THE INFLUENCE OF MOTORISED TRAFFIC ON PEDESTRIAN FLOWS - NEW INSIGHTS USING BUS STOP DATA -

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ABSTRACT

This paper assesses the influence of motorised traffic on pedestrian mobility in an area in London surrounded by major roads. Pavement and crossing flows obtained by a video survey are analysed in comparison with data on bus stop usage. The flows along the busiest road are lower than it would be expected given the location of the road along the walking routes to bus stops. The propensity to cross the road (overall and informally) correlates negatively with traffic levels, especially in roads with medium traffic speeds. The hypothesis that local residents avoid crossing the road away from designated facilities is also supported by differences in the number of passengers boarding and alighting buses at different stops.

1. BACKGROUND AND CONTRIBUTION

Motorised traffic inhibits the movement of pedestrians, with potentially far-reaching consequences on the wellbeing of the residents in affected areas. High traffic levels create air pollution and noise, cause delays and detours, and force pedestrians to engage in risky crossing behaviours. The persistence of these effects may lead to the suppression of walking trips (Owen et al. 2004, which is associated with lower levels of accessibility to goods and services, physical exercise, and social interaction (Mindell and Karlsen 2012).

There is a growing body of research on the relationships between walking behaviour and characteristics of the built environment such as road infrastructure and motorised traffic (Talen and Koschinsky 2013). This literature is complemented by surveys or qualitative studies of people's perceptions and attitudes about the presence of roads in their neighbourhoods (Mullan 2003). These two types of methods provide useful guidelines for local governments to improve walkability, but need to be validated with information about street activity in the areas where policies are implemented. This information can be obtained by on-the-spot observation or video surveys (May et al. 1985).

The effect of roads on people moving about in an area may be assessed by counting the flows of pedestrians walking along and crossing busy roads. The estimated propensity for crossing the road is a simple indicator of the barrier effect of traffic on pedestrians. This approach was used by Hine and Russell (1993, 1996), who suggested the use of "crossing ratios", obtained by calculating the number of pedestrians crossing the road as a proportion of the pedestrians walking along the pavement. The propensity to cross informally, and not in designated crossing facilities, is another useful indicator. For example, Sisiopiku and Akin (2003) proposed a “spatial compliance ratio” to measure the proportion of pedestrians who cross away but within 3 meters from a formal crossing facility.

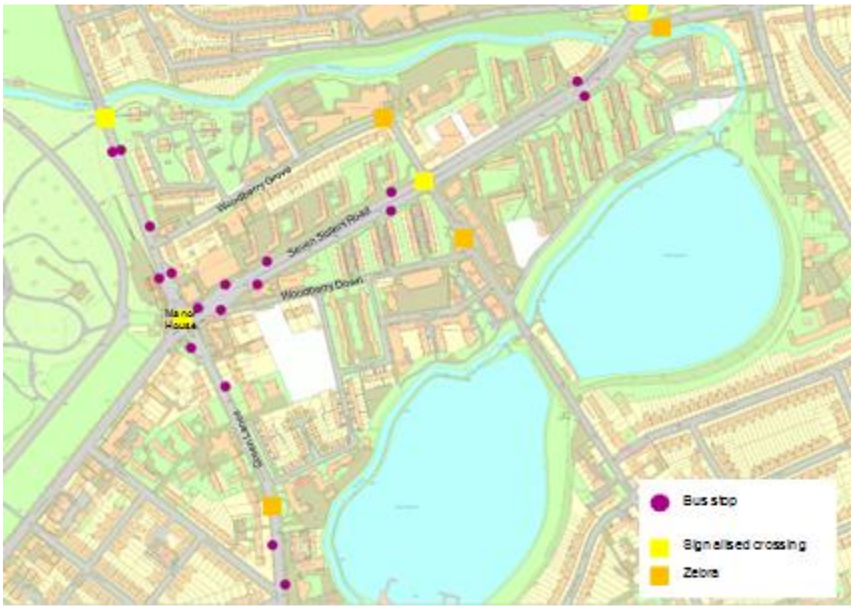
This paper adds to these efforts by investigating the role of traffic levels and speeds in explaining discrepancies between observed and expected pavement and crossing flows. The observed flows were calculated from a video survey and the expected flows were obtained by analysing the number of passengers using bus stops and by applying network analysis to derive the optimal walking routes to those bus stops. The use of this approach is facilitated by the characteristics of the case study area, a neighbourhood with very few destinations for pedestrians other than bus stops.

The rest of the paper is organised as follows. Section 3 introduces the characteristics of traffic, pedestrian infrastructure, and land use in the study area. Sections 3 and 4 present the results of the analysis of pavement flows and crossing ratios. Section 5 concludes the paper and proposes directions for further research.

2. STUDY AREA AND METHODS

Woodberry Down is a residential neighbourhood in North London surrounded by two major roads, a large park, a canal, and two water reservoirs (Figure 1). The neighbourhood is split by Seven Sisters Road, a busy six-lane road (Figure 2). The only designated crossing facilities in the 1km section of the road traversing this area are three signalised crossings (at both ends and halfway between them) and an underpass in the western end, which is linked to the Manor House underground station. This western end is particularly problematic, as pedestrian desire lines to a series of bus stops are interrupted by vehicles negotiating a confusing junction of major and minor roads and by buses stopped or U-turning. Unlike in other parts of the road, there is no central reservation which could be used as a pedestrian refuge in this location. There are three other roads in this area: a busy 4-lane road (Green Lanes) and two quieter 2-lane roads (Woodberry Grove and Woodberry Down). The rest of the neighbourhood is accessed by driveways and pedestrian-only passageways.

The Woodberry Down area is being subject to extensive regeneration over the next 20 years. It is hoped that the present study provides evidence on the barrier effect of Seven Sisters Road on local residents and emphasizes the need to include the improvement of pedestrian environment as a part of the regeneration program.



Source of base map: EDINA Digimap Ordnance Survey Service

Figure 1: Woodberry Down

Figure 2: The four roads of Woodberry Down

The area is also an interesting case study because of the role of bus stops as the main destination for pedestrians. The neighbourhood is residential and contains no supermarkets or long strips of shops like similar areas in London located near an underground station. The only major facility is a health centre, which is located at the south-western extreme of the neighbourhood, beyond walking distance to many residents. Most residents need to walk to the underground station or bus stops to go to work or to access shops and other facilities in surrounding areas. A survey parallel to the present study found that 48% of 100 respondents cross Seven Sisters Road to use public transport most days and a further 27% cross that road 2-3 times a week. Because the walking flows to local destinations other than bus stops are small, the analysis of data on bus stop usage can provide insights on the expected pedestrian flows along the streets leading to those bus stops. The discrepancy the observed and expected flows may be explained in part by high traffic levels or other negative aspects of the road infrastructure or motorised traffic.

The use of buses to travel to most of daily destinations also provides a way for residents to overcome the danger and unpleasant effects of crossing the road. In another initiative parallel to this study, workshops with local residents found that some older residents get on or off buses one stop before or after the stop that serves their home, in order to cross the road in a safer location. Once again, the analysis of data on bus stop usage can shed light on the prevalence of this type of behaviour, which would signal the existence of a severe negative effect of road traffic on the local community.

To investigate these questions, a video survey was set up to count vehicular traffic and the number of pedestrians walking along and crossing roads. The survey was done on a weekday (16 September 2014) between 7AM and 10PM. A total of fifteen cameras were installed in the four main roads. The objective was to cover all the formal and informal crossing points in Seven Sisters Road and points on the other three roads where crossing facilities were located near informal crossing points that serve noticeable pedestrian desire lines. The counts were based on a sample of the footage (from 16 to 30 minutes past every hour) and then extrapolated for the whole survey period. The average road traffic speed in all sections of the road and the average delay for pedestrians in all formal and informal crossing points were also measured, using a sample of the footage.

Data on the daily number of people boarding and alighting buses in each stop in the study area was provided by Transport for London. The data was processed in order to derive values for the same time period as the video survey (7AM-10 PM).

3. PAVEMENT FLOWS

3.1 Spatial distribution

The presence of road traffic affects the wellbeing of pedestrians even if they do not wish to cross the road, due to visual intrusion and intimidation by vehicles and exposure to air pollution and noise. Main roads with large traffic volumes also tend to have a high density of junctions with side streets, interrupting pedestrian circulation and creating obstacles to people with mobility restrictions, if dropped kerbs are not provided. Pedestrians may then choose alternative routes in order to avoid walking along main roads. This hypothesis is tested in this section, which analyses the distribution of flows of pedestrians walking along the pavements in the four roads in the Woodberry Down area. The differences between the observed flows and the flows that would be expected from modelling the optimal pedestrian routes to bus stops are then related to traffic levels and speeds.

Figure 3 shows the daily pedestrian flows in several locations in the four roads. The pavement flows are the sum of pedestrians walking on both directions in each side of the pavement. The sections of Green Lanes and Seven Sisters Road leading to the Manor House junction have by far the highest pedestrian flows. The flows on the eastern pavement of Green Lanes are much higher than the ones on the western pavement, as the former gives access to the northern part of the residential neighbourhood and the latter runs along the borders of a large park. The flows on the north pavement of the western section of Seven Sisters Road are also higher than the ones on the south side, which is explained by the flows of people interchanging between buses and the underground.

The most striking result, however, is the relatively low pedestrian flows in the other sections of Seven Sisters Road when comparing with the flows observed in Woodberry Down, despite the fact that Seven Sisters Road has much higher connectivity with other local roads and streets and contains all the stops for longitudinal bus services serving the area.

Note: Rectangle size is proportional to flow value

Figure 3: Pavement flows

3.2 Using bus stop data to compare observed and expected flows

The hypothesis that pedestrians avoid walking along main roads if there is an alternative route can be tested by looking at the relationship between observed and expected flows. In an area such as Woodberry Down, where the main destinations for pedestrians are bus stops, a possible approach to derive the expected pedestrian flows is to generate the origins and the walking routes of people boarding and alighting buses in each stop.

The first steps in this method are to estimate the fastest routes from each building in the study area to the nearest bus stop and calculate the service area of each stop, that is, the set of buildings for which that bus stop is the nearest. The estimation of the fastest routes is based on a model of the pedestrian network built on a Geographical Information System. The model includes all the pedestrian pavements along roads, links that are exclusive to pedestrians (such as passageways between buildings and through parks) and all formal and informal crossing points. The time to traverse crossings includes the average delay that was observed from the video footage.

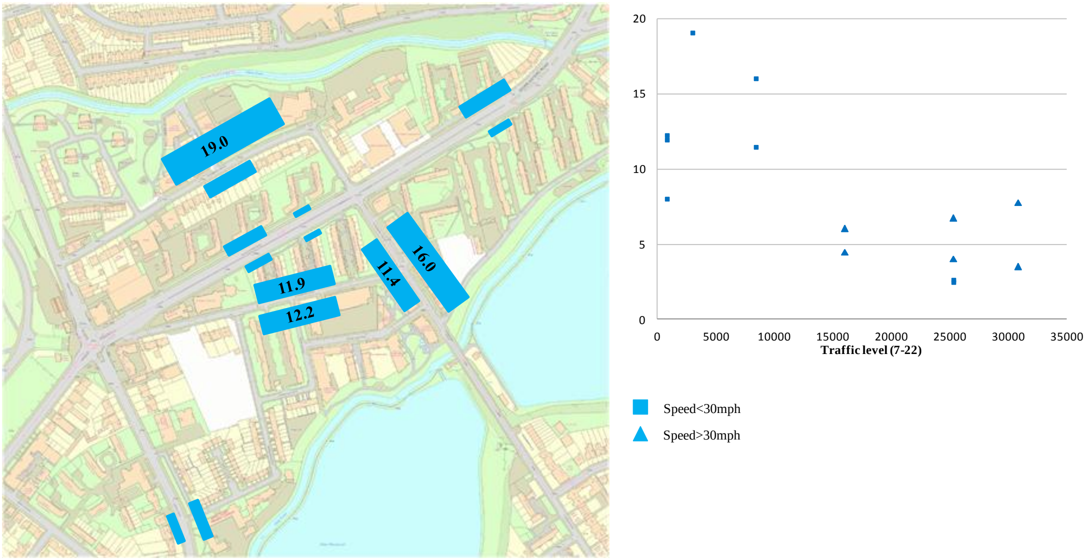
The daily number of users of each bus stop is then assigned to the routes ending in that stop proportionately to the total area of the building where they start. This area was calculated from the buildings' footprint on the ground (measured in maps) and the number of floors (identified in field visits). The flows from buildings to bus stops were finally summed up for each link of the pedestrian network.

While information on the number of people entering and exiting Manor House underground station is also available, the walking routes to the station are not used in this study to derive the expected pedestrian flows. This is because the station is used by a large number of users living in other neighbourhoods, as the area surrounding Woodberry Down has a low density of stations. It is difficult to disaggregate, even theoretically, the total number of users of the station into local and non-local users. In addition, many local users also use buses to access the station, given their location in one of edges of the neighbourhood.

The pedestrian pavements adjacent to Manor House station are excluded from this part of the analysis due to the large number of people interchanging from buses to the underground station and the fact that it is not feasible to assign a single "nearest bus stop" to residents living nearby, as may access stops in both Seven Sisters Road and Green Lanes, depending on the bus service, contrary to most of the residents in other parts of the study area, who are not within walking distance to both roads and normally use buses to go to Manor House and then interchange to a different bus service.

A ratio can be calculated between the observed pedestrian flows and the theoretical flows obtained using the methods described above. The analysis of this ratio assumes that flows of non-residents walking in the area and of residents accessing destinations other than bus stops are proportional to the observed flows in all pavements being analysed, and that the differences between the ratios calculated in each pavement reflect only divergences between the fastest routes and the chosen walking routes.

Figure 4 maps the ratio between the observed and expected pedestrian flows along pedestrian pavements and compares this ratio with road traffic levels and speeds. The map shows that the ratio is much lower in Seven Sisters Road than in the two surrounding minor roads. This result suggests that some pedestrians use these minor roads as alternative for longitudinal routes, rather than walking on Seven Sisters Road. This hypothesis is confirmed by the chart, which shows a clear negative relationship between daily traffic levels and the ratio between observed and expected pedestrian flows. The minor roads, which have traffic levels below 10,000 vehicles per day, have observed walking flows 10 times higher than those estimated from the fastest routes to bus stops. In the two main roads, which have traffic levels of up to 30,000 vehicles per day, the ratio between observed and expected flows is much smaller. However, within the set of main roads, the ratio is higher in the sections with higher average speed.



Note: Rectangle size is proportional to ratio. Only the labels of the highest values are shown.

Figure 4: Ratio between observed and expected flows

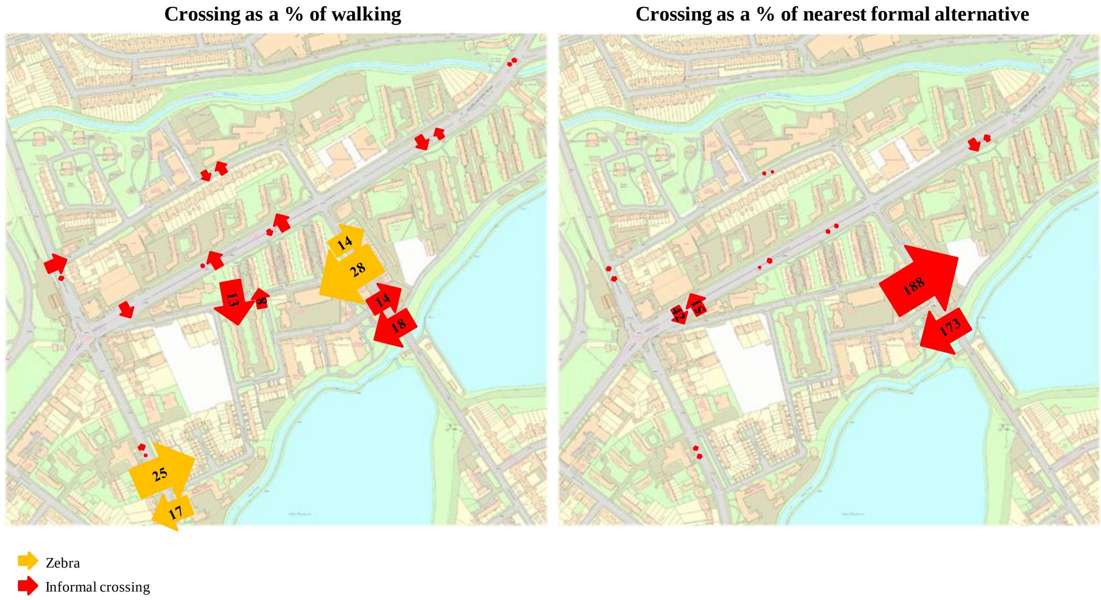
4. CROSSING RATIOS

4.1 Spatial distribution and relationships with road traffic

Large roads represent a barrier to the movement of pedestrians as they interrupt the connectivity of pedestrian pavements. The road may present a physical, absolute, barrier, as in the case of motorways or roads with guard railings separating pavements from the carriageway. However, even when crossing is physically possible, large traffic levels or speeds reduce the opportunities for pedestrians to cross the road safely. It is expected that the propensity for pedestrians to cross the road is lower in roads where this barrier effect exists. The range of different locations where pedestrians cross will also be small, and in some cases will be limited to designated crossing facilities. These hypotheses are tested in this section by analysing how crossing ratios vary in roads with different number of lanes, traffic levels, and average traffic speeds. Further insights on the hypothesis that people avoid crossing away from designated areas are derived from the study of differences between people boarding and alighting bus at stops.

An indicator of "crossings as a proportion of walking" is defined as the number of pedestrians crossing the road from a given pavement divided by the number of people walking in both directions along that pavement. Each road section has two crossing ratios, calculated in each of the two pavements. The ratio was not calculated for signalised crossings in 4-way junctions, as it is theoretically difficult to identify a suitable denominator, given the multiplicity of pedestrian movements and the fact that pedestrians may cross a road immediately after crossing another road, perpendicular to the first one.

An indicator of "crossing as proportion of nearest formal alternative" is defined as the number of pedestrians crossing the road informally (that is, away from crossings facilities) divided by the number of pedestrians crossing the road in the nearest crossing facility (signalised crossing or zebra).



Note: Rectangle size is proportional to ratio. Only the labels of the highest values are shown.

Figure 5: Crossing ratios

Figure 5 maps the two crossing ratios. The highest proportions of crossing flows as a proportion of walking occur in the zebra crossing in Green Lanes and in both the zebra and the informal crossing point in the southern section of Woodberry Grove. The crossing ratios reach a very high value (28%) in one direction of the zebra crossing in this section. The ratios in Seven Sisters Road are very low comparing with those obtained in the roads mentioned above.

The highest proportions of informal crossing flows are again found in the southern section of Woodberry Grove, with values above 100% in both directions and far above all the other crossing points in the area. The second highest values (42% and 51%) and found in the most dangerous section of Seven Sisters Road for pedestrians, near Manor House junction, despite the proximity of a signalised crossing. This result may be explained by the presence of several bus stops away from the signalised crossing, and the delay and detour to access this crossing. The proportion of informal crossings in the southern section of Green Lanes is very small. The informal crossing point in this section is an alternative to the use of a nearby zebra to access the health centre. It would be expected that the relatively large proportion of pedestrians with health problems would lead to a low proportion of risky crossing behaviours. In fact, it was calculated that the proportion of people using that zebra crossing who have a mobility restriction (14%) is much higher than in any other pavement or crossing in this area (usually in the interval 0-5%)

Figure 6 show how the crossing ratios relate to traffic conditions. The figure confirms that the highest ratios of crossings per walking flow are found in zebra crossings, rather than informal crossing points. There is also a visible negative relationship between those ratios and daily road traffic levels. The ratios in roads where the traffic is higher than 20,000 vehicles are always below 10%. Roads with higher average speeds (above 30 mph) also tend to be associated with lower crossing ratios.

The same negative association between road traffic levels and crossing ratios is also visible in the case of crossing as a proportion of the nearest formal alternative, although in this case there are two clear outliers, which correspond to the crossing point in Woodberry Grove identified above. Again, there is some evidence that roads with higher traffic speeds are associated with lower crossing ratios.

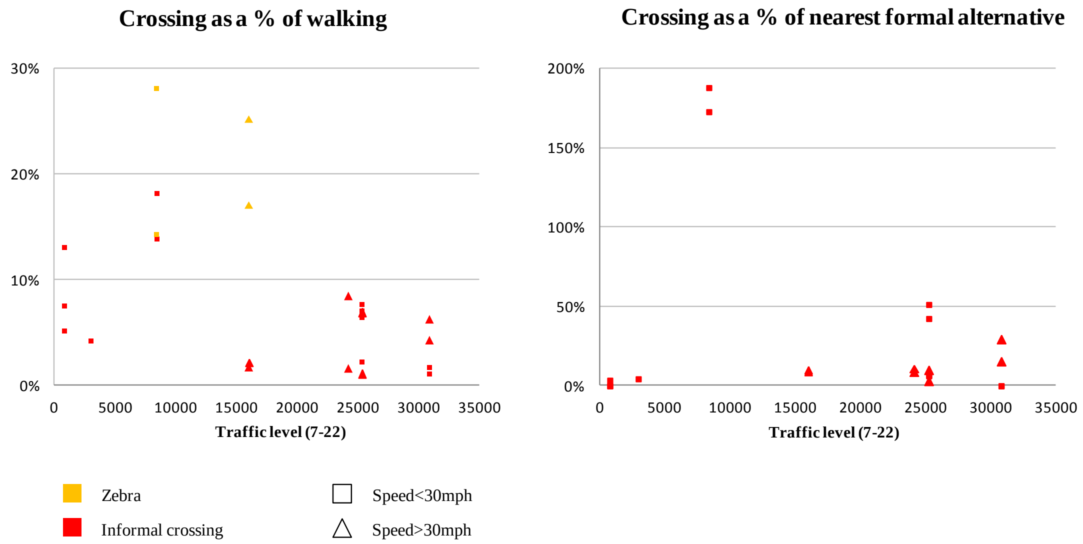


Figure 6: Crossing ratios vs. traffic levels

The hypothesis that crossing ratios in main roads are negatively associated with traffic levels is confirmed when using more detailed data on both variables. Table 1 shows the Pearson correlations between crossing ratios and traffic levels calculated hourly in all locations. A small number of outliers (corresponding to cases where hourly walking flows are very low) were excluded from the analysis.

The correlation between traffic levels and crossing as a proportion of walking in zebra crossings is negative and significant at the 5% level. The values found in subsets of roads with different average speeds are also negative but not significant at the 10% level. Both ratios are negatively and significantly associated at the 1% level with traffic levels in informal crossings. This is also valid for the sections of Seven Sisters Road with lower speeds, in the case of the ratio of crossing as a proportion of walking. In smaller roads with small speeds, the correlations are positive. In sections of the main roads with higher speeds, the correlations are insignificant. Overall, the strongest evidence of a negative impact of traffic levels on crossing ratios is found on the sections of the main road with lower speeds.

Table 1: Pearson correlations between hourly crossing ratios and traffic levels

Facility	Speed	Road	% walking *n*	% walking *correl.*	% formal *n*	% formal *correl.*
Zebra	All		57	-0.321**		
	<30	Woodberry Grove	27	-0.163		
	>30	Green Lanes	25	-0.242		
Informal crossing	All		290	-0.261***	237	-0.308***
	<30	All	170	-0.243***	118	-0.230**
	<30	Seven Sisters Road	90	-0.276***	60	-0.147
	<30	W. Down/ W. Grove	87	0.552***	57	0.641***
	>30	All	113	0.141	116	-0.044
	>30	Seven Sisters Road	60	-0.018	60	-0.008
	>30	Green Lanes	57	0.149	59	0.000

Significance levels: ***: 1%, **: 5%

4.2 Using bus stop data to test avoidance of informal crossings

Bus stop data can be used once again to derive conclusions on pedestrians' reaction road traffic. People may use bus stops at different locations in the two legs of the daily return trip, instead of using a pair of stops opposite each other. By doing so, they will be able to cross the road in a safer location. If a substantial number of people adopt this behaviour, and if the service areas of each bus stop are not equally balanced among both sides of the road (due to different population densities or patterns of land use), then we would expect a gap between the daily number of people boarding and alighting buses in the pairs of stops located in informal crossing points and in the pairs of stops near designated crossing facilities.

This hypothesis is studied for the case of three pairs of stops in Seven Sisters Road (Figure 7). Only the residents in the service area of these three pairs of stops are included in the analysis. Residents living in the service area of the pair of stops *A* can avoid crossing the road informally by using the bus stop in *A* that is located on their side of the road in one of the trip legs and then use the bus stop in *B* that is on the opposite side. Residents living in the service area of stops *C* can adopt a similar behaviour.

If this hypothesis holds, then the absolute difference between boardings and alightings in the pair of stops *B* would be similar to the number of residents who would theoretically use stops *A* and *C* but who would use stops *B* if they started avoiding informal road crossings. This number can be estimated by comparing the fastest routes from residences to the nearest bus stops on the two sides of the road and the fastest routes that do not use informal crossings. These latter routes were obtained by removing from the pedestrian network model all informal crossings and the central reservation running along some sections of the road. The data on bus stop users was then reassigned to the revised set of routes. The flows in routes ending in each bus stop were finally aggregated, and compared with the flows that were obtained in the case where residents do not avoid informal crossings.

The chart of the right side of Figure 7 shows that the theoretical number of additional users of the pair of bus stops *B* when residents avoid informal crossings is remarkably close to the observed difference between the number of people boarding and alighting buses in that stop. Most of the additional users are residents who previously used stops *C*. The decrease in the number of users of stops *C* is only slightly smaller, in absolute value, than the observed difference in number of boardings and alightings in those stops. The only case where the hypothesis studied does not seem to hold is in point *A*, as the decrease in users of the stops at that point is very small, but the absolute difference between boardings and alightings is very high. This could be due to the proximity of point *A* to Manor House junction, and the effect of flows of residents and non-residents interchanging from buses to the underground station. Overall, the analysis of bus boardings and alightings suggests that some residents in Woodberry Down avoid crossing in places without crossing facilities by adjusting the origins or destinations of their bus trips.

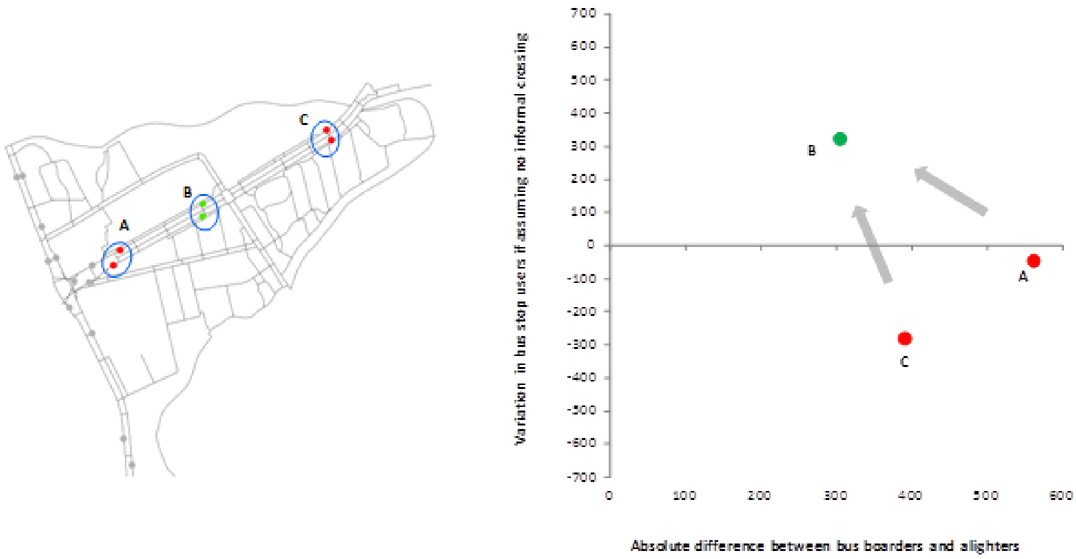


Figure 7: Avoidance of informal crossings vs. bus boardings and alightings

5. CONCLUSIONS AND FURTHER WORK

This paper analysed the impact of road traffic on pedestrian pavement and crossing flows in a suburban neighbourhood in London. The study adds to the existing literature by using bus stop data to derive conclusions about pedestrian behaviour, including the choice of quiet streets as an alternative to walking along main roads, and accessing bus stops in different locations in the two legs of bus trips in order to avoid crossing a road in unsafe locations.

The analysis found evidence suggesting that some pedestrians avoid the main road running through the area, which has high traffic levels and speeds. The propensity to cross the road is much higher in quieter roads, when comparing both with the number of pedestrians walking along the road and crossing in formal crossing facilities. The propensity to cross tend to decrease with traffic levels, both when considering the daily crossing flows in different crossing points across the study area, and when considering the variations in traffic levels throughout the day in the same location.

Further evidence can be obtained by extracting more detailed information from the video footage, such as aspects of pedestrian behaviour at informal crossings. The analysis can also be extended by comparing sites with different patterns of land use, street layout, and types of crossing facilities.

Acknowledgements

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Note: All websites accessed on 26 August 2015.