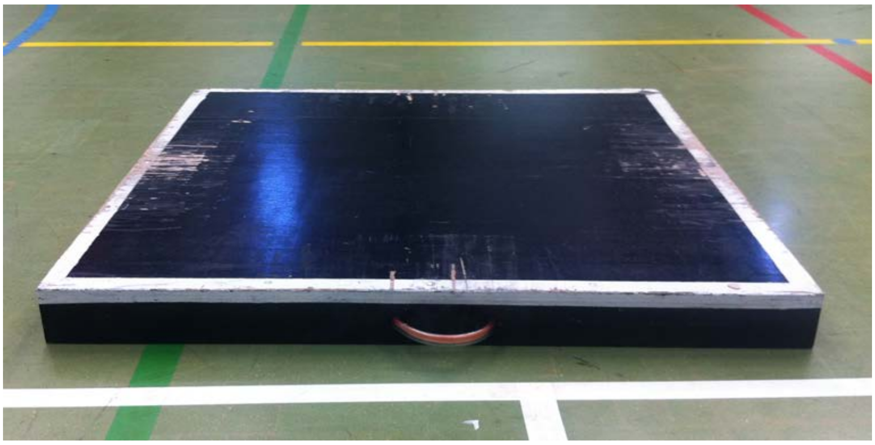

Figure 9.3 Advanced change in level

Figure 9.4 Kerb exercise

The last stage in the skills training session was to learn how to tackle a long gradual slope, a steeper slope and for advanced participants, how to travel up and down two steps, as shown in Figure 9.5. Slope training helps manual wheelchairs users to use the ramps that are used to board buses and train carriages, as well as facilities inside and outside the home.

Figure 9.5 Slope and step training

Results for Case Study II in Table 9.1, summarises the characteristics of the 15 participants who took part in the wheelchair skills training case study and the change observed in their Transport Ability and Life Space scores. The average age of all the participants that completed Survey II was 41 years, with ages ranging from 28 to 55. There were eight females and seven males, while three of the participants lived alone. By definition, all participants in the sample were wheelchair users and none reported anything less than full vision. Transport Ability was observed to increase by 1.2 logits and Life Space score was reported to increase by 13 points following participation in the course.

Table 9.1 Characteristics of wheelchair skills training participants

Person No.	Gender	Age	Live Alone	Trans-port Ability before	Trans-port Ability after	Change in Trans-port Ability	Life Space score before	Life Space score after	Change in Life Space score
1	Female	32	Yes	-0.28	2.15	2.43	72.0	90.0	18.0
2	Male	44	No	-1.13	-0.16	0.97	55.5	61.5	6.0
3	Male	53	No	0.93	0.28	-0.65	60.0	67.5	7.5
4	Female	38	No	-0.62	0.09	0.71	69.0	66.0	-3.0
5	Female	25	No	-0.16	2.23	2.39	64.5	82.5	18.0
6	Female	41	No	-1.37	-0.49	0.88	48.0	55.5	7.5
7	Male	34	No	0.08	2.23	2.15	63.5	81.5	18.0
8	Female	55	No	-1.3	-0.54	0.76	55.5	69.0	13.5
9	Female	28	Yes	0.56	1.33	0.77	69.0	89.0	20.0
10	Male	37	No	-0.39	0.56	0.95	58.5	69.0	10.5
11	Male	42	Yes	-0.39	0.81	1.20	42.0	75.0	33.0
12	Male	55	No	-1.38	0.08	1.46	49.5	61.5	12.0
13	Female	43	No	-0.88	0.32	1.20	55.5	67.5	12.0
14	Male	54	No	-0.17	0.55	0.72	60.0	69.0	9.0
15	Female	39	No	-0.62	0.78	1.40	57.0	67.5	10.5
Mean		41		-0.47	0.68	1.16	58.6	71.5	12.8
Median		41		-0.39	0.55	0.94	58.5	69.0	10.5
Std Dev		9.4		0.66	0.89	0.23	8.0	9.8	1.8

Table 9.2 summarises the changes in questionnaire responses among wheelchair training participants. The biggest improvements were to alighting buses and tubes, with boarding these modes also improving significantly. As these are raw Likert scores, the changes and relative difficulties give an indication of trends but the units themselves are less meaningful than the logit scores produced by Rasch analysis. The questions relating to scooters, carer transport, buddying/walking, stairs and escalators were not relevant to this group, so are not shown.

Table 9.2 Summary of changes in questionnaire responses among wheelchair skills training participants

Transport type	Task	Wheelchair skills			
		Average difficulty before	Average difficulty after	Difference	Part of Instrument II
Black cab	Booking a taxi	2.0	2.0	0.0	
	Boarding a taxi	3.8	3.8	0.0	
	Moving inside a taxi	3.4	3.2	-0.2	
	Getting out of a taxi	4.2	4.0	-0.2	
MiniCab	Finding a minicab	2.0	1.9	-0.1	
	Getting in a minicab	3.9	3.8	-0.1	
	Moving inside a minicab	3.0	2.8	-0.2	
	Getting off a minicab	4.0	3.9	-0.1	
General Public Transport	Familiar areas	2.4	2.1	-0.3	Yes
	Unfamiliar areas	4.5	3.8	-0.7	Yes
	Crowded situations	4.7	4.1	-0.5	Yes
	Travelling at night	4.3	4.2	-0.1	Yes
London Bus	Getting to station/stop	2.8	2.2	-0.7	Yes
	Boarding the bus	4.3	3.4	-0.8	Yes
	Manoeuvring on the bus	3.6	3.3	-0.3	Yes
	Alighting the bus	4.2	2.8	-1.3	Yes
Tube	To station/stop	2.6	2.1	-0.4	
	Navigation in station	3.3	2.7	-0.6	Yes
	Boarding	3.0	2.0	-1.0	Yes
	Manoeuvring	3.4	3.1	-0.3	Yes
	Alighting	3.1	2.0	-1.1	Yes
Train	To station/stop	3.3	3.0	-0.3	
	Navigation in station	3.7	3.0	-0.7	
	Boarding	4.6	3.9	-0.7	
	Manoeuvring	3.8	3.3	-0.5	
	Alighting	4.9	4.2	-0.7	

Table 9.2 shows that while both boarding and alighting buses had been rated as among the more difficult tasks at 4.3 and 4.2 on average, alighting improved to a rating of 2.8 after the training, while boarding reduced in difficulty by a smaller amount to 3.4. Both boarding and alighting the tube had previously been rated as a middling difficulty tasks at 3.0 and 3.1 respectively but still improved to become among the easier tasks in the list at 2.0.

The difficulty of boarding and alighting trains fell by a smaller amount and remained more difficult than boarding and alighting buses and tubes. This may be related to the larger gap between the train and the platform. In contrast to the public transport modes, there was virtually no change to the difficulty of any of the taxi related tasks, including boarding and alighting.

The wheelchair skills training led to a modest decrease in the reported difficulty of travelling in unfamiliar areas and in crowded situations, but made little difference to traveling at night.

Overall the wheelchair skills training seems to have been most effective at improving participants' technical skills to allow them to manoeuvre on and off of public transport modes more easily. This is in contrast to the ScootAbility scheme, which was shown in section 8.4.1 to have had a modest effect in reducing the difficulty of specific obstacles but showed the biggest improvement in empowering participants to travel in unfamiliar and challenging situations, possibly by improving confidence.

9.4.1 Change in Transport Ability

Figure 9.6 shows the change in Transport Ability that was experienced by each participant after they took part in the wheelchair skills training session, with Transport Ability before the training shown on the x-axis and one week after the training shown on the y-axis. The diagonal line is the identity line where x=y, which represents no change. As all but one of the data points were above this line, this showed that nearly every participant experienced an improvement in Transport Ability. There was one clear outlier whose Transport Ability decreased by 0.7 logits after the training. However, the majority of participants experienced a positive change in Transport Ability by between 0.7 and 2.5 logits.

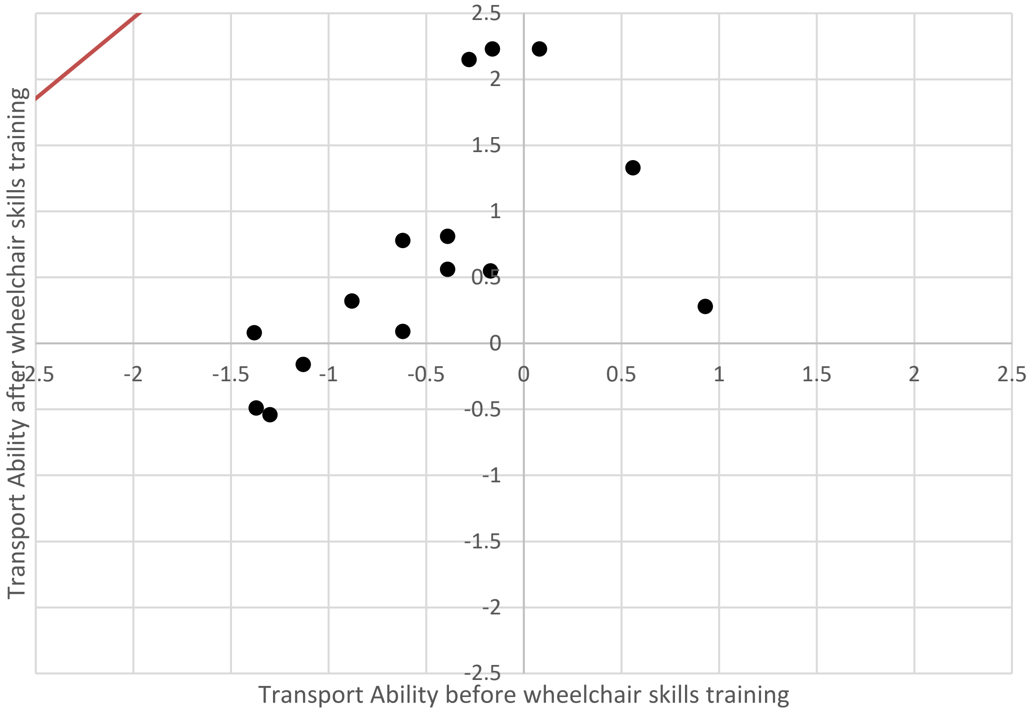

Figure 9.6 Transport Ability before and after wheelchair skills training

Figure 9.7 shows the Transport Ability level of each participant before taking part in wheelchair skills training in comparison to the change in Transport Ability after taking part in the training scheme. There was no correlation between Transport Ability before training and difference in Transport Ability after training, as Table 9.3. shows that the parameter estimate of -0.22 was not significantly different from zero at the 5% level.

The outlying data point represents a person who reported no change in the difficulty of any item after the training, except for travelling in crowded situations, which was given a difficulty of 4 compared to 3 before the training. It is implausible that a person's ability to use transport would be significantly impaired after receiving training designed to improve their ability, especially given that the training did not particularly address travelling in crowded situations, so it is possible that this negative change was due to something other than the training. Unfortunately, it was not possible to contact the participants after the training to gain further insight into reasons for their responses. It was, therefore, justifiable to repeat the analysis with the outlying data point excluded.

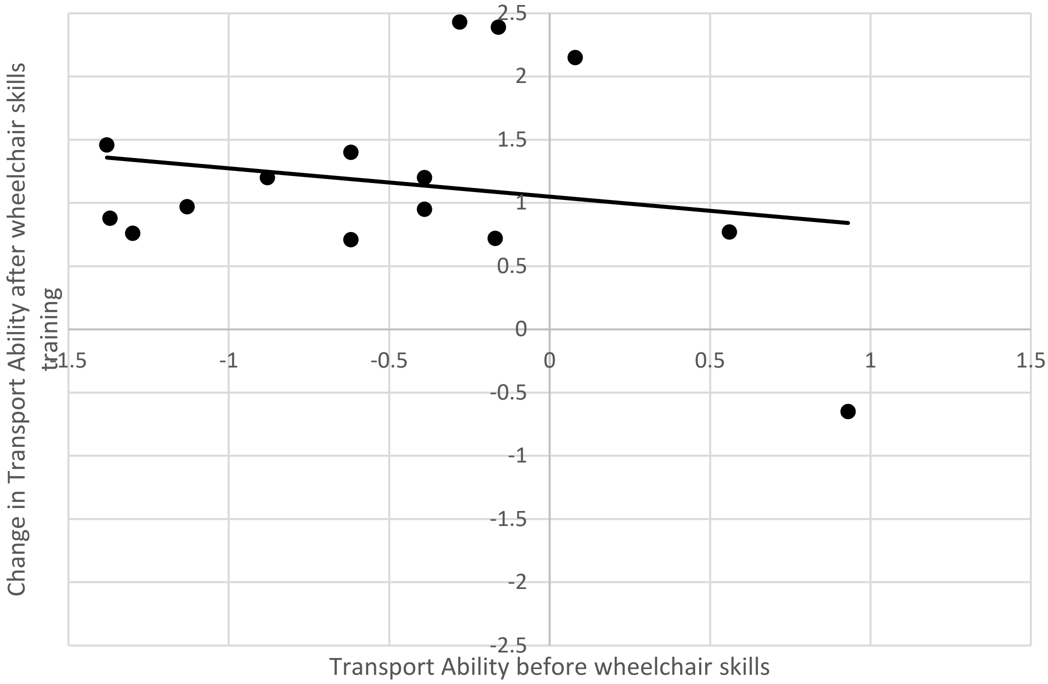

Figure 9.7 **Relationship between the change in Transport Ability and Transport Ability before wheelchair skills training**

RSquare 0.04

Table 9.3 **Parameter estimates for Transport Ability after wheelchair skills training**

Term	**Estimate**	**Prob>|t|**
Intercept	1.05	0.001
Transport Ability before wheelchair skills training	-0.22	0.48

Figure 9.8 replicates Figure 9.7 but excludes the individual whose Transport Ability decreased after training. The effect of Transport Ability before training on the improvement in ability after the training is shown in Table 9.4 not to be significantly different from zero at the 5% level. This is similar to the finding from the ScootAbility case study in Chapter Six, where initial Transport Ability was not found to be significantly correlated with improvement in Transport Ability. This suggests that in both cases the benefits of participating do not disproportionately accrue to participants with either low or high ability

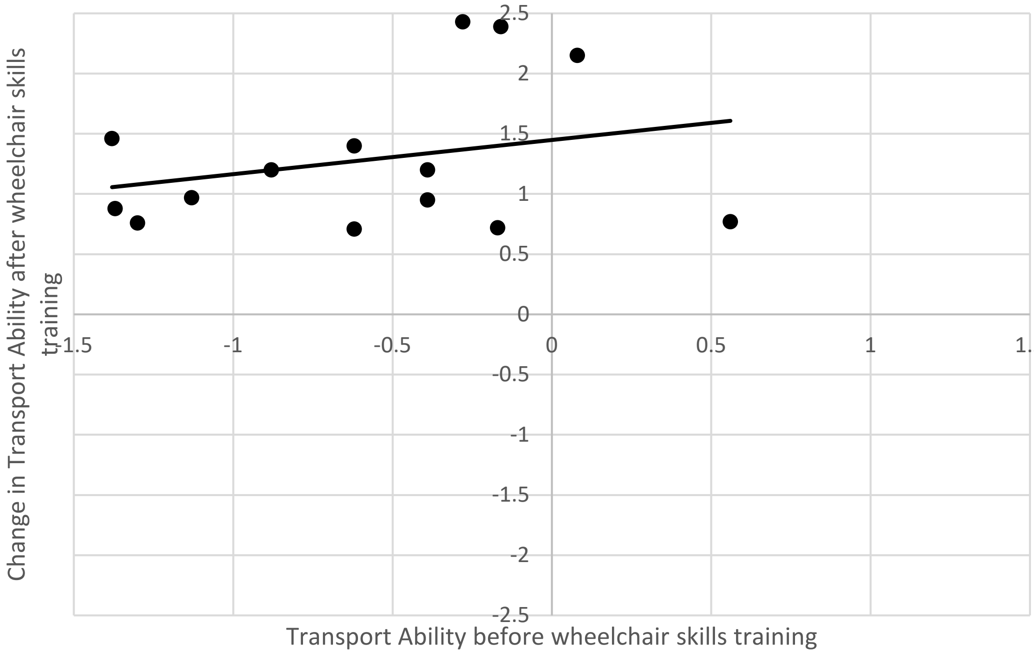

Figure 9.8 **Relationship between the change in Transport Ability and initial Transport Ability before wheelchair skills training (Cleaned)**

Summary of Fit

R Squared 0.07

Table 9.4 **Parameter estimates for Transport Ability after wheelchair skills training**

Term	**Estimate**	**Prob>|t|**
Intercept	1.45	<.0001
Transport Ability before wheelchair skills training	0.28	0.35

9.4.2 Change in Life Space score

Figure 9.9 summarises the change in Life Space score reported by each participant after they took part in the wheelchair skills training. Again, the diagonal line is the identity line where x=y, which represents no change. Only one participant was below this line showing that the majority of people experienced a positive change in Life Space score, travelling further afield on a more frequent basis. This illustrates that, on the whole, participation in wheelchair skills training had a positive impact on travel behaviour.

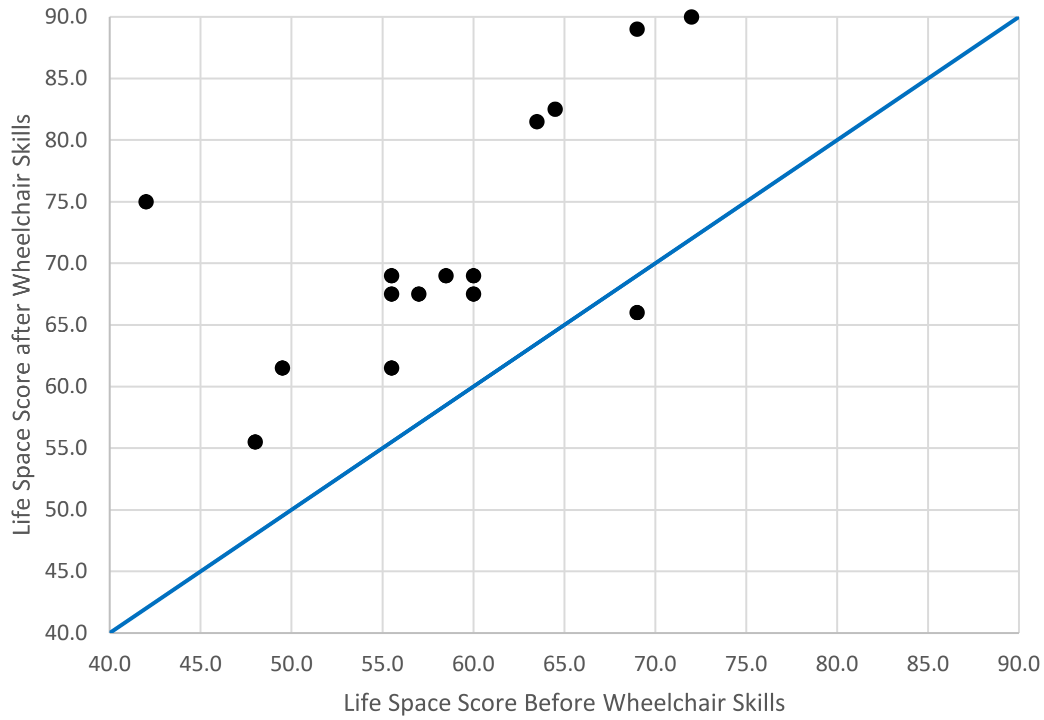

Figure 9.9 Change in Life Space score after wheelchair skills training

Figure 9.10 shows the Life Space score for each participant before taking part in the wheelchair skills training scheme in comparison to the change in Life Space score after taking part in the training. The trend line suggests a negative correlation, with larger improvements experienced by participants with lower initial scores. However, the effect of Life Space score before training on the improvement in ability after training is shown in Table 9.5 not to be significant at the 5% level. However, Figure 9.10 includes two notable outliers. One participant showed a dramatic 33-point improvement in Life Space score, going from having the lowest score of 42 before taking part in the wheelchair training to a relatively high score of 75 after completing the course. While the possibility that the training had such a large effect on this person shouldn't be discounted, it may also be due to an improvement in some other factor in their life that affected their Life Space score, including temporary effects such as sickness or weather. In contrast, one participant started with a comparatively large Life Space score of 69 before the course and reported a Life Space score of 66 after taking part in the training session, showing that this participant reported that they travelled less far, less frequently, which is the opposite trend reported by other participants who took part in the training.

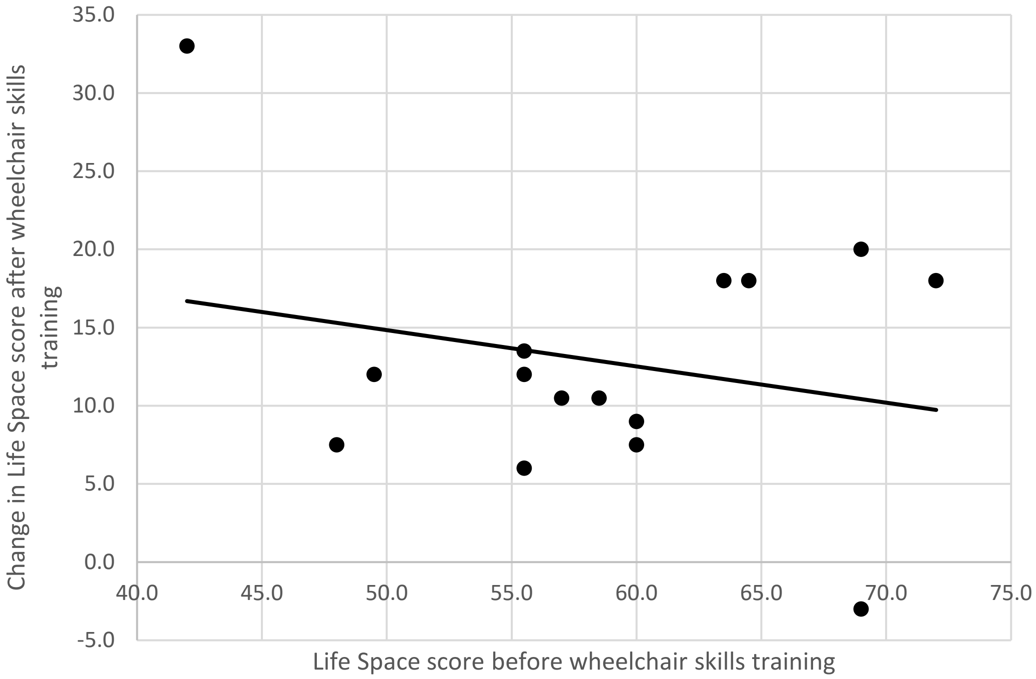

Figure 9.10 Relationship between the difference in Life Space score and initial Life Space score before wheelchair skills training

Summary of Fit

R Squared 0.056

Table 9.5 Parameter estimates for Life Space score after wheelchair skills training

Term	Estimate	Prob>|t|
Intercept	26.44	0.11
Life Space score before wheelchair skills training	-0.23	0.39

Figure 9.11 replicates the analysis from Figure 9.10, excluding the data points from the two outlying individuals whose Life Space scores increased dramatically or fell following training. After excluding these outliers, the effect of Life Space score before training was found to have a significant impact on the change in Life Space score after training, as shown in Table 9.6, with every point of Life Space score prior to training correlated with an increase in the benefit from training of 0.5 points.

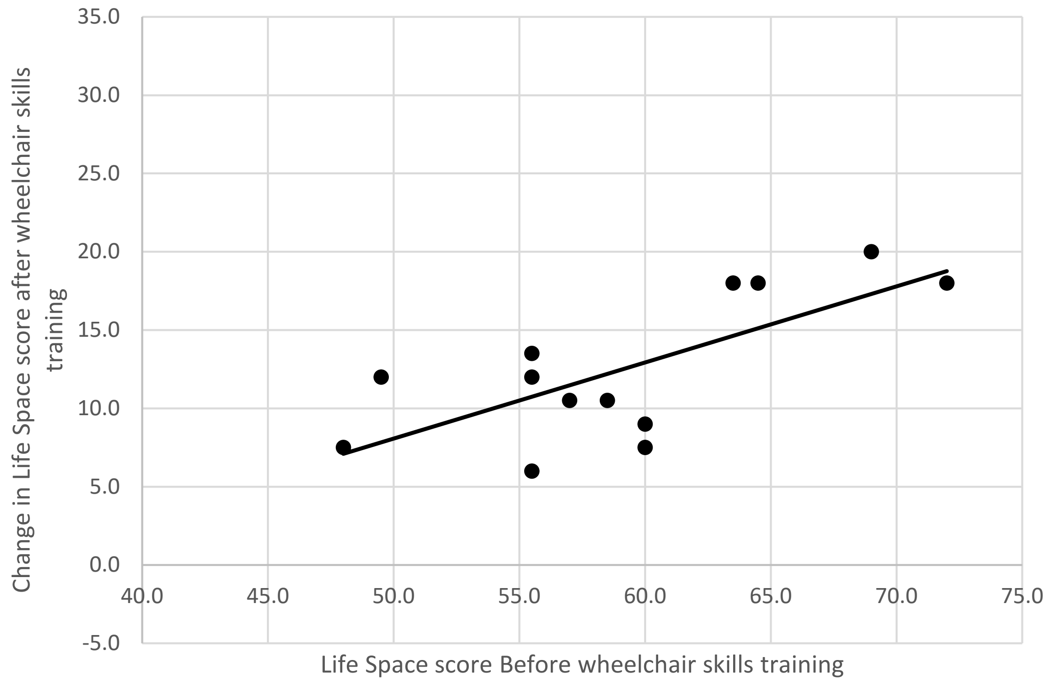

Figure 9.11 Relationship between the difference in Life Space score and initial Life Space score before wheelchair skills training

Summary of Fit

R Squared 0.52

Table 9.6 Parameter estimates for Life Space score after wheelchair skills training

Term	Estimate	Prob>|t|
Intercept	-16.23	0.08
Life Space score before wheelchair skills training	0.49	0.006

In contrast to the ScootAbility case study, where no correlation was found between initial Life Space score and change in Life Space score, this suggests that participation in wheelchair skills training led to greater increases in the extent and frequency of travel among participants who already undertook more travel.

9.4.3 Relationship between the Change in Life Space score and Transport Ability

Figure 9.13 illustrates the change in Transport Ability and Life Space score that each of the 12 participants experienced after completing the wheelchair training exercise, excluding the three outliers identified in sections 9.4.1 and 9.4.2. Each unit increase in Transport Ability was estimated to correspond to an increase Life Space score of 4.2, an effect that Table 9.7 shows is significant at the 5% level. This shows that improvements to ability did translate into more frequent travel over longer distances overall.

As the changes were positive, this shows that apart from the outliers all participants who took part in the study experienced a positive change in both Transport Ability and Life Space score. The majority of the participants experienced an improvement in Transport Ability of between 0.7 and 2.5 logits, improving their Life Space score by between 6 and 20 points.

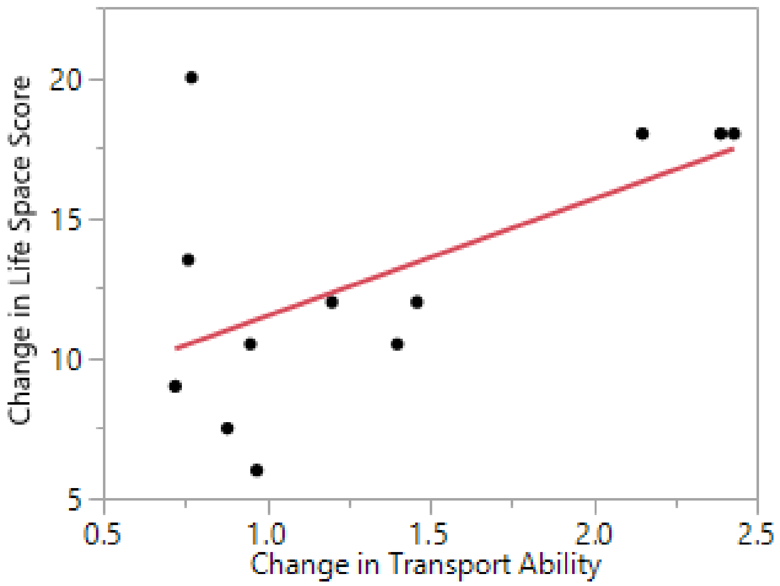

Figure 9.12 Change in Transport Ability and Life Space score after wheelchair skills training

Summary of Fit

RSquare	0.34

Table 9.7 Parameter estimates for change in Life Space score

Term	Estimate	Prob>|t|
Intercept	7.32	0.023
Change in Transport Ability	4.17	0.048

Nevertheless, a notable outlier was present, who reported a very large increase in Life Space score relative to their increase in Transport Ability. This could have been because the participant had a change in circumstances that caused a significant increase in their mobility, independent of the training.

It is possible that the training had a significant psychological impact on some participants, meaning that, for example, the participant who reported a large change in mobility patterns may have gained a new-found confidence in their ability levels as a result of the training. This suggests that there are many variables that influence a person's perceived mobility and Transport Ability levels in addition to the skills being assessed in the case study. This technique used to evaluate the outcome for the wheelchair skills training session could, therefore, also be used as a way to monitor a person's progress over a longer period and to highlight those who may need additional support in either physical or emotional ways or those who experience erratic, irregular behaviour.

9.4.4 Matched Pair Analysis

In Figure 9.13, the y-axis shows the difference in Transport Ability for each of the participants, excluding the outlier identified in section 9.4.1, before and after taking part in wheelchair skills training and the x-axis shows the mean of the pre- and post-training Transport Ability for each person. The vertical bold red line is the mean of each participant's mean Transport Ability before and after the training. The horizontal bold red line is the mean difference in Transport Ability before and after training and the dashed red lines are the 95% confidence interval for this mean. As all points are above zero, this shows that all participants experienced an increase in Transport Ability after taking part in the training, with an average increase of 1.3 logits, significant at the 5% level. One logit measures the increase in Transport Ability or decrease in item difficulty required to increase the probability of a successful outcome by a factor of e or 2.718, the base of the natural logarithm, therefore the average increase in Transport Ability was by a factor of 1.3e.

Table 9.8 Summary table for Matched Pair Analysis for change in Transport Ability

Transport Ability After	0.71
Transport Ability Before	-0.58
Mean Difference	1.29
Std Error	0.16
Upper 95%	1.64
Lower 95%	0.93
Correlation	0.78
Prob > |t|	<.0001

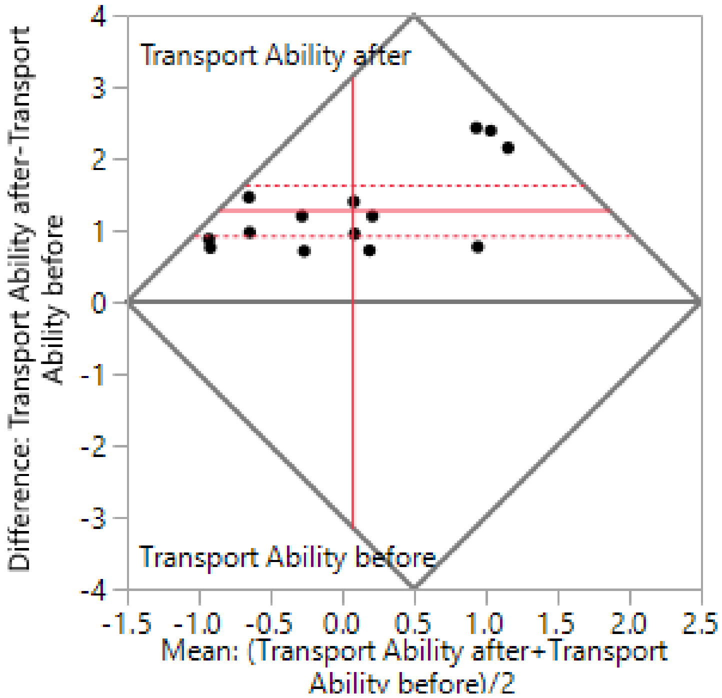

Figure 9.13 Matched Pair Analysis for the change in Transport Ability before and after the wheelchair skills training

The y-axis in Figure 9.14 represents the difference in Life Space score for each participant before and after taking part in wheelchair skills training, excluding the two outliers identified in section 9.4.2, and the x-axis shows the mean of the before and after Life Space scores for each person. The bold red lines represent the mean difference in Life Space score and the average pre- and post-training Life Space score. As all points are above 0, this shows that the Life Space score of participants improved after taking part in the training, with an average increase of 12.5, which is shown in Table 9.9 to be significant at the 5% level. The graph shows that participants with a higher mean Life Space score, represented by the points on the right of the graph, experienced higher than average increases in Life Space score after the training.

Table 9.9 Summary of Matched Pair Analysis for change in Life Space score

Life Space score after	71.6
Life Space score before	59.1
Mean Difference	12.5
Standard Error	1.29
Upper 95%	15.3
Lower 95%	9.7
Correlation	0.95
Prob > |t|	<.0001

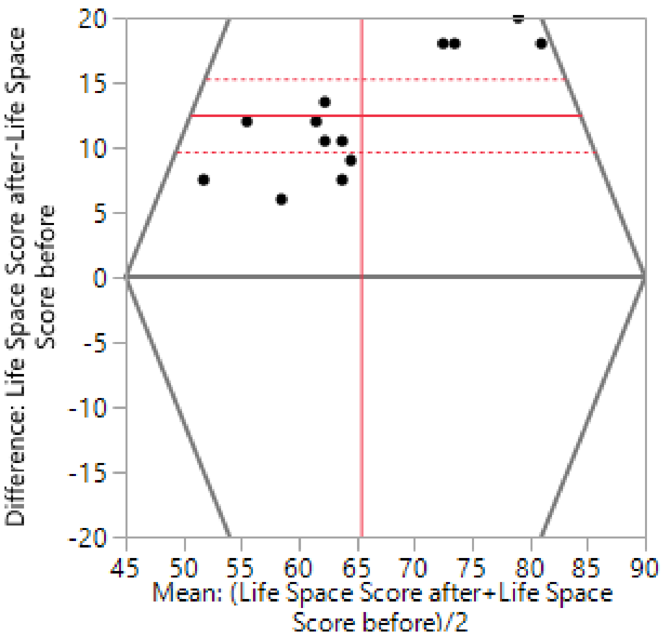

Figure 9.14 Matched Pair Analysis for the change in Life Space score before and after the wheelchair skills training

Table 9.10 shows that the increases in the median scores for both Transport Ability and Life Space score were statistically significant at the 5% level, as the p-values were below the threshold value of 0.05, meaning that the hypothesis that the samples had the same distribution before and after participants took part in wheelchair skills training could be rejected. The Wilcoxon signed rank test is used as the distribution does not approximate a normal distribution and the two measurements are not independent of each other. The test is a non-parametric test based on the ranking of individuals, so is independent of the statistic being measured.

Table 9.10 Wilcoxon Signed Rank test for Transport Ability and Life Space score

	Transport Ability After-Transport Ability Before	Life Space After-Life Space Before
Test Statistic S	52.5	45.5
Prob>|S|	0.0001	0.0002
Prob>S	<.0001	.0001
Prob<S	0.9999	0.9999

9.5 Overall Discussion

This chapter addressed the research question of whether Transport Ability and Life Space scores could be used to evaluate the wheelchair skills training scheme operated at Stanmore hospital by the Back-Up Trust. It was hypothesised that Instrument II, developed in Chapter Six could be used to analyse the effectiveness of a scheme to develop the skillset of participants, improving their ability to use transport. To investigate this, Survey II was administered to a sample group of 15 people one week before and one week after their participation in their first wheelchair skills training session. The ratings given to transport items before and after the training session were combined with the anchored item difficulties for those items produced by the analysis described in Chapter Six, to calculate a Transport Ability for each participant for before and after the training. Similarly, answers to the Life Space section of the questionnaire were used to calculate a Life Space score for before and after the training for each participant. It was predicted that the wheelchair skills training would increase Transport Ability and Life Space scores, as it was expected that participants would receive a boost to their confidence and ability, motivating them to travel further afield and more frequently than they did previously.

The analysis illustrated that the vast majority of participants who took part in the wheelchair training case study experienced increases in both Transport Ability and overall Life Space score, showing that they were travelling further afield more frequently, which was in line with the results of the ScootAbility case study described in Chapter Eight. All but one of the participants who took part in the wheelchair skills training reported an increase in Transport Ability, with these increases ranging from 0.7 to 2.5 logits and averaging 1.2 logits. With the exception of two outliers, one of whom reported a reduction in Life Space score and the other who reported an unfeasibly large increase in Life Space score following the training, participants reported increases in Life Space score of between 6 and 20 points, with an average increase of 13 points.

Three participants were identified as potential outliers in the wheelchair skills training results. One participant exhibited a decrease in Transport Ability, one participant reported a decrease in Life Space score and one participant reported a very large increase in Life Space score. These outliers could have been because of a change in their life outside of the training that had a significant impact on their ability or travel patterns, such as illness or weather.

The participant who reported a decrease in Transport Ability may have found the training confusing, resulting in a negative impact on their Transport Ability. Equally, if the participant was not engaged with the training or did not enjoy the session they may have reported greater difficulty with the items after training as a form of protest or in order to avoid having to participate in similar sessions again. It may be the case that this individual would benefit more from an alternative type of training or a different strategy entirely to improve their Transport Ability.

The participant who reported a large increase in Life Space score may have gained a new-found independence or increased confidence in their ability after participating in the training. Furthermore, the participant who experienced a slight decrease in Life Space score may have felt less confident or able to travel as they may have felt their ability level was less than they previously thought, having had their confidence knocked by seeing other, more able wheelchair users at the training. It should also be borne in mind that the very act of measuring Transport Ability and Life Space score may encourage participants to report improvements irrespective of whether they occurred. To combat this, had there been a large enough pool of participants it may have been useful to have a control group complete the questionnaire who did not participate in the training. This demonstrates how it is very difficult to state that the changes experienced by participant in both their ability to use transport or their overall Life Space patterns are solely caused by the wheelchair skills training.

Nonetheless, the strength of this technique of evaluating a person's response to either a new scheme or form of training also remains that it produces a numerical outcome measurement that can be used to describe a person's reported ability level. Furthermore, this technique can be used to monitor a person's progress or even highlight those who may need additional support, either physically or emotionally, or those who display irregular behaviour. Analysis can also be used to understand whether the amount of benefit gained by a scheme is related to a person's initial ability and mobility levels, which may help to improve the way that training courses or accessibility schemes are delivered. The physical process of completing the assessment form also allows each participant to reflect on their own experiences and improvements, which may allow them to see the rate at which they are improving or increase their ability confidence and independence.

9.5.1 Comparison with ScootAbility

Table 9.11 gives a summary comparison of the participants in the ScootAbility scheme, described in Chapter Eight, and wheelchair skills training. The ScootAbility participants were significantly older than the wheelchair skills participants on average, and also reported lower initial Transport Ability and Life Space scores. This was to be expected as younger, more able people would generally be more likely to use a self-propelled wheelchair, while older people would be more likely to use a powered scooter. Furthermore, the lower initial Life Space scores among ScootAbility participants may in part reflect the lack of availability of a scooter prior to joining the scheme.

The ScootAbility participants showed a larger improvement in both Transport Ability and Life Space score than the wheelchair skills participants. However, this was from a lower base and represented an improvement over a six-month period, rather than in a week subsequent to the training, as was the case for the wheelchair skills participants. Nevertheless, there may have been some instances where lower ability individuals on the wheelchair skills course would gain more from joining the ScootAbility scheme instead, although this would have to be set against the availability and relative cost of the scheme relative to the skills training. In some cases, high ability participants in the ScootAbility scheme might be better suited to undertaking wheelchair skills training instead, especially if similar benefits could be gained at a lower cost.

Table 9.11 Comparison of ScootAbility and wheelchair skills training participants

	Mean of ScootAbility participants	Mean of wheelchair skills training participants
Age	65	41
Transport Ability before	-1.35	-0.47
Transport Ability after	0.28	0.68
Change in Transport Ability	1.63	1.16
Life Space score before	38.2	58.6
Life Space score after	63.0	71.5
Change in Life Space score	24.8	12.8

In line with the ScootAbility scheme, the wheelchair skills training case study found no correlation between increases in Transport Ability after participating in the training and initial ability. This suggests that these schemes do not disproportionately deliver benefits to low or high ability participants. However, unlike the ScootAbility scheme, it was shown in section 9.4.2 that the wheelchair skills training appeared to provide a bigger boost to Life Space score for participants with a high initial Life Space score than a low initial score. This suggests that participants with low initial Life Space scores require more than just skills training to experience the same boost to the extent and frequency of travel observed among participants with high initial Life Space scores.

A significant correlation was found between the increase in Transport Ability observed after participating in the wheelchair skills training and the reported increase in Life Space score. This suggests that the training had improved participants' skills, which in turn had led them to travel further and more frequently.

This is in contrast with the ScootAbility scheme, where no such correlation was found, as shown in section 8.4.3. This suggests that ability is a greater determinant of travel patterns among wheelchair users than among scooter users, which fits with the different characteristics of the two aids; with the former being self-propelled and the latter being powered.

In practical terms, this may mean that some more advanced training could be offered to ScootAbility participants to improve technical skills as well as confidence, and the wheelchair skills training could be adapted for less able participants to include more focus on improving confidence and reducing the feeling of vulnerability. It may even be the case that the most able people on the ScootAbility scheme would benefit from wheelchair skills training, whereas the least able participants in wheelchair skills training could be candidates for the ScootAbility scheme and that Council A could improve outcomes without necessarily increasing costs by offering both.

Chapter 10 Case Study III: Comparing Transport Ability & Mobility Matrix scores

10.1 Introduction

This chapter will compare the Transport Ability measure generated by Instrument II with a measure used to assess mobility to assist with real-world decision making. It will compare the performance of Transport Ability with a tool used by Council A to assess its applicants' eligibility for Blue Badges, Taxicards and the Disabled Persons Freedom Pass.

The Blue Badge scheme is a national scheme, administered by local authorities, of on-street parking concessions for people with permanent and severe mobility problems (DfT, 2014). The London Taxicard is a London-wide scheme of subsidised door-to-door transport for people with serious mobility impairment who have difficulty using public transport and is funded by the participating London Boroughs and the Mayor of London (Taxicard, 2016). The Disabled Persons Freedom Pass is also a London-wide scheme, funded by the London Boroughs, which allows eligible disabled people to use public transport within London and buses across the country for free (London Councils, 2016).

The Transport Abilities generated for each participant in Survey II were compared with previous assessments of applications conducted by Council A, where available, which were the basis for granting or denying requests for one or more of the aforementioned concessions. By comparing the Transport Ability tool developed in this study with a tool that is actually used by occupational therapists to assist with real-world decisions, the extent to which an approach based on Rasch analysis agrees with the approach currently used in practice could be determined. Close agreement between the Rasch analysis-based approach and that used by Council A would suggest that it is possible to develop new tools using Rasch analysis that measure the same latent traits as existing approaches in a consistent way.

The Mobility Matrix scores generated by Council A's assessment form (see section 10.3) and the Transport Ability measure developed in this study will be compared. Logistic regression analysis will be used in section 10.6 to calculate the probability of Disabled Persons Freedom Passes, Blue Badges and Taxicards being allocated based on Mobility Matrix score and Transport Ability. Receiver Operating Characteristic (ROC) analysis will then be used in section 10.7 to examine the level of similarity between the two different measures and how accurately each measure can be used to predict whether transport concessions will be allocated.

10.2 Background to Concession Allocation

Every year in London thousands of applications for Disabled Persons Freedom Passes, Taxicards and Blue Badges are made to councils by their residents. While for each of these concessions some groups of people will automatically be eligible, significant number of applicants will have to have their mobility assessed by the council to decide whether they meet the eligibility criteria. Each council's occupational therapists assess the applicants and adjudicate upon the concessions awarded in each case.

Currently, the Department for Transport provides brief guidance to help each council develop an independent Medical Assessment to use in the allocation of Blue Badges, however, as shown in the Blue Badge Scheme Local Authority Guidance (England) (Dft, 2014: 22), the specific assessment and criteria used are decided by the Council themselves:

> *"Ultimately it is a matter for each individual local authority to adopt an assessment approach that they believe complies with the legislation and that best suits their circumstances. The independent review found that intelligent use of independent mobility assessments in combination with initial cross-checking of existing council records and well-designed desk -based assessments (to filter out those applicants who are 'self -evidently' eligible or ineligible) was the most cost effective and robust method of assessing an applicant's eligibility under the 'subject to further assessment' walking criterion."*

Local Councils in England must therefore develop their own transport assessment, utilising the experience of their occupational therapists to decide the best methodology to allocate Blue Badges (DfT 2014). The guidelines for the allocation of Taxicards and the Disabled Persons Freedom Pass are similar (Taxicard 2016, London Councils 2016), meaning that it is usually most practical to assess eligibility for all applied for concessions in the same way and at the same time.

Certain groups of people are automatically eligible for these concessions and are therefore not required to undertake an assessment if they receive certain benefits, such as the higher rate mobility components of the Disability Living Allowance, or are, in the words of the Blue Badge scheme guidance, “self-evidently eligible”, meaning that in the view of the occupational therapist their mobility impairment is obvious and severe enough to render a mobility assessment unnecessary.

The applicants undertaking assessment are therefore people who have mobility issues but whose eligibility is not self-evident to the occupational therapist from their application.

10.3 Eligibility Assessment Forms

Many boroughs conduct their own eligibility assessments, which are carried out by occupational therapists in a face-to-face session. Participants are questioned about their impairments, how they are disabled by inaccessible transport services and the effect that this has on their daily life, as well as being monitored while standing, moving to and from a seated position and walking.

The assessment form that Council A used before 2012 did not have a formal scoring system to be used as a guide to assess eligibility. This meant that the allocation of Disabled Persons Freedom Passes, Blue Badges and Taxicards was largely at the discretion of the occupational therapist based on their observation of the applicant during the assessment.

In 2012, the assessment form changed to include a section that generated a score for each participant based on their overall health, ability to use transport, mobility, Activities of Daily Living (ADL) and mobility aid use. This questionnaire is not available for public access, so a copy of this questionnaire will be available on request. The four sections are weighted to provide an overall score out of 40, with scores of up to five given for each of the categories health, transport, ADL and mobility aid use, and mobility is broken down into four subcategories, each also scored out of five. The four mobility subcategories are based on the occupational therapist's assessment of the applicant's walking ability, with a score of up to five given for each of the distance walked, speed walked at, length of time walked for and manner of walking. For example, an applicant able to walk more than 150 metres would receive a score of zero for the distance section of the mobility assessment, while an applicant unable to walk 27 metres would receive a score of five.

The score generated from Council A's assessment form is referred to as the Mobility Matrix score. The higher the Mobility Matrix score, the greater the level of difficulty experienced by the applicant. In this chapter, the assessment form used by Council A will be referred to as the Mobility Matrix Survey.

The Mobility Matrix score is used as a benchmark to guide the decisions made by occupational therapists through eligibility cut-off points. A Disabled Persons Freedom Pass has a suggested cut-off point of 18, a Taxicard has a suggested cut-off point of 22 and a Blue Badge has a suggested cut-off point of 24. Mobility Matrix scores alone are not the sole basis for deciding whether a person is eligible for the disabled transport concession(s) applied for, as in borderline cases the occupational therapist will use their knowledge and experience, along with the specifics of the individual case, to make a final decision.

10.4 Methodology

Council A were able to provide the Mobility Matrix scores for a total of 20 Survey II participants who had completed the Mobility Matrix Survey after its introduction in 2012, along with data on the concessions applied for and whether these applications were successful. This dataset would allow direct comparison of the Transport Ability measures with the Mobility Matrix scores generated for the 20 participants for whom both scores are available. Council A also provided data on the concessions applied for and awarded to a further 18 participants who applied prior to 2012, so did not have a Mobility Matrix score. The small number of participants with a Mobility Matrix score was because most participants either hadn't applied for any of the three concessions, applied prior to 2012 or were 'self-evidently eligible' in the opinion of the Occupational Therapist, which negated the need for any assessment. Data on concessions applied for and awarded was only available for a further 18 participants who applied prior to 2012, in part because some were 'self-evidently eligible' but also because the records kept were incomplete. While Council A had complete records of the concessions awarded, data on the concessions applied for but not awarded was not kept for most cases.

10.5 Participant Characteristics

Table 10.1 summarises the characteristics of the 20 participants for whom Mobility Matrix scores were available, while Table 10.2 shows the same summary for the 18 participants for whom only concession application and acceptance data were available. Table 10.3 show the equivalent summary for the two groups combined.

Table 10.1 Characteristics of participants with Mobility Matrix scores

Sample size	20				
	Mean	**Median**	**Range**	**Interquartile range**	**Standard deviation**
Age	55.0	56	24 to 78	46 to 62	13.2
Vision Level	7.9	9	4 to 10	7 to 9	2.1
Transport Ability	-1.6	-1.7	-3.7 to 0.0	-2.7 to -0.6	1.2
Life Space score	35.7	35	7 to 58.5	28 to 45	17.7
Mobility Matrix score	17.2	16	10 to 27	9 to 13	5.0
	Males	**% Males**	**Females**	**% Females**	
Gender	8	40%	12	60%	
	Yes	**Yes %**	**No**	**No %**	
Live alone	8	40%	12	60%	
Mobility Aid User	20	100%	0	0%	
Low vision (V1-V7)	5	25%	15	75%	

Comparing Table 10.1 and Table 10.2 suggests that the differences between the participants groups with and without Mobility Matrix scores are small, with a slightly different gender balance perhaps being the most notable difference. Participants with a Mobility Matrix score are on average slightly younger, with slightly worse vision and a slightly lower Life Space score than participants without a Mobility Matrix score.

Table 10.2 Characteristics of participants without Mobility Matrix scores

Sample size	18				
	Mean	**Median**	**Range**	**Interquartile range**	**Standard deviation**
Age	57.6	57	44 to 88	54 to 60	9.3
Vision Level	8.7	9	5 to 10	8 to 9	1.2
Transport Ability	-1.7	-1.8	-3.0 to -0.1	-2.2 to -1.2	0.8
Life Space score	39.1	34	17 to 100	23 to 53	21.7
	Males	**% Males**	**Females**	**% Females**	
Gender	10	56%	8	44%	
	Yes	**Yes %**	**No**	**No %**	
Live alone	8	44%	10	56%	
Mobility Aid User	17	94%	1	4%	
Low vision (V1-V7)	1	4%	17	96%	

Table 10.3 summarises the overall characteristics of the 38 participants for whom transport concession application and acceptance data was available, whether or not they had a Mobility Matrix score. Compared to Table 7.1 in Chapter Seven, which summarises the characteristics of all 231 participants in Survey II, participants in this group were on average slightly older with lower Transport Ability and Life Space scores. The gender balance and proportion who lived alone or used one or more mobility aids were similar, while the 38 participants had a lower incidence of low vision than the participants in Survey II.

Table 10.3 Characteristics of participants for whom concession application data was available

Sample size	38				
	Mean	**Median**	**Range**	**Interquartile range**	**Standard deviation**
Age	56.2	57.0	24 to 88	48 to 62	11.5
Vision Level	8.3	9	4 to 10	7 to 9	1.8
Transport Ability	-1.6	-1.7	-3.7 to 0.1	-2.5 to -0.9	1.0
Life Space score	37.3	35.3	7 to 100	23 to 46	17.9
	Males	**% Males**	**Females**	**% Females**	
Gender	18	47%	20	53%	
	Yes	**Yes %**	**No**	**No %**	
Live alone	16	42%	22	58%	
Mobility Aid User	37	97%	1	3%	
Low vision (V1-V7)	6	16%	32	84%	

Table 10.4 summarises the number of applications made and accepted for each type of concession and any concession. Over 70% of applicants applied for a Freedom Pass, while less than half applied for a Taxicard and just over a third applied for a blue badge. In inner London boroughs such as Council A, car ownership levels are relatively low and public transport provision is relatively good (Transport for London, 2016), which probably explains why there were so many more applications for a Freedom Pass than a Blue Badge. It is not clear why there is a lower application rate for Taxicards compared to Freedom Passes, but this may reflect a recognition among participants that the Freedom Pass concession is sufficient for their needs and a Taxicard is not necessary given the provision of public transport in the borough. Two thirds of Freedom Pass applications were accepted, compared to under half of applications for Blue Badges and Taxicards, and 68% of applicants received at least one of the concessions applied for.

Table 10.4 Summary of concession application and acceptance

Concession	Applied	% applied	Accepted	Acceptance rate
Freedom Pass	27	71%	18	67%
Blue Badge	14	37%	6	43%
Taxicard	18	47%	8	44%
Any concession	38	100%	26	68%

Figure 10.1 shows a plot of Mobility Matrix score against Transport Ability for the 20 participants for whom both were available. There was a strong correlation, with an R squared value of 0.97, as every one unit increase in Transport Ability was associated with a reduction in Mobility Matrix score of 4.3. The correlation was negative because higher Mobility Matrix scores were associated with greater mobility impairment, whereas for Transport Mobility the reverse is true. This relationship suggests that Transport Ability was measuring the same underlying trait as the Mobility Matrix score measure used by Council A to inform the allocation of transport concessions. However, as both measures are based on surveys relating to the difficulty encountered in completing transport-related tasks, perhaps it should not be surprising that consistent results are produced.

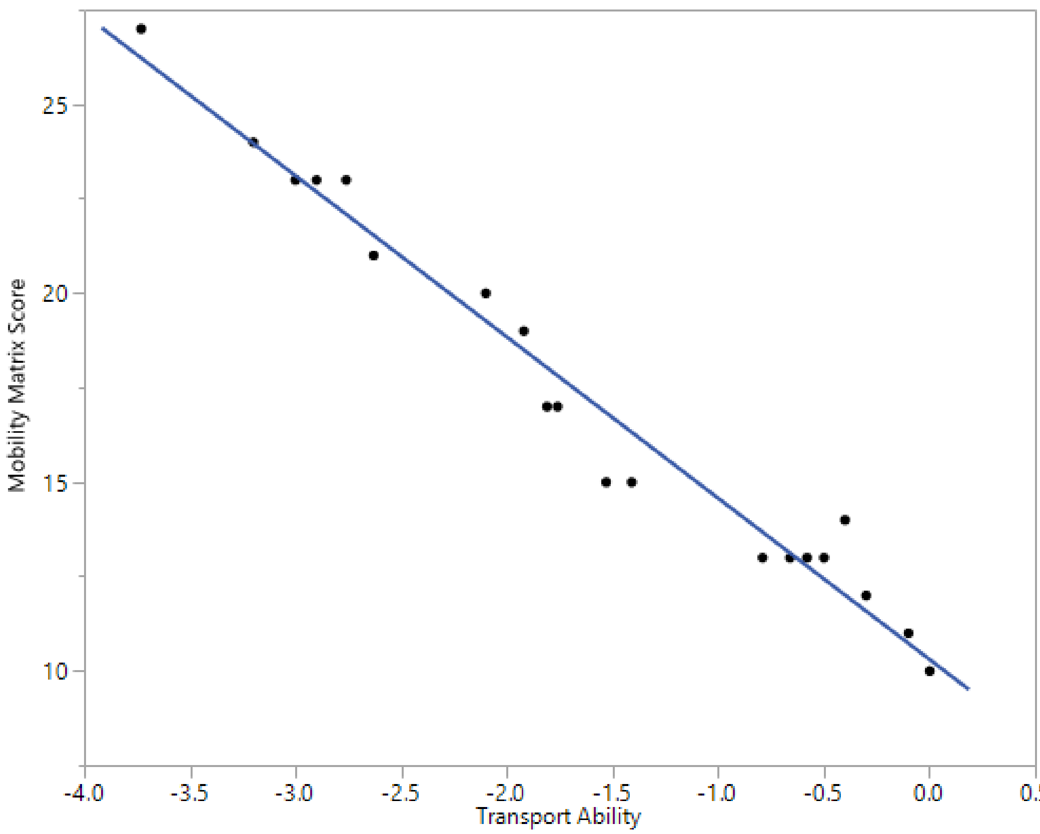

Figure 10.1 **Plot of Mobility Matrix score against Transport Ability**

Table 10.5 **Parameter estimates for relationship between Transport Ability and Mobility Matrix score**

RSquared	0.97
Intercept	10.3
Estimate	-4.3
Prob > [t]	<.0001

10.6 Logistic Regression Analysis

Similar to other forms of regression analysis, logistic regression makes use of one or more predicting variables that may be either continuous or categorical. However, unlike ordinary least squares regression, logistic regression is used for predicting binary dependent variables rather than a continuous outcome. In this situation the assumptions of linear regression are violated and the residuals cannot be normally distributed, which may result in nonsensical predictions for a binary dependent variable. In order to turn a binary variable into a continuous one that can analyse dichotomous data, logistic regression calculates the odds of the event happening for different levels of each independent variable, then takes the ratio of those odds and the logarithm of that ratio to create a continuous criterion as a transformed version of the dependent variable. The logit of success is then fitted to the predictors using linear regression analysis. The predicted value of the logit is converted back into predicted odds via the inverse of the natural logarithm, i.e. the exponential function.

Logistic regression is well suited for examining hypotheses about relationships between a categorical outcome variable and one or more categorical or continuous predictor variables, in order to determine the likelihood of dichotomous outcomes (Peng *et al*. 2002). It is used widely in many fields, including the medical and social sciences. Many other medical scales used to assess medical severity have been developed using logistic regression (Kologlu *et al*. 2001, Biondo *et al*. 2000, Marshall *et al*. 1995 and Le Gall *et al*. 1993). The technique can also be used in engineering, especially for predicting the probability of failure for a given process, system or product (Strano and Colosimo, 2006, and Palei and Das, 2009). Logistic regression analysis was therefore used to allow the probability of a yes or no outcome to be determined, making it an appropriate technique to calculate the probability of a person being allocated a Blue Badge, Disabled Person's Freedom Pass or Taxicard based on their Transport Ability.

10.6.1 Transport Ability

Logistic regression analysis was used to calculate the probability of a person being allocated a Disabled Persons Freedom Pass, Blue Badge or Taxicard based on a person's Transport Ability.

Figure 10.2 shows the relationship between Transport Ability and Disabled Persons Freedom Pass allocation. The whole model test in Table 10.6 shows that the relationship shown by the overall model was statistically significant, and that the parameter estimate for Transport Ability as shown in Table 10.7 was also significant.

The data points underneath the blue line in Figure 10.2 were allocated a Disabled Persons Freedom Pass and each data point above the blue line represents a person who was not successful in their application. The downward slope of the curve shows that as the Transport Ability of a person increased, there was a statistically significant decrease in the probability that they were be successful in their Disabled Persons Freedom Pass application, with the probability falling sharply once Transport Ability was above -1.5.

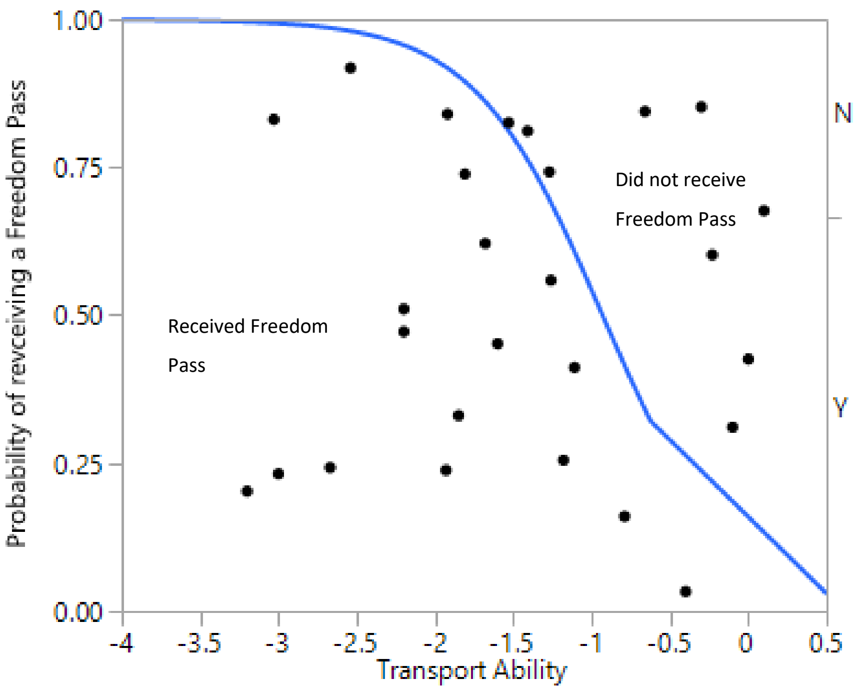

Figure 10.2 Logistic regression curve for Disabled Persons Freedom Pass allocation and Transport Ability

Table 10.6 Whole Model Test for probability of receiving a Freedom Pass

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	7.24	1	14.48	0.0001

Table 10.7 Parameter estimates for probability of receiving a Freedom Pass

Term	Estimate	Std Error	ChiSquare	Prob> ChiSq	Unit odds ratio
Intercept	-2.27	1.14	3.95	0.047	
Transport Ability	-2.44	0.91	7.22	0.007	0.09

Figure 10.3 shows the relationship between Transport Ability and Blue Badge allocation. The model and the parameter estimates were all significant at the 5% level as shown in Table 10.8 and Table 10.9 retrospectively. The points underneath the blue line in Figure 10.3 were allocated a Blue Badge, whereas the points above the blue line were not successful in their application. Figure 10.3 shows that as the

Transport Ability of a person increased, the probability of being successful in their Blue Badge application decreased. The downward slope of the curve is almost vertical showing that the probability of getting a Blue Badge changed from 100% to 0% very quickly once Transport Ability exceeded -2. Aside from one outlier, Transport Ability above -2 did not result in the allocation of a Blue Badge, whereas scores below -2 all did. This suggests that Transport Ability is a very powerful predictor of Blue Badge allocation.

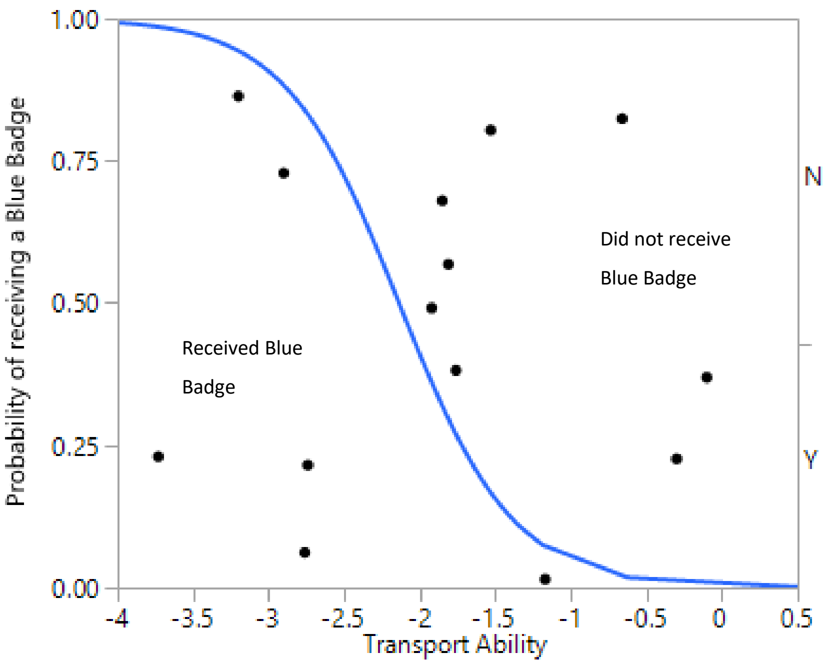

Figure 10.3 Logistic regression curve for Blue Badge allocation and Transport Ability

Table 10.8 Whole Model Test for probability of receiving a Blue Badge

Model	**-LogLikelihood**	**DF**	**ChiSquare**	**Prob>ChiSq**
Difference	4.66	1	9.32	0.002

Table 10.9 Parameter estimates for probability of receiving a Blue Badge

Term	**Estimate**	**Std Error**	**ChiSquare**	**Prob> ChiSq**	**Unit odds ratio**
Intercept	-5.65	2.94	3.71	0.045	
Transport Ability	-2.65	1.37	3.70	0.045	0.07

Figure 10.4 shows the relationship between Transport Ability and Taxicard allocation. Those underneath the blue line were allocated a Taxicard, whereas those above the blue line were not successful in their application. As the Transport Ability of a person increased, their probability of being successful in their Taxicard application decreased. The almost vertical downwards slope of the curve in Figure 10.4 shows that the chances of getting a Taxicard fell very quickly from nearly 100% for Transport Ability of -2 to 0% of Transport Ability of -1.5, an even faster rate of change than for Blue Badges. While the whole model was found to be significant at the 5% level, as shown in Table 10.10, the parameter estimate was not significant at the 5% level, as shown in Table 10.11.

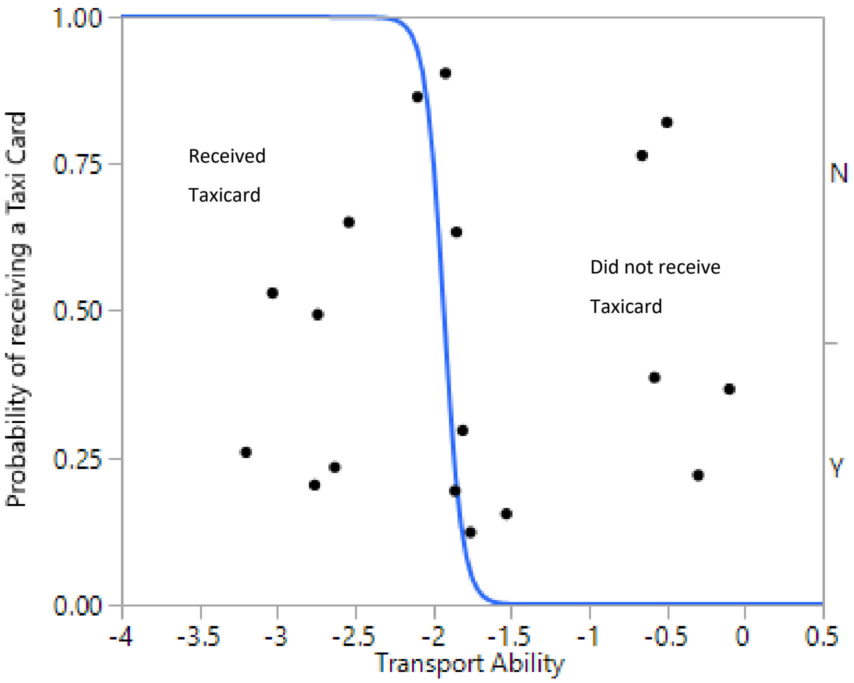

Figure 10.4 Logistic regression curve for Taxicard allocation and Transport Ability

Table 10.10 Whole Model Test for probability of receiving a Taxicard

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	9.84	1	19.68	<.0001

Table 10.11 Parameter estimates for probability of receiving a Taxicard

Term	Estimate	Std Error	ChiSquare	Prob> ChiSq	Unit odds ratio
Intercept	-32.34	27.79	1.35	0.24	
Transport Ability	-16.74	14.77	1.28	0.26	5.3e-8

10.6.2 Mobility Matrix score

Logistic regression analysis was used to calculate the probability of a person being allocated a Disabled Persons Freedom Pass, Blue Badge or Taxicard based on a person's Mobility Matrix score. These results will therefore allow comparison of how the allocation of each Transport concession varies according to a person's Transport Ability and Mobility Matrix score.

Figure 10.5 shows the relationship between Mobility Matrix score and Disabled Persons Freedom Pass allocation. Data points underneath the blue line were allocated a Disabled Persons Freedom Pass and each data point above the blue line represents a person who was not successful in their application. The upwards slope of the curve shows that the as the Mobility Matrix score of a person increases, their probability of success in their Disabled Persons Freedom Pass application increases.

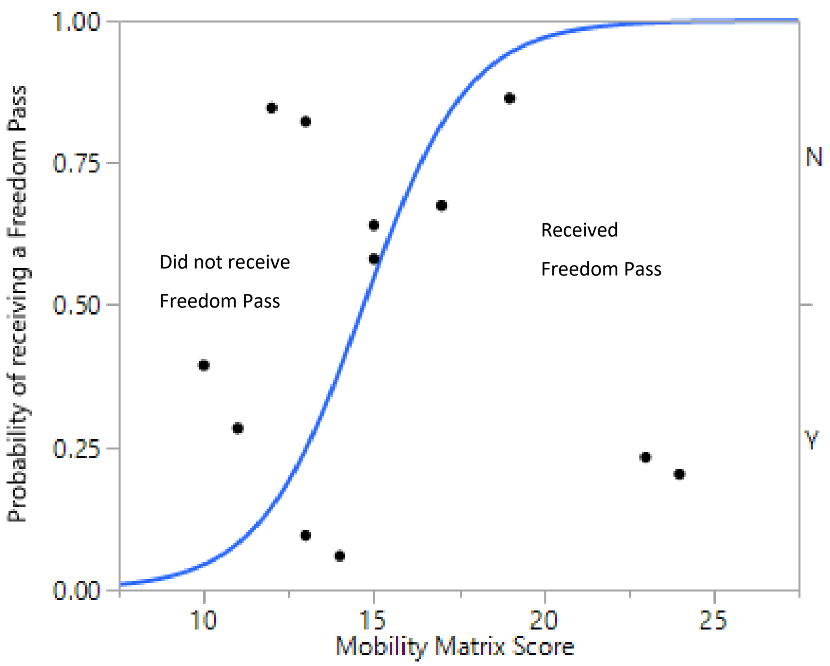

Figure 10.5 Logistic regression curve for Freedom Pass allocation and Mobility Matrix score

However, whilst the whole model test in Table 10.12 shows that the model is a good fit for the data, the parameter estimate for Mobility Matrix score is shown not to be significant at the 5% level, as shown in Table 10.13. This may be because of the relatively small sample size of 12, combined with the fact that two of the six successful applicants had Mobility Matrix scores well below both the suggested threshold score of 18 and the scores of two unsuccessful candidates. This suggests that the judgement of occupational therapists led to a different allocation of Freedom Passes than would have been expected based on the Mobility Matrix scores alone.

Table 10.12 Whole Model Test for probability of receiving a Freedom Pass

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	3.54	1	7.09	0.008

Table 10.13 Parameter estimates for probability of receiving a Freedom Pass

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq	Unit odds ratio
Intercept	-9.63	5.88	2.68	0.101	
Mobility Matrix score	0.65	0.41	2.54	0.111	1.92

Figure 10.6 shows the relationship between Mobility Matrix score and Blue Badge allocation. Those underneath the blue line were allocated a Blue Badge and each data point above the blue line represents a person who was not successful in their application. As with Transport Ability, a clear cut off point was identified at a Mobility Matrix score of between 20 to 22; with people with a score of over 22 qualifying for a Blue Badge and those with a lower score being denied a Blue Badge. As no applicants had a score of 20 to 22 the precise location of the cut off cannot be determined. This suggests that the current suggested cut-off qualification mark or 24 for Blue Badge allocation may be too high as occupational therapists are granting applicants with a slightly lower score onto the scheme, possibly because in their professional opinion other factors mean that the person should be eligible. However, these findings are subject to the small data sample of 11 applicants who also had Mobility Matrix scores and would therefore need to be verified on a larger sample. The parameter estimates are not shown as they are not of any practical use where the sample size is small and the likelihood of success changes rapidly from 0% to 100%.

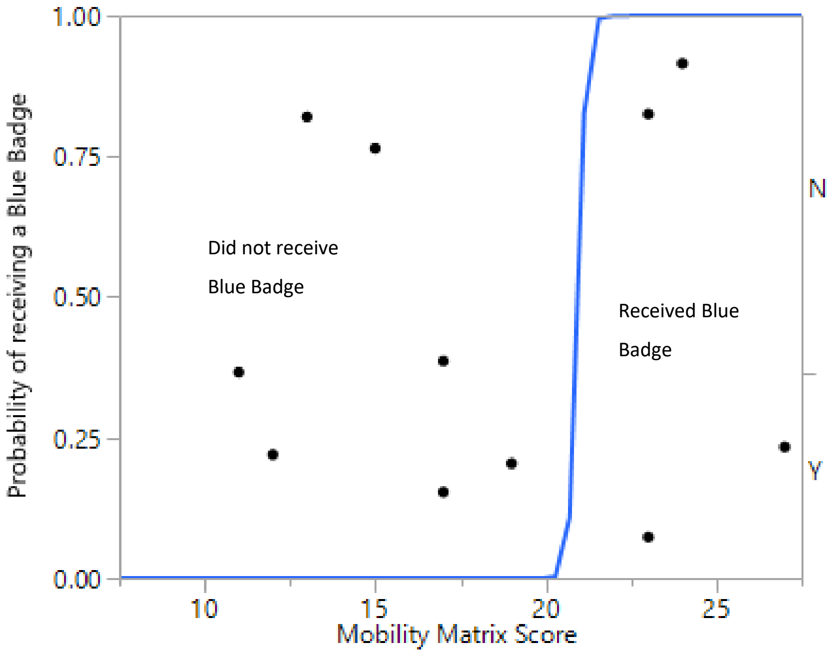

Figure 10.6 Logistic regression curve for Blue Badge allocation and Mobility Matrix score

Table 10.14 Whole Model Test for probability of receiving a Blue Badge

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	7.21	1	14.42	<.0001

Figure 10.7 shows the relationship between Mobility Matrix score and Taxicard allocation. Data points to the right of the blue line were allocated a Taxicard and each data point to the left of the blue line represents a person who was not successful in their application. As with Transport Ability, the probability of being allocated a Taxicard changes from 0% to 100% at a clear cut off point. This was identified at a Mobility Matrix score of 20; with people with a score of over 20 qualifying for a Taxicard and those with a lower score being denied one. This indicates that the current suggested cut-off qualification mark or 22 for Taxicard allocation may be too high as occupational therapists are allowing applicants with a slightly lower score onto the scheme. However, these findings are subject to the small data sample of 13 applicants who were also allocated Mobility Matrix scores and would therefore need to be verified on a larger sample.

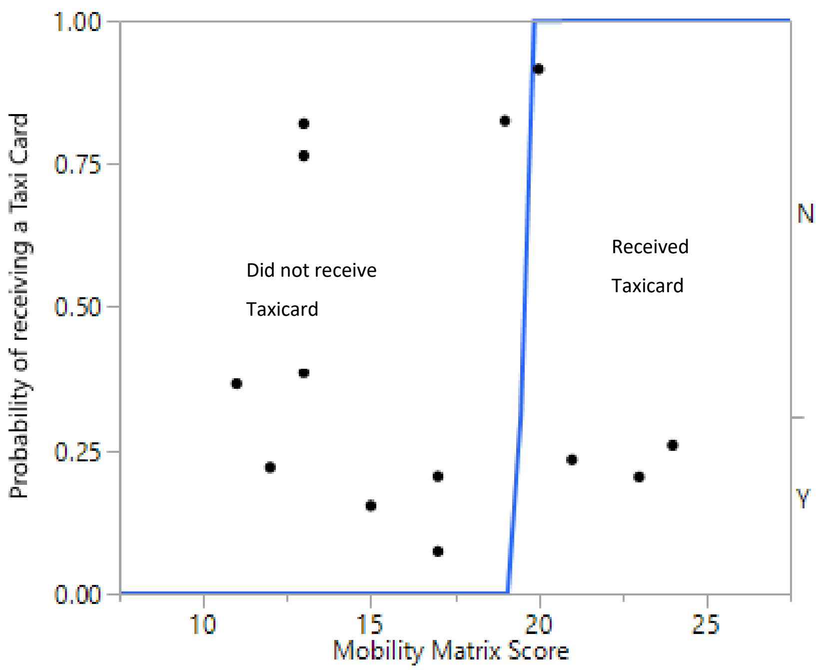

Figure 10.7 Logistic regressions curve for Taxicard allocation and Mobility Matrix score

Table 10.15 Whole Model Test for probability of receiving a Taxicard

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	8.02	1	16.05	<.0001

Overall, the results from the logistic regression analysis identified clear cut-off points for both the Blue Badge and Taxicard schemes using either the Transport Ability or Mobility Matrix score. Applicants were found to qualify for the Blue Badge scheme or Taxicards with a Transport Ability of -2 or less or a Mobility Matrix score of 20 or more. Logistic regression identified the allocation of Disabled Persons Freedom Passes as being less clear cut, and therefore less predictable. However, a significant relationship was identified with an increase in Transport Ability or reduction in Mobility Matrix score resulting in a reduced likelihood of receiving a Freedom Pass. This result suggests that there is a significant amount of professional judgement being used by occupational therapists when allocating Freedom Passes, meaning that scoring systems such as Mobility Matrix scores and Transport Ability are used to assist and validate the judgement of trained professionals, not as a replacement.

The whole model tests showed that the models have predictive power at the 5% level for the allocation of Disabled Persons Freedom Passes, Blue Badges and

Taxicards, for both Transport Ability and Mobility Matrix scores. However, Transport Ability as a predictor of Disabled Persons Freedom Pass and Blue Badge eligibility were the only statistically significant parameter estimates. Disabled Persons Freedom Pass allocation based on Mobility Matrix score was not shown to be significant at the 5% level. However, this may be because of the smaller sample size of participants with a Mobility Matrix score in comparison to the sample size of those with a Transport Ability measure.

10.7 Receiver Operating Characteristic Analysis

Receiver Operating Characteristic (ROC) analysis was conducted to understand how accurately both Transport Ability and Mobility Matrix scores can be used to predict the allocation of transport concessions, by analysing the rate of false positive (Type I error) and false negative (Type II error) results at different decision thresholds.

Disabled Persons Freedom Pass, Blue Badge and Taxicard allocations were grouped together due to the small sample size of 20 people with an allocated Mobility Matrix and 38 people with a Transport Ability measure.

10.7.1 Transport Ability

Figure 10.8 shows the relationship between Transport Ability and the allocation of any transport concession. Table 10.16 and Table 10.17 show that the model and the parameter estimate of the coefficient of Transport Ability are both significant at the 5% level, suggesting that Transport Ability is a useful predictor of concession allocation. The data points underneath the blue line in Figure 10.8 represent applicants who were allocated one or more transport concessions, whereas each data point above the blue line represents an applicant unsuccessful in all of their applications.

The downward slope of the blue line in Figure 10.8 shows that the as the Transport Ability of a person increases, their probability of being successful in an application decreases. The odds ratio shown in Table 10.17 shows that a unit increase in

Transport Ability will on average reduce the chances of getting a transport concession by over 91%. More usefully though, the blue line shows that the chances of receiving a concession decrease from close to 100% at Transport Ability -2 to around 50% at -1 and close to zero at 0. This analysis does not take into account which concessions were applied for, meaning that some of the unsuccessful applicants could have been successful if they'd applied for a different concession, which might have changed the shape of the curve significantly.

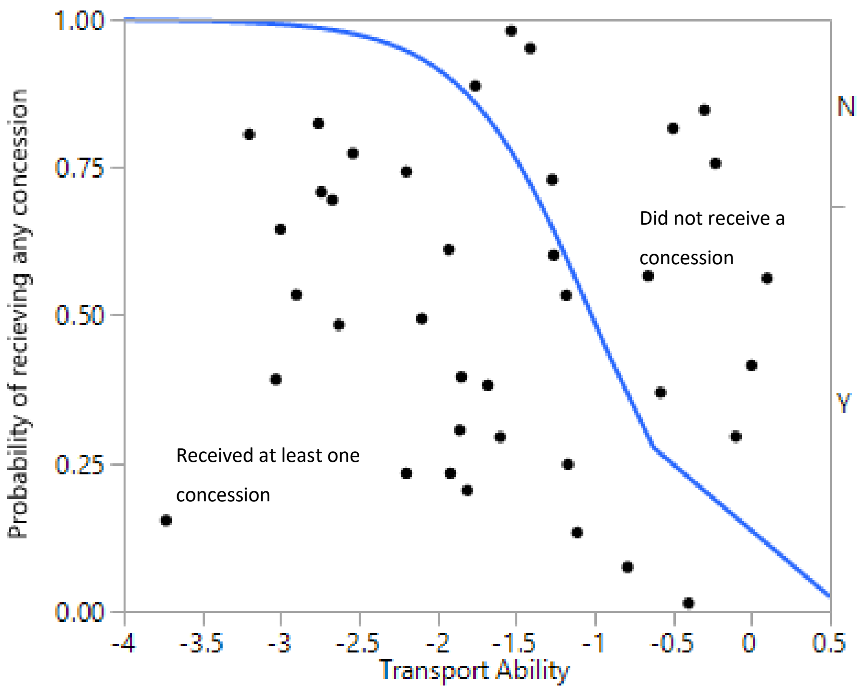

Figure 10.8 Logistic regression curve for allocation of any concession and Transport Ability

Table 10.16 Whole Model Test for probability of receiving any concession based on Transport Ability

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	10.40	1	20.81	<.0001

Table 10.17 Parameter estimates for probability of receiving any concession based on Transport Ability

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq	Unit odds ratio
Intercept	-2.49	1.04	5.70	0.017	
Transport Ability	-2.44	0.78	9.84	0.002	0.087

Figure 10.9 shows the ROC curve for Transport Ability as a predictor of the allocation of travel concessions. The x-axis shows the rate of false positive results, and the y-axis the corresponding rate of true positives, for varying decision threshold scores.

The area under the curve is 0.91, which means that a randomly selected person, who would be allocated a concession based on their Transport Ability, has a 91% probability of having a lower Transport Ability than a randomly selected person who would not be allocated a concession.

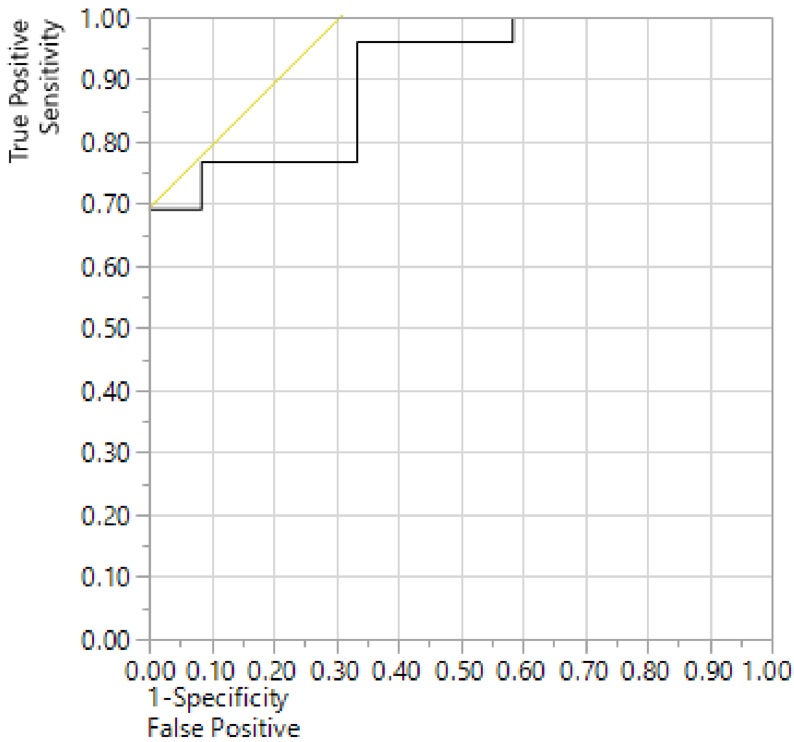

Figure 10.9 Receiver Operating Characteristic for Transport Ability

Area under curve 0.91
Using All Concessions='Y' to be the positive level

10.7.2 Mobility Matrix

Figure 10.10 shows the relationship between Mobility Matrix score and travel concession allocation. The data points underneath the blue line represent successful transport concession applicants, whilst each data point above the blue line represents an unsuccessful applicant. The upwards slope of the curve shows that the as the Mobility Matrix score of a person increases, their probability of success in their application increases.

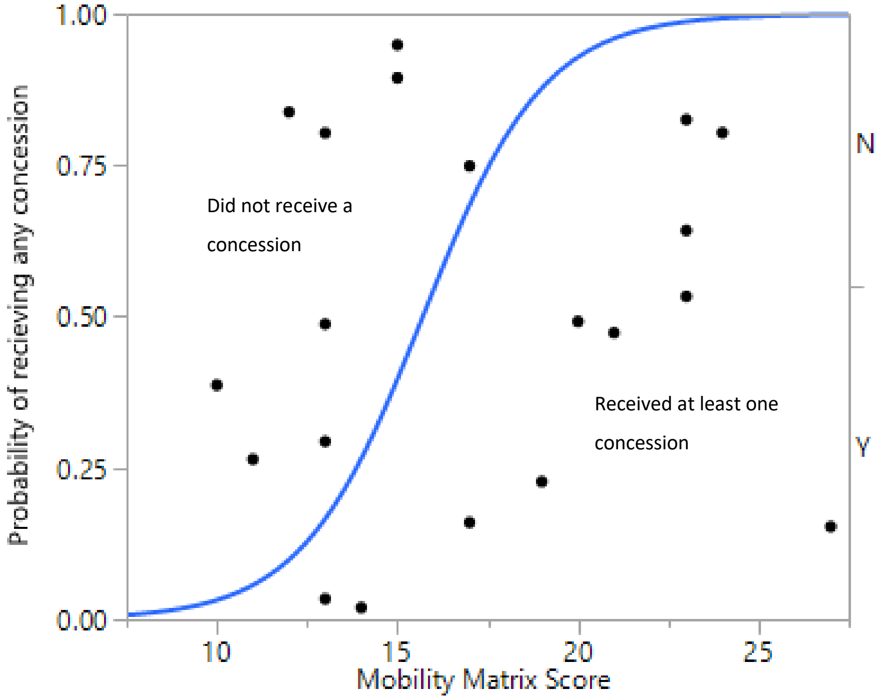

Figure 10.10 Logistic Regression Curve for allocation of any concession and Mobility Matrix score

The whole model test in Table 10.18 shows that the model is a good fit for the data and the parameter estimate for Mobility Matrix score is shown to be significant at the 5% level in Table 10.19. The odds ratio shown in Table 10.19 shows that a unit increase in Mobility Matrix score will on average increase the chances of getting a transport concession by 82%. As discussed in section 10.7.1, this analysis does not take into account which concessions were applied for, meaning that some of the unsuccessful applicants could have been successful if they had applied for a different concession, which might have changed the shape of the curve significantly.

Table 10.18 Whole Model Test for probability of receiving any concession based on Mobility Matrix score

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	7.07	1	14.13	0.0002

Table 10.19 Parameter estimates for probability of receiving any concession based on Mobility Matrix score

Term	Estimate	Std Error	ChiSquare	Prob> ChiSq	Unit odds ratio
Intercept	-9.39	4.05	5.37	0.020	
Mobility Matrix score	0.60	0.26	5.15	0.023	1.82

Figure 10.11 shows the ROC curve for Mobility Matrix score as a predictor of the allocation of transport concessions. The x-axis shows the rate of false positive results, and the y-axis the corresponding rate of true positives, for varying decision threshold scores.

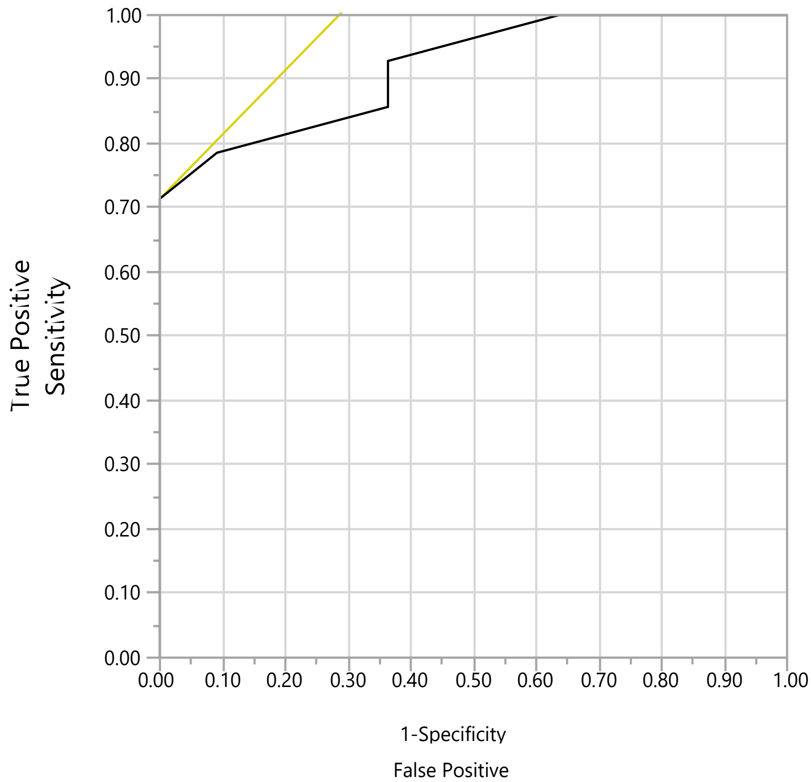

Figure 10.11 Receiver Operating Characteristic for Mobility Matrix score

Area under curve 0.92
Using All Concessions='Yes' to be the positive level

The area under the curve is 0.92, which means that a randomly selected person, who would be allocated a concession based on their Mobility Matrix score, has a 92% probability of having a higher score than a randomly selected person who would not be allocated a concession.

10.7.3 Transport Ability and Mobility Matrix

As shown in Figure 10.12, the areas under the ROC curves for both Transport Ability and Mobility Matrix score are very similar, and as shown in sections 10.7.1 and 10.7.2 respectively the area under each curve is 0.91 and 0.92, suggesting that both tests give similar results.

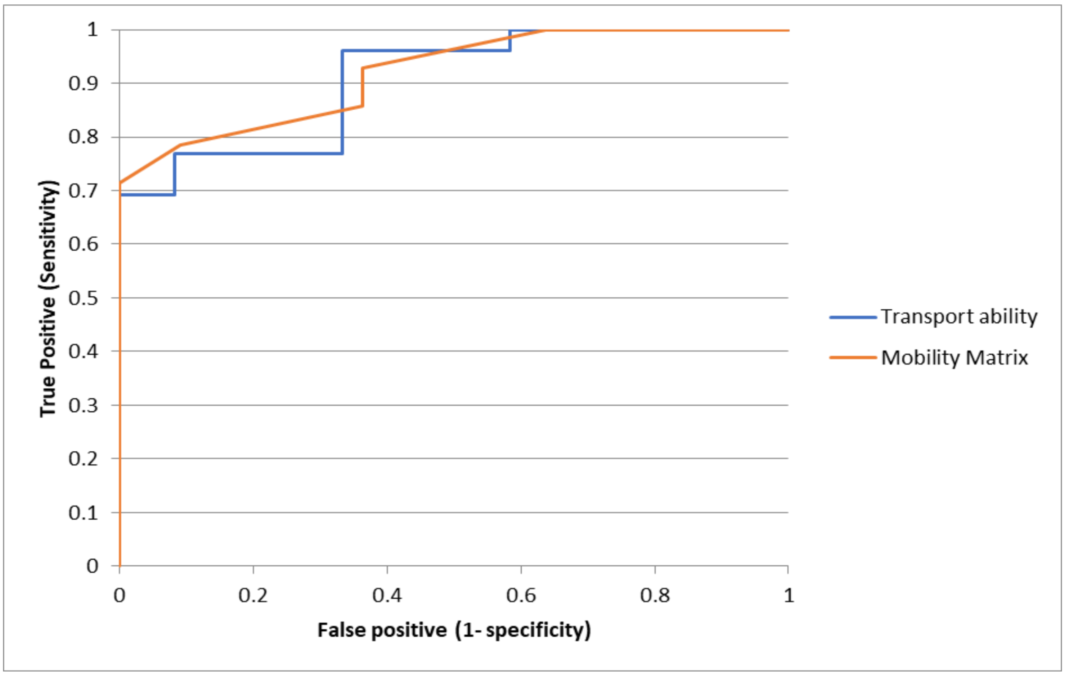

Figure 10.12 Transport Ability and Mobility Matrix score ROC Curves for allocation of any concession

This suggests that Transport Ability and Mobility Matrix scores may be used as similar qualification measures. Given that the Mobility Matrix score takes into account a wide number of factors; such as Activities of Daily Living; general health; how far a participant can walk; their speed, walking technique and tolerance levels; and the frequency with which participants use a range of transport modes including buses, tubes, trains, taxis and private cars; the close correlation between Transport Ability and Mobility Matrix scores is encouraging. Consequently, assessing how closely a person's Transport Ability and Mobility Matrix score compare would help to validate Transport Ability and also determine whether Transport Ability could be used to predict whether an applicant would be successful.

10.8 Discussion

Overall, the Transport Ability measure developed in this study was found to be similar to the Mobility Matrix scoring system developed by Council A to help occupational therapists to determine whether applicants should qualify for specific transport concession schemes.

This is a positive result for the Transport Ability measure developed in this study, validating it against a scoring system that is currently used to measure mobility by Council A to make real-life decisions. Mobility Matrix scores are allocated to individuals by health professionals taking into account a wide number of factors, so the close correlation between the Transport Ability and Mobility Matrix scores is very encouraging.

Whilst this result is strong evidence that Mobility Matrix score and Transport Ability are measuring the same underlying trait, it does not follow that Council A could use Transport Ability instead of Mobility Matrix score in its concession allocation process. The process involved in generating Transport Ability scores for individuals relies on truthful responses to the transport difficulty questionnaire, so is ill-suited to situations where there is any incentive for the participant to misrepresent their ability, such as when applying for transport concessions.

The process used to generate Transport Ability scores is better suited to evaluating the impact of accessibility-related interventions, such as Case Studies I and II, to determine who among the participants has benefitted and by how much. It also has the benefit of being self-reported, so is much cheaper to administer than an assessment that must be conducted by another person. However, should Council A or any other authority wish to adopt a Rasch analysis-based approach to mobility assessment it may be possible to develop an instrument that can be applied by an occupational therapist rather than self-reported, which could mitigate the problem of misrepresentation by the individual. Such a process would need further validation and careful design of the transport items included.

The suggested cut-off points for the allocation of concessions based on Mobility Matrix scores do not quite match the cut-off points that appear to be used in practice, especially for the allocation of Blue Badges and Taxicards. A Disabled Persons Freedom Pass has a suggested cut-off point of 18, a Taxicard has a suggested cut-off point of 22 and a Blue Badge has a suggested cut-off point of 24. The logistic regression analysis showed that either Transport Ability or Mobility Matrix score could be used to predict fairly accurately whether a person would qualify for either the Blue Badge or Taxicard scheme. Participants qualified for the Blue Badge scheme or for a Taxicard with either a Transport Ability of -2 or less or a Mobility Matrix score of 20 or more. This suggests that in practice the cut-off point for Blue Badges Taxicards is 20, based on this sample. The cut-off point in practice for Disabled Freedom Pass allocation is less predictable, as the logistic regression analysis identified the allocation of Disabled Persons Freedom Passes to not have a clear cut-off point regarding Mobility Matrix score.

The structure of how Mobility Matrix scores are generated does suggest that there is a limit to how similar Transport Ability and Mobility Matrix scores can be, particularly as Mobility Matrix scores are discrete, so must be whole numbers, whereas Transport Ability is continuous. Mobility Matrix scores are also structured through weighted mobility sections, with only a small focus on public transport use, whereas Transport Ability focuses on little outside a person's ability to use public transport. Additionally, Mobility Matrix scores are calculated by a health professional assessing the level of mobility they perceive a person to have, whereas Transport Ability is based on ratings generated through a self-assessment transport questionnaire. Both scoring systems, therefore, have different benefits and limitations, although they could be used in combination to help validate decisions made or even estimate who may qualify for certain schemes before completing a transport assessment.

Chapter 11 Conclusions

11.1 Introduction

This study developed, validated and analysed an instrument that measures ability to use transport, termed Transport Ability, and Life Space patterns (the extent and frequency of travel outside a person's home) for people with low vision and/or mobility problems. This chapter gives a brief summary of each chapter, before discussing the study's main achievements and how each of the research objectives were addressed, before going on to suggest possible further research applications for the instrument developed in this study and other issues that would benefit from further investigation.

11.2 Chapter Overview

Chapter One outlined the thesis background regarding transport accessibility and the important role it plays in improving quality of life. The growing importance of understanding where transport accessibility improvements need to be focused and understanding the effectiveness of schemes, regarding improved accessibility and mobility on both an aggregate and disaggregate level, helped to justify the research. The aims of the research project and research objectives were also presented and used to structure the data analysis within each chapter.

Chapter Two reviewed existing literature, concepts and past research to identify research pertaining to the main issues of this study. Within the field of transport for visually and mobility impaired people, a key recommendation, highlighted in section 2.2, was that planners should take a more holistic approach to accessibility (DfT, 2001), as every part of the journey chain must be accessible for the journey to be completed.

While numerous studies have attempted to measure mobility quantitatively, as discussed in section 2.3, De Vries *et al.* (2012) found that the instruments used vary widely. Titheridge *et al.* (2010) argued that the opportunity measures commonly used by planners, including the software tools discussed in section 2.3.2, do not adequately reflect transport accessibility as experienced by individual, and that an ideal methodology would model the capability of each person separately at a specific moment in time. This focus on measuring the ability of individuals was identified as a research gap, with specific focus on older people and people with visual and mobility impairments. The Life Space model, discussed in section 2.3.4, was shown to be more appropriate than other mobility measures, such as the Activities of Daily Living, as comparator to the measure developed in this study.

A research gap was identified in section 2.4, relating to the study of vision loss and transport accessibility, as little research has been made into whether AMD, which predominantly affects the central visual field, or glaucoma, which affects peripheral vision, affect the ability to use transport differently. Given that clinical measures of visual acuity are very labour intensive to conduct, the self-assessment questionnaire used by Grundy *et al.* (1999), discussed in section 2.4.4, was identified as the most appropriate way to categorise visual ability as it is quick and simple yet a well-defined method that has been used in other studies, such as Dalke and Conduit (2010).

The capability approach, which addresses the capabilities of individuals relative to the requirements of the environment, was identified in section 2.5 as a better framework with which to evaluate transport accessibility than the cost benefit analysis techniques usually employed to evaluate transport schemes. This is because the benefits of accessibility are generally intangible, social benefits, which are very difficult to convert to monetary values, so cannot be measured easily.

Patient-based self-assessment questionnaires, reviewed in section 2.6, were shown to be a well-established technique in the field of visual impairment, with potential to be expanded to cover mobility impairment. Rasch analysis, discussed in section 2.7, was identified as the most appropriate model to use in this study, as it can turn ordinal responses to questionnaires into interval measures of the ability of individuals and the difficulty of tasks. These units therefore have meaning and can be compared with other questionnaires measuring the same latent trait. Whilst Rasch analysis is widely used in ophthalmology, it has rarely been used in transport studies, with Turano *et al.* (1998) being a rare instance of such an application, while Massof *et al.* (2007) compared the outputs of Rasch analysis with the Life Space model. This study has built upon this approach.

Chapter Three outlined the background and process for the development of the self-assessment instrument Transport Survey I, loosely based on a patient assessment questionnaire developed by Turano *et al.* (1998). This was carried out using a group of 414 participants from across Greater London, recruited through the Macular Society and PAMELA. The participants had a range of different vision levels, the majority of whom have AMD, while only 7% had glaucoma and around a third of whom require a mobility aid, see Table 5.1. The relatively small number of participants with glaucoma meant that it was not possible to meaningfully compare the effects of glaucoma with AMD. Section 3.3.1 showed how Life Space patterns were assessed according to the extent and frequency of travel in specified zones within the home and beyond, and with or without assistance, based on an instrument developed by Peel *et al.* (2005). Visual acuity is also measured using the Vision Level scale from Grundy *et al.* (1999), as shown in section 3.3.2.

Chapter Four described the process through which Transport Survey I was validated using Rasch Analysis, as well as the process through which the original data was cleaned. In section 4.2.1 the category probability curve shown in Figure 4.1 showed that the construct validity of the instrument was strong. In section 4.2.2 Instrument I was found to be sensitive enough to consistently discriminate between participants of varying abilities and items of varying difficulty, having a person and item separation and reliability scores within the generally accepted thresholds for reliable instruments.

The 30 participants with glaucoma were omitted because they were too small a group to conduct a meaningful comparison with the participants with AMD. Furthermore, responses from a further of 88 participants were omitted due to either misfit, missing data or ceiling and floor effects, leaving 296 participants in total. The infit and outfit statistics suggested that the tasks that related to reading information from a distance were not measuring the same latent transport difficulty trait as other tasks, so these items are omitted. Also omitted were items subject to ceiling and floor effects, as well as items found to be significantly correlated with other items, leading to redundancy and reduced instrument efficiency, meaning that 15 items were omitted leaving 10 items.

The concept of the item-person map was introduced, which maps individuals' Transport Ability relative to the Item Difficulty of the tasks used in the Survey I. Transport Ability and item difficulty are scores, measured in logits, assigned to participants and tasks respectively during the Rasch analysis process. The magnitude of Transport Ability relative to item difficulty is a measure of the likelihood that the person can achieve the task successfully, with equal scores indicating a 50% chance. The means of abilities and difficulties matched fairly closely, as shown by the Item Person Map in Figure 4.7, confirming that the instrument was reasonably well targeted, although it would have improved the instrument's ability to discriminate consistently throughout the scale if some more difficult and easy items were included.

Differential item functioning and multidimensionality were found to be absent from the model in sections 4.3.3 and 4.3.4 respectively, further confirming that Transport Ability was the only latent trait being measured by the instrument. Initial findings in this study were identified to be logical; demonstrating the hypothesised relationship between mobility aid use, visual ability and Transport Ability, with lower visual ability correlated with lower Transport Ability and with mobility aid use compounding this effect, as shown in section 4.3.5.

Chapter Five analysed and discussed results from Survey I, investigating how individual characteristics affect Transport Ability and overall Life Space patterns. Table 5.1 in section 5.3 summarised the characteristics of study participants recruited from across Greater London, who had a mean age of almost 80 years, 81% of whom were female, 82% of whom had AMD and one third of whom used one or more mobility aids.

The results of a series of regression analyses were summarised in Chapter Five, with Table 5.10 in section 5.5 showing that low vision and mobility aid use reduced Transport Ability by 2.0 and 1.7 logits respectively. This was in line with the hypothesis, set out in section 1.3, that impaired vision and reduced mobility will result in lower levels of Transport Ability. Table 5.11 showed that the interaction term between low vision and mobility aid use was only approaching significance at the 5% level. This result meant that the hypothesis that mobility use had a compounding effect on low vision could be rejected. Use of one walking stick was found to be associated with a reduction in Transport Ability of 1.9 logits, whereas the reduction associated with personal assistance was 1.2 logits, suggesting that the comprehensive support provided by personal assistance enhances Transport Ability to a greater extent than the more basic aid in the form of a walking stick.

Transport Ability was shown to be a major determinant of Life Space score, with Table 5.14 showing that Life Space score increased by 4.3 points for every 1 logit increase in Transport Ability. This was as hypothesised in section 1.3, as it is logical that more able people would travel further and more frequently. Age was also found to have a significant impact on Life Space score that was separate to its impact on Transport Ability. It was speculated that this age effect was related to employment status, with older participants less likely to regularly commute to work.

Chapter Six showed the development and validation of Survey II, which was developed in cooperation with Council A, using 308 applicants for transport concessions resident in Borough A, in order to measure Transport Ability on an extended number of accessible transport modes for people with limited mobility and varying levels of vision. The validation steps mirror those described in Chapters Three, Four and Five; namely (i) Category performance; (ii) Fit; (iii) Item-person match; (iv) Differential Item Functioning (DIF) and (v) multidimensionality investigation.

The results were consistent with Survey I, with category performance shown to be strong in Figure 6.2 and person and item reliability and separation scores, summarised in section 6.3.2, showing that the instrument is capable of consistently discriminating between people of different ability and items of differing difficulty. Items with a response rate below 50% were removed, as were items that were significantly correlated with other item, so as to reduce redundancy. As in section 4.2.2, the analysis of infit and outfit statistics suggested that tasks related to reading transport information from a distance were not measuring the same latent trait of Transport Ability as the other tasks, so were also removed, leaving the final instrument with 12 items.

The item-person map, shown in Figure 6.9, demonstrated that the means of person abilities and item difficulties were within 1 logit of each other and the spreads were similar to each other, meaning that the instrument was able to discriminate between items and people consistently throughout the scale. Differential Item Functioning and multidimensionality were shown to be absent from the instrument in sections 6.4.3 and 6.4.4 respectively, which confirmed that Transport Ability was the only latent trait being measured by the instrument.

The 8 items that were common, or in two cases similar and highly correlated, between Instruments I and II are compared in section 6.5. The comparison, summarised in Table 6.22, showed that each common item was given a higher difficulty by Instrument II than Instrument I, with the exception of ‘Travelling at night’. ‘Travelling at night’ may have been an outlier because of the higher incidence of low vision among participants in Survey I than Survey II.

After excluding ‘Travelling at night’ from the comparison, Figure 6.18 showed that the trend line of the comparison of the remaining seven item difficulties has a slope close to 1, which shows that the two instruments were discriminating between the items in a consistent way. Due to the relative average item difficulties of the common items, the item difficulties for items in Survey II were 0.8 logits greater than for Survey I. This is confirmed by the Bland Altman analysis summarised in section 6.5.1, which shows that the seven common items had a mean difference in item difficulty scores of 0.8 with a standard deviation of 0.45 and all common items had differences between scores well within two standard deviations of the mean difference between scores, suggesting that the two instruments were measuring the same latent trait in a consistent way.

The validation of a further sample of 308 participants with a range of vision and mobility levels, further confirmed that individual ability levels were estimated well by the Rasch model. Through using the Rasch scores allocated to each participant and Rasch measures allocated to each transport item by the Rasch model, Chapter Six showed that it is possible to measure Transport Ability for a further group of people in a consistent way.

This result suggests that the Rasch model approach could potentially be used on a larger scale, although the tasks included in the instrument and the makeup of the sample to which the instrument is applied should be carefully considered if they are to be compared with a prior study.

Chapter Seven analysed the results from Survey II and compared the characteristics of the two survey samples. Survey I participants were found to have a higher Transport Ability, as well as a larger spread of abilities, than Survey II participants, as summarised in Table 7.8. The sample for Survey II was mostly drawn from applicants to Council A for a mobility-related transport concession, whereas Survey I participants had a wider range of mobility impairments or no impairment, so it was logical that they should have been more able despite being older and more visually impaired. The greater spread of abilities may be related to this in part but may also have been because Survey I participants were drawn from across Greater London, so experience a diverse range of urban and suburban transport environments, whereas Survey II participants all reside in Borough A in Inner London, so have a more uniform set of transport experiences.

Regression analyses, summarised in section 7.5 showed that low vision and mobility aid use were correlated with reduced Transport Ability. The final regression equation, summarised in Table 7.14, showed that low vision was associated with a 3.3 logit reduction in Transport Ability, compared to 2.8 and 2.9 logit reductions respectively associated with use of one walking stick and personal assistance. Furthermore, the interaction terms between low vision and each mobility aid type were statistically significant and had positive coefficients. This mean that, contrary to the hypothesis set out in section 1.3, the combined negative effect on Transport Ability of low vision and mobility aid use was less than the sum of the individual effects. This meant that for people with low vision, the negative effect of mobility aid use on Transport Ability was smaller than for people with good vision, and similarly among mobility aid users the negative impact of low vision on Transport Ability was smaller than among non-users of mobility aids. These results further confirm the hypothesis that low vision and mobility impairment are negatively correlated with Transport Ability but provide evidence against the hypothesis that mobility impairment compounds the negative impact of low vision on Transport Ability.

There was further confirmation that, as hypothesised, there was a positive correlation between Transport Ability and Life Space score, as shown in Figure 7.2. Table 7.17 shows that a one logit increase in Transport Ability was correlated with an increase in Life Space score of 6.7. Low vision did not have a statistically significant effect on Life Space score, suggesting that visual impairment did not affect travel patterns directly, only through its effect on Transport Ability.

Chapter Eight investigated the application of Instrument II to Case Study I, the ScootAbility scheme operated by Council A, to investigate Rasch analysis could be applied to assess the effectiveness of a transport accessibility scheme. Survey II was administered to a small sample group of 8 people both before and six months after they had joined the ScootAbility scheme, with the responses to the 12 items included in Instrument II used to calculate a Transport Ability relative to the anchored item difficulties from Instrument II for each participant before and after joining the ScootAbility scheme.

The participants experienced a mean improvement in Transport Ability of 1.6 logits and a mean improvement in Life Space score of 26 points six months after being given access to mobility scooters, as summarised in Table 8.1. This supported the hypothesis that the ScootAbility scheme would increase Transport Ability and, therefore, Life Space score, giving individuals the confidence and ability to travel further more frequently than they did previously.

No significant correlation was found between either initial Transport Ability or initial Life Space score and the change in these measures after joining the ScootAbility scheme, as summarised in sections 8.4.1 and 8.4.2. Furthermore, no correlation was found between change in Transport Ability and change in Life Space score, suggesting that the ScootAbility scheme increased the extent and frequency of travel among participants by a mechanism other than by increasing participants' Transport Abilities.

A possible explanation for this was found among the responses to specific transport items, summarised in Table 8.2. There was negligible change to the reported difficulty of using specific modes of public transport, but the biggest changes related to travelling in crowds, unfamiliar areas and at night, tasks that were not specific technical challenges but generally difficult and risky situations. This suggested that the use of powered wheelchairs and scooters reduces the perceived risk inherent in unpredictable situations, so would help participants to become more confident when faced with crowds, unfamiliar places and travelling at night.

Chapter Nine analysed the application of Instrument II to Case Study II, a wheelchair skills training scheme operated by the Back-Up Trust at Stanmore Hospital. To investigate this, Survey II was applied to a sample group of 15 people before and after they had participated in a wheelchair skills training course and, as in Chapter Eight, Transport Abilities were calculated using the anchored item difficulties from Instrument II. As summarised in section 9.4, the training session aimed to teach technical skills and techniques that will improve the ability of participants to deal with everyday obstacles.

Participants who took part in Case Study II experienced mean increases in Transport Ability and Life Space score of 1.2 logits and 12 points respectively, suggesting that the course was beneficial to participants. While there was no significant correlation between initial Transport Ability and change in Transport Ability due to the wheelchair skills training, there was a significant correlation between initial Life Space score and change in Life Space score, as shown in Table 9.6. After excluding two outliers, each additional point in initial Life Space score was estimated to be correlated with an additional 0.5-point increase in Life Space score after participating in the training. This was in contrast to the ScootAbility scheme in Case Study I and suggested that the scheme increased the extent and frequency of travel among more able people to a greater extent than among less able people.

The changes in responses to specific transport items, summarised in Table 9.2, showed that the items with the biggest reduction in difficulty relate to boarding and alighting buses and tubes. These technical obstacles were precisely what the training aimed to teach participants to tackle, so this pattern was not surprising but did contrast starkly with Case Study I where there was virtually no change in the response to these items. There were modest reductions in the reported difficulty of travelling in unfamiliar areas and crowded situations as a result of the wheelchair skills training, items that showed the biggest improvements in the ScootAbility study. This may suggest that the training boosted confidence and reduced the perception of the risk associated with these situations to a certain extent, although this effect did not extend to travelling at night, which improved significantly in the ScootAbility case study but saw virtually no change in difficulty as a result of the wheelchair skills training.

Table 9.7 showed that there was a positive correlation between change in Transport Ability and change in Life Space score, significant at the 5% level. This showed that larger increases in ability were associated with further and more frequent travel, while smaller increases in ability were correlated with smaller changes to travel patterns. This was in contrast with Case Study I, where there was no obvious relationship between the increases in Transport Ability and Life Space score because most participants saw a significant increase in their Life Space score irrespective of whether they saw a small or large improvement in their Transport Ability.

The results of Case Studies I and II were compared in Table 9.11, which showed that the average improvement in Transport Ability and Life Space score was larger among participants in the ScootAbility scheme than participants in wheelchair skills training. However, participants in the ScootAbility scheme were starting from a much lower base and were studied over a longer period, so these results did not suggest that ScootAbility was in any way superior to wheelchair skills training, although there may have been some instances where lower ability individuals on the wheelchair skills course would gain more from joining the ScootAbility scheme instead and vice versa. It may, therefore, be possible for local authorities to improve outcomes without necessarily increasing costs by offering access to both schemes.

It would not necessarily be the case that the high ability participants from Case Study I would necessarily benefit from wheelchair skills training, or that lower ability participants in Case Study II would benefit more from ScootAbility than wheelchair skills, especially in the long run. The analysis can be used to identify people who are not benefitting from training as much as others, which may allow the course to be adapted for their needs, by, for example, splitting the wheelchair skills training into introductory and advanced sessions.

Chapter Ten covered Case Study III, which compared the Transport Ability scale developed in this study with the Mobility Matrix score used to allocate Disabled Persons Freedom Passes, Blue Badges and Taxicards by Council A. Council A were able to provide the Mobility Matrix scores for 20 of the participants in Survey II, and concession allocation data for a further 18 participants, which predated the introduction of Mobility Matrix scores. A strong correlation was found between Mobility Matrix score and Transport Ability, as shown in Figure 10.1, which was logical given that the two measures were based on transport difficulty surveys covering similar areas.

Logistic regression analysis, as summarised in section 10.6, showed that Transport Ability could be used to predict fairly accurately whether an applicant would qualify for either the Blue Badge or Taxicard scheme, as for both concessions Transport Ability of -2 appeared to be an obvious threshold. As shown in Figure 10.3 and Figure 10.4, applicants with Transport Ability of -2 or below received a Blue Badge or Taxicard respectively, whereas, one outlier in Figure 10.3 excepted, applicants with higher Transport Ability were not allocated a concession. This matched the result for Mobility Matrix score, which was actually used as part of the decision-making process, which was observed to have an acceptance threshold of around 20 in practice, as shown in Figure 10.6 and Figure 10.7, where only scores of 20 or above received either a Blue Badge or Taxicard.

A significant relationship was also identified between Transport Ability and Disabled Persons Freedom Pass allocation, as shown in Figure 10.2; with the likelihood of receiving the concession falling sharply for Transport Abilities greater than -1.5. As shown in Figure 10.5, despite being part of the decision-making process for allocating a Disabled Persons Freedom Pass, Mobility Matrix score did not appear to have a clear threshold score in practice, as some applicants with scores above 15 did not receive a pass while some with scores below 15 did, due to other factors taken into consideration by the occupational therapist. This demonstrated that a clear threshold was not apparent when comparing Transport Ability with Disabled Persons Freedom Pass allocation because the allocation decision was based on more than mobility, as measured by either Mobility Matrix score or Transport Ability.

This was a positive result for the Transport Ability measure developed in this study, as it had been validated against a scoring system used to measure mobility by Council A, in order to make real-life decisions.

Receiver Operating Characteristic (ROC) analysis, summarised in section 10.7, analysed the rate of Type I and Type II errors in the allocation of concessions at different decision thresholds. The areas under the ROC curves for both Transport Ability and Mobility Matrix score were both around 0.90, which indicated that the Transport Ability measure developed in this study would be likely to lead to similar allocation decisions as the Mobility Matrix scoring system used by Council A.

As discussed in section 10.8, these results provided evidence that Mobility Matrix score and Transport Ability measured the same latent trait, which validated Transport Ability against a measure used by occupational therapists to inform real-life decisions. However, this did not mean that Transport Ability could replace Mobility Matrix scores in Council A's decision-making process because accurate Transport Ability scores can only be generated if participants respond to the transport questionnaire truthfully. As there is a strong incentive to misrepresent one's ability when applying for transport concessions, truthful responses are unlikely to be given.

This highlighted the fact that any instruments that rely on self-reporting are vulnerable to misrepresentation of ability should there be an incentive to do so, so are better suited to evaluation of the impact of transport accessibility interventions, such as in Case Studies I and II, where there was less incentive for participants to misrepresent their abilities. In such a situation a self-reported instrument is a powerful yet low-cost way of evaluating the benefits of the intervention and to whom those benefits accrue. It may be possible to develop an instrument based on Rasch analysis that is administered by another person, thereby limiting the scope for misrepresentation of ability, but this would require careful design of the items included and may significantly increase the cost of applying the analysis technique.

11.3 Objectives and Achievements of this Thesis

This thesis outlined four main objectives, which were:

1. To develop a new evaluation technique that can measure the ability to use transport reliably and consistently for people with low vision and/or mobility problems (Chapters Three, Four and Six)
2. To apply this technique to investigate the impact of low vision and/or mobility on Transport Ability and Life Space scores and the overall relationship between the ability to use transport and Life Space patterns (Chapters Five and Seven)
3. To measure Transport Ability levels in groups of people with different visual conditions and mobility related problems (Chapters Five and Seven)
4. To examine whether Transport Ability and Life Space patterns can be used to evaluate existing transport accessibility projects and schemes (Chapters Eight, Nine and Ten)

To investigate the first objective, it was hypothesised that a latent trait of Transport Ability could be measured reliably and consistently for people with low vision and/or mobility problems, which could be used to help develop and validate a new evaluation technique. Survey I was developed in Chapter Three, while Chapter Four summarised the stages involved in validating the survey instrument.

The category performance was shown to be strong is section 4.2.1, while the person and item separation and reliability scores were shown to be above the generally accepted thresholds, indicating that the instrument was able to reliably discriminate between different person abilities and item difficulties. The fit statistics identified that tasks relating to reading travel information from a distance did not fit the model well, probably because they measured a different latent trait to the other items, so these were removed from the instrument along with items that were subject to ceiling and floor effects and items that were highly correlated with other items and therefore redundant. The item-person map, shown in section 4.3.2, showed that while the mean and spread of the item difficulties for the resultant 10 item instrument could have matched the person abilities better if there were more easy and difficult tasks in the questionnaire, the instrument was still able to discriminate between majority of items and participants well.

Section 4.3.3 summarised Differential Item Functioning analysis, which showed that there was no observed item bias among participants relating to gender, age, visual ability or living alone. Principle component analysis, summarised in section 4.3.4, showed that the instrument is unidimensional, so is only measuring a single underlying trait, namely Transport Ability, rather than multidimensional.

Taken together, these validation stages provide very strong evidence that Survey I measured the single underlying latent trait Transport Ability reliably and consistently, for a sample of people with varying levels of visual and mobility impairment. Furthermore, the same validation stages were used in Chapter Six to validate Survey II, with similar results. This confirmed the hypothesis that it is possible to measure Transport Ability reliably and consistently and achieved the objective of developing an evaluation technique with which to do so.

To investigate the second objective, it was predicted that people with more severe visual impairment and/or more limited mobility experience lower levels of Transport Ability, resulting in more restricted Life Space patterns. It was also predicted that Transport Ability could be used as a predictor for Life Space score, with lower ability levels resulting in a fewer and shorter journeys outside the home. In Chapters Five and Seven, statistically significant evidence in support of both of these hypotheses was found among the results of the analysis of two separate case studies.

Chapter Five summarised the analysis of the results of applying Survey I, including a number of regression analyses that investigated the relationships between visual ability, mobility aid use, Transport Ability and Life Space score. In section 5.5. Low Vision and use of any type of mobility aid were shown to have a negative effect on Transport Ability, as summarised in Table 5.12. In Table 5.14 Low Vision was not found to be correlated with Life Space score at the 5% level, while Transport Ability was shown to be positively correlated with Life Space score, indicating that higher ability resulted in further and more frequent travel, as predicted. However, age was also found to be a significant confounder to be adjusted for.

In Chapter Seven similar results were found, as in the final regression equation, summarised in Table 7.14, low vision and use of any mobility aid were both negatively correlated with Transport Ability, while Life Space score was found to be correlated with Transport Ability but not low vision, as shown in Table 7.17.

Altogether, the analyses of Surveys I and II in Chapters Five and Seven showed that there was a strong statistical correlation between both low vision and mobility aid use and a reduction in Transport Ability. In turn, Transport Ability was strongly correlated with Life Space score, meaning that less able individuals found it more difficult complete transport tasks, and consequently travel less far and less frequently.

To investigate the third objective, it was predicted that mobility impairment would compound the negative impact that low vision has on Transport Ability. However, no evidence was found to support his hypothesis. In Chapter Five the interaction terms between mobility aid use and low vision were not statistically significant, and in Chapter Seven the same interaction terms were significant at the 5% level but had positive coefficients, as summarised in Table 7.14. This showed that participants with low vision who also used one or more mobility aids had lower Transport Ability on average than participants who had only low vision or were a mobility aid user, but that the effect of both low vision and mobility aid use was less than the sum of the individual effects, contradicting the hypothesis that it would be greater than the sum of the individual effects.

It was not possible to investigate whether there was a significant difference in Transport Ability and Life Space score between participants with AMD and participants with glaucoma due to the small sample size of participants with glaucoma among the responses to Survey I. Similarly, the responses to Survey II did not yield sufficient users of mobility aid types other than one walking stick and personal assistance to be analysed separately. Nevertheless, the final regression equations summarised in Table 5.12 and Table 7.14 show that use of one walking stick, personal assistance and other mobility aids had a different and statistically significant effects on Transport Ability in both Survey I and Survey II, relative to no mobility aid. This supports the hypothesis, set out in section 1.3, that different mobility aid types would be correlated with differing negative effects on Transport Ability.

To address the fourth objective, it was hypothesised that Transport Ability and Life Space score could be used to analyse the effect of transport accessibility schemes, by comparing results from before and after the intervention, and that different types of intervention would have different effects.

The results of Case Study I, summarised in Chapter Eight, found that the ScootAbility scheme caused significant increases in both Transport Ability and Life Space score among participants. Similarly, in Case Study II, summarised in Chapter Nine, the majority of participants experienced improvement in their Transport Ability and Life Space scores after participating in wheelchair skills training. While, the wheelchair skills training participants reported smaller average increases in Transport Ability and Life Space score, this may have been because they were starting from a higher base for both measures and were studied over a much shorter time period.

These results showed that Transport Ability and Life Space score can be used to evaluate accessibility schemes and support the hypothesis that different interventions may have different effects. Further research would be needed on a larger scale to fully evaluate the differences between schemes, but these small-scale case studies show that it is possible to measure the effect that schemes have and compare the outcomes.

Furthermore, Case Study III, summarised in Chapter Ten, validated Transport Ability against the Mobility Matrix score used by Council A to inform decisions to allocate Disabled Persons Freedom Passes, Blue Badges and Taxicards. This was evidence that the latent trait being measured by Transport Ability is the same trait being assessed when transport concessions are being allocated, suggesting that it was the correct trait to analyse to evaluate the effect of transport accessibility schemes.

11.4 Contribution to knowledge

This study was the first to apply the Rasch analysis technique to develop an interval scale to measure Transport Ability and Item Difficulty, in order to investigate the ability of mobility and visually impaired people to use public transport, and how this affects the extent and frequency of travel, as measured by Life Space score.

The study evaluated changes in Transport Ability, at both an individual and aggregate level, and the instrument developed has the flexibility to be applied to a number of different transport schemes that aim to improve transport accessibility by either improving a person’s ability to use transport, providing a mobility aid or making a transport task easier to perform. The measure has been validated against a scale that is currently used by Council A to measure mobility, as a vital tool in its decisions to allocate valuable transport concessions. Furthermore, this study has also addressed whether use of a mobility aid compounds the negative effect of visual impairment on Transport Ability.

This study adds to the growing body of research in mobility and low vision transport studies. In particular, it is the first study to investigate the relationship between low vision and mobility aid use with regard to specific transport related items, using an analytical technique common in clinical ophthalmological research, to develop a Transport Ability scale. This study has the potential to be one of the first steps of a wider project to develop and evaluation methodology for transport accessibility projects. Rasch analysis is relatively commonplace in the study of education and health, but there has been limited application of this analytical technique in transport studies in general, or in transport accessibility more specifically. This is the first transport accessibility study to use Rasch analysis as its primary analytical tool and has shown that it is a viable technique to use in this field.

The finding that different mobility aids and different accessibility schemes have different effects on Transport Ability could have implications for policy. It is possible that simpler and cheaper interventions can still provide many benefits relative to more expensive, labour intensive or hi-tech solutions. This focus on value for money in accessibility policy is only likely to grow in importance over time.

The fields of ophthalmology and transport have rarely been studied in combination in the past, however the multidisciplinary approach taken in this study has shown that the two fields must work in combination to ensure that the accessibility issues faced by people with low vision are robustly analysed. Doing so will allow ophthalmological expertise to inform transport design, helping the public realm to complement clinical intervention to the benefit of people with low vision.

11.5 Research Limitations

There are a number of limitations that need to be accounted for within this study. Public transport issues investigated in this paper are almost entirely related to London, meaning that studies that focus on travel elsewhere may not reach the same conclusions due to differing types of transport, different public transport infrastructure, different cultural norms and other changes in the context relating to transport. Nevertheless, due to the lower rates of car ownership and associated higher rates of public transport usage seen in London compared to the rest of the UK, focussing on London meant that participants could be found more readily and results could be generated more efficiently. Furthermore, the findings are very relevant to the large number of regular public transport users in the UK's capital city and are potentially relevant to residents of many other large cities around the world with similarly dense public transport networks.

More specifically the participants in Surveys I and II were drawn from residents of Greater London and Borough A respectively, meaning that the results of these studies pertain particularly to the transport environments prevalent in these places. Even within London the variety of transport contexts faced by respondents to the two surveys may have limited the extent to which results could be compared between the surveys, because the items described by the questionnaires may be qualitatively different in different areas or open to interpretation. This suggests that more specific definitions for some of the transport items would have made the results more comparable between studies.

Conclusions made through regression analysis also need to take into account the fact that the results may be more or less significant due to the overall characteristic traits of the participants included in the study. Some characteristics were underrepresented among the study participants, which made analysis of those characteristics very difficult. It would have been beneficial to include more users of other mobility aids in the study, as this would have allowed examination of the effects of a range of different mobility aids such as wheelchairs, scooters and Zimmer frames more accurately. Consequently, the findings made in this study are specific to the characteristic structure and distribution of the participants who took part in the study. Findings related to different vision groups, visual conditions and mobility aid group users would therefore need further investigation with a larger sample group, characterised with a more evenly distributed visual ability and participants who consistently use a wide range of different mobility aids.

The feasibility studies in Chapters Eight, Nine and Ten are also limited due to the restricted sample size of the participant sample that took part in each study. ScootAbility participants were collected over a period of a year. However, only 12 participants joined the scheme in Council A of which 8 were prepared to participate in the study. Furthermore, the wheelchair skills case study was limited to participants attending two initial sessions because the sessions were organised on an ad-hoc basis when there was sufficient demand, rather than on a regular timetable, and these were the only sessions that occurred in the four-month timeframe of the study. As with the ScootAbility case study, only around two-thirds of potential participants were willing to take part in the wheelchair skills study.

The analysis of the allocation of transport concessions by Council A was inhibited by the limited availability of information relating to the success or failure of applications for Disabled Persons Freedom Passes, Blue Badges and Taxicards. Out of a total of 308 people who took part in this study, Council A were only able to retrieve records for 38 individuals. A larger number of records would have produced more robust results and allowed a better understanding of the relationship between Mobility Matrix score and Transport Ability.

11.6 Future Research

There are a number of ways in which the Rasch Analysis technique demonstrated in this study could be further applied in the fields of transport and accessibility in the future. It could be adapted to different transport modes in different cities or regions in the UK, Europe or beyond in order to examine the extent to which this technique can measure the ability to use transport in places other than London.

However, applying the approach to residents of a large area is likely to give a wider spread of responses due to the variety of transport contexts experienced by respondents, meaning that more consistent results are likely to be found by applying the tool to an urban area with fairly homogenous transport environments. Doing so would mean that a large number of people can be sampled yet the items in the sample would be similar for all participants. An extension of this could be to apply the approach to users of a specific rail or tube line, bus route or even station, which would ensure that items referring to, for example, stairs within stations are referring to the same stairs for all participants.

This approach could then be combined with the evaluation technique shown in Chapters Eight and Nine, by applying a Rasch instrument to the users of a specific station before and after a change, it may be possible to evaluate who was affected by the change and to what extent, and possibly how the change compared to other changes.

The study was conducted in conjunction with Council A, but future studies could widen this to other authorities, such as London boroughs, who use mobility assessments to allocate disabled transport concessions. It would be useful to understand the extent to which the Transport Ability measure developed in this study correlates with other mobility measured used by other authorities. Doing so could allow Transport Ability to be developed into a tool to ensure consistency between the concession allocation procedures of different local authorities.

Rasch Analysis could also be applied to a larger sample to further test the effectiveness of the instrument in measuring improvement in Transport Ability. This would further test its effectiveness in evaluating the impact of transport-related schemes and case studies. It would be especially useful to collect samples to allow comparison of specific characteristics that this study was unable to analyse satisfactorily. For example, samples greater numbers of people with glaucoma or users of less common mobility aids such as wheelchairs, scooters and Zimmer frames would allow better analysis of how the Transport Abilities of these people differ from people with other visual conditions and users of other and no mobility aids. The scope of the study could be widened to understand how well this instrument measures the ability to use transport among people with other conditions that were not examined in this study, such as learning difficulties and hearing impairment.

A useful addition to this tool would be a technique that allows the Rasch measures generated as part of this study to be converted into more tangible units. Converting the scores into journey time equivalents could help people to better understand the impact of improved accessibility and could also aid transport planning. However, such a process would probably involve a large scale stated preference survey, which would be a significant undertaking.

Furthermore, Rasch measures could be converted into monetary equivalents, which would mean that cost-benefit analysis could be applied accessibility interventions. This would allow the full benefits of each potential intervention to be weighed against cost, allowing the best value approach to be taken. It would also mean that the benefits and costs to mobility and visually impaired people of any changes to the transport system could be taken into account alongside the needs of other groups on a monetary equivalent basis. This would mean that when infrastructure changes are proposed a more comprehensive assessment can be made of the overall costs and benefits to all affected users. This would ensure that accessibility considerations were as integral to the planning process as any other costs and benefits. However, this task would be far from simple.

Chapter 12 References

Achuthan, K., Titheridge, H. and Mackett, R.L. (2007) 'Measuring pedestrian accessibility', Proceedings of the Geographical Information Science Research UK (GISRUK) Conference 2007, Maynooth, Ireland, 264-269. Available at: https://pdfs.semanticscholar.org/14a7/d5fdad1837d8b7e224482552b545d55bdbe9.pdf#page=276 (accessed 9/11/2016)

Alexander, M.S., Lajoie, K., Neima, D.R., Strath, R.A., Robinovitch, S.N. and Marigold, D.S. (2014) 'Effects of age-related macular degeneration and ambient light on curb negotiation', Optometry and vision science, 91(8): 975-989

Alsnih, R. and Hensher, D.A. (2003) 'The mobility and accessibility expectations of seniors in an aging population', Transportation Research Part A: Policy and Practice, 37(10): 903-16

Altman, D.G. and Bland, J.M. (1983) 'Measurement in medicine: the analysis of method comparison studies', The Statistician, 32(3): 307-317

Anderson, J. (1971) 'Space–time budgets and activity studies in urban geography and Planning', Environment and Planning, 3(4): 353–368

Axhausen, K.W., Zimmermann, A., Schönfelder, S., Rindsfüser, G. and Haupt, T. (2002) 'Observing the rhythms of daily life: A six-week travel diary', Transportation, 29(2): 95-124

Backman, H. and Williams, R. (2002) 'Living with age-related macular degeneration', Journal of Visual Impairment and Blindness, 96(5): 345-348

Baker, P.S., Bodner, E.V. and Allman, R.M. (2003) 'Measuring life-space mobility in community-dwelling older adults', Journal of the American Geriatrics Society, 51(11): 1610-1614

Balkrishnan, R., McMichael, A.J., Camacho, F.T., Saltzberg, F., Housman, T.S., Grummer, S., and Chren, M.M. (2003) 'Development and validation of a health-related quality of life instrument for women with melisma', British Journal of Dermatology, 149(3): 572-577

Barnes, L.L., Wilson, R.S., Bienias, J.L., Mendes de Leon, C.F., Kim, H.J.N., Buchman, A.S and Bennett, D.A. (2007) 'Correlates of Life Space in a Volunteer Cohort of Older Adults', Experimental Aging Research: An International Journal Devoted to the Scientific Study of the Aging Process, 33(1): 77-93

Benavent-Caballer, V., Sendín-Magdalena, A., Lisón, J.F., Pedro Rosado-Calatayud, P., Amer-Cuenca, J.J., Salvador-Coloma, P., Segura-Ortí, E., (2016) 'Physical Factors Underlying the Timed "Up and Go" Test in Older Adults', Geriatric Nursing, 37(2): 122-127

Benenson, I., Martens, K., Rofé, Y. and Kwartler, A., (2010) 'Public transport versus private car GIS-based estimation of accessibility applied to the Tel Aviv metropolitan area', The Annals of Regional. Science, 47: 499–515

Berdeaux, G.H., Nordmann, J.P., Colin, E. and Arnould, B., (2005) 'Vision-related quality of life in patients suffering from age-related macular degeneration', American Journal of Ophthalmology, 139: 271–279

Bernth-Petersen, P. (1981) 'Visual functioning in cataract patients', Acta ophthalmologica, 59(2): 198-205

Biondo, S., Ramos, E., Deiros, M., Ragué, J.M., De Oca, J., Moreno, P., Farran, L. and Jaurrieta, E. (2000) 'Prognostic factors for mortality in left colonic peritonitis: a new scoring system', Journal American College of Surgeons, 191(6): 635-642

Black, A.A, and Wood, J. M. (2005) 'Vision and falls', Clinical and Experimental Optometry, 88(4): 212-222

Black, A.A., Wood, J.M., and Lovie-Kitchin, J.E. (2011) ‘Inferior field loss increases rate of falls in older adults with glaucoma’, Optometry & Vision Science, 88(11): 1275-1282

Breeze, E., Jones, D.A., Wilkinson, P., Bulpitt, C.J., Grundy, C., Latif, A.M. and Fletcher, A.E. (2005) ‘Area deprivation, social class, and quality of life among people aged 75 years and over in Britain’, International Journal of Epidemiology, 34(2): 276–283

Brennan, M., Horowitz, A. and Su, Y.P. (2005) ‘Dual sensory loss and its impact on everyday competence’, The Gerontologist, 45(3): 337-346

Bressler, N.M. (2004) ‘Age-related macular degeneration is the leading cause of blindness’, Journal of the American Medical Association, 291(15): 1900-1901

Bridenbaugh, S.A. and Kressig, R.W. (2010) ‘Laboratory review: the role of gait analysis in seniors’ mobility and fall prevention’, Gerontology, 57(3): 256-264

Brömmelstroet, M., Curtis, C., Larsson, A. and Milakis, A. (2016) ‘Strengths and weaknesses of accessibility instruments in planning practice: technological rules based on experiential workshops’, European Planning Studies, 24(6): 1175-1196

Brown, B., Brabyn, L. Welch, L. Haegerstrom-Portnoy, G and Colenbrander, A. (1986) ‘Contribution of vision variables to mobility in age-related maculopathy patients’, American Journal of Optometry and Physiological Optics (63): 733-739

Brown, M. and Wood, T. (2004) ‘Accession - Accessibility Analysis for Local Transport Planning’, in Proceedings of the European Transport Conference 2004, Association for European Transport

Bruce, I., McKennell, A. and Walker, E. (1991) ‘Blind and partially sighted adults in Britain: the RNIB survey’, London: HMSO

Bullimore, M.A., Bailey, I.L. and Wacker, R.T. (1991) 'Face recognition in age-related maculopathy', Investigative Ophthalmology Visual Science (32): 2020-2029

Byles, J.E., Leigh, L., Vo, K., Forder, P. and Curryer, C. (2014) 'Life space and mental health: a study of older community-dwelling persons in Australia', Aging and Mental Health, 19(2): 1-9

Carta, A., Braccio, L., Belpoliti, M., Soliani, L., Sartore, F., Gandolfi, S. A. and Maraini, G. (1998) 'Self-assessment of the quality of vision: association of questionnaire score with objective clinical tests', Current Eye Research, 17(5): 506-512

Casas, I. (2007) 'Social exclusion and the disabled: An accessibility approach', The Professional Geographer, 59(4): 463-477

Celler, B. G., N. H. Lovell, J. Basilakis, F. Magrabi, and M. Mathie. (2001) 'Home telecare for chronic disease management', Proceedings of the 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 4: 3586–3589

Cepolina, E.M. and Tyler, N. (2004) 'Microscopic Simulation of Pedestrians in Accessibility Evaluation', Transportation Planning and Technology, 27(3): 145-180

Chen, S., Claramunt, C. and Ray, C. (2014) 'A spatio-temporal modelling approach for the study of the connectivity and accessibility of the Guangzhou metropolitan network', Journal of Transport Geography, 36: 12–25

Church, R.L. and Marston, J.R. (2003) 'Measuring Accessibility for People with a Disability', Geographical Analysis, 35(1): 83-96

Clemons, T.E., Chew, E.Y., Bressler, S.B. and McBee, W. (2003) ‘National Eye Institute Visual Function Questionnaire in the Age-Related Eye Disease Study (AREDS): AREDS report no. 10’, Archives of Ophthalmology, 121: 211-217

Coast, J., Flynn, T.N., Natarajan, L., Sproston, K., Lewis, J., Louviere, J. and Peters, T.J. (2008) ‘Valuing the ICECAP capability index for older people’, Social Science & Medicine, 67: 874–882

Coman, L. and Richardson, J. (2006) ‘Relationship between self-report and performance measures of function: A systematic review’, Canadian Journal of Aging, 25: 253-270.

Cook, G., Keith, B and Harris, J. (1997) ‘Colour Contrast and Perception: Design Guidance for Internal Built Environments’, University of Reading: Research Group for Inclusive Environments and the Department of Psychology

Cookson, R. (2005) ‘QALYs and the capability approach’, Health Economics, 14(8): 817–829

Cortina, J.M. (1993). ‘What is coefficient alpha? An examination of theory and applications’, Journal of Applied Psychology, 78: 98–104

Council A, ScootAbility. (2015). Available at: http://www.islington.gov.uk/services/socialcarehealth/olderpeople/accessibletransportmobility/ Pages/scootability.aspx. (accessed 12/11/2016)

Crabb, D. P., Smith, N. D., Glen, F. C., Burton, R. and Garway-Heath, D. F. (2013) ‘How does glaucoma look?: patient perception of visual field loss’, Ophthalmology, 120(6): 1120-1126

Crabtree, H.L., Hildreth, A. J., O’Connell, J. E., Phelan, P.S., Allen, D., & Gray, C.S. (1999) ‘Measuring visual symptoms in British cataract patients: the cataract symptom scale’, British Journal of Ophthalmology, 83(5): 519-523

Crowe, M., Andel, R., Wadley, V.G., Okonkwo, O.C., Sawyer, P. and Allman, R.M. (2008) ‘Life-space and cognitive decline in a community-based sample of African American and Caucasian older adults’, The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 63(11): 1241–1245

Cruess, A., Zlateva, G., Xu, X. and Rochon, S. (2007) ‘Burden of illness of neovascular age-related macular degeneration in Canada’, Canadian Journal of Ophthalmology, 91: 1303-7

Curcio, C.L., Alvarado, B.E., Gomez, F., Guerra, R., Guralnik, J. and Zunzunegui, M.V. (2013) ‘Life-Space Assessment scale to assess mobility: validation in Latin American older women and men’, Aging Clinical Experimental Research, 25: 553

Currie, G., Richardson, T., Smyth, P., Vella-Brodrick, D., Hine, J., Lucas, K., Stanley, J., Morris, J., Kinnear, R. and Stanley, J. (2009) ‘Investigating links between transport disadvantage, social exclusion and well-being in Melbourne—Preliminary results’, Transport Policy, 16(3): 97-105

Curriero, F.C., Pinchoff, J., van Landingham, S.W., Ferrucci, L., Friedman, D.S. and Ramalu, P.Y. (2013) ‘Alteration of travel patterns with vision loss from glaucoma and macular degeneration’, JAMA Ophthalmology, 131(11): 1420-6

Curtis, C. and Scheurer, J. (2010) ‘Planning for sustainable accessibility: Developing tools to aid discussion and decision making’, Progress in Planning, 74: 53–106

Dalke, H., Conduit, G.J., Conduit, B D., Cooper, R.M., Corso, A., and Wyatt, D.F. (2010) ‘A colour contrast assessment system: design for people with visual impairment’, Designing Inclusive Interactions, Springer, London (pp. 101-110)

Daltroy, L.H., Phillips, C.B., Eaton, H.M., Larson, M.G., Partridge, A.J., Logigian, M. and Liang, M.H. (1995) ‘Objectively measuring physical ability in elderly persons: The Physical Capacity Evaluation’, American Journal of Public Health, 85:558-560

Dauphin, A.P., Guillemin, F., Virion, J.M., and Briançon, S. (1999) ‘Bias and Precision in Visual Analogue Scales: A Randomized Controlled Trial’, American Journal of Epidemiology, 150(10): 1117-1127

DeCarlo, D.K., Scilley, K., Wells, J. and Owsley, C. (2003) ‘Driving habits and health-related quality of life in patients with age-related maculopathy’, Optometry and Vision Science, 80(3): 207-13

Department for Health (1998) ‘Modernising social services: promoting independence, improving protection, raising standards.’ London, HMSO. Available at: http://webarchive.nationalarchives.gov.uk/20100604145230/http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4081593 (accessed 9/11/2016)

Department for Health (2000) ‘The NHS plan: a plan for investment, a plan for reform.’ London, Stationery Office. Available at: http://webarchive.nationalarchives.gov.uk/20121102184216/http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4002960 (accessed 9/11/2016)

Department for Transport (2001) ‘Older people: Their transport needs and requirements’, London, DfT . Available at: http://webarchive.nationalarchives.gov.uk/+/http://www.dft.gov.uk/pgr/inclusion/older/olderpeopletheirtransportnee3260 (accessed 9/11/2016)

Department for Transport (2004) ‘Technical guidance on accessibility planning in local transport plans’, London, Df . Available at: http://webarchive.nationalarchives.gov.uk/20110720204754/http://www2.dft.gov.uk/pgr/regional/ltp/accessibility/guidance/gap/index.html (accessed 9/11/2016)

Department for Transport (2005) ‘Inclusive mobility’, originally published 2002, updated 2005, London, DfT. Available at: https://www.gov.uk/government/publications/inclusive-mobility

Department for Transport (2006) ‘Accessibility Planning Guidance: Summary’, London, DfT. Available at:
http://webarchive.nationalarchives.gov.uk/20110720221715/http://www2.dft.gov.uk/pgr/regional/ltp/accessibility/guidance/gap/accessibilityplanningguidanc3633.html (accessed 9/11/2016)

Department for Transport (2009) ‘2008 Core National Local Authority Accessibility Indicators’, Final Report, November 2009, London, DfT
Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/372139/accessibility-statistics-guidance.pdf (accessed 9/11/2016)

Department for Transport (2013) ‘Rail Vehicle Accessibility Regulations (RVAR) exemption orders’, London, DfT. Available at:
https://www.gov.uk/government/collections/rail-vehicle-accessibility-regulations-rvar-exemption-orders (accessed 9/11/2016)

Department for Transport (2014) ‘The Blue Badge Scheme Local Authority Guidance (England)’, London, DfT . Available at:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/519091/blue-badge-scheme-local-authority-guidance-paper.pdf (accessed 9/11/16)

Department for Transport (2017) ‘Draft transport accessibility action plan’, London, DfT. Available at:
https://www.gov.uk/government/consultations/draft-transport-accessibility-action-plan (accessed 9/11/2016)

De Vries, N.M., Van Ravensberg, C.D., Hobbelen, J.S.M., Rikkert, M.O., Staal, J.B. and Nijhuis-van der Sanden, M. W. G. (2012) ‘Effects of physical exercise therapy on mobility, physical functioning, physical activity and quality of life in community-dwelling older adults with impaired mobility, physical disability and/or multi-morbidity: a meta-analysis’, Ageing Research Reviews, 11(1): 36-149

Disability Discrimination Act (2005), HMSO. Available at: https://www.legislation.gov.uk/ukpga/2005/13/contents (accessed 9/11/2016)

Doherty, S.T. and Miller, E.J. (2000) 'A computerized household activity scheduling Survey', Transportation, 27 (1): 75–97

Donald, I.P. (1997) 'Development of a modified Winchester disability scale - the elderly at risk rating scale. Journal of Epidemiology and Community Health, 51:558-563

Douglas, G., Corcoran, C., and Pavey, S. (2006) 'Network 1000: the changing needs and circumstances of visually impaired people: project overview', British Journal of Visual Impairment, 22: 93-100

DPTAC (2002) 'Attitudes of Disabled People to Public Transport: Research Study Conducted for Disabled Persons Transport Advisory Committee', DPTAC, London

DPTAC (2015) 'Policy paper: Accessible rail transport', DPTAC, London

Duffy, M. (2015) 'Macular Degeneration, Central Vision Loss, and Preferred Retinal Location: New Research May Enable New Approaches to Low Vision Rehabilitation', Vison Aware blog. Available at: https://www.visionaware.org/blog/visionaware-blog/macular-degeneration-central-vision-loss-and-preferred-retinal-location-new-research-may-enable-new-approaches-to-low-vision-rehabilitation-2016/12 (accessed 24/02/2018)

Employers' Forum on Disability (2008) 'Disability and public transport', Forum on Disability

Equality Act (2010) Government Equality Office

Evans, J. (1996) 'Causes of blindness and partial sight in England and Wales 19990-1991: studies on medical and population subjects', 57, London: HMSO

Fidler, G.S. and Fidler, J.W., (1978) ‘Doing and becoming: Purposeful action and self-actualization’, American Journal of Occupational Therapy, 32:305-10

Fine, S.L., Berger, J.W., Maguire, M.G. and Ho, A.C. (2000) ‘Age-related macular degeneration’, New England Journal of Medicine, 342(7): 483-492

Fletcher, A. E., Ellwein, L. B., Selvaraj, S., Vijaykumar, V., Rahmathullah, R., and Thulasiraj, R. D. (1997) ‘Measurements of vision function and quality of life in patients with cataracts in southern India: report of instrument development’ Archives of Ophthalmology, 115(6): 767-774

Fox, T.G and Bond, C.M. (2007) ‘Applying the Rasch Model: Fundamental Measurement in the Human Sciences’, Routledge: Abingdon

Friedman, D.S., Freeman, E., Munoz, B., Jampel, H. and West, S.K. (2007) ‘Glaucoma and Mobility Performance: The Salisbury Eye Evaluation Project’, Ophthalmology, 114(12): 2232-2237

Friedman, D.S., O’Colmain, B.J., Munoz, B., Tomany, S.C., McCarty, C., De Jong, P.T., Nemesure, B., Mitchell, P. and Kempen, J., (2004) ‘Prevalence of age-related macular degeneration in the United States’, Archives of Ophthalmology, 122(4): 564-572

Frost, N.A., Sparrow, J.M., Durant, J.S. (1998) ‘Development of a questionnaire for measurement of vision-related quality of life’, Ophthalmic Epidemiology, 5(4): 185–210

Gabriel, Z. and Bowling, A. (2004) ‘Quality of life from the perspectives of older people’, Ageing & Society, 24(5): 675-691

Garamendi, E., Pesudovs, K., Stevens, M. J. and Elliott, D.B. (2006) ‘The Refractive Status and Vision Profile: evaluation of psychometric properties and comparison of Rasch and summated Likert-scaling’, Vision research, 46(8-9): 1375-1383

Garway-Heath, D.F., Lascaratos, G., Bunce, C., Crabb, D.P., Russell, R.A. and Shah, A. (2013) 'The United Kingdom Glaucoma Treatment Study: a multicenter, randomized, placebo-controlled clinical trial: design and methodology', Ophthalmology, 120(1): 68-76

Geurs, K.T. and Ritsema van Eck, J.R., (2001) 'Accessibility measures: review and applications. Evaluation of accessibility impacts of land-use transportation scenarios, and related social and economic impact', National Institute of Public Health and Environment, Urban Research Centre, Utrecht University

Geurs, K.T., and Wee, B. (2004) 'Accessibility evaluation of land- use and transport strategies: review and research directions', Journal of Transport Geography, 12: 127-140

Glen, F.C., Crabb, D.P. and Garway-Heath, D.F. (2011) 'The direction of research into visual disability and quality of life in glaucoma', BMC Ophthalmology, 11(1): 19

Golledge, R.G. and Marston, J.R. (1999) 'Towards an Accessible City: Removing Functional Barriers to Independent Travel for Blind and Vision-Impaired Residents and Visitors.' Research Report, California Partners for Advanced Transit and Highways (PATH), Institute of Transport Studies, Berkeley

Gothwal, V.K., Wright, T.A., Lamoureux, E.L., & Pesudovs, K. (2009). 'Rasch analysis of the quality of life and vision function questionnaire', Optometry & Vision Science, 86(7): 836-844

Gould, D., Kelly, D., Goldstone, L. and Gammon, J. (2001) 'Examining the validity of pressure ulcer risk assessment scales: developing and using illustrated patient simulations to collect the data - Information Point: Visual Analogue Scale', Journal of Clinical Nursing, 10(5): 697-706

Graf, C. (2008) 'The Lawton instrumental activities of daily living scale', American Journal of Nursing, 108(4): 52-62

Granger, C.V. and Gresham, G.E. (1993) ‘Functional assessment in rehabilitation medicine: introduction and brief background.’ Physical Medicine and Rehabilitation Clinics of North America, 4: 417-423

Grundy, E. (1999) ‘Disability in Great Britain: results from the 1996/97 disability follow-up to the family resources survey’, (No. 94) Corporate Document Services

Halden, D., Jones, P., and Wixey, S. (2005) ‘Measuring Accessibility as Experienced by Different Socially Disadvantaged Groups: Accessibility analysis literature review’, Transport Studies Group, University of Westminster

Hambleton, R.K and Cook, L.L (1997) ‘Latent trait models and their use in the analysis of educational test data’, Journal of Educational Measures, 14: 75–96

Hambleton, R.K., Swaminathan, H. and Rogers, H. (1991) ‘Fundamentals of Item Response Theory’, Newbury Park, California: Sage Publications

Harada, K., Shimada, H., Sawyer, P., Asakawa, Y., Nihei, K., Kaneya, S., Furuna, T., Ishizaki, T. and Yasumura, S. (2010) ‘Life-space of community-dwelling older adults using preventive health care services in Japan and the validity of composite scoring methods for assessment’, [Nihon koshu eisei zasshi] Japanese journal of public health, 57(7): 526-537

Hardy, P. (2004). ‘Powered wheelchair mobility: An occupational performance evaluation perspective’, Australian Occupational Therapy Journal, 51(1): 34-42

Hart, D.L. and Wright, B.D. (2002) ‘Development of an index of physical functional health status in rehabilitation’, Archives of Physical Medicine Rehabilitation, 83: 655-665

Hassan, S.E., Lovie-Kitchin, J.E. and Woods, R.L. (2002) ‘Vision and mobility performance of subjects with age-related macular degeneration’, Optometry and Vision Science, 79(11): 697-707

Hassell, J.B., Lamoureux, E.L. and Keeffe, J.E. (2006) 'Impact of age related macular degeneration on quality of life', British Journal of Ophthalmology, 90(5): 593-596

Herman, T., Giladi, N., Gurevich T. and Hausdorff, J.M. (2005) 'Gait instability and fractal dynamics of older adults with a "cautious" gait: Why do certain older adults walk fearfully?', Gait & Posture, 21(2): 178-185

Hill, M.R. (1984) 'Stalking the urban pedestrian: a comparison of questionnaire and tracking methodologies for behavioral mapping in large-scale environments', Environment and Behavior, 16(5): 539-550

Hirsch, J.A., Winters, M., Clarke, P. and McKay, H. (2014) 'Generating GPS activity spaces that shed light upon the mobility habits of older adults: a descriptive analysis', International Journal of Health Geographics, 13(1): 51

Hirsch, J.A., Winters, M., Ashe, M.C., Clarke, P.J. and McKay, H.A. (2016) 'Destinations that older adults experience within their GPS activity spaces: relation to objectively measured physical activity', Environment and behavior, 48(1): 55-77

Hochberg, C., Maul, E., Chan, E.S., Van Landingham, S., Ferrucci, L., Friedman, D. S. and Ramulu, P.Y. (2012) 'Association of vision loss in glaucoma and Age-Related Macular Degeneration with IADL', Investigative Ophthalmology & Visual Science, 53(6): 3201-3206

Hooper, P., Jutai, J.W., Strong, G. and Russell-Minda, E. (2008) 'Age-related macular degeneration and low-vision rehabilitation: a systematic review', Canadian Journal of Ophthalmology, 43(2): 180-187

Inoi, H. and Nitta, Y. (2005) 'The planning of the community transport from the viewpoint of well-being: applying Amartya Sen's capability approach', Proceedings of the Eastern Asia Society for Transportation Studies, 5: 2330–2341

Ivers, R.Q., Cumming, R.G. and Mitchell, P. (1998) ‘Visual impairment and falls in older adults: the Blue Mountains Eye Study’, Journal of the American Geriatrics Society, 46: 58–64

James, B.D., Boyle, P.A., Buchman, A.S., Barnes, L. L. and Bennett, D.A. (2011) ‘Life space and risk of Alzheimer disease, mild cognitive impairment, and cognitive decline in old age’, The American Journal of Geriatric Psychiatry, 19(11): 961-969

Jensen, G., Iwarsson, S. and Ståhl, A. (2002) ‘Theoretical understanding and methodological challenges in accessibility assessments focusing the environmental component: An example from travel chains in urban public bus transport’, Disability and Rehabilitation, 24(5): 231-242

Jette, A.M. (2006) ‘Towards a common language for function, disability, and health’, Physical Therapy, 86(5): 726-734

Jette, A. M., Haley, S. M. and Coster, W.J. (2002) ‘Late Life function and disability instrument: I. Development and evaluation of the disability component’, The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 57(4): M209-M216

Jones, P. W., Harding, G., Berry, P., Wiklund, I., Chen, W. H. and Leidy, N. K. (2009) ‘Development and first validation of the COPD Assessment Test’, European Respiratory Journal, 34(3): 648-654

Judge, J.O., Schechtman, K., Cress, E., Group FISCSIT, (1996). ‘The relationship between physical performance measures and independence in instrumental activities of daily living’, Journal of the American Geriatrics Society, 44(11): 1332–1341

Jung, J.J., Chen, C.Y., Mrejen, S., Gallego-Pinazo, R., Xu, L., Marsiglia, M., Boddu, S. and Freund, K.B., (2014). ‘Baseline predictors for good long-term visual outcomes in the treatment of neovascular AMD with intravitreal anti-VEGF therapy’, Investigative Ophthalmology & Visual Science, 55(13): 3954-3954

Katz, S., Ford, A.B., Moskowitz, R.W., Jackson, B.A. and Jaffe, M.W. (1963) ‘Studies of illness in the aged. The Index of ADL: A standardized measure of biological and psychosocial function’, JAMA, 185(21): 914–919

Kelly, C.E., Tight, M.R., Hodgson, F.C. and Page, M.W. (2011) ‘A comparison of three methods for assessing the walkability of the pedestrian environment’, Journal of Transport Geography, 19(6): 1500-1508

Kerr, J., Marshall, S., Godbole, S., Neukam, S., Crist, K., Wasilenko, K., Golshan, S. and Buchner, D. (2012) ‘The relationship between outdoor activity and health in older adults using GPS’, International journal of environmental research and public health, 9(12): 4615-4625

Keul, A. and Kühberger, A. (1997) ‘Tracking the Salzburg tourist’ Annals of Tourism Research, 24(4), 1008-1012

Khadka, J., Gothwal, V. K., McAlinden, C., Lamoureux, E. L., & Pesudovs, K. (2012) ‘The importance of rating scales in measuring patient-reported outcomes’, Health and Quality of Life Outcomes, 10(1): 80

Khadka, J., Huang, J., Mollazadegan, K., Gao, R., Chen, H., Zhang, S., Wang, Q. and Pesudovs, K. (2014) ‘Translation, cultural adaptation, and Rasch analysis of the visual function (VF-14) questionnaire’, Investigative Ophthalmology & Visual Science, 55(7): 4413-4420

Kitchen, R.M. and Jacobson, R.D. (1997) ‘Techniques to Collect and Analyse the Cognitive Map Knowledge of Persons with Visual Impairment or Blindness: Issues of Validity’, Journal of Visual Impairment & Blindness, 91(4): 360-376

Klein, B.E., Klein, R., Lee, K.E. and Cruickshanks, K.J., (1998) ‘Performance-based and self-assessed measures of visual function as related to history of falls, hip fractures, and measured gait time: the Beaver Dam Eye Study’, Ophthalmology, 105(1): 160-164

Kolko, M., (2015) ‘Present and new treatment strategies in the management of glaucoma’, Open Ophthalmology Journal, 9 (Supplement 1. M5): 89-100

Kologlu, M., Elker, D., Altun, H. and Sayek, I. (2001) ‘Valdation of MPI and OIA II in two different groups of patients with secondary peritonitis’, Hepato-Gastroenterology, 48(37): 147-151

Kubicki, A. (2014) ‘Functional assessment in older adults: Should we use timed up and go or gait speed test?’, Neuroscience letters, 577: 89-94

Kuyk, T., Elliot, J.L. and Fuhr, P.S. (1998) ‘Visual correlates of mobility in real world settings in older adults with low vision’, Optometry Visual Science, 75(7): 538-47

Kuyk, T., Elliott, J.L., Wesley, J., Scilley, K., McIntosh, E., Mitchell, S and Owsley, C. (2004) ‘Mobility function in older veterans improves after blind rehabilitation’, Journal of Rehabilitation Research & Development, 41(3): 337-346

Kwan, M. P. and Neutens, T. (2014) ‘Space-time research in GIScience’, International Journal of Geographical Information Science, 28(5): 851-854

Labiris, G., Katsanos, A., Fanariotis, M., Tsirouki, T., Pefkianaki, M., Chatzoulis, D. and Tsironi, E. (2008) ‘Psychometric properties of the Greek version of the NEI-VFQ 25’, BMC ophthalmology, 8(1): 4

Lahav, O. and Mioduser, D. (2000) ‘Multisensory virtual environment for supporting blind persons' acquisition of spatial cognitive mapping, orientation, and mobility skills’. Proceedings 3rd International Conference of Disability, Virtual Reality and Associated Technology, ICDVRAT 2000: 53-58

Lai, J., Teresi, J. and Gershon, R. (2005) ‘Procedures for the Analysis of Differential Item Functioning (DIF) for Small Samples’, Evaluation & the Health Professionals, Sage

Laitinen, A., Sainio, P., Koskinen, S., Rudanko, S., Laatikainen, L., Aromaa, A. (2007) ‘The association between visual acuity and functional limitations: Findings from a nationally representative population survey’, Ophthalmic Epidemiology, 14(6): 333-42

Lamoureux, E. L., Pallant, J. F., Pesudovs, K., Hassell, J. B. and Keeffe, J. E. (2006) ‘The Impact of Vision Impairment Questionnaire: an evaluation of its measurement properties using Rasch analysis’, Investigative Ophthalmology & Visual Science, 47(11), 4732-4741

Lamoureux, E.L., Pallant, J.F., Pesudovs, K., Tennant, A., Rees, G., O'Connor, P.M. and Keeffe, J.E. (2008) ‘Assessing participation in daily living and the effectiveness of rehabiliation in age related macular degeneration patients using the impact of vision impairment scale’, Ophthalmic Epidemiology, 15(2): 105-113

Lamoureux, E.L., Mitchell, P., Rees, G., Cheung, G., Yeo, I., Lee, S.Y., Liu, E. and Wong, T.Y. (2011) ‘Impact of early and late age-related macular degeneration on vision-specific functioning’, British Journal of Ophthalmology, 95(5): 666-670

Lavery, I., Davey, S., Woodside, A. and Ewart, K. (1996) ‘The vital role of street design and management in reducing barriers to older peoples' mobility’, Landscape and Urban Planning, 35(2): 181-192.

Lawton, M.P. and Brody, E.M. (1969) ‘Assessment of older people: self-maintaining and instrumental activities of daily living’, The Gerontologist, 9(3_Part_1): 179-186

Lawton, M.P., Moss, M, Fulcomer, M. and Kleban, M.H. (1982) ‘A research and service oriented multilevel assessment instrument’, Journal of Gerontology, 37(1): 91-99

Le Gall, J.R., Lemeshow, S., Saulnier, F. (1993) ‘A new Simplified Acute Physiology Score (SAPS II) based on a European/North American multicentre study’, Journal of the American Medical Association, 270: 2957-2963

Lee, S.P., Dufek, J., Hickman, R. and Schuerman, S. (2016) 'Influence of procedural factors on the reliability and performance of the timed up-and-go test in older adults' International Journal of Gerontology, 10(1): 37-42

Lei, T.L. and Church, R.L. (2010) 'Mapping transit-based access: integrating GIS, routes and schedules', International Journal of Geographical Information Science, 24(2): 283-304

Likert, R.A. (1932) 'A technique for the measurement of attitudes', Archives of Psychology, 140: 1-55

Linacre, J.M. (2002) Optimizing rating scale category effectiveness. Journal of Applied Measurement, 3(1): 85-106

Linacre, J.M. (2007) 'WINSTEPS Rasch measurement computer program: version 3.64.1', Chicago, Winsteps.com

Litman, T. (2003) 'Measuring transportation: Traffic, mobility, and accessibility', ITE Journal, 73(10): 28–32

Liu, S. and Zhu, X. (2004) 'An integrated GIS approach to accessibility analysis', Transactions in GIS, 8(1): 45-62

Llorens, L. A. (1991) 'Performance tasks and roles throughout the life span', Occupational therapy: Overcoming human performance deficits, 44-66

London Councils (2016), Disabled Freedom Pass information available from http://www.londoncouncils.gov.uk/services/freedom-pass/disabled-persons-freedom-pass. (accessed 05/11/2016)

Loprinzi, P.D., Swenor, B.K. and Ramulu, P.Y. (2015) 'Age-related macular degeneration is associated with less physical activity among US adults: cross-sectional study', PloS One, 10(5): e0125394

Lord, F.M. and Novick, M.R. (1968) 'Statistical theories of mental test scores', Reading, MA: Addison-Welsley Publishing Company

Lotery, A., Xu, X., Zlatava, G. and Loftus, J. (2007) 'Burden of illness, visual impairment and health resource utilisation of patients with neovascular age-related macular degeneration: results from the UK cohort of a five-country cross-sectional study', British Journal of Ophthalmology, 91(10): 1303-1307

Lovie-Kitchin, J., Mainstone, J. Robinson, J. and Brown, B. (1990) 'What areas of the visual field are important for mobility in low vision patients?' Clinical Vision Sciences, 5(3): 249-264

Lucas, K., Tyler, S. and Christodoulou, G. (2009) 'Assessing the "value" of new transport initiatives in deprived neighbourhoods in the UK', Transport Policy 16(3): 115-122

Lucas, K. (2012) 'Transport and social exclusion: Where are we now?' Transport policy, 20: 105-13

Mackett, R.L. and Titheridge, H. (2004) 'A methodology for the incorporation of social inclusion into transport policy', World Conference on Transport Research, Istanbul, Turkey

Mackett, R. L., Achuthan, A and Titheridge, H. (2008a) 'AMELIA: Making streets more accessible for people with mobility difficulties', Urban Design International, 13: 80-89

Mackett, R. L., Achuthan, K. and Titheridge, H. (2008b) 'AMELIA: A tool to make transport policies more socially inclusive', Transport Policy, 15: 325-412

Mackett, R., Achuthan, K. and Titheridge, H. (2010) 'Increasing accessibility cost-effectively for people who are socially excluded', Presentation at TRANSED: International Conference on Mobility and Transport for Elderly and Disabled Persons, Hong Kong, China

Mackett, R., Titheridge, H. and Achuthan, K. (2011) ‘A methodology for consulting the community about walking: AMELIA’, Paper written for the WALK, 21:12. Available at:
https://www.researchgate.net/profile/Roger_Mackett/publication/228437174_A_methodology_for_consulting_the_community_about_walking_AMELIA/links/00b7d51d58bc03ec6d000000.pdf (accessed 9/11/2016)

Mackett, R.L., Titheridge, H. and Achuthan, K; (2012) ‘The impact of changes in access to local facilities on the wellbeing of elderly and disabled people’, Presentation at TRANSED: International Conference on Mobility and Transport for Elderly and Disabled Persons, Delhi, India

Mallinson, T. (2007) ‘Why measurement matters for measuring patient vision outcomes’, Optometry and Vision Science, 84(8): 675-682

Mangione, C.M., Phillips, R.S. and Seddon, J.M., (1992) ‘Development of the Activities of Daily Vision Scale: A measure of visual functional status’, Medical Care, 30: 1111–26

Mangione, C.M., Gutierrez, P.R., Lowe, G., Orav, E.J. and Seddon, J.M. (1999) ‘Influence of age-related maculopathy on visual functioning and health-related quality of life’, American Journal of Ophthalmology, 128(1): 45-53

Mangione, C.M., Lee, P.P., Gutierrez, P.R., Spritzer, K., Berry, S. and Hays, R.D. (2001). Development of the 25-list-item national eye institute visual function questionnaire’, Archives of Ophthalmology, 119(7): 1050-1058

Marshall, J.C., Cook, D.J. and Christou, N.V. (1995) ‘Multiple Organ Dysfunction Score: A reliable descriptor of a complex clinical outcome’, Critical Medicine Care, 23(10): 1638-1652

Marston, J.R., Church, R.L. (2005) ‘A relative access measure to identify barriers to efficient transit use by persons with visual impairments’, Disability Rehabilitation, 27(13): 769-79

Marston, J.R. and Golledge, R.G. (2003) 'The hidden demand for activity participation and travel by persons who are visually impaired or blind', Journal of Visual Impairment and Blindness, 97(8): 475-488

Massof, R.W. (1995) 'A systems model for low vision rehabilitation I: Basic concepts', Optometry & Vision Science, 72(10): 725-736

Massof, R.W. (1998) 'A systems model for low vision rehabilitation II: Measurement of vision disabilities', Optometry & Vision Science, 75(5): 349-373

Massof, R.W. (2002) 'The measurement of vision disability' Optometry and Vision Science, 79(8): 516-552

Massof, R. W., Deremeik, J. T., Park, W. L. and Grover, L. L. (2007) 'Self-reported importance and difficulty of driving in a low-vision clinic population', Investigative ophthalmology & visual science, 48(11): 4955-4962

Massof, R.W. and Rubin, G.S. (2001) 'Visual function assessment questionnaires', Survey of Ophthalmology, 45(6): 531-548

Mathie, M.J., Basilakis, J. and Celler, B.G. (2001) 'A system for monitoring posture and physical activity using accelerometers', In Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd annual international conference of the IEEE, 4: 3654-3657

Mathie, M.J., Coster, A.C., Lovell, N.H. and Celler, B.G. (2004) 'Accelerometry: providing an integrated, practical method for long-term, ambulatory monitoring of human movement', Physiological Measurement, 25(2): R1

Mathew, R.S., Delbaere, K., Lord, S.R., Beaumont, P. and Madigan, M.C. (2011) 'Depressive symptoms and quality of life in people with age-related macular degeneration', Ophthalmic and Physiological Optics, 31(4), 375-380

Matthews, S.A. and Yang, T.C. (2013) ‘Spatial Polygamy and Contextual Exposures (SPACEs) Promoting Activity Space Approaches in Research on Place And Health’, American Behavioral Scientist, 57(8): 1057-1081

Matthews, H., Beale, L., Picton, P. and Briggs, D. (2003) ‘Modelling Access with GIS in Urban Systems (MAGUS): capturing the experiences of wheelchair users’, Area, 35(1): 34-45

Mavoa, S., Witten, K., McCreanor, T. and O’Sullivan, D. (2012) ‘GIS based destination accessibility via public transit and walking in Auckland, New Zealand’, Journal of Transport Geography, 20(1): 15-22

May, D., Nayak, U.S.L. and Isaacs, B. (1985) ‘The Life-Space Diary: a measure of mobility in old people at home’, International Rehabilitation Medicine, 7(4):182-186

Maynard, A. (2009) ‘Can measuring the benefits of accessible transport enable a seamless journey?’ Journal of Transport and Land Use, 2(2): 21-30

McCormack, G.R., Giles-Corti, B. and Bulsara, M. (2008) ‘The relationship between destination proximity, destination mix and physical activity behaviors’, Preventive Medicine, 46(1): 33-40

McDowell I. (2006) ‘Measuring Health: A Guide to Rating Scales and Questionnaires’, 3rd ed. New York: Oxford University Press

Meadows, K.A. (2011) ‘Patient-reported outcome measures: an overview’. British Journal of Community Nursing, 16(3): 146-51

Merbitz, C., Morris, J. and Grip, J.C. (1989) ‘Ordinal scales and foundations of misinference’, Archives of Physical Medicine and Rehabilitation, 70(4), 308-312

Metz D. (2003) ‘Transport policy for an ageing population’, Transport Reviews, 23(4): 375-86

Metz, D. (2008) ‘The myth of travel times saving’, Transport Reviews, 28(30): 321-336

Mitchell, J. and Bradley, C. (2006) ‘Quality of life in age-related macular degeneration: a review of the literature’, Health and Quality of Life Outcomes, 4(1), 97

Molen, H.H., Rothengatter, J.A. and Vinje, M.P. (1981) ‘Blueprint of an Analysis of the Pedestrian’s Task’, Accident Analysis & Prevention, 13(3): 175-191

Mollenkopf, H., Baas, S., Marcellini, F., Oswald, F., Ruoppila, I., Széman, Z., Tacken, M. and Wahl, H.M. (2005) ‘A new concept of out-of-home mobility’, in: Mollenkopf, H., Marcellini, F., Ruoppila, I., Széman, Z., Tacken, M. (Eds.) ‘Enhancing mobility in later life. Personal coping, environmental resources and technical support. The out-of-home mobility of older adults in urban and rural regions of five European countries’. IOS Press, Amsterdam: 257–277

Mönestam, E. and Wachtmeister, L. (1999) ‘Impact of cataract surgery on visual acuity and subjective functional outcomes: a population-based study in Sweden’, Eye (London), 13(6): 711-719

Montarzino, A., Robertson, B., Aspinall, P., Ambrecht, A., Findlay, C., Hine, J. and Dhillon, B. (2007) ‘The impact of mobility and public transport on the independence of visually impaired people’, Visual Impairment Research, 9(2-3): 67-82

Murakami, E. and Wagner, D.P. (1999) ‘Can using global positioning system (GPS) improve trip reporting?’ Transportation Research, 7(2–3): 149–165

Nguyen, A.M., Arora, K.S., Swenor, B.K, Freidman, D.S., and Ramulu, P.Y. (2015) ‘Physical activity restriction in age-related eye disease: a cross-sectional study exploring fear of falling as a potential mediator’, BMC Geriatrics, 12(15): 64

Noe, G., Borth, J.F., Lamoureux, E., Franzco, J.R. and Keefe, J. E. (2003) ‘Associations between glaucomatous visual field loss and participation in activities of daily living’, Clinical and Experimental Ophthalmology, 31(6): 482-486

Nussbaum, M.C. (2000) ‘Women and Human Development: The Capabilities Approach’, Cambridge, Cambridge University Press

Office for Disability Issues (ODI) (2010) Family Resources Survey 2010

Office for Disability Issues (ODI) (2011) ONS Opinions Survey 2011

O'Sullivan, D., Morrison, A. and Shearer, J. (2000) ‘Using Desktop GIS for the Investigation of Accessibility by Public Transport: An Isochrone Approach’, International Journal of Geographical Information Science, 14(1): 85-104

Owen, C.G., Fletcher, A.E., Donoghue, M., Rudnicka, A.R. (2003) ‘How big is the burden of visual loss caused by age-related macular degeneration in the United Kingdom?’ British Journal of Ophthalmology, 87(3): 312-7

Owen, C.G., Jarrar, Z., Wormald, R., Cook, D.G., Fletcher, A.E. and Rudnicka, A.R. (2012) ‘The estimated prevalence and incidence of late stage age related macular degeneration in the UK’, British Journal of Ophthalmology, 96(5): 752-756

Páez, A., Scott, D., Potoglou, D., Kanaroglou, P. and Newbold, K.B. (2007) ‘Elderly mobility: demographic and spatial analysis of trip making in the Hamilton CMA, Canada’, Urban Studies, 44(1): 123-146

Palei, S.K., and Das, S.K. (2009) ‘Logistic regression model for prediction of roof fall risks in bord and pillar workings in coal mines: An approach’, Safety Science, 47(1): 88–96

Pallant, J.F. and Tennant, A. (2007) 'An introduction to the Rasch measurement model: an example using the Hospital Anxiety and Depression Scale (HADS)', British Journal of Clinical Psychology, 46(1): 1-18

Palmer, J.R. Espenshade, T.J., Bartumeus, F., Chung, C.Y., Ozgencil, N.E. and Li, K. (2013) 'New approaches to human mobility: Using mobile phones for demographic research', Demography, 50(3): 1105-1128

Pavey, S., Dodgson, A., Douglas, G and Clements, B. (2009) 'Travel, Transport, and Mobility of people who are blind and partially sighted in the UK: Final report for the RNIB', University of Birmingham, UK.

Pavlovskaya, M. (2006) 'Theorizing with GIS: a tool for critical geographies?', Environment and Planning A, 38(11): 2003-2020

Peel, C., Sawyer-Baker, P., Roth, D.L., Brown, C. J., Bodner, E. V. and Allman, R.M. (2005) 'Assessing Mobility in older Adults: The UAB Study of Aging Life-Space Assessment', Journal of the American Physical Therapy Association, 85(10): 1008-1019

Peng, C.Y.J., Lee, K. L. and Ingersoll, G. M. (2002) 'An introduction to logistic regression analysis and reporting', The Journal of Educational Research, 96(1): 3-14

Pesudovs, K. (2006) 'Patient-centred measurement in ophthalmology–a paradigm shift', BMC ophthalmology, 6(1): 25

Pesudovs, K. and Coster, D.J. (1998) 'An instrument for assessment of subjective visual disability in cataract patients', British Journal of Ophthalmology, 82(6): 617-624

Pesudovs, K., Garamendi, E., Keeves, J.P. and Elliott, D.B. (2003) 'The Activities of Daily Vision Scale for cataract surgery outcomes: re-evaluating validity with Rasch analysis', Investigative Ophthalmology & Visual Science, 44(7): 2892-2899

Pesudovs, K., Burr, J.M., Harley, C. and Elliott, D.B. (2007) ‘The development, assessment, and selection of questionnaires’, Optometry and Vision Science, 84(8): 663-674

Podsiadlo, D. and Richardson, S. (1991) ‘The timed: “Up & Go”: a test of basic functional mobility for frail and elderly persons’, Journal of the American Geriatrics Society, 39(2): 142-148

Popescu, M.L., Boisjoly, H., Schmaltz, H., Kergoat, M.J., Rousseau, J., Moghadaszadeh, S., Djafari, F. and Freeman, E.E. (2011) ‘Age-related eye disease and mobility limitations in older adults’, Investigative Ophthalmology & Visual Science, 52(10): 7168-7174

Portegijs, E., Iwarsson, S., Rantakokko, M., Viljanen, A. and Rantanen, T. (2014) ‘Life-space mobility assessment in older people in Finland; measurement properties in winter and spring’, BMC research notes, 7(1), 323

Portegijs, E., Rantakokko, M., Viljanen, A., Sipilä, S. and Rantanen, T. (2016) ‘Identification of older people at risk of ADL disability using the life-space assessment: a longitudinal cohort study.’ Journal of the American Medical Directors Association, 17(5): 410-414

Prager, T.C., Chuang, A.Z., Slater, C.H., Glasser, J.H. and Ruiz, R.S. (2000) ‘The Houston vision assessment test (HVAT): an assessment of validity’, Ophthalmic Epidemiology, 7(2): 87-102

Preston, C.C. and Colman, A.M. (2000) ‘Optimal number of response categories in rating scales: reliability, validity, discriminating power, and respondent preferences’, Acta Psychologica, 104(1): 1-15

Prieto, L., Alonso, J. and Lamarca, R. (2003) ‘Classical test theory versus Rasch analysis for quality of life questionnaire reduction’, Health and Quality of Life Outcomes, 1(1): 27

Quigley, H.A. and Broman, A.T. (2006) ‘The number of people with glaucoma worldwide in 2010 and 2020’. British Journal of Ophthalmology, 90(3): 262-267

Ramrattan, R.S., Wolfs, R.C., Panda-Jonas, S., Jonas, J.B., Bakker, D., Pols, H.A., Hofman, A. and de Jong, P.T. (2001) ‘Prevalence and causes of visual field loss in the elderly and associations with impairment in daily functioning: the Rotterdam Study’, Archives of Ophthalmology, 119(12): 1788-1794

Ramulu, P.Y., Maul, E., Hochberg, C., Chan, E.S., Ferrucci, L. and Friedman, D.S. (2012). ‘Real-world assessment of physical activity in glaucoma using an accelerometer’, Ophthalmology, 119(6), 1159-1166

Rasch, G. (1980) ‘Probabilistic Models for Some Intelligence and Attainment Tests’, Chicago, MESA Press

Reuben, D.B. and Siu, A.L. (1990) ‘An objective measure of physical function of elderly outpatients’, Journal of the American Geriatrics Society, 38(10): 1105-1112

Rovner, B.W., Casten, R.J. and Tasman, W.S. (2002) ‘Effect of depression on vision function in age-related macular degeneration’, Archives of Ophthalmology, 120(8): 1041–410

Rovner, B.W., Casten, R.J., Hegel, M.T., Massof, R.W., Leiby, B.E., Ho, A.C. and Tasman, W.S. (2014) ‘Low vision depression prevention trial in age-related macular degeneration: a randomized clinical trial’, Ophthalmology, 121(11): 2204-2211

Rozzini, R., Frisoni, G.B., Ferrucci, L., Barbisoni, P., Bertozzi, B. and Trabucchi, M. (1997) ‘The effect of chronic diseases on physical function. Comparison between activities of daily living scales and the Physical Performance Test’, Age and Ageing, 26(4): 281-287

Rubin, G.S., West, S.K., Munoz, B., Bandeen-Roche, K., Zeger, S., Schein, O. and Fried, L.P. (1997) ‘A comprehensive assessment of visual impairment in a population of older Americans: The SEE Study, Salisbury Eye Evaluation Project', Investigative Ophthalmology & Visual Science, 38(3): 557-568

Ryan, B. and Culham, L. (1999) 'Fragmented Vision: Survey of low vision services in the UK', London, Royal National Institute for the Blind

Sengupta, S., Nguyen, A.M., Van Landingham, S.W., Solomon, S.D., Do, D.V., Ferrucci, L., Friedman, D.S. and Ramulu, P.Y. (2015) 'Evaluation of real-world mobility in age-related macular degeneration', BMC Ophthalmology, 15(1), 9

Shah, R.C., Maitra, K., Barnes, L.L., James, B.D., Leurgans, S. and Bennett, D.A. (2012) 'Relation of driving status to incident life space constriction in community-dwelling older persons: a prospective cohort study', Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences, 67(9): 984-989

Shergold, I. and Parkhurst, G. (2012) 'Transport-related social exclusion amongst older people in rural Southwest England and Wales', Journal of Rural Studies, 28(4): 412-21

Sikkes, S. A., De Lange-de Klerk, E.S., Pijnenburg, Y.A. and Scheltens, P. (2009) 'A systematic review of Instrumental Activities of Daily Living scales in dementia: room for improvement', Journal of Neurology, Neurosurgery & Psychiatry, 80(1): 7-12

Slakter, J.S. and Stur, M. (2005) 'Quality of life in patients with age-related macular degeneration: impact of the condition and benefits of treatment', Survey of Ophthalmology, 50(3): 263-273

Sloane, M.E., Ball, K., Owsley, C., Bruni, J.R. and Roenker, D.L. (1992) 'The Visual Activities Questionnaire: developing an instrument for assessing problems in everyday visual tasks', Technical Digest, Noninvasive Assessment of the Visual System, 1, 26-29

Smith, W., Mitchell, P. and Wang, J.J. (1997) ‘Gender, oestrogen, hormone replacement and age-related macular degeneration: Results from the Blue Mountains Eye Study’, Australian and New Zealand journal of ophthalmology, 25(4): 13-15

Smith, W., Assink, J., Klein, R., Mitchell, P., Klaver, C.C., Klein, B.E. and De Jong, P.T. (2001) ‘Risk factors for age-related macular degeneration: pooled findings from three continents’, Ophthalmology, 108(4): 697-704

Snih, S.A., Peek, K.M., Sawyer, P., Markides, K.S., Allman, R.M. and Ottenbacher, K.J. (2012) ‘Life space mobility in Mexican Americans aged 75 and older’, Journal of the American Geriatrics Society, 60(3), 532-537

Spaulding, S.J., Patla, A.E., Elliott, D.B., Flanagan, J., Rietdyk, S. and Brown, S. (1994) ‘Waterloo Vision and Mobility Study: gait adaptations to altered surfaces in individuals with age-related maculopathy’, Optometry and Vision Science: Official Publication of the American Academy of Optometry, 71(12), 770-777

Spearman, C. (1904). ‘"General Intelligence," objectively determined and measured’, The American Journal of Psychology, 15(2), 201-292

Spector, W.D., Katz, S., Murphy, J.B. and Fulton, J.P. (1987) ‘The hierarchical relationship between activities of daily living and instrumental activities of daily living’, Journal of Chronic Diseases, 40(6): 481-9

Stein, J.D., Brown, M.M. and Brown, G.C. (2003) ‘Quality of life with macular degeneration: perceptions of patients, clinicians, and community members’, British Journal of Ophthalmology, 87(1): 8-12

Stein, J.D. (2004) ‘Disparities between ophthalmologists and their patients in estimating quality of life’, Current Opinion in Ophthalmology, 15(3): 238-43

Steinberg, E.P., Tielsch, J.M., Schein, O.D., Javitt, J.C., Sharkey, P., Cassard, S.D., Legro, M.W., Diener-West, M., Bass, E.B., Damiano, A.M., Sommer, A. and

Steinwachs, D.M. (1994) 'The VF-14: an index of functional impairment in patients with cataract' Archives of Ophthalmology, 112(5): 630-638

Stelmack, J.A., Szlyk, J.P., Stelmack, T.R., Demers-Turco, P., Williams, R.T. and Massof, R.W. (2006) 'Measuring outcomes of vision rehabilitation with the veterans' affairs low vision visual functioning questionnaire', Investigative Ophthalmology & Visual Science, 47(8): 3253-3261

Stevenson, M.R., Hart, P.M., Montgomery, A.M., McCulloch, D.W. and Chakravarthy, U. (2004) 'Reduced vision in older adults with age related macular degeneration interferes with ability to care for self and impairs role as carer', British Journal of Ophthalmology, 88(9), 1125-1130

Strano, M. and Colosimo, B.M. (2006) 'Logistic regression analysis for experimental determination of forming limit diagrams', International Journal of Machine Tools and Manufacture, 46(6): 673–682

Subhi, Y. and Sørensen, T.L. (2016) 'Physical activity patterns in patients with early and late age-related macular degeneration', Danish Medical Journal, 63(11), A5303

Sugiyama, T. and Thompson, C.W. (2007) 'Measuring the quality of the outdoor environment relevant to older people's lives', in W.C. Thompson and P. Travlou (Eds) Open Space - People Space: 153-162, London, Taylor & Francis

Suzuki, Y., Kodama, K., Takahashi, F. and Nitta, Y. (2007) 'Study on application of the socioeconomic evaluation technique to traffic barrier-free improvement/development projects', in 11th International Conference on Mobility and Transport for Elderly and Disabled Persons (TRANSED) Transport Canada, Transportation Research Board

Szabo, S.M., Janssen, P.A., Khan, K., Potter, M.J. and Lord, S.R. (2008) 'Older Women with Age Related Macular Degeneration Have a Greater Risk of Falls: A

Physiological Profile Assessment Study', Journal of the American Geriatrics Society, 56(5): 800-807

Szlyk, J.P., Arditi, A. and Coffey-Bucci, P. (1990) 'Self-report in functional assessment of low vision', Journal of visual impairment & blindness American Foundation for the Blind, 84(2): 61-66

Taxicard website (2016) available at: http://www.taxicard.org.uk/. (accessed 05/11/2016)

Tennant, A. and Conaghan, P.G. (2007) 'The Rasch measurement model in rheumatology: what is it and why use it? When should it be applied, and what should one look for in a Rasch paper?' Arthritis Care & Research, 57(8): 1358-1362

Tham, Y.C., Li, X., Wong, T.Y., Quigley, H.A., Aung, T., & Cheng, C.Y. (2014) 'Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis', Ophthalmology, 121(11): 2081-2090

Thomas, V.S., Rockwood, K. and McDowell, I. (1998) 'Multidimensionality in instrumental and basic activities of daily living', Journal of clinical epidemiology, 51(4): 315-21

Thoreau, R. and Tyler, N. (2008) 'Moving Forward: The Debate Over Accessibility and Capabilities', Research report submitted to UK Department for Transport

Thornton, P.R., Williams, A.M. and Shaw, G. (1997) 'Revisiting Time-Space Diaries: An Exploratory Case Study of Tourist Behaviour in Cornwall, England', Environment and Planning A, 29(10): 1847-1867

Titheridge, H., Achuthan, K., Mackett, R. and Solomon, J. (2009) 'Assessing the extent of transport social exclusion among the elderly.' Journal of Transport and Land Use, 2(2): 31-48

Titheridge, H., Mackett, R. and Achuthan, K. (2010) ‘A comparison of accessibility as measured by planners and accessibility as experienced by older people and those with disabilities’, TRANSED International Conference on Mobility and Transport for Elderly and Disabled Persons, Hong Kong, China

Titheridge, H. and Solomon, J. (2007) ‘Benchmarking Accessibility for Elderly Persons’, TRANSED International Conference on Mobility and Transport for Elderly and Disabled Persons, Montreal, Canada

Transport Research Laboratory (2006) Street Mobility Audit Tool, available at www.trl.co.uk. (accessed 05/11/2016)

Transport for London (2016) ‘Travel in London, Report 9’. Available at http://content.tfl.gov.uk/travel-in-london-report-9.pdf (accessed 9/11/2017)

Turano, K, A., Broman, A, T., Bandeen-Roche, K., Munoz, B., Rubin, G. and Sheila, K. (2004) ‘Association of Visual Field Loss and Mobility Performance in Older Adults: Salisbury Eye Evaluation Study’, Optometry & Vision Science, 81(5): 298-307

Turano, K,A., Geruschat, D.R., Stahl, J.W. and Massof, R.W. (1998) ‘Perceived Visual Ability for Independent Mobility in Persons with Retinitis Pigmentosa’, Investigative Ophthalmology & Visual Science, 40(5): 865-877

Turano, K.A., Massof, R.W. and Quigley, H.A. (2002) ‘A Self-Assessment Instrument Designed for Measuring Independent Mobility in RP Patients: Generalizability to Glaucoma Patients’, Investigative Ophthalmology & Visual Science, 43(9): 2874-2880

Turano, K.A., Rubin, G. S. and Quigley, H.A. (1999) ‘Mobility performance in glaucoma’, Investigative Ophthalmology and Visual Science, 40(12): 2803-2809

Turano, K., and Schuchard, R.A. (1991) ‘Space perception in observers with visual field loss’, Clinical Vision Sciences, 6(4): 289-299

Tyler, N.A. (2002) ‘Accessibility and the bus system’, London, Thomas Telford.

Tyler, N.A. (2006) ‘Capabilities and radicalism: Engineering accessibility in the 21st century’, Transport Planning and Technology, 29(5), 331-358

Üstün, T., Kostanjsek, N., Chatterji, S. and Rehm, J. (2010) ‘Measuring Health and Disability: Manual for WHO Disability Assessment Schedule WHODAS 2.0’, Malta, WHO Press

Van Landingham, S.W., Massof, R.W., Chan, E., Friedman, D. S., & Ramulu, P.Y. (2014) ‘Fear of falling in age-related macular degeneration’, BMC ophthalmology, 14(1): 10

Verghese, J., LeValley, A., Hall, C.B., Katz, M.J., Ambrose, A.F. and Lipton, R.B. (2006) ‘Epidemiology of gait disorders in community-residing older adults’, Journal of the American Geriatrics Society, 54(2): 255-261

Viswanathan, M., Bergen, M., Dutta, S. and Childers, T. (1996) ‘Does a single response category in a scale completely capture a response?’, Psychology and Marketing, 13(5): 457-479

Weih, L.M., Hassell, J.B. and Keeffe, J. (2002) ‘Assessment of the impact of vision impairment’, Investigative Ophthalmology & Visual Science, 43(4): 927-935

West, S.K., Munoz, B. and Rubin, G.S. (1997) ‘Function and visual impairment in a population-based study of older adults’, Investigative Ophthalmology and Visual Science, 38: 72–82

Wilcox, D.T. and Burdett, R., (1989) ‘Contrast sensitivity function and mobility in elderly patients with macular degeneration’, Journal of the American Optometry Association, 60(7): 504-507

Williams, R.A., Brody, B.L. and Thomas, R.G. (1998) ‘The psychosocial impact of macular degeneration’, Archives of Ophthalmology, 116(4): 514–20

Willis, J.R., Vitale, S.E., Agrawal, Y. and Ramulu, P.Y. (2013) ‘Visual impairment, uncorrected refractive error, and objectively measured balance in the United States’, JAMA Ophthalmology, 131(8): 1049-1056

Wolfson, L., Whipple, R., Amerman, P. and Tobin, J.N. (1990) ‘Gait assessment in the elderly: a gait abnormality rating scale and its relation to falls’, Journal of Gerontology, 45(1): M12-M19

Wong, W.L., Su, X., Li, X., Cheung, C.M.G., Klein, R., Cheng, C.Y. and Wong, T.Y. (2014) ‘Global prevalence of age-related macular degeneration and disease burden projection for 2020 and 2040: a systematic review and meta-analysis’, The Lancet Global Health, 2(2): 106-116

Wood, J.M., Lacherez, P., Black, A.A., Cole, M.H., Boon, M.Y. and Kerr, G.K. (2011) ‘Risk of falls, injurious falls, and other injuries resulting from visual impairment among older adults with age-related macular degeneration’, Investigative ophthalmology & visual science, 52(8): 5088-5092

World Health Organization (2001), ‘International Classification of Functioning, Disability and Health, ICF’, World Health Organisation.

Xue, Q.L., Fried, L.P., Glass, T.A., Laffan, A. and Chaves, P.H. (2007) ‘Life-space constriction, development of frailty, and the competing risk of mortality: the Women's Health and Aging Study I’, American Journal of Epidemiology, 167(2): 240-248

Zeitler, E. and Buys, L. (2015) ‘Mobility and out-of-home activities of older people living in suburban environments: ‘Because I'm a driver, I don't have a problem'’, Ageing & Society, 35(4): 785-808

Chapter 13 Appendix

Appendix 1: Transport Difficulty Survey I

This survey is part of a research project at University College London. The aim of this project is to understand how low vision and mobility problems affect public transport navigation. This will help us understand how we can improve transport accessibility and overall quality of life for those with low vision and reduced mobility. This research is supervised by Professor Gary Rubin from the Institute of Ophthalmology and Moorfields Eye Hospital and Dr Taku Fujiyama from University College London.

This questionnaire is separated into four parts. The first two parts of the questionnaire are related to modes of public transport. The third part addresses how far you travel and how many times you leave your home. The final part is a section about you and your level of vision. Please answer as many questions as you can. All information provided in this questionnaire will be strictly confidential and will not be passed onto anyone else.

If you have any difficulty reading this form or would like to give your answers by phone please contact Natalie Chan.

We would be grateful if you could return this survey at your earliest convenience. Thank you for giving your time to help with this research project, helping us to better understand this important aspect of daily life.

Natalie Chan (PhD research student)
Civil, Environmental and Geomatic Engineering Department, Chadwick Building,UCL, Gower Street, London WC1 6BT

Questionnaire Part 1

Directions: Read each mobility situation given below and circle the number which best expresses the level of difficulty you feel in the situation when using a normal level of assistance (e.g. cane, companion, guide dog, etc). On a scale of 1 to 5, 1 represents no difficulty and 5 represents extreme difficulty. N/A represents not applicable.

1. General Public Transport

1.1. How difficult do you find travelling to familiar areas?

1 2 3 4 5 N/A __

1.2. How difficult do you find travelling in unfamiliar areas?

1 2 3 4 5 N/A __

1.3. How difficult do you find moving about in crowded situations?

1 2 3 4 5 N/A __

1.4. How difficult do you find travelling at night?

1 2 3 4 5 N/A __

---

2. Bus

2.1. Do you travel by bus? Yes No

If YES, please answer the questions below. If NO, go to question 3

2.2 Is it important for you to be able to use the bus?

Yes No

2.3. How frequently do you use the bus?

Less than once a week 1-3 times a week

4-6 times a week Daily

2.4 How difficult do you find getting to the bus stop?

1 2 3 4 5 N/A __

2.5. How difficult do you find reading bus numbers?

1 2 3 4 5 N/A __

2.6. How difficult do you find boarding the bus?

1 2 3 4 5 N/A __

2.7. How difficult do you find manoeuvring on the bus?

1 2 3 4 5 N/A __

2.8. How difficult do you find alighting the bus?

1 2 3 4 5 N/A __

---

3. Tube (London Underground)

3.1. Do you travel by tube? Yes No

If YES, please answer the questions below. If NO, go to question 4

3.2 Is it important for you to be able to use the tube?

Yes No

3.3. How frequently do you use the tube?

Less than once a week   1-3 times a week

4-6 times a week   Daily

3.4. How difficult do you find getting to the tube station?

1 2 3 4 5 N/A __

3.5. How difficult do you find navigating in the tube station?

1 2 3 4 5 N/A __

3.6. How difficult do you find using escalators in the tube station?

1 2 3 4 5 N/A __

3.7. How difficult do you find using stairs in the tube station?

1 2 3 4 5 N/A __

3.8. How difficult do you find reading tube arrival boards?

1 2 3 4 5 N/A __

3.9. How difficult do you find boarding the tube carriage?

1 2 3 4 5 N/A __

3.10. How difficult do you find manoeuvring inside the tube carriage?

1 2 3 4 5 N/A __

3.11. How difficult do you find alighting from the tube carriage?

1 2 3 4 5 N/A __

4. Train (Network Rail)

4.1. Do you travel by train? Yes No

If YES, please answer the questions below. If NO, go to question 5

4.2 Is it important for you to be able to use the train?

Yes No

4.3. How frequently do you use the train?

Less than once a week 1-3 times a week

4-6 times a week Daily

4.4. How difficult do you find getting to the train station?

1 2 3 4 5 N/A __

4.5. How difficult do you find navigating in the train station?

1 2 3 4 5 N/A __

4.6. How difficult do you find using escalators in the train

1 2 3 4 5 N/A __

4.7. How difficult do you find using stairs in the train station?

1 2 3 4 5 N/A __

4.8. How difficult do you find reading train arrival boards?

1 2 3 4 5 N/A __

4.9. How difficult do you find boarding the train carriage?

1 2 3 4 5 N/A __

4.10. How difficult do you find manoeuvring inside the train carriage?

1 2 3 4 5 N/A __

4.11. How difficult do you find alighting the train carriage?

1 2 3 4 5 N/A __

Questionnaire Part 2

1. List three things that cause you the most stress when using private or public transport:

……………..…………………………………………………………………..
………………………………………………………………………………….
………………………………………………………………………………….

2. Do you own a Taxicard? Yes No

3. Do you have a freedom pass? Yes No

4. Do you have any other health problems that contribute to limitations in getting around?

Yes No

If yes, please (specify)

....……………………………………………..
………………………………………………………………………….
………………………………………………………………………….

5. Do you limit travel by yourself due to your vision loss?

Yes No

6a. How often do you ask someone to accompany you when you leave your house?

Always Usually

Sometimes Never

6b. If so, who accompanies you?

…………………………………………………………………………….

7. Are you satisfied with your current level of travel?

Yes No

8. Have you ever had any kind of training to help you use public transport? If so, please provide details below:

……………………………………………………………………………………

……………………………………………………………………..………..

9. How do you plan your journey?

Online travel planning ☐

Contact transport organisations by telephone ☐

Ask a family member or friend for help ☐

Other (Please specify) ……………………………………………

10a. Do you use a mobility aid?

Guide Dog

Cane

Other (Please specify) ………………………….

10b. If so, in what situations?

Outdoors Indoors

Unfamiliar areas Other (Please specify) ……..……….

11a. Do you believe that your ability to travel by yourself is less than that of people with normal vision?

Yes No

12b. If yes, in which situations?

Outdoors Indoors

Unfamiliar areas Other (Please specify) ……..……….

Questionnaire Part 3 - Life Space: this part of the questionnaire will address how frequently you travel on a regular basis

1a. Can you access other rooms in your home besides the room where you sleep?

Yes No

1b. How often do you access these rooms?

Less than once a week 1-3 times a week

4-6 times a week Daily

2a. Can you access areas outside your home such as your porch, deck or patio, hallway of an apartment building or your garden, driveway or garage?

Yes No

2b. How often do you access these areas?

Less than once a week 1-3 times a week

4-6 times a week Daily

3a. Can you access areas in your local neighbourhood, for example a local shop?

Yes No

3b. How often do you go there?

Less than once a week 1-3 times a week

4-6 times a week Daily

4a. Can you access places outside your own neighbourhood, but within your town?

Yes No

4b. How often did you access these places?

Less than once week 1-3 times a week

4-6 times a week Daily

5a. Can you access places outside your town?

Yes No

5b. How often do you travel outside your own town?

Less than once a week 1-3 times a week

4-6 times a week Daily

6. For each of these tasks, did you use aids, equipment or help from another person?

Personal assistance

Equipment only

No equipment or personal assistance required

Questionnaire Part 4 - About you: All information in this section is strictly confidential

Date of Birth: _ _ / _ _ / _ _ _ _

Are you: Male Female

Do you live alone? Yes No

Postcode:……………………………………………….……

Do you have problems with your vision? Yes No

If yes, please (specify)

....……………………………………………..

……………………………………………………………………………….

……………………………………………………………………………….

(Please turn over for the last page)

Visual Ability – Please tick the statements that are relevant to you when using your usual vision aid:

I cannot tell by the light where the windows are □

I cannot see the shapes of furniture in a room □

I cannot recognise a friend if close to his/her face □

I cannot recognise a friend who is at arm's length away □

I cannot read a newspaper headline □

I cannot read a large print book □

I cannot recognise a friend across a room □

I have difficulty recognising a friend across the road □

I have difficulty reading ordinary newspaper print □

I have full visual ability □

End of questionnaire

Thank you very much for taking part. Your participation is extremely important for us to find out more about this much neglected aspect of daily life.

Appendix II: Transport Survey II

This questionnaire takes approximately 5 minutes to complete and asks you to rate on a scale between 1 and 5, the difficulty you experience when completing certain transport tasks. You only need to fill in the sections for the transport modes you use. Please answer as many questions as you can.

All information provided in this questionnaire will **NOT** be linked to individual personal data and will be strictly confidential. Please do **NOT** write your name on this survey.

Thank you for giving your time to help us with this project

Tranzacct Client ID no.

(Clinical assessment)

Questionnaire Part 1

Directions: Read each mobility situation given below and circle the number that best expresses the level of difficulty you feel in the situation when using a normal level of assistance (e.g. mobility or visual aid). On a scale of 1 to 5, 1 represents no difficulty and 5 represents extreme difficulty. N/A represents not applicable.

Council A Transport Modes

1. Day Care Transport

1.1. Do you travel by Day Care Transport? Yes No

If YES, please answer the questions below. If NO, go to question 2

1.2. How frequently do you use Day Care Transport?

Less than once a week 1-3 times a week

4-6 times a week Daily

1.3. How difficult do you find getting in the vehicle?

1 2 3 4 5 N/A ___

☺ 😐 ☹

1.4. How difficult do you find moving inside the vehicle?

1 2 3 4 5 N/A ___

☺ 😐 ☹

1.5. How difficult do you find getting off the vehicle?

1 2 3 4 5 N/A ___

☺ 😐 ☹

---

2. ScootAbility

2.1. Do you travel by Scooter? Yes No

If YES, please answer the questions below. If NO, go to question 3

2.2. How frequently do you use a scooter?

Less than once a week 1-3 times a week

4-6 times a week Daily

2.3. How difficult do you find accessing a scooter?

1 2 3 4 5 N/A ___

☺ 😐 ☹

2.4. How difficult do you find getting on a scooter?

1 2 3 4 5 N/A ___

☺ 😐 ☹

2.5. How difficult do you find moving on a scooter?

1 2 3 4 5 N/A ___

☺ 😐 ☹

2.6. How difficult do you find charging a scooter?

1 2 3 4 5 N/A ___

☺ 😐 ☹

2.7. How difficult do you find getting off a scooter?

1 2 3 4 5 N/A ___

☺ 😐 ☹

---

3. Taxi / Black Cab

3.1. Do you travel by taxi / Black Cab? Yes No

If YES, please answer the questions below. If NO, go to question 4

3.2. How frequently do you travel by taxi / black cab?

Less than once a week 1-3 times a week

4-6 times a week Daily

3.3. How difficult do you find booking a taxi / black cab?

1 2 3 4 5 N/A ___

☺ 😐 ☹

3.4. How difficult do you find getting in a taxi / black cab?

1	2	3	4	5	N/A ___
☺		😐		☹	

3.5. How difficult do you find moving inside a taxi / black cab?

1	2	3	4	5	N/A ___
☺		😐		☹	

3.6. How difficult do you find getting off a taxi / black cab?

1	2	3	4	5	N/A ___
☺		😐		☹	

---

4. Minicab

4.1. Do you travel by minicab? Yes No

If YES, please answer the questions below. If NO, go to question 5

4.2. How frequently do you travel by minicab?

Less than once a week	1-3 times a week
4-6 times a week	Daily

4.3. How difficult much difficulty do you have finding a minicab?

1	2	3	4	5	N/A ___
☺		😐		☹	

4.4. How difficult do you find getting in a minicab?

1	2	3	4	5	N/A ___
☺		😐		☹	

4.5. How difficult do you find moving inside a minicab?

1	2	3	4	5	N/A ___
☺		😐		☹	

4.6. How difficult do you find getting off a minicab?

1	2	3	4	5	N/A ___
☺		😐		☹	

5. Carer Transport

5.1. Do you travel by carer transport? Yes No

If YES, please answer the questions below. If NO, go to question 6

5.2. How frequently do you travel by carer transport?

Less than once a week 1-3 times a week

4-6 times a week Daily

5.3. How difficult do you find organising carer transport?

1	2	3	4	5	N/A ___
☺		😐		☹	

5.4. How difficult do you find getting in the vehicle?

1	2	3	4	5	N/A ___
☺		😐		☹	

5.5. How difficult do you find moving inside the vehicle?

1	2	3	4	5	N/A ___
☺		😐		☹	

5.6. How difficult do you find getting off the vehicle?

1	2	3	4	5	N/A ___
☺		😐		☹	

---

6. Buddying/walking

6.1. Do you walk/use buddying? Yes No

If YES, please answer the questions below. If NO, go to question 7

6.2. How frequently do you walk / use buddying?

Less than once a week 1-3 times a week

4-6 times a week Daily

6.3. How difficult do you find organising buddying?

1 2 3 4 5 N/A ___

☺ 😐 ☹

6.4. How difficult do you find kerbs?

1 2 3 4 5 N/A ___

☺ 😐 ☹

6.5. How difficult do you find crossing the road?

1 2 3 4 5 N/A ___

☺ 😐 ☹

6.6. How difficult do you find walking along pavements?

1 2 3 4 5 N/A ___

☺ 😐 ☹

London Public Transport Modes

7. General Travel

7.1. How difficult do you find travelling to familiar areas?

1 2 3 4 5 N/A ___

☺ 😐 ☹

7.2. How difficult do you find travelling in unfamiliar areas?

1 2 3 4 5 N/A ___

☺ 😐 ☹

7.3. How difficult do you find moving about in crowded situations?

1 2 3 4 5 N/A ___

☺ 😐 ☹

7.4. How difficult do you find travelling at night?

1 2 3 4 5 N/A ___

☺ 😐 ☹

8. Bus (London Public Bus)

8.1. Do you travel by bus? Yes No

If YES, please answer the questions below. If NO, go to question 9

8.2. How frequently do you use the bus?

Less than once a week 1-3 times a week

4-6 times a week Daily

8.3. How difficult do you find getting to the bus stop?

1	2	3	4	5	N/A ___
☺		😐		☹	

8.4. How difficult do you find reading bus numbers?

1	2	3	4	5	N/A ___
☺		😐		☹	

8.5. How difficult do you find getting on the bus?

1	2	3	4	5	N/A ___
☺		😐		☹	

8.6. How difficult do you find moving on the bus?

1	2	3	4	5	N/A ___
☺		😐		☹	

8.7. How difficult do you find getting off the bus?

1	2	3	4	5	N/A ___
☺		😐		☹	

---

9. Tube (London Underground)

9.1. Do you travel by tube? Yes No

If YES, please answer the questions below. If NO, go to question 10

9.2. How frequently do you use the tube?

Less than once a week	1-3 times a week
4-6 times a week	Daily

9.3. How difficult do you find getting to the tube station?

1	2	3	4	5	N/A ___
☺		😐		☹	

9.4. How difficult do you find getting around the tube station?

1	2	3	4	5	N/A ___
☺		😐		☹	

9.5. How difficult do you find using escalators in the tube station?

1	2	3	4	5	N/A ___
☺		😐		☹	

9.6. How difficult do you find using stairs in the tube station?

1	2	3	4	5	N/A ___
☺		😐		☹	

9.7. How difficult do you find reading tube arrival boards?

1	2	3	4	5	N/A ___
☺		😐		☹	

9.8. How difficult do you find getting on the tube carriage?

1	2	3	4	5	N/A ___
☺		😐		☹	

9.9. How difficult do you find moving inside the tube carriage?

1	2	3	4	5	N/A ___
☺		😐		☹	

9.10. How difficult do you find getting off from the tube carriage?

1	2	3	4	5	N/A ___
☺		😐		☹	

10. Train (National Rail)

10.1. Do you travel by train? Yes No

If YES, please answer the questions below. If NO, go to Part 2

10.2. How frequently do you use the train?

Less than once a week	1-3 times a week
4-6 times a week	Daily

10.3. How difficult do you find getting to the train station?

1	2	3	4	5	N/A ___
☺		😐		☹	

10.4. How difficult do you find moving around the train station?

1	2	3	4	5	N/A ___
☺		😐		☹	

10.5. How difficult do you find using escalators in the train station?

1	2	3	4	5	N/A ___
☺		😐		☹	

10.6. How difficult do you find using stairs in the train station?

1	2	3	4	5	N/A ___
☺		😐		☹	

10.7. How difficult do you find reading train arrival boards?

1	2	3	4	5	N/A ___
☺		😐		☹	

10.8. How difficult do you find getting on the train carriage?

1	2	3	4	5	N/A ___
☺		😐		☹	

10.9. How difficult do you find moving inside the train carriage?

1	2	3	4	5	N/A ___
☺		😐		☹	

10.10. How difficult do you find getting off the train carriage?

1	2	3	4	5	N/A ___
☺		😐		☹	

Questionnaire Part 2

1. Do you own a Taxicard? Yes No

2. Do you have a freedom pass? Yes No

3. Do you limit travel by yourself due to your mobility/vision?
Yes No

4. Do you have any other health problems that contribute to limitations in getting around? Yes No

If Yes, Please specify

…………..…………………………………………………………

…………………………………………………………………………..

5a. How often do you ask someone to accompany you when you leave your house?

Always Usually

Sometimes Never

5b. If so, who accompanies you?

…………………………………………………………………………..

6. Are you satisfied with your current level of travel?

Yes No

7. Have you ever had any kind of training to help you use public transport? If so, please provide details below:

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………..

8. How do you plan your journey?

- ☐ Online travel planning
- ☐ Contact transport organisations by telephone
- ☐ Ask a family member or friend for help
- ☐ Other (Please specify) ……………………………..…

9a. Do you use a mobility aid?

Yes No

9b. If so, please specify:

Walking stick Crutch

Wheelchair Three wheeler

Other (Please specify): ………………………………..…

Questionnaire Part 3 - Life Space: this part of the questionnaire will address how frequently you travel on a regular basis

1a. Can you access other rooms in your home besides the room where you sleep? Yes No

1b. How often do you access these rooms?

Less than once a week 1-3 times a week

4-6 times a week Daily

2a. Can you access areas outside your home such as your porch, deck or patio, hallway of an apartment building or your garden, driveway or garage?

Yes No

2b. How often do you access these areas?

Less than once a week 1-3 times a week

4-6 times a week Daily

3a. Can you access areas in your local neighbourhood, for example a local shop? Yes No

3b. How often do you go there?

Less than once a week 1-3 times a week

4-6 times a week Daily

4a. Can you access places outside your own neighbourhood, but within your town?

Yes No

4b. How often do you access these places?

Less than once week | 1-3 times a week
4-6 times a week | Daily

5a. Can you access places outside the Borough of Council A?

Yes | No

5b. How often do you travel outside the Borough of Council A?

Less than once a week | 1-3 times a week
4-6 times a week | Daily

6. For each of these tasks, did you use aids, equipment or help from another person?

Personal assistance

Equipment only

No equipment or personal assistance necessary

Questionnaire Part 4 - About you: All information in this section will not be linked to individual data and is strictly confidential

Date of Birth: _ _ / _ _ / _ _ _ _

Are you: Male Female

Do you live alone? Yes No

Postcode:……………………………………………….

Do you have problems with your vision? Yes No

If yes, please specify below:

…………………………………………………………………………………

……………………………...

....

Visual Ability – Please tick the statements that are relevant to you:

I cannot tell by the light where the windows are ☐

I cannot see the shapes of furniture in a room ☐

I cannot recognise a friend if close to his/her face ☐

I cannot recognise a friend who is at arm’s length away ☐

I cannot read a newspaper headline ☐

I cannot read a large print book ☐

I cannot recognise a friend across a room ☐

I have difficulty recognising a friend across the road ☐

I have difficulty reading ordinary newspaper print ☐

I have full visual ability ☐

End of questionnaire

Thank you very much for taking part. Your participation is extremely important for us to find out more about this important aspect of daily life.