THE USE OF "BIG DATA" TO EVALUATE ACCESSIBILITY MEASURES FOR WHEELCHAIR AND MOBILITY SCOOTER USERS: THE CASE OF LONDON BUS NETWORK

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Abstract

As recognized by the Social Exclusion Unit poor transport access can contribute to the causes of social exclusion. People who require the use of a powered wheelchair or a mobility scooter in order to be able to carry out their daily activities are most likely to experience transport disadvantage, primarily due to architectural barriers present within the network that limit accessibility. Formulation of new policies is of primary importance to increase the transport network accessibility. Policy-making and evaluation are often based mainly on qualitative approaches. Although this can give a good appreciation of the users prospective, it fails to consider the more global impact that new and existing policies can have. The use of big datasets from automated fare collection systems could improve this aspect, allowing for a more quantitative approach to measuring accessibility measures. Furthermore these datasets could benefit from a more disaggregated classification to help categorise travel patterns and behaviour specific to wheelchairs and mobility scooter users.

Keywords: bus network, social exclusion, powered mobility users, automated fare collection systems, large datasets

1 Background

The presence of a functional and reliable transport system plays a fundamental role in the development of modern cities. It provides access to education, business, leisure, important goods and opportunities, contributing hugely to the well-being of the inhabitants. Public transport is one of the most important factors in the formulation of new plans and policies for urban development, due to considerations of sustainability and the service needs of people who do not own a private vehicle (Murray et al. 1998). For people with severe mobility impairments the ability of effectively use the public transport system is closely related to accessibility.
When a public transport system fails to provide for members of society, these members often become socially excluded. The concept of social exclusion is not clearly defined, but it is recognised to be a complex mix of many different aspects related to the individual, the local area and global economic policies. The report from the Social Exclusion Unit in 2003 established strong links between poor transport access and social disadvantage such as unemployment, poor education and health disadvantages. However social disadvantage and transport

disadvantage are not necessarily the same thing; they are independent elements that can interact and cause inaccessibility to goods and opportunities that in turn lead to social exclusion (Lucas 2012).
In 2006 the Department for Transport in the UK established the need, for local authorities, to include in the planning process an accessibility evaluation, with the aim of developing a more inclusive transport network (Grieco & Urry 2011).
However, the methods used to evaluate new policies and their implementation are often qualitative such as semi-structured interviews and focus groups. Although these approaches can provide accurate data on users perception and satisfaction in relation to different issues or policies, they fail to capture the broader impact that accessibility measures might have on the transport network usage. On the other hand, automated fare collection systems are collecting a vast array of quantitative data, which could provide a more quantitative approach to examine the effect of these policy decisions to the actual accessibility of the public transport system. This fact has the potential to redefine the problem by investigating its deeper cause, as it allows one to observe and analyse the actual passenger behaviour. The example of spatial analysis presented in this paper offers an interesting reflection point on the impact that different factors might or might not have on how disabled people interact with their local transport network.

2 Transport disadvantage

Transport disadvantage is a complex phenomenon often caused by the combined action of different factors. Church et al. (2000) identified seven categories of social and geographical factors, which have a negative impact on the transport system accessibility and consequentially on people well-being (see Table 1).

Category	Description
Physical Exclusion	Physical conditions can affect the ability of the person to effectively use the transport network. Examples are people with reduced mobility, learning disabilities, visual impairments or age related difficulties
Geographical exclusion	Longer commutes from place of living and workplaces or amenities can make them difficult to reach due to temporal or financial aspects
Exclusion from facilities	Lack of transport services within the area is likely to cause transport exclusion, particularly for people who do not own a car
Economic exclusion	Whenever low financial income affects the ability of a person to afford transport costs
Time based exclusion	When personal factors or duties reduce the time available for travelling. This phenomenon is particularly common among carers who lacks of an adequate social support network
Fear-based exclusion	Fear for personal safety can easily discourage individuals from using the transport network or other public spaces
Space exclusion	Space management can affect the perception and consequentially the use of public spaces and services.

Table 1: Factors of transport disadvantaged as identified by Church 2000 (p.198-200)

It is important to notice that it is rare to see phenomena within these categories occur singularly (Church et al. 2000). Coexisting factors are more likely to reduce or eliminate the use of public transport, leading to possible social exclusion. When considering the population of wheelchairs and mobility scooters users it is intuitive to identify aspects of physical exclusion as a starting point when trying to eliminate social disadvantage. However it is widely recognised that people affected by disability also have an average income that is 20% lower than non-disabled individuals of the same age (Jenkins & Rigg 2004). Additionally fear for personal safety or fear of anti-social behaviour is likely to discourage old people and those with disabilities from using public transport (Jolly et al. 2006). Geographical and logistic factors can also play a role. Specifically the first (from the house to a bus stop) and last mile (from bus stop to house) can present a challenge in their own right for individuals with severe mobility impairments. With a view to improving the accessibility and therefore reducing transport disadvantage of those with disabilities, TfL have introduced two schemes: The Mobility Aid Recognition Scheme (MARS) and the advertising campaign to highlight the rights of wheelchair users to the Wheelchair Priority Area (WPA). These will now be discussed in sections 2.1 and 2.2 respectively.

2.1 The London situation and the Mobility Aid Recognition Scheme

Transport for London (TfL) estimates that there are approximately 119,000 wheelchair users in the capital and a number of mobility scooters ranging between 11,700 and 43,000 (Transport for London 2014). People with disability have been found to travel an average of 30% less compared to non-disabled people. Although there is no specific data concerning the frequency of travel for wheelchair and mobility scooter users, the difference is likely to be much higher.

Since the diffusion of these new accessibility guidelines, Transport for London has adopted several measures through the years in order to improve the accessibility of its network. Introduction of low floor buses and trains, boarding ramps for the underground, accessible bus stops, step free stations, travel mentoring service and improved training concerning disability challenges for staff (Transport for London 2014).
Buses are the means of transport more commonly used by power mobility users within the public transport network (Transport for London 2012*c*). Reasons for this phenomenon can be found in the large proportion of low floor buses and accessible bus stops compared to other components of the TfL system, and in the greater diffusion of the bus network that causes "over 94 per cent of Londoners to live within 400 meters of a bus stop" (Transport for London 2013*b*) Despite the improved level of accessibility almost 60% of wheelchair users find it very difficult or impossible to use the bus network without help (Transport for London 2012*c*).
The access to TfL buses for powered wheelchairs and mobility scooters is regulated by a new Mobility Aid and Recognition Scheme (MARS). Launched in 2012, this scheme issues a permit card certifying that the mobility aid meets the criteria of class, size, weight and turning radius which allows safe boarding and position in the dedicated space.
The class of the wheelchair or scooter is determined following governmental guidelines regarding invalid carriages where:

- Class 1 includes manual wheelchairs
- Class 2 consists of powered wheelchairs and mobility scooters with a speed limit of 4 mph (6km/h) intended to be used on a pavement
- Class 3 contains mobility scooter with a speed limit of 8mph (12 km/h) and con be used on roads and/or footpaths (provided they respect the lower speed limit when used on the pavements).

Mobility aids suitable to be approved for the MARS card falls in Class 2, however devices included in Class 1 are free to apply if they wish. Dimensions for mobility aids allowed to board have to meet the following criteria:

- Electric wheelchairs: maximum width 700mm, maximum length 1200mm
- Mobility Scoter: maximum width 600mm, maximum length 1000mm, maximum turning radius 1200mm

Variations between dimensional limits for wheelchair and mobility scooters are due to differences concerning driving characteristics and wheelbases (Transport for London 2012*a*). Additionally, the ability of the user to board and safely position within the Wheelchair Priority Area (WPA) is evaluated through a journey accompanied by one of the travel mentors, often planned along of the usual route travelled by the user. This is due to the fact that the internal layouts of buses can vary within the standard permitted by regulations, and variations can affect the way wheelchair or scooter users will position themselves in the WPA. This in turn may create additional challenges whenever travelling on an unfamiliar route. Some users' feels that if the layout were to remain consistent among differing models of buses this will allow more freedom and confidence when travelling (Transport for London 2012*d*).

If the mobility aid meets the criteria mentioned above and the person is considered able to manoeuvre the device, the MARS card is automatically issued by the travel mentor. If the applicant fails the ability test, or succeeded but still does not feel comfortable when travelling, it is possible to require additional accompanied journeys with the Travel Mentoring Service, up to a maximum of ten journeys. Since the scheme was launched in July 2012, 385 inquiries have been made for a card, 292 of which were successful and 93 refused (J. Mamode TfL, personal communication January 6, 2015).

It is important to notice that the card is aimed to certify that a certain mobility aid and user are considered able to safely use the bus network, however it is not mandatory nor will it guarantee the access to a specific bus. The possibility to board on the bus will always be at the discretion of the bus driver, who will consider safety aspects and the availability of the WPA (Research Institute for Consumer Affairs 2013).

A report to evaluate the impact of the Mobility Aid Recognition Scheme was carried out by TfL in August 2013. Sixty-nine car holders and bus drivers from two different garages were interviewed in order to assess level of satisfaction with the application process, effectiveness of the scheme as perceived by users, awareness of the scheme among drivers, issues and difficulties of bus travelling for powered mobility users and eventual room for improvements (Transport for London 2013*a*). From the data collected, MARS seems to have had a positive impact on users so far, holders are generally satisfied with the card, 72% feels that it has increased their confidence in using the bus network and over 80% found the application process easy and reasonably quick (Transport for London 2013*a*).However less than 60% of holders declared that drivers recognised their cards most of the times and 30% were still not allowed on board a bus, with no clear reason given. Additionally 65% of users stated to have encountered difficulties concerning the occupation of the WPA (Transport for London 2013*a*). Both drivers and users said the MARS should be better advertised and given a bigger role in training (Transport for London 2013*a*). Additionally the use of labels on the mobility aid or making the card more personalised through a personal photo or details of the scooter was suggested, by drivers, as a measure against possible frauds (Transport for London 2013*a*).

2.2 Wheelchair Priority Area (WPA)

In 2012 TfL undertook research in order to understand and reduce the conflicts often related with the entitlement of the WPA. The study was conducted in two sections, the first consisted of ninety minute discussions with separate groups of wheelchair users, buggy users and bus drivers. The aim was to understand the different points of view voiced and to capture the difficulties encountered. Subsequently two-hour workshops were carried out with a mixed audience to increase the cooperation among the groups and identify effective strategies to reduce conflicts. Research findings seem to suggest that there are mainly three challenges shared among all group of participants: anxieties, practical issues and uncertainty about rights and rules. Stress and anxieties are mainly related to the attitude of other passengers for buggy and wheelchairs users, and the necessity to have to mediate or solve emerging conflicts, for bus drivers. Practical issues concern the possibility of not being able to board, use of the ramps and positioning in the wheelchair/buggy space particularly during peak hours when the vehicle might be crowded (Transport for London 2012*b*). Uncertainty is related to the actual rules and rights concerning the occupation of the space and the role of the drivers in enforcing this (Transport for London 2012*b*). It was highlighted, that across all groups the lack of clarity and consistency in the communication and application of the rule are the biggest cause of stress and defensive behaviour which could lead to conflicts (Transport for London 2012*b*). Data obtained from this study led to the launch of the "Wheelchair priority space campaign". The campaign was aimed to clarify the wheelchairs users rights to claim the dedicated space when needed as "It is the only place in which a wheelchair user can safely travel", while promoting more cooperative behaviour from other passengers (Transport for London 2012*d*). It is unclear how affective this campaign has been.

3 A "big datasets" approach on quantifying policy implementation effectiveness

It is clear from these examples that TfL are implementing changes to the network with aim of making it more accessible. However, the interventions have not been ubiquitously implemented. In fact it is difficult to know exactly when and where the interventions are working well and when and where they are failing. Despite the insights gleaned by the focus groups and interviews conducted by TfL we believe the lack of quantitative evidence makes it harder to characterise the impact of adopted policies on a larger scale. We will now describe some initial analysis we have done to explore the data from London's Automated Fare Collection Systems. First we focus on the big picture and then look into the specific case of Croydon in South London.

3.1 Example data analysis using Automated Fare Collection Systems – the big picture

TfL's own automated fare collection system uses RFID stamped cards (called Oyster cards) as a unified transportation ticketing system for many public means of travel. This includes the underground (including the Overground service), National Rail and other rail services, and finally buses. Within these cards, information related to individual trips is captured each time the Oyster card is used.

Perhaps the most important attribute that makes Oyster card a good candidate for analysis within the scope of this study as set in the introduction, is the fact that it holds information distinguishing disabled people from the rest of the population. This, combined with information on travel preferences, has the potential of revealing mobility patterns at a very high temporal level which could then be used to provide an image of the spatio-temporal habits of disabled individuals.

On the other hand, the definition of disability in the Oyster card is very broad and directly linked to disability categories as described by local borough councils. This includes (London Councils 2014):

- People who are blind or partially sighted
- People who are profoundly or severely deaf
- People without speech
- People who have a disability, or have suffered an injury, which has left them with a substantial and long-term adverse effect on their ability to walk

- People who do not have arms or have a long-term loss of the use of both arms
- People who have a learning disability that is defined as "a state of arrested or incomplete development of mind which includes significant impairment of intelligence and social functioning"

As was already mentioned, buses are the primary mode of transport for wheelchair / mobility scooter users. Plotting the histogram of disabled versus non-disabled Oyster card bus passengers (Fig. 1) one observes the distinct temporal structure of bus usage for people with disabilities. Specifically there can be seen a gradual increase of bus use during the day, peaking in the afternoon hours and then slowly declining in later hours. This structure lacks the, commute from and to work, double peak shape of Non-Disabled population.

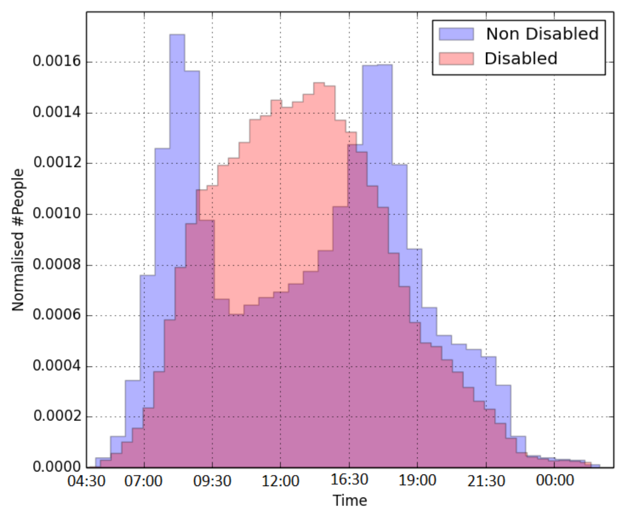


Figure 1: Normalised histogram of Disabled vs Non-Disabled Oyster card users.

Elements explaining this pattern can be found throughout literature. Purdam et al. (2008) considered unemployment as a driving factor shaping the temporal behaviour of people with disability towards the use of public transport. In contrast, Jolly et al. (2006)) found that overcrowded services is one of the most important variables contributing to the difference in the temporal behaviour patterns between disabled and non-disabled passengers. Further possible causes may be stress, lack of confidence as well as practical challenges associated with peak hour travelling for mobility impaired people.

3.2 Transport disadvantage and the Croydon case study

In an attempt to evaluate evidence of transport related social exclusion, London's borough of Croydon was used as case study since it represents a borough with an average percentage of disabled population with respect to its general population (London's Poverty Profile 2014). Fig. 2 shows the study area along with the bus stops/rail stations.

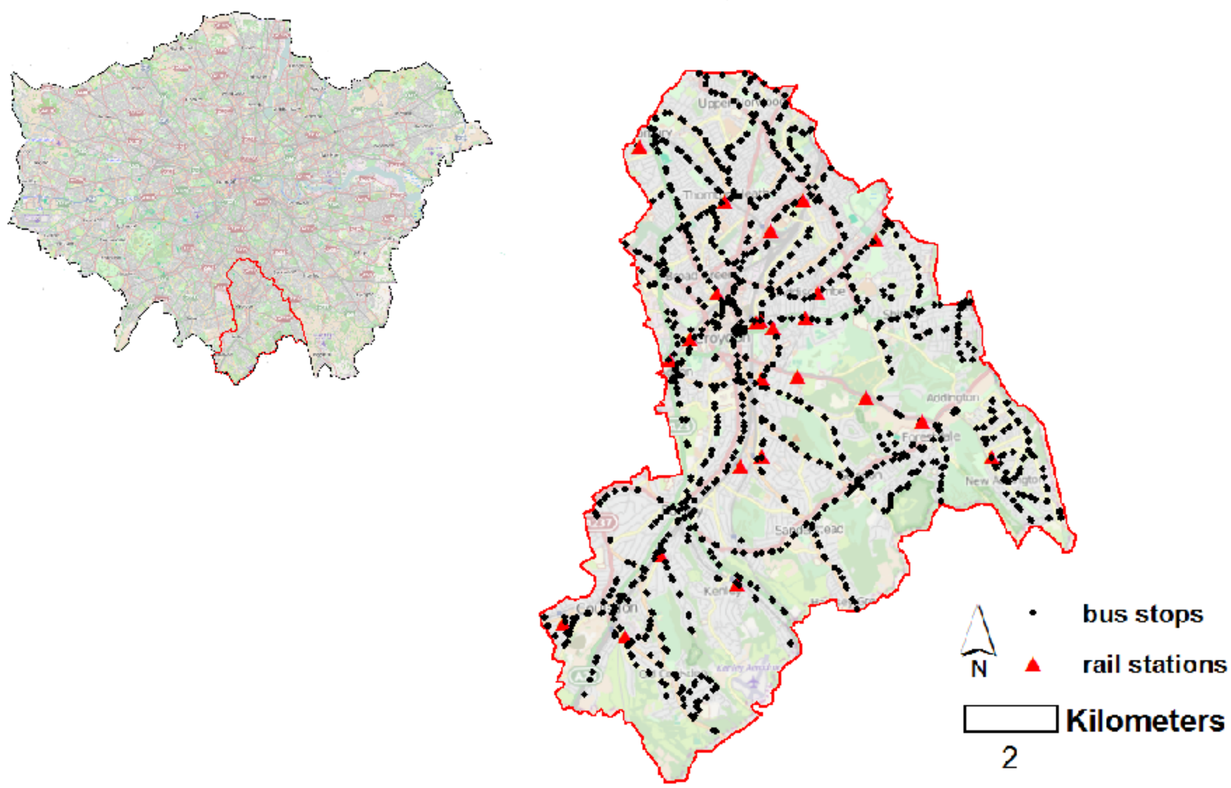


Figure 2: Study area

The analysis for the Oyster card dataset was performed on Oyster card records having the disability indication while the total number of passengers (with disability or not) was used as a standardisation term. The first step of the analysis was to identify starting points of their journeys. To do this we needed to divide the map of Croydon into areas. These areas were defined using a combination of a buffer distance around the bus stops and a Voronoi tessellation.

[1] The buffer radius was chosen to be 200m to encourage the creation of a spatially contiguous area, as far as this was possible.
Assuming that people with disabilities will be using the bus stops located within a close proximity of their residence, it is reasonable to assume that there will be a diffusion of Oyster card observations between these stops. To achieve this the following criterion was used: If two or more areas overlap, they are assumed to form a cluster. This cluster defines the most probable bus stops likely to be used by a disabled passenger residing in the proximity of each of these areas. This approach results in a structure illustrated in Fig. 3.

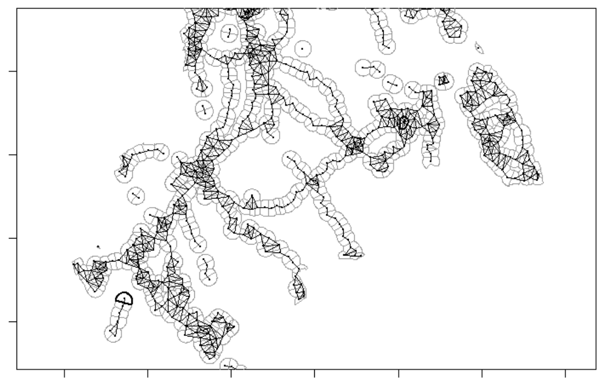
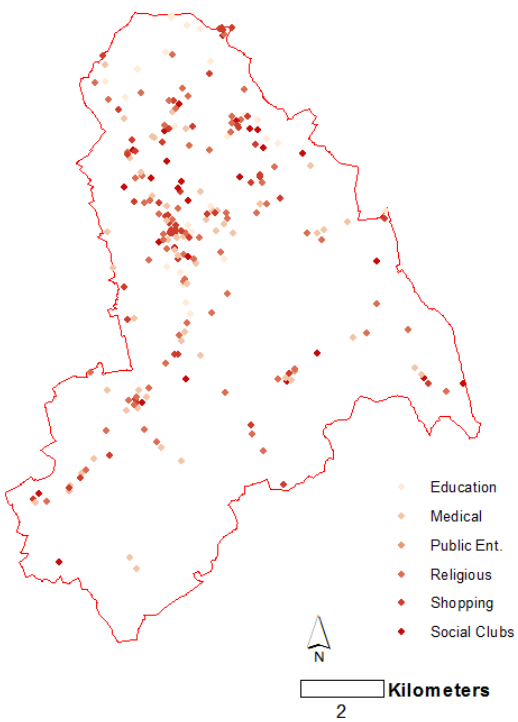


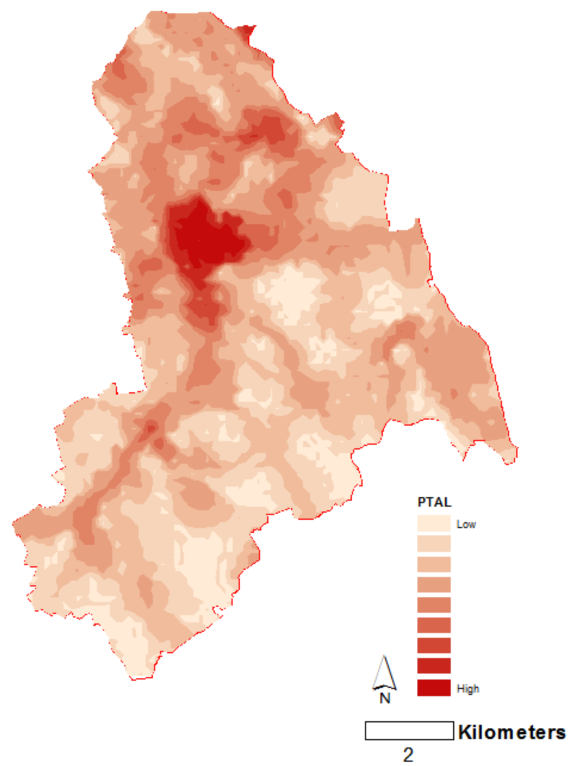
Figure 3: Neighbourhood structure (detail from Croydon borough)

The next step of the analysis was the actual modelling. In the context of this paper, we were interested to see whether certain areas tend to attract, or not, people. To do this, we first had to account for elements not directly relevant to social exclusion that could be contributing to this attraction. We identified two of these elements in this analysis. The first one was possible destinations for people. To represent this, we used openstreetmap.com points of interest (Openstreetmap.org 2014) belonging to the following categories: a) public entertainment, b) medical, c) religious, d) education, c) shopping, and d) social clubs. Fig. 4a below shows how these are distributed on the area: The second element was an index representing the level of accessibility to public transport. The PTAL (Public Transport Accessibility Level) was used for this task. For more details regarding the computation of this index the reader is referred to (Transport for London 2010). For the study area, PTAL levels are shown in Fig. 4b Thirdly, in order to account for the different frequencies of bus stop/rail station usage, the data were normalised by the total number of passengers (having the disable indication or not).
After accounting for these aspects the remaining variation in the disabled people's use of public transport could be attributed to the way we divided the study area. Fig. 5a shows the areas where people are most likely to be attracted and areas where people are most likely to avoid. For a more thorough description of the model and methods the reader is referred to (Bantis et al. 2015)

[1]A Voronoi tessellation simply divides the area into regions around each point, in this case the bus stop, so that the borders of the defined regions are equidistant from the two nearest points.



(a) Openstreetmap.com Points of Interest

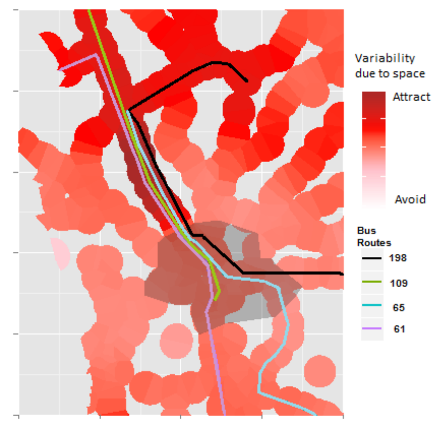


(b) Public Transport Accessibility Levels

Figure 4

Looking at Fig. 5b we can see a clustering tendency in the north of the borough, particularly where 4 bus routes overlap. Comparing Fig. 5a with the points of interest and the PTAL map, one would expect an increased preference for the Croydon city centre as both PTAL levels and number of points of interest are increased in that area. However, one could still see a pattern which provide evidence of reduced preference for the particular area. Although claims of causality are arguable, it would be useful to examine the contribution of different social and geographic factors as presented by Church et al. (2000).

(a) Spatial variability



(b) Bus routes and Croydon city center (transparent black polygon)

Figure 5

3.3 Oyster card limitations and the need for a more disaggregated approach

Following from the above, it is evident that data collected from AFC systems can provide a unique window of opportunity to evaluate objectively the effects of public transport policy decisions for people with disability. Perhaps the most important feature that made this possible is the fact that the dataset holds disaggregated information for a range of passengers including those with disability. However, is this information sufficient?

As already been mentioned, the range of disabilities covered by the Oyster card is very broad, suppressing the significant variations within each disability type that affect mobility requirements. For instance, the category referring to the inability to walk includes pushchair users, self-propelled wheelchair users, mobility scooter users, users with crutches / walking sticks etc. all of them having unique needs and capabilities. In contrast, MARS cards are offering such a disaggregated approach for mobility impaired users by assessing the user's ability to appropriately manoeuvre the mobility aid.

Another limitation of Oyster cards which has to be addressed is the potential lack of representativeness in the sample as some people, for practical reasons, choose not to validate their Oyster cards when boarding or alighting. An attempt to address this issue has been made by

analysing the mass of zero values in in the original Oyster card dataset and was found that the probability of people not "touching" their Oyster cards is 2%, hence very small to have an effect to the overall modelling approach.
Following from the above, integrating the Oyster card with the MARS card scheme could potentially enrich the knowledge of mobility impaired people's behaviour in public transport and provide policy makers with a more quantitative approach towards assessing the needs of mobility impaired user groups.

4 Conclusions

People with severe mobility impairments that require them to use mobility aids such as wheelchairs or mobility scooters are subjected to several factors which can affect their ability to effectively use the transport system. This can potentially lead to social exclusion with negative consequences for the person and society at large. TfL takes into consideration the needs of wheelchairs and mobility scooters users and has taken positive steps towards a more inclusive transport system through introduction of new policies, campaigns and structural modifications. Although qualitative methods using semi-structured interviews can provide valuable information on application and evaluation of new measures, a more holistic approach using quantitative data could be beneficial. To this end, the use of "big datasets", such as the ones obtained from automated fare collection systems, could prove to be an important source of information as far as characterising travel patterns of disabled people is concerned. Additionally, statistics concerning spatial distribution can contribute to define specific elements of transport disadvantage affecting different areas, allowing a more detailed analysis with the purpose of establish the importance of different contributing factors. However, in order to acquire data useful for specific classifications, a more disaggregated approach is needed. The implementation of RFID on MARS cards could provide significant information to help evaluate the scheme and identify room for targeted improvements.

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