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Using triangulation to assess a suite of tools to measure community severance

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ABSTRACT

There is a lack of tools to identify and measure community severance caused by large roads and motorised traffic, despite the evidence of its negative impacts on local communities. This paper reports the development of a suite of tools to measure and value community severance, undertaken as a part of the Street Mobility and Network Accessibility research project. The tools include participatory mapping, spatial analysis, a video survey, street audits, a health and neighbourhood mobility survey, and a valuation tool based on a stated preference survey. They were tested in the area around Finchley Road, a busy arterial road in North London. The study found that Finchley Road is an unpleasant place for pedestrians due to high traffic levels, air and noise pollution, and the lack and poor quality of pedestrian crossing facilities. This has a negative impact on the mobility and accessibility of local residents and, to some extent, on their health and wellbeing. The analysis showed coherence between the findings from the different measurement tools applied individually, but also revealed interconnections between factors which contribute to severance, demonstrating that overall the suite is reliable for assessing community severance in urban areas. Overall, the paper provides a multidisciplinary approach to developing standardised methods to measure a negative impact of transport that is still relatively unknown.

1. Introduction

Community severance occurs when transport infrastructure and/or the speed or volume of traffic interferes with the ability of individuals to access goods, services, and personal networks. The concept has been defined in many different ways since the 1960s, usually emphasizing the barrier effect of roads on the movement of pedestrians (Anciaes, 2015; Mindell and Karlsen, 2012). However, severance is a broader phenomenon, with impacts on what people do or not, and on how they feel (Appleyard and Lintell, 1972; Appleyard et al., 1981). We propose a broader definition which takes account of the wider spatial and social processes which shape the impact of community severance on people and their area over time, as follows:

> *"Transport-related community severance is the variable and cumulative negative impact of the presence of transport infrastructure or motorised traffic on the perceptions, behaviour, and well-being of people who use the surrounding areas or need to make trips along or across that infrastructure or traffic."*
>
> [(Anciaes, 2015)]

Most existing research on community severance has focused on urban, arterial roads (Lassière, 1976; Hine and Russell, 1993, 1996; Tate, 1997; Guo et al., 2001; James et al., 2005), but with some evidence about roads in rural areas (Poole, 2003) or with specific features such as elevated sections (Kang and Cervero, 2009), large roundabouts (Rajé, 2004), or parking lanes (Hine, 1996). Restricted-access transport infrastructure, such as motorways (Olsen et al., 2016; Foley et al., 2016) and railways (Chang et al., 2014; Lee and Sohn, 2014), tend to be a more absolute barrier to pedestrians' mobility. More broadly, authors such as Jacobs (1961) and Héran (2011, p. 75–77) mention the urban fragmentation caused by all large transport infrastructure, including ports, airports, railway stations, goods yards, canals, and car parking areas.

There is evidence that roads with high traffic levels or speeds tend to discourage walking and physical activity (Hüttenmoser, 1995; Giles-Corti and Donovan, 2002; Olsen et al., 2016) and reduce interaction between the communities on the two sides of the road (Appleyard et al., 1981; Bosselmann et al., 1999; Mullan, 2003;

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Transportation Alternatives, 2006; Sauter and Hüttenmoser, 2008; Hart and Parkhurst, 2011). Separate evidence relates physical activity (Reiner et al., 2013) and neighbourhood social capital (Holt-Lunstad et al., 2010; Moore et al., 2011; Mohnen et al., 2014) to health and wellbeing. Foley et al. (2016), using a natural experiment, found that living near a new motorway worsened local residents' wellbeing, especially among people with chronic health conditions. However, the paths through which the presence of roads and motorised traffic eventually lead to deterioration in health and wellbeing are still not well known (Mindell and Karlsen, 2012).

Community severance is often mentioned in the transport and urban geography literature (Hine, 1996; Hine and Russell, 1993; Mitchell and Lee, 2014; Noonam, 2005) but tends to be ignored in transport appraisal, compared with other local impacts of transport such as noise and air pollution (Anciaes et al., 2016a). In most countries, severance is either not considered in transport appraisal or is assessed using qualitative or indirect methods (Odgaard et al., 2005; Mackie and Worsley, 2013). Earlier manuals for transport appraisal in Sweden (Vejdirektoratet, 1992) and Denmark (Vägverket, 1986) included formulae to measure severance based on traffic data and indicators of the need for crossing the road, but more recent versions do not.

The relative neglect of community severance in policy and research is primarily because of difficulties in identifying and measuring such severance (Handy et al., 2003). A number of methods have been proposed in the literature but none have been operationalised as routine methods used by transport and urban planners (Anciaes et al., 2016a). For example, Clark et al. (1991) proposed an index based on the impact of transport infrastructure on walking accessibility to key facilities; Tate (1997) used questionnaires about perceived danger caused by traffic; and Lassière (1976) used mapping exercises to understand the effects of busy roads on individuals' perceptions about their neighbourhood. Several studies have used stated preference methods to estimate the value of policy interventions to reduce community severance (Soguel, 1995; Grudemo et al., 2002; Garrod et al., 2002; Grisolía et al., 2015; Cantillo et al., 2015).

The aim of the Street Mobility and Network Accessibility project was therefore to develop a suite of tools to measure and value the degree of community severance due to busy roads and its impacts. This paper summarises the development of these tools and their validation through triangulation of findings in a case study arterial road in North London.

Triangulation is the combination of methods in the study of the same phenomena (Denzin, 1978). This technique is particularly useful in social science because convergence of results from individual methods "enhances our belief that the results are valid and not a methodological artefact" (Bouchard, 1976, p. 268). It also produces a "more complete, holistic, and contextual portrayal of the units under study" (Jick, 1979, p. 603). The observation of elements of both the built environment and human behaviour using a combination of qualitative and quantitative methods allows for broad understanding of the causes and consequences of community severance.

2. Case study area

The study looks at the section where Finchley Road crosses through the neighbourhood of South Hampstead, in North London (Fig. 1). Finchley Road, built in 1829 as a new route for (horse-drawn) traffic from central London to the north, has subsequently become vital for the distribution of motorised traffic between central London, its growing northerly suburbs, and the M1 motorway. The road was widened and redesigned in the 1960s to accommodate increased car traffic, effectively becoming an urban motorway, with three lanes of motorised traffic in each direction (Fig. 2a) and physical barriers separating pedestrian pavements from the carriageway, which in some places are at different heights (Fig. 2b). Several east-west railway lines contribute to physical separation in the area.

The population in the Census output areas in the study area was over 30,000. The population density is higher than the London average; the age structure is similar, with 11% of the population aged 65+; the proportion of households with no private vehicle (54%) and the proportions of adults in full time work (47%) and with a university degree (62%) are higher; fewer adults have no qualifications (8%); and fewer households are in social housing (19%).

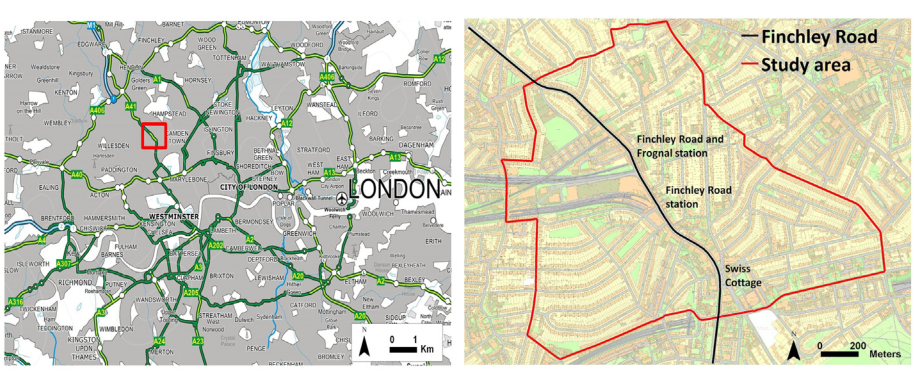
3. Methods

3.1. Overview

The research started with three interdisciplinary workshops to identify concepts and approaches used by the different disciplines and to build a common framework (Anciaes et al., 2016b). The 12 researchers involved in the project and 24 external participants representing local authorities, NGOs, universities and consultancies participated. We selected a range of approaches from different disciplines to identify, and where possible quantify, community severance (see graphical abstract): participatory mapping, spatial analysis, a video survey, street audits, a health and neighbourhood mobility survey, and a stated preference survey. Existing tools were used where possible and adapted for the project. The tools were piloted elsewhere in inner London (Woodberry Down), then modified and used in Finchley Road.

3.2. Participatory mapping

To understand local perceptions about the impact of busy roads on residents' daily practices, we selected a participatory mapping approach, undertaken August–September 2014. Visits to the area, to gain familiarity with centres where people gather (e.g. community centre, shopping centre), were followed by a programme of community engagement events. During four days of rapid appraisal mapping, people were stopped in areas such as parks, libraries, and markets and were asked to spend a little time contributing information (Cinderby, 2010).



a b

Fig. 1. Finchley Road location within London (a) and boundaries of case study area (b). Note: Background maps © Copyright and Database Right 2016. Ordnance Survey (Digimap License).

a b c

Fig. 2. Aspects of Finchley Road: a) Lack of formal crossings, b) Barriers preventing pedestrians crossing, c) Swiss Cottage junction.

Additionally, two community mapping workshops allowed participants to explore and discuss issues more fully.

A total of 101 local residents participated in these activities. The age profile of the participants reflected the focus of the study on older people. Participants were asked about their perceptions of the area and their experience of living near Finchley Road. Responses were recorded on 73 maps, using participatory mapping of locations of main destinations, places avoided, and walking routes. Participants were then prompted to think in more detail about issues they raised concerning road traffic, pedestrian crossing facilities, use of public transport, social networks, and neighbourhood boundaries. Mapping sessions were followed by the second stage: in-depth individual interviews. Participants were recruited from those who participated in the first stage and from community groups, to gain deeper insights into the issues that emerged from the maps and the rapid appraisal.

3.3. Spatial analysis and walkability model

Utilising space syntax methods (Hillier et al., 2010; Hillier and Vaughan, 2007), we carried out street network structural analysis to understand which roads and pathways are most important for street activity and movement through the area. This method considers the geometry and connectivity of the network as independent variables in shaping pedestrian and motorised transport, isolating street network configuration from 'push' or 'pull' factors that influence behaviour to provide a spatial account of the area's street network.

While the space syntax analysis provided insight into the local properties of the street network and its potential for structuring pedestrian activity, it could not fully account for pedestrian demand related to other factors. To address this, we developed a detailed model of pedestrian demand based on existing walkability modelling approaches (Frank et al., 2005). 'Walkability' represents the potential of the built environment to promote walking: a high walkability score does not necessarily mean either high pedestrian flows or a pleasant pedestrian environment. The model has four components: land use diversity and intensity; access to public transport; street network accessibility (measured using space syntax); and residential density. These four components were generated from Ordnance Survey mapping and address databases. This model accounted for 95% of the variance in observed pedestrian activity (based on a large database of measured pedestrian activity across London) (Dhanani and Vaughan, 2016).

3.4. Video survey

Video observation of road traffic movement and pedestrian flows were obtained from fixed cameras at 20 locations in the study area. The methods used to collect the data followed recommendations by Transport for London (2007). The survey was conducted on a weekday (6th November 2014) from 07:00 to 24:00. The cameras were located along Finchley Road and some of its side roads. The selection of the locations considered the results of the space syntax analysis in order to have a range of likely pedestrian usage intensities. We counted the number of vehicles using the road and the number of pedestrians walking along pavements and crossing the road (at formal and informal crossing points) between 16 and 30 minutes past the hour and extrapolated to estimate total daytime flows. We disaggregated motorised traffic by type of vehicle; pedestrian flows were classified into people with full or visibly restricted mobility (using or pushing a wheelchair, using a walking aid, pushing a pram, carrying a large suitcase).

We calculated crossing ratios (the number of pedestrians crossing the road divided by the number walking along both sides of the pavement at that location) and the proportion of pedestrians with mobility restrictions for each pavement and crossing point. The pattern of pedestrian flows along the pavement (pavement flows), across the road (crossing flows), and crossing ratios throughout the day in each location was compared with motor traffic data to assess whether higher motor traffic flows, or higher proportion of heavy goods vehicles, were associated with a lower propensity for pedestrians to cross the road or with a lower proportion of pedestrians with mobility restrictions.

3.5. Street audits

We conducted street audits to assess barriers to walking related to physical elements of the road and pedestrian infrastructure. We constructed a model of the pedestrian network, containing all the links and road crossings that might be used by pedestrians, including pedestrian pavements and cut-throughs (e.g. parks, shopping centres, stations, car parks). Crossings included designated crossing facilities (signalised crossings, footbridges, and underpasses), other provision to facilitate crossings (e.g. traffic islands) and likely locations for informal crossing due to desire lines (e.g. near bus stops). Data on road width, number of lanes for motorised traffic, and physical barriers (e.g. guard railings) were collected for each link; waiting times were measured at each signalised pedestrian crossing.

The quality of the links and crossings was assessed using the Pedestrian Environment Review System (PERS) developed by the Transport Research Laboratory (TRL) (Clark, 2009). Links were assessed based on 14 attributes and Crossings on 12 attributes (Box 1).

Standards were defined beforehand by ranking, for each attribute, a set of 45 streets around London. Three different auditors assessed a sample of streets in the pilot area to investigate differences in the understanding of the assessment criteria. The main stage of the audit in Finchley Road, conducted July–September 2015, involved field trips by a single auditor at different times of day on weekdays and at weekends, and in dry and rainy weather conditions.

The audit considered 133 links and 57 crossings. Separate links were assessed for the pavements on both sides of busy roads and a single link elsewhere, representing the conditions on both sides. Crossings were assessed only on Finchley Road and on the junctions between Finchley Road and side roads. Each attribute was scored on a seven-point scale from −3 (worst) to +3 (best), with 0 representing the average conditions of links and crossings in London. The overall scores for each link and crossing were obtained by using TRL's recommended weights (TRL, 2010).

Box 1
TRL's Pedestrian Environment Review System (PERS) (Clark, 2009)

Links	Crossings	Links and Crossings
Colour contrast	Capacity	Dropped kerbs
Effective width	Crossing provision	Gradient
Lighting	Delay	Legibility
Permeability	Deviation from desire lines	Maintenance
Personal security	Legibility for sensory impaired people	Obstructions
Quality of the environment	Performance	Surface quality
Tactile information		
User conflict		

3.6. Health and neighbourhood mobility survey

3.6.1. Data collection

A self-completion pen-and-paper questionnaire (Appendix A) was developed on health, wellbeing, and mobility in the neighbourhood. Existing validated questions were used for demographics (age, sex), socio-economic position (highest educational qualification), self-reported health and longstanding illness, taken from the Health Survey for England (Mindell et al., 2012); area social capital was measured using questions about people's perceptions of their neighbourhood (Breeze and Laing, 2008).

Questions on local travel behaviour and perceptions of the local environment, designed as indicators of community severance, were developed, using published information on community severance (Appleyard, 2011; Appleyard and Lintell, 1972; Mindell and Karlsen, 2012) and information volunteered by local residents from participatory mapping work in the first case study area. Questions asked about the area within about one mile (1.6 km) or 20 minutes' walk of the participant's home; their own road; and the busiest road near them (as identified by the participant).

New questions underwent cognitive testing and piloting elsewhere. An amended survey was tested in a second pilot study, in the Finchley Road area. The 30 pilot questionnaires were collected by members of the research team; respondents were also asked to map the area that they considered to be their neighbourhood, their main walking route, and areas they liked and disliked. After the pilot, the fourteen-item Warwick-Edinburgh Mental Well Being Scale in the questionnaire was replaced with the short version (SWEMWBS), comprising only seven items (Stewart-Brown et al., 2009; Ng Fat et al., 2016) to reduce respondent burden.

Both this survey and the stated preference survey (Section 3.7 below) were approved by the University College London Research Ethics Committee. An advance letter was posted to randomly selected addresses in the study area, then trained interviewers visited to recruit one adult participant (aged 18+) per household. Where possible, a male and a female were recruited from alternate households (using a Kish grid for random selection where more eligible adults were available) but where there was no eligible or consenting individual of the relevant gender, another adult was recruited where available. The interviewer left the self-completion questionnaire and collected it a few days later, or provided a stamped, addressed envelope. Of the 1496 randomly selected addresses sent information about the survey, 313 were visited by interviewers. (The target was to obtain completed questionnaires from 170 participants (plus the 30 pilot participants): interviewers stopped visiting addresses once the target was met.) The response rate was 57% (179/313) among those visited. The survey was conducted June–August 2015.

3.6.2. Analysis

Raw wellbeing scores were transformed to metric scores, enabling use of SWEMWBS as an interval scale for parametric analysis.[1] A SWEMWBS score in the lowest decile (national data) defined participants as having low wellbeing. The street network distance from participants' geocoded residential locations to the road they named as the busiest road near them was determined using Geographic Information System (GIS) software (ArcGIS, version 10.3, ESRI Redlands, CA) and was grouped into four categories (0–100 m; 101–200 m; 201–400 m; 401–800 m).

After descriptive statistics were computed, bivariate associations of demographic, socioeconomic, and health characteristics with community severance indicators were examined. The chi-square (χ^2) test was used to analyse differences for categorical variables across the four categories of network distance. This test has the assumptions of simple random sampling; sufficiently large sample sizes; expected cell counts of 5 or more in all cells of a cross-tabulation; and independent observations. As with all hypothesis tests, the observed value of the test statistic and its accompanying p-value depend upon both the magnitude of the estimated association and the sample size. p-Values were computed using the statistical software package Stata (StataCorp, 2013) using the Rao and Scott (1984) correction. Differences with $p < 0.05$ were deemed statistically significant. Direct age-sex standardisation was performed using the England 2014 population to ensure comparability across the four groups classified by network distance from the busiest road.

3.7. Stated preference survey

A stated preference survey was developed to understand how local residents balance factors related to crossing busy roads, such as collision risk, walking time, inconvenience of using certain types of crossing facilities, and the utility derived from accessing places across the road. The main survey was informed by an initial qualitative study, consisting of four 90-minute focus groups (average eight participants per group) and seven in-depth 30-minute interviews. Those participants were recruited from two areas, one each in London and Birmingham, to represent a more diverse geographic, demographic, and socio-economic context.

The participants in the main survey were recruited from those who participated in the health and neighbourhood mobility survey and who crossed Finchley Road at least once a week. The survey was conducted when the health and neighbourhood mobility survey was collected, August 2015. Participants were asked about their last walking trip; to rate how comfortable they feel using different types of crossing facilities; and to participate in three stated preference exercises (a sequence of choices regarding crossing a road). The conditions of the road (number of lanes, presence of a median strip, traffic levels and speeds) and other attributes (walking time, type of crossing facility, value of cost saving) were systematically varied.

3.8. Other data

Additional data sources were used to complement, validate, and explain the data collected using the six methods described above. Pedestrian flows in areas not covered by the video survey were provided by Transport for London (TFL), from a survey covering the vicinity of two underground stations. The results of street audits were compared with

[1] www2.warwick.ac.uk/fac/med/research/platform/wemwbs/development/swemwbs.

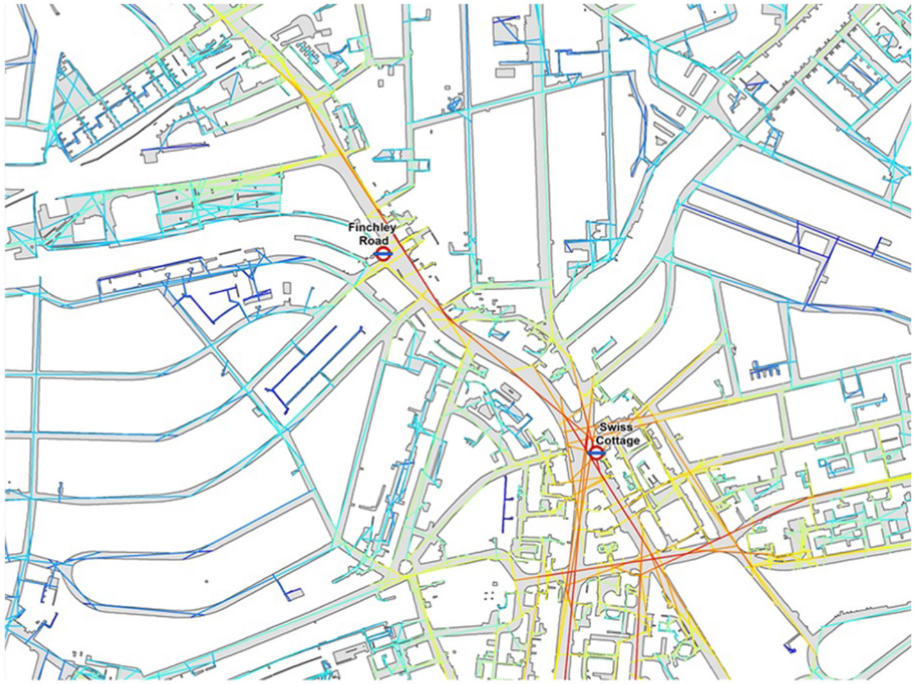


Fig. 3. Space syntax analysis (local scale). Note: Space syntax street network analysis of choice (betweenness) at 800 m search radius showing Finchley Road as the most central street network segments (colour scale indicates values from high to low, red to blue). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

those from previous assessments done for TFL covering the areas around the stations (Transport Research Laboratory, 2007a, 2007b). Data on vehicle-pedestrian collisions was provided by TFL. Online mapping tools[2] were used to extract data on traffic levels, air pollution, noise, health indicators, indices of deprivation, and crime incidents.

3.9. Triangulation

Primary data from each measurement tool and secondary data from external sources were analysed separately. The results from the different approaches were then compared thematically, to assess the extent to which the findings contradicted or supported conclusions from other tools. The triangulation used the framework derived from the initial series of interdisciplinary workshops, which takes into consideration the effect that each tool focuses on (within the chain of effects linking busy roads with health and wellbeing), and the degree of complexity of the tool in terms of spatial and time scales, object of analysis, type of information used, and relation to policy solutions and community engagement, described in detail in Anciaes et al. (2016b).

4. Results

This section reports the results by themes that emerged from across the data sources, integrating the findings from the separate tools.

4.1. Walkability and connectivity

The space syntax analyses showed that Finchley Road is structurally important for pedestrian activity both in the local area and in London as a whole. The street network sections that comprise Finchley Road were the most important in terms of local connectivity (measured at a network distance of around 800 m, approximating a 10 min walk) and were therefore most likely to attract the most pedestrian demand for street activity and movement through the area (Fig. 3). The walkability model (Fig. 4) shows that Finchley Road is one of the peak walkability locations in London, so would be expected to attract a high intensity of pedestrian flows. Several participants in the mapping sessions and the in-depth interviews also reported that the road is a strategic destination with popular local amenities, including a farmers' market, a leisure centre, and a shopping and entertainment centre.

However, overlaying traffic flow data from the Department for Transport with the walkability model identified Finchley Road as not only being one of the most (potentially) walkable areas of London, but also a critical artery, with the highest motorised traffic levels of any non-motorway road in London. Having great potential for walking but also potential traffic barriers to walking suggests that it is one of the locations in London where the loss of walking potential due to community severance is likely to be the highest.

Data from the other analyses suggest that Finchley Road is a boundary separating different neighbourhoods in the area. Maps of pedestrian flows obtained from the video survey (Fig. 5a) reveal a major imbalance between the number of people walking on the pavements on the two sides of the road. Pedestrian flows on the west side are up to three times as high as those on the east side. This may indicate the lack of permeability of the road for pedestrians, as it is reasonable to expect that in major shopping areas where there is no barrier effect caused by the road, pedestrians would use both sides of the road equally. There are more shops and facilities on the west side of the road, while in most shopping streets in London the number is more balanced (see for example Jones et al., 2007).

There is also evidence that Finchley Road is a psychological barrier separating different communities. The road defined the limits of the neighbourhood maps drawn by half of the 30 residents who were interviewed when the pilot health and neighbourhood mobility survey questionnaires were collected. This may reflect the role of Finchley Road as a boundary demarcating different property markets. Linking the residents' maps with their survey data did not reveal any consistent pattern of responses by age, gender, or socio-economic group. However, publicly available maps of multiple deprivation indices show a marked

[2] www.dft.gov.uk/traffic-counts, londonair.org.uk/london/asp/annualmaps.asp, http://services.defra.gov.uk/wps/portal/noise/maps, hna.londonhp.nhs.uk, dclgapps.communities.gov.uk/imd/idmap.html, https://www.police.uk/metropolitan/E05000133/crime.

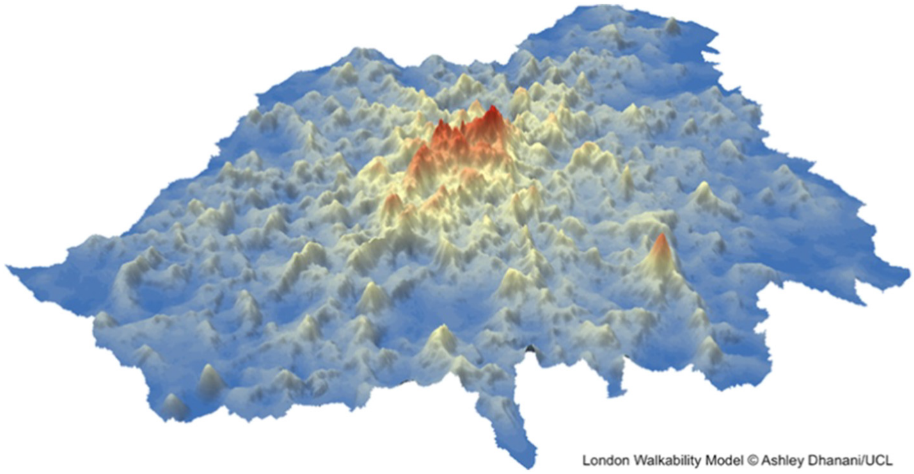


Fig. 4. London's walkability model.

social divide between the residential areas on the two sides of the road, with deprivation indices higher in Census lower super output areas on the west side of the road than on the east. This was confirmed in the qualitative data, as exemplified by quotes from residents in different parts of the study area:

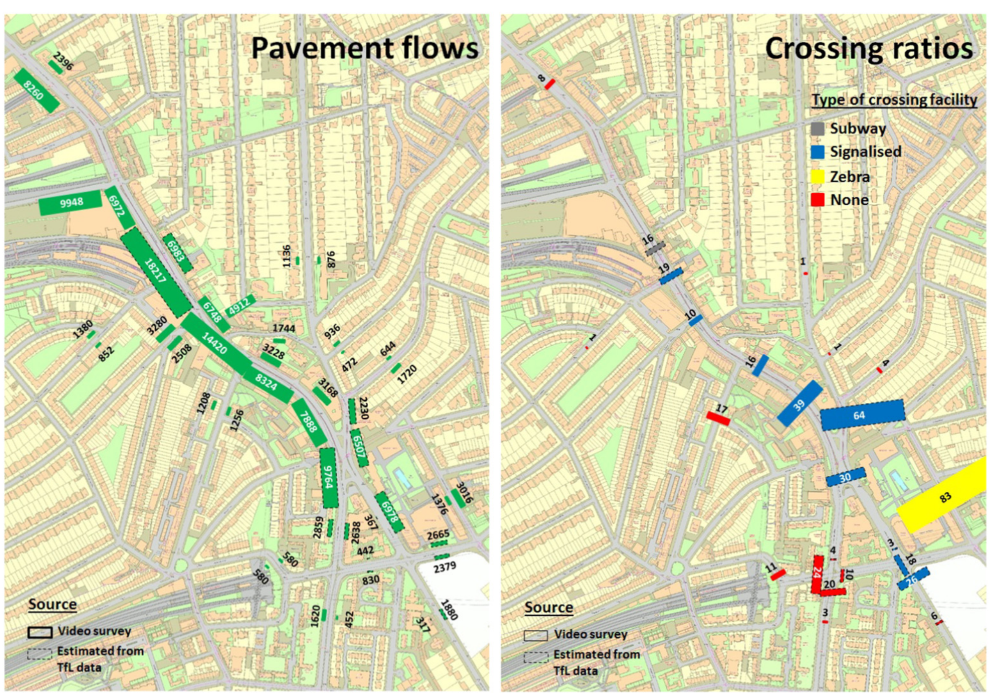
> *"People on the other side of Finchley Road would probably call the police if they saw me walking down their road, they would think I was casing the joint or after stealing their Porsche"* (Male, 62, participatory mapping)

> *"I don't browse the shops on Finchley Road - to be honest apart from O2 and Waitrose it's all a bit takeaway and charity shop world."* (Female, 52, in-depth interviews)

4.2. Mobility and accessibility

4.2.1. Walking in the local area

The video survey showed that motorised traffic levels along Finchley Road are very high, estimated as 39,500 to 46,500 vehicles (depending on the road section) during 07:00–24:00. Some of the roads leading to Finchley Road also have relatively high traffic levels (12000–17,000 vehicles), while others have lighter traffic (c.5000 vehicles). In general, the roads not leading to Finchley Road have small traffic levels (1000–2000 vehicles). Analysis of traffic composition revealed that the proportion of heavy goods vehicles and buses/coaches is relatively high. Participants in the mapping sessions and in the health and neighbourhood mobility survey stated that the number of airport buses using Finchley Road was one of the most unpleasant aspects of walking there.



a b

Fig. 5. Pedestrian flows (a) and crossing ratios (b). Note: Flows are based on pedestrians walking between 15 and 30 minutes past each hour between 07.00 and 24.00, multiplied by four. Background maps © Copyright and Database Right 2016. Ordnance Survey (Digimap License).

Table 1
Perceptions of survey participants of factors affecting their ability to walk around the local area.

Factors	Never affected (%)	Occasionally affected (%)	Often or always affected (%)
Volume of traffic, N (%)	109 (53%)	66 (32%)	30 (15%)
Speed of traffic, N (%)	111 (54%)	65 (32%)	29 (14%)
Other, N (%)	160 (79%)	29 (14%)	14 (7%)

Almost half the participants in the health and neighbourhood mobility survey reported that their ability to walk to local places was at least occasionally affected by the speed of traffic or its volume in the roads around their home (Table 1). The proportion reporting barriers to walking locally varied by network distance from the busiest road, being higher for participants who lived closer. Among participants living within 100 m, i.e. 3 minutes walking distance of what they reported as the busiest road in their area, 58% were at least occasionally affected by speed of traffic ($p = 0.022$ for the χ^2test of association) and nearly 60% were at least occasionally affected by the traffic volume ($p = 0.014$, Table 2). 25% of participants in the health and neighbourhood mobility survey who did not live on the busiest road reported that they avoided walking along it. This was confirmed by both the open-ended questions included in this survey and in the participatory mapping:

> *"Finchley Road is probably the most congested, dangerous, noisy, dirty road in the world."* (Male, 65–74 age group, health and neighbourhood mobility survey)

> *"I hate walking on Finchley Road - even though the pavements are wide it feels dangerous with baby buggies, children on scooters, cyclists and pedestrians all mixed together, you don't hear them coming and the next thing they are rushing past you and you feel as though you could get knocked over."* (Female, 84, participatory mapping)

The mapping of PERS scores of pedestrian links (Fig. 6a) also revealed that there are clusters of links with poor pedestrian environment in other parts of the study area, away from Finchley Road, decreasing the connectivity between the different neighbourhoods. This is especially the case for the north-west part of the study area, where there is a concentration of railways and dark alleyways. Analysis of published noise maps showed that noise levels in the streets near railways are almost as high as those along Finchley Road.

4.2.2. Crossing the road

The data gathered from and analysed using the various strands of our study show that crossing the Finchley Road is a major challenge for pedestrians. Street audits revealed that crossing is not physically possible along the section with highest pedestrian flows due to the existence of guard railings and walls (Fig. 2a). The number of signalised crossings is insufficient and pedestrians face long waiting times (up to 2 minutes) to cross at the few existing crossings.

18% of participants in the health and neighbourhood mobility survey mentioned lack of crossing points as a difficulty they encounter walking around their area; 25% mentioned that the signalised crossings did not allow adequate time to cross. Mapping crossing points along Finchley Road (Fig. 6b) shows that long stretches have no formal crossing points. Most existing formal crossing points have a negative PERS score, mainly due to delay (signal timings for controlled crossings, lack of availability of gaps for uncontrolled crossings), poor legibility (especially in complex crossings), and gradient (in both existing underpasses, which have steps but neither ramps nor lifts).

The health and neighbourhood mobility survey revealed that 37% of participants cross Finchley Road most days, a relatively low proportion considering that Finchley Road is the major shopping street serving a densely populated area. 7% of participants cross the road only once every 2–3 months or less often. People may not cross Finchley Road as often as expected because of high motorised traffic levels but the video survey data revealed there is no strong association between crossing ratios and traffic levels (or vehicle composition) in different locations or at different times of day. The imbalance in the distribution of shops and facilities among the two sides of the road does not have a significant effect on the frequency of crossing the road, as the average number of times residents in the west and east sides cross the road did not differ significantly.

The crossing ratios obtained from the video observation (Fig. 5b) show that the propensity to cross the road is highest around Swiss Cottage underground station. However, several local residents in the qualitative study reported that they avoid crossing the road at this junction due to the risks involved. Participants were especially troubled by traffic coming from all directions and the multiple crossings required to complete crossing the road there (Fig. 2c). People identified it as a dangerous 'hotspot' needing improvement, stating that they found it unpleasant

Table 2
Relationship between travel or health factors and network distance from the busiest road (age-standardised).

Characteristic	Network distance from the busiest road				p value
	≤100 m	>100 to ≤ 200 m	>200 to ≤ 400 m	>400 to ≤ 800 m	
N	46	24	53	60	
Problems on their own road					
Busy road or danger from traffic (%)	49	33	24	19	0.017
Lack of crossing points (%)	24	6	14	18	0.241
Crossings do not allow time to cross (%)	21	15	15	10	0.567
Poor lighting, pavements or paths (%)	14	6	13	7	0.511
Noise and air pollution (%)	48	30	10	10m	<0.001
Fear of crime (%)	15	12	6	1	0.100
Other (%)	6	10	9	13	0.717
Self-reported health and wellbeing					
Poor self-reported health (%)	0	1	5	2	0.321
Limiting longstanding illness (%)	16	36	14	9	0.125
Low wellbeing (%)	19	0	5	0	0.007
Problems at least occasionally affectingability to walk around the local area					
Speed of traffic (%)	58	55	33	29	0.022
Volume of traffic (%)	59	55	41	26	0.014
Problems often or always affectingability to walk around the local area					
Speed of traffic (%)	25	18	6	8	0.031
Volume of traffic (%)	25	18	7	7	0.040

Fig. 6. Pedestrian Environment Review System (PERS) scores of links (a) and crossings (b). Note: The higher the score, the better the pedestrian environment.

and stressful. This is confirmed by collisions data: the area around Swiss Cottage junction is the main 'hotspot' for vehicle-pedestrian collisions in this area.

> *"I avoid the crossing at Swiss Cottage - there isn't enough time to cross - the traffic is so quick and the buses and coaches all trying to beat the lights on Finchley Road is very intimidating."* (Female, 75, participatory mapping)

At this junction, pedestrians can cross using the underpass leading to Swiss Cottage underground station. However, this underpass is heavily used during peak hours, creating pedestrian congestion. Another underpass serves the second busiest section of the road, near Finchley Road station but it had the worst PERS scores of all crossings in the study area. It is not an alternative for people with mobility restrictions, due to the absence of ramps or lifts, and has issues of personal security and poor hygiene. Respondents to the stated preference survey gave an average rating of 72% to signalised crossings, 59% to footbridges, and 53% to underpasses. When asked to trade-off between walking time and the use of different facilities, participants chose to use footbridges or underpasses only if they saved 1.6 and 3.6 minutes walking time respectively when using these facilities, compared with using straight signalised crossings (Fig. 5).

Personal security is an important factor for pedestrians. In the health and neighbourhood mobility survey, 11% of the participants mentioned fear of crime as a difficulty associated with walking around the local area. In the mapping sessions, fear of crime was also raised as a deterrent to using underpasses by several participants. However, publicly available crime data show that the locations with most crime incidents were not the underpasses but the busy areas around stations and shopping centres and the streets around a park and community centre, which have low pedestrian flows at night. The relevance of fear of crime found in our results is consistent with the results of Grisolía et al. (2015) who found that the willingness of local residents to contribute to a project to bury a road is higher when the newly created pedestrian space contains equipment (CCTV) to prevent crime.

The qualitative study also revealed that the problems in crossing the road are related not only to the characteristics of roads, motorised traffic, and crossing facilities, but with wider social and psychological factors. For example, crossing the road can become a very unpleasant experience when pedestrians feel intimidated by drivers.

> *"I saw a car driver shaking his fist and pulling road rage faces at a poor lady trying to cross the road - she was so flustered he was banging on his horn - frightened the life out of her"* (Female, 45, participatory mapping)

The stated preference survey confirmed the negative impact of roads and motorised traffic on pedestrians. On average, participants prefer to avoid crossing roads without crossing facilities and would choose to do so only if they could make a saving by crossing to the other side (e.g. access a cheaper shop, or a bus stop in a cheaper travel zone). The required saving value is lower when the road conditions are better. The differences in the required value can be used as indicators of the benefits of interventions to reduce severance: £1.92 per person per trip to reduce the number of lanes from three to two; £1.61 to add a central reservation where pedestrians can stop when crossing the road; £1.07 to reduce traffic levels from high to medium and £2.64 to reduce from high to low; and £0.91 to reduce traffic speeds to below 30mph (50kph).

4.3. Health and wellbeing

4.3.1. General

Data from the 2011 Census show that the Finchley Road area has a low proportion of people reporting bad or very bad health or having limitations to their day-to-day activities, compared with nearby areas. However, there are variations within this area. The health and neighbourhood mobility survey showed that the proportion of participants in the low wellbeing category was highest among those who lived closest to the road they identified as the busiest ($p = 0.007$, Table 2). Differences in health levels within the study area may also be explained by spatial segregation of populations with different socio-economic status, reinforced by the role of Finchley Road as a boundary. Using age-standardised data, 17% of participants living on the west side of the road reported a limiting long-standing illness, compared with 10% of participants living on the east side (although this difference was not statistically significant). These results point to the existence of multiple links between severance, segregation, and deprivation, previously found by Noonam (2005), King and Blackmore (2013), and Mitchell and Lee (2014).

4.3.2. Specific issues

Noise and air pollution were consistently cited by local residents as a major deterrent to walking along Finchley Road. 36% of participants in the health and neighbourhood mobility survey reported that noise or air pollution affected their walking around the local area. This was particularly so for those who lived closest to their busiest road ($p < 0.001$,

Table 2). In mapping sessions and interviews, the main reason cited for avoiding walking on Finchley Road other than for essential journeys was poor air quality generated by the motor traffic.

> *"Finchley Road is 'just a big pain', traffic is so heavy, buses, coaches and lorries - it's not the speed as such, sometimes there is too much congestion for anyone to speed - it's a river of traffic constant, non-stop and you don't want to breath in the air it's so full of exhaust fumes."* (Female, 60, participatory mapping)

These concerns were borne out by available measurements of air pollution along Finchley Road: the mean nitrogen dioxide (NO_2) level for the year October 2014 to October 2015 was 61 μg/m^3, 21 μg/m^3 more than the European Union annual limit (40 μg/m^3).

Other environmental aspects were also evident from the results of street audits. Several links scored poorly for soft landscaping, quality of materials, cleanliness, drainage, evidence of neglect, seasonal foliage, and graffiti. Such issues were also mentioned by several participants in the mapping sessions:

> *"The design of the road with the guard rail on the road looks ugly, there are no trees!! Unfortunately no green spaces"* (Male, 64, participatory mapping)

These problems are concentrated on some links in the area; the links farther from Finchley Road have a better pedestrian environment. The proximity to green spaces and pleasant back routes were highlighted by several participatory mapping participants as positive factors of walking in some parts of the area.

The proportion of people noted with mobility restrictions in the pedestrian flows (<0.5%, video survey estimate) was generally lower than their proportion in the local population (5% in 2011 Census), and lower in the road crossings than the pedestrian links. The street audits showed that the streets adjacent to Finchley Road in the eastern part of the area were steep, possibly creating barriers for people with restricted mobility. Some local residents reported that pavement conditions are inadequate for people with disabilities, although the street audits assessed most links and crossings as average or just above average (compared with those assessed across London) for surface quality and maintenance.

> *"I have arthritis and use a walking stick. Many of the pavements are cracked and I have fallen on several occasions."* (Female, 65–74 age group, health and neighbourhood mobility survey)

5. Discussion and conclusions

5.1. Discussion

Appleyard and Lintell famously found that highly trafficked roads have a negative impact on the social networks of local residents and their use of streets as social spaces (Appleyard et al., 1981). Subsequent analysis (Mindell and Karlsen, 2012) has suggested the need for a wider reading of the impact of severance, both on physical health and wellbeing; transportation research has highlighted the essential conflict between arterial roads and creating pleasant street settings (Jones et al., 2007) while urban design research has also pointed to the importance of design in the long-term vitality of local residential areas (Geddes and Vaughan, 2014; Vaughan et al., 2013).

This study has established that interdisciplinary analysis can identify community severance and measure its wider societal impact. Information from the mapping sessions, open-ended survey questions, and neighbourhood maps drawn by local residents were consistent regarding the locations presenting the most problems for pedestrians. These findings complemented and were supported by the findings from space syntax analyses, walkability modelling, street environment audits, and video surveys of motor and pedestrian traffic flows and behaviours.

These seven tools, providing different data and assessment approaches, together complemented the information produced by each individual tool, providing good evidence for the validity of these tools to measure aspects of community severance. After analysing these data, the tools were refined slightly and used in two further case studies outside London, aiming to produce a suite of complementary tools that will be usable to estimate the impact of busy roads on local residents. Each tool can be used by practitioners and academics; how many and which ones would be used will depend on local circumstances and concerns. Two tools, the participatory mapping and the health and neighbourhood mobility questionnaire, were specifically developed to be usable by community groups as well, with emphasis on pen-and-paper self-completion for the survey so local groups can use them relatively easily to gather indicative evidence to present to local government staff and politicians while also being useful for health, transport and spatial planners and researchers. The other five tools generally require more resources and/or expertise.

5.2. Strengths and limitations

The complementary use of different approaches revealed several aspects of the problems faced by pedestrians in this area, highlighting the risk and inconvenience of walking along or crossing Finchley Road. Issues raised in the qualitative participatory mapping were echoed in the survey responses. Both sources identified problems with noise and air pollution, borne out by London and local authority data. Pedestrian conflict from motor traffic speed and volume resonated with conclusions from juxtapositioning of the London walkability model with both TFL and video camera data of traffic flows. Participants' dislike of underpasses and difficulties crossing the six lanes of Finchley Road were borne out by the stated preference survey results and street audits.

Differences of interpretation were found between the tools in some cases. For example, while the PERS survey identified a poor pedestrian environment in many respects, the quality of the pavement was seldom noted as poor, although that was a common perception in the participatory mapping exercise.

The individual tools have some limitations. Video surveys can provide evidence only on people's actual walking behaviour and not on the effect of roads on suppressing walking trips, nor on pedestrian route choice. Ideally, interpretation of crossing ratios should refer to the ratio that would be expected if there were no barrier effect caused by the road, but this can be done only by modelling the potential pedestrian routes of residents and non-residents to local destinations, which is a complex task (Anciaes and Jones, 2016). The purpose of our stated preference surveys was to provide inputs for the valuation tool we are developing to value the impacts of current community severance and estimate benefits of different policies to reduce severance.

Being cross-sectional, the surveys cannot ascribe causality. Due to limited resources, the sample sizes are also relatively small (200 for the health and neighbourhood mobility survey, 100 for the stated preference survey). This has limited our ability to detect statistically significant associations and to adjust for potential confounding factors particularly age, socio-economic position, and health status. For example, the trend towards poorer health of those living near busy roads may be due to lower incomes in less healthy groups and/or poorer health in lower income groups, with rents being lower on average for properties closer to busy roads. However, persons in lower socioeconomic groups are also more susceptible to the adverse consequences of being near busy roads, so reducing community severance could contribute towards reducing socio-economic inequalities in health. We are analysing the combined data from a total of four case studies, to overcome this location-specific limitation.

The use of triangulation to validate the results neutralizes the limitations of the individual methods, because in most cases, the methods have different limitations (Rohner, 1977, p. 134). In the case of this project, for example, the surveys provide information about potential impacts of community severance on suppressed walking trips, which cannot be captured by video surveys. On the other hand, video surveys and street audits, provide detail on specific features of the built environment that cause severance which may not be mentioned by participants in the surveys or in the community mapping due to the small samples.

Many organisations may not need or have the resources to use the full set of tools described in this paper. Video surveys and stated preference surveys are expensive; street audits can be time consuming; and space syntax requires specialist expertise. The triangulation of the results carries extra financial and time costs, as it requires multidisciplinary analysis. However, it is possible to use a simplified version of some of the tools. For example, the analysis of video survey data can be made for parts of the day only (for example, peak times); street audits can cover only the main road and/or consider only a small set of attributes, or simpler audits can be conducted.

5.3. Conclusions

This paper has reported on the development of a suite of tools to identify and measure community severance, using as a case study a busy arterial road in North London. The analysis used participatory mapping, spatial analysis, a video survey, street audits, a health and neighbourhood mobility survey, and a stated preference survey. In the absence of a recognised 'gold standard' for measuring community severance, we have triangulated the findings from the several different approaches and data sources as a way of validating the suite of tools and enrich the insights obtained. We have developed a toolkit with guidance on use of the individual tools by local government, communities, and researchers. The toolkit was prepared after workshops with a range of end-users to help us ensure the tools are as useful, usable, and user-friendly as we can make them. The toolkit is available on the study website (http://www.ucl.ac.uk/street-mobility/toolkit).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jtrangeo.2017.02.013.

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