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Improving the accessibility of urban transportation networks for people with disabilities

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ABSTRACT

What is the most effective way to enhance the accessibility of our oldest and largest public transportation systems for people with reduced mobility? The intersection of limits to government support with the growing mobility needs of the elderly and of people with disabilities calls for the development of tools that enable us to better prioritise investment in those areas that would deliver the greatest benefits to travellers. In principle and, to a lesser extent, in practice, many trains and buses are already accessible to nearly all users, leaving the stations and interchanges as the single largest and most expensive challenge facing operators trying to improve overall access to the network.

Focussing on travel time and interchange differences, we present a method that uses network science and spatio-temporal analysis to rank stations in a way that minimises the divergence between accessible and non-accessible routes. Taking London as case study, we show that 50% of the most frequently followed journeys become 50% longer when wheelchair accessibility becomes a constraint. Prioritising accessibility upgrades using our network approach yields a total travel time that is more than 8 times better than a solution based on random choice, and 30% more effective than a solution that seeks solely to minimise the number of interchanges facing those with mobility constraints. These results highlight the potential for the analysis of 'smart card' data to enable network operators to obtain maximum value from their infrastructure investments in support of expanded access to all users.

1. Introduction

The spread of cheap, low-power sensors on our person and throughout our environment is enabling a new class of 'smarter city' to emerge in which the digital traces left by the movement and interaction of individuals and objects can be collected and analysed to improve the number and resilience of services available to residents. Data from devices such as mobile phones have been used to study a range of phenomena, including: how the movement of people affects the spread of viruses (Balcan et al., 2010; Dezsö and Barabási, 2002); how knowledge of individual journeys can be used to encourage car sharing (Trasarti et al., 2011); how mobile phones can be used to characterise urban activity (Reades et al., 2007) and the impact of social events (Calabrese et al., 2010); and how mobility data can help network operators to optimise urban transportation networks (Bielli et al., 2002; Pinelli et al., 2009; Zheng et al., 2011).

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More recently, public transport smart card data has been used to study travel behaviour with a particular focus on travel time (Roth et al., 2011), Origin/Destination matrices (Liu et al., 2009), and the prediction of journey time and destination (Lathia et al., 2010) with the aim of providing personalised routing recommendations (Lathia and Capra, 2011a,b). However, to the best of our knowledge, this type of data has not been used to examine the accessibility of a public transport network as *whole* for people with disabilities. So we here contrast the purpose of our research with those approaches – such as personalised route planning for people with physical impairments (Kasemsuppakorn and Karimi, 2009) and machine-learning techniques to support navigation by disabled people (Karimanzira et al., 2006) – designed to support *individual* mobility.

Previous work on disabled access to public transport has relied solely on survey data (e.g. (Svensson, 2009)), but the importance of accessible transport can be gauged from the abundant work on existing need (e.g. (Steinfeld et al., 2010; Committee on Disability in America and Alan Jette, 2007; Tisato, 1996)), as well as the emergence of policy specifically designed to expand and improve access (see, for example, the European Policy on Urban Transport[1]). Consequently, we feel that it is important to consider whether a system exists that would enable us to measure and identify the potential improvements that maximise benefits to disabled users as a group. In other words, if we were in a position to selectively upgrade parts of the network, then which stations would enable us to realise the greatest benefits for accessibility and accessible travel times?

2. Materials and methods

2.1. Study area

We focused our case study on metropolitan London since the city has a particularly large public transport network consisting of no less than seven discrete systems: underground rail (the Underground, also known as the Tube), aboveground rail (the Overground), light rail (the Docklands Light Railway, or DLR for short), trams, boats, busses, and suburban and intercity rail (See Fig. 2). All buses in regular use are low-floor vehicles that are technically accessible to wheelchair users, and these users also have boarding priority. For the rail system – Underground, Overground, Tramlink, and DLR – the picture is more mixed: at the time of our research there were 64 accessible stations.[2] Unfortunately, step-free access to platforms does not mean that a station is fully accessible since the vertical and horizontal gaps between the train and platform may still preclude access to those with mobility impairments.

In 2006, the network operator, Transport for London (TfL), embarked on an ambitious upgrade plan that would have seen a quarter of Tube stations fully-accessible by 2010, with a third accessible by 2013 (Transport for London, 2006, 2013). Priority in accessibility upgrades was given to high-demand stations and, internally, TfL employs a hybrid model based on survey and Oyster data to understand flows and predict changes once improvements are in place. Clearly, the prioritisation of work has to also take into account a multitude of external factors such as legal requirements when doing major works to make stations compliant with the DDA (Disability Discrimination Act), and the scheduling of major external events – such as the Olympic and Paralympic Games – when reaching decisions on new investment.

However, even under normal circumstances TfL would face challenges upgrading access since London's network is one of the world's oldest and most complex: the first line opened to passengers in 1863 (London Transport Museum, 2012) and some station platforms are more than 55 m below ground-level (Transport for London, 2012a) with other infrastructure passing under, over, and around them. However, the ongoing financial crisis and its impact on public infrastructure investment has placed further constraints on the operator's ability to invest in upgrades; attention has tended to focus on stations where major redevelopment is already occurring (such as at Tottenham Court Road and Victoria). In short, although TfL is spending heavily to increase accessibility, there are still many places in the network where those with mobility constraints experience substantial difficulties (see Fig. 1).

Intuitively, we would expect a transit network with constraints on accessibility investment to sacrifice either travel time or interchange frequency. In other words, assuming that an operator had not been able to build every station to be accessible right from the start, then the optimal strategy would seem to be either: (a) ensuring that some set of accessible interchanges would allow disabled users to access the majority of the network even if they could not do so as quickly as non-disabled users; or (b) ensuring that some set of high-demand stations were accessible so as to allow more disabled users to reach more destinations quickly even if users of less-trafficked routes experienced much greater difficulty in completing their journey.

In spite of TfL's efforts with respect to strategy 'b', however, the age of London's rail infrastructure still offers wheelchair users the worst of both worlds: disabled users tend to have longer trips *and* more interchanges regardless of journey type. Moreover, wheelchair-accessibility is only *one* type of challenge faced by disabled users of a public transit system, but mobility impairments will be particularly difficult to address in an older network. However, the ageing of Britain's population makes it likely that mobility challenges will become an even bigger issue in the near future, making planning and investment a priority today. Fig. 1 illustrates the scope of the problem: a person needing wheelchair-accessible transportation between

[1] http://www.eukn.org.

[2] This represented roughly 10% of all London stations at that time (Transport for London, 2011). As of November 2012, there are 66 accessible stations (Transport for London, 2012).