Multiple transport disadvantages: A cluster analysis of the social distribution of accessibility and pedestrian mobility in a metropolitan area

Paulo Rui Anciaes
Giles Atkinson

London School of Economics and Political Science, United Kingdom

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Abstract

The concept of social justice is often used in the assessment of the social and environmental sustainability of urban transport policies. This paper brings together two strands of the literature on this topic: the role of accessibility in social inclusion and the distribution of the environmental impacts of transport. Using the Lisbon Metropolitan Area as case study, we test if there are cumulative social inequalities in terms of accessibility and pedestrian mobility, considering that the latter depends on local environmental quality.

GIS methods are used to estimate a set of neighbourhood-level indicators such as private and public transport accessibility to jobs and urban facilities, community severance, and pedestrian exposure to traffic noise. Neighbourhoods are then classified based on the scores of those indicators in two moments in time. Six clusters can be identified. Accessibility increases and pedestrian mobility decreases as we move from the 'main centre' towards the 'suburban', 'small centres', 'semi-rural' and 'rural' clusters. A sixth cluster is labelled 'multiple disadvantages' and groups dispersed neighbourhoods that fare poorly in all indicators.

The clusters are then characterized in terms of their socio-economic composition. Central areas have elderly populations, while rural areas and the "multiple disadvantaged" cluster have low-qualified populations. We also tested if disadvantages based on a neighbourhood's location persist after accounting for the daily destinations and travel modes used by its population. It was found that 'multiple disadvantaged' areas have the poorest scores in time to work, effects of congestion, and pedestrian noise exposures for commuters on the way to work. The main conclusion is that 'hotspots' of multiple transport-related disadvantages tend to have populations traditionally at risk of social exclusion.

1. Introduction

Claims for incorporating social justice in urban transport policy are based on the argument that the distribution of the benefits and costs of transport should not be disadvantageous for groups that are already at disadvantage in terms of income or political power. The problem has a geographic dimension, as those groups may face limitations regarding residence location, travel destinations and transport modes. Developments in Geographic Information Systems (GIS) have facilitated the study of this question, by quantifying the local effects of transport, which are then related statistically with the location and mobility patterns of different groups. One strand of this literature has studied inter-group differences in levels of accessibility. Low-income groups are often at disadvantage in job accessibility due to the mismatch between residences and jobs (Cervero *et al*. 1999, Stoll *et al*. 2000) or lack of access to private transport (Wang 2003, Ong and Miller 2005). The latter may also explain inequalities in access to public parks (Omer 2006, Jones *et al*. 2009), food shops (Smoyer-Tomic *et al*. 2006, Lee and Lim 2009) and health facilities (Lovett *et al*. 2002, Martin *et al*. 2008). A parallel strand of the literature has focused on the distribution of the local environmental costs of transport, often finding inequalities along age, socio-economic or racial lines (Brainard *et al*. 2002, 2003, Buzzelli and Jerrett 2004, Pearce *et al*. 2006, Havard *et al*. 2009).

The interpretation of inequalities in terms of social justice depends, however, on the comparison of the distribution of different impacts across different groups. Empirical studies have rejected the hypothesis of multiple disadvantage when disaggregating accessibility by type of destination (Scott and Horner 2004, Tsou *et al*. 2005, Macintyre *et al*. 2008), or when considering several types of environmental effects (Brainard *et al*. 2002, 2003). There is little research on the relationships between the distributions of accessibility and environmental effects. While some insights can be drawn from studies that overlay the spatial distributions of social groups, car ownership and pollution (Mitchell and Dorling 2003, Kingham *et al*. 2007), a clearer picture can be obtained by using detailed measures of accessibility, which account not only for the advantages of car ownership but also for factors such as the location of destinations and the availability and quality of the private and public transport infrastructure.

There is also a lack of knowledge on the role of pedestrian mobility as an additional distributive concern of urban transport, and on its relationships with the distribution of both accessibility and environmental quality. Walking is a means to reach nearby places or to access public transport, and so pedestrian mobility is a condition or a complement to accessibility. In addition, the quality of pedestrian mobility depends on environmental factors, especially when we consider walking as an activity with its own value. While groups such as the elderly or low-income households are at a potential disadvantage due to higher reliance on walking, this disadvantage also has a geographic dimension, if the areas where they walk have low levels of pedestrian mobility. Nevertheless, walking trips are not usually included in the assessment of social differences in accessibility, while the assessment of environmental inequalities tends to refer to exposures at home and not to exposures felt by pedestrians.

The main objective of this paper is to assess if social disadvantages in terms of accessibility and transport's environmental effects are cumulative or compensatory. In addition, the analysis builds on previous research by developing two methodological issues. The first is the incorporation of pedestrian mobility in the assessment of both accessibility and environmental quality. The second issue is the separation of the assessment of indicators that depend only on the location of residences, potential destinations and transport facilities, and indicators that also depend on the populations' actual travel behaviour. We consider that the choice of daily destinations and travel modes affects both the way that individuals fulfil the accessibility potential of the places where they live and the levels of exposure to noise that they face during the day as pedestrians.

The analysis is applied to the case of Lisbon Metropolitan Area, providing an evaluation of the changes in the transport system in the period between the last two population censuses (1991-2001). The combination of unprecedented changes in the road network with urban fragmentation and population ageing in this period has raised questions about the adequacy of the transport improvements for meeting the needs of elderly and low-qualified populations. The effects of those changes are assessed by looking at changes occurring in the different parts of the metropolitan area and their relationship with changes in the neighbourhood socio-economic compositions.

We first introduce the indicators used to characterize the neighbourhoods (Section 2). Accessibility is measured by ease of access to jobs and urban facilities by different means of transport, while environmental quality refers to the impacts of the transport system in the exposure of pedestrians to noise. All indicators are estimated at the level of the enumeration district. In a first stage of analysis (Section 3), we use cluster analysis to classify the districts according to the indicators that depend only on location, while in a second stage (Section 4), the clusters found are characterized in terms of the socio-economic structure of their population and of indicators that depend on travel behaviour.

2. Measuring accessibility and environmental quality

Modelling potential destinations and the transport network

The evaluation of accessibility and environmental quality requires a detailed modelling of potential destinations and the location, performance and environmental effects of the transport system. These variables are modelled separately for two moments in time (1991 and 2001).

We define a set of major centres of employment (207 and 240 points in 1991 and 2001). This set was constructed considering employment levels at the municipality level by sector of activity, which were then disaggregated based on the number of employees of companies registered at smaller areal units, and finally assigned to specific locations, identified using ancillary information. A different set of travel destinations includes urban facilities, represented by tax departments and health centres. These are good indicators of two types of locations in each municipality, as tax departments are usually located in the traditional administrative centres, while health centres are found in less central, more residential areas.

We assume that individuals walk to work or to run errands and socialize. In both cases, the location of destinations is specific to each enumeration district, and is obtained by a sampling process that ensures that each district has between 4 and 12 possible destinations, at a maximum distance of 800m. The attractiveness of each destination for pedestrians is then defined as the population living nearby, corrected by a factor depending on distance.

The private and public transport networks consist of information on links, services and travel times by time of day. The optimal private transport routes include walking to parking areas and public transport routes includes walking to stops/stations, waiting, and interchange time. Non-bus public transport times are inferred from schedules, while car and bus times are modelled using two alternatives: theoretical and actual travel times. Theoretical times depend on speed limits, assumptions on driving above limits, road hierarchy and quality, slopes, and intersections. Actual times also incorporate the effects of congestion, based on road capacity, traffic levels and compositions. These are modelled by disaggregating geographically and temporally the available data on commuting flows of workers and students, personal trips, work-related trips, freight transport and bus traffic. These flows are then assigned to the respective optimal routes calculated using theoretical travel times.

Traffic levels and compositions are also used to estimate peak and off-peak noise levels on the road and rail networks. These levels are then used alongside information on industrial noise and flight paths to estimate a detailed noise surface covering the study area, based on noise propagation from each source and using several GIS datasets representing local conditions.

Location-based indicators

We define **job accessibility** as the proximity of a district to relation to major centres of employment when using the transport network under theoretical travel times. This concept is assessed by a gravity measure (Hansen 1959). A district's job accessibility by a certain travel mode is the sum of jobs at each centre starting at each period of the day, weighted by a negative function[1] of travel times to access that centre using in that mode and in that period. We define accessibility for private and public transport separately. However, public transport job accessibility is included in subsequent analysis as a ratio of private transport accessibility, in order to capture spatial differences that are not the result of geographic proximity to centres but instead on different relative levels of provision of public and private transport.

Accessibility to facilities is included in the analysis as a separate accessibility concern because the relevant public policies tend to be linked to the provision of public transport services in routes and times that may not coincide with those of major commuting flows. We define an indicator that captures issues such as the need of trip chaining and variations in the availability of public transport throughout the day. This indicator is defined as the minimum time in a round trip from home to a tax department and an health centre, assuming that the first facility is visited at peak time while travel between facilities and the trip back home occurs at off-peak time.

A third indicator measures transport-related **community severance** as a limitation to pedestrian accessibility, attending to the fact that large transport infrastructure acts as a deterrent to walking and to community interaction (Clark *et al.* 1991, Bradbury *et al.* 2007). We define the indicator of community severance of an enumeration district as the attractiveness score of the pedestrian destinations that cannot be reached on the street network

[1] We adopt a negative exponential form for this function, with a value of 0.005 for the steepness of the decay of accessibility with travel time. This value was obtained by modelling commuting flows between administrative areas as a function of times and using a trip-distribution gravity model (Ortúzar and Willumsen 2006, chap.5).

unless crossing large transport infrastructure, given as a proportion of the attractiveness score of all the destinations of that district, as previously defined.

The local environmental effects of the transport system are assessed by an indicator of **exposure to noise** of pedestrians walking around their neighbourhood. We assume individuals living in a given enumeration district are exposed along the optimal walking routes to the set of pedestrian destinations of that district. The indicator is then the sum for all destinations of the length-averaged noise levels on those routes, multiplied by the relative attractiveness of those destinations. We assume that the probability of walking is constant throughout the day and as such daily noise exposures are a weighted average of exposures to noise levels at peak and off-peak times.

Mobility-based indicators

While location-based indicators measure the potential of a neighbourhood in terms of accessibility and environmental quality, this potential may not be fully realized by the neighbourhood's population in terms of actual time to work and exposures to local environmental nuisances. In fact, individuals may face limitations in the choice of daily destinations and in the transport modes used to access them, which may lead to a possible "modal mismatch" between the most efficient modes available in a neighbourhood and the modes actually used by the population. Levels of realized accessibility in the different neighbourhoods may also be affected to congestion by different degrees. As they move around the city during the day as pedestrians, the individuals' daily exposure to noise may also differ substantially from the potential exposure to noise when walking around their neighbourhoods.

We define **time to work** of the population living in a given district as the weighted average of actual travel times (including congestion) to each destination at each period of the day by each transport mode (private, public or walking). Available commuting data is used to derive the proportion of workers walking to work. The respective trips are assigned to the set of pedestrian destinations previously defined. Trips by private and public transport are assigned to major centres of employment and disaggregated by period of time.

Two further indicators are derived from estimating the ratio of actual and theoretical times to work. The **effect of travel mode** on time to work is defined as the ratio between actual time and the time when using the fastest transport modes available to access each destination. The **effect of congestion** on time to work is the ratio between actual time and the time when using the transport network under uncongested conditions. It should be noted that both effects depend on the proportion of the district's population using each travel mode and on the relative efficiency of each mode for accessing the destinations chosen.

Finally, the indicator of pedestrian **exposure to noise on the way to work** is the weighted average of the daily exposures for workers travelling to each destination at each period of the day by each transport mode. As we assume that workers walking to work access the same destinations as the population walking around the neighbourhood, their exposures are identical to the indicator of noise exposure around one's neighbourhood defined in the previous section. The exposures of workers commuting by private or public transport is the equivalent exposure level of the exposures in all walking sections of the return trip to work, considering noise levels in the relevant time of day.

3. Clustering (location-based indicators)

Clustering methods define sub-sets of observations in a data set that are relatively similar to each other and distinct from other observations according to some defined criteria. The method is often used to synthesize the spatial distributions of a series of variables and to provide partitions of the data set according to their homogeneity. The use of cluster analysis to assess multiple transport inequalities is especially relevant in the case of the Lisbon Metropolitan Area. This region is highly heterogeneous, including the country capital but also rural areas at 80km from the capital, with a predominantly agricultural economy and few functional links with other areas. In addition, the estuary of the River Tejo acts as a barrier separating two distinct economic and social regions. Therefore, differences in accessibility or exposures to noise between two given neighbourhoods in the metropolitan area may not correspond to disadvantages linked to transport but simply be the reflex of the different geographical context and functional roles of the two places within the metropolitan space. The mapping of the clusters of areas with homogeneous values for the set of indicators defined help to assess the validity of those two hypotheses.

The cluster analysis uses the two-year pooled dataset of the location-based indicators of accessibility and environmental quality at the enumeration district level. The use of pooled data creates a classification scheme that applies to both years, this allowing for the assessment of the effects of the transport projects implemented in the period concerned on the character of the different districts.

Due to the size of the data set (18758 and 27397 inhabited enumeration districts in 1991 and 2001 respectively), the standard hierarchical clustering procedure is not feasible, as this method requires the calculation of a matrix of distance (dissimilarity) measures between all pairs of observations. As such, we require a two step method which scales down the data set before applying more robust clustering algorithms.

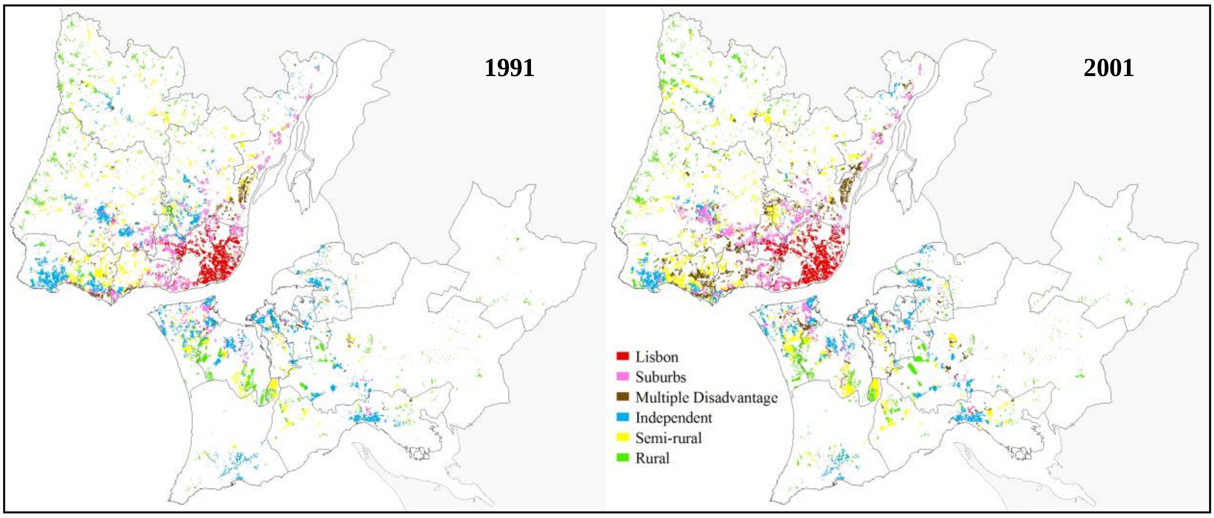
We use a procedure based on the BIRCH method (Zhang *et al* 1996) and which is available on the SPSS software package. In this method, the observations are pre-grouped into a defined number of sub-clusters according to a sequential process that assigns each observation to a new cluster or to previously formed clusters based on the distance criterion. In a second stage, the sub-clusters are aggregated using the agglomerative hierarchical clustering method, which combines existing clusters into sequentially smaller sets, by merging at each stage the two closest clusters. The distance between clusters is defined as the average of the distances between all pairs of observations coming from the two clusters. In both stages, we use as the distance measure the Euclidean distance applied to the standardized variables. Although the number of clusters can be found automatically using the BIRCH method, we chose to compare solutions with different number of clusters and present the solution that yields a more intuitive interpretation.

Table 1 gives the composition of the clusters found. The spatial distribution of the clusters in 1991 and 2001 is then mapped in **Figure 1**.

Table 1: Cluster averages and standard deviations

	All	**Lisbon**	**Suburbs**	**Multiple disadv.**	**Indep.**	**Semi Rural**	**Rural**
Private transport job accessibility (000s)	134.2 (72.5)	266.1 (44.1)	158.1 (49.1)	136.0 (44.5)	103.0 (34.4)	94.7 (37.5)	56.9 (28.4)
Ratio public-private tr. job accessibility	0.11 (0.06)	0.21 (0.04)	0.13 (0.03)	0.08 (0.03)	0.12 (0.03)	0.07 (0.02)	0.04 (0.02)
Public transport. time to facilities	29.7 (17.1)	15.1 (5.2)	20.8 (6.9)	36.5 (11.0)	20.3 (7.4)	39.7 (7.4)	63.8 (20.1)
Community severance	0.16 (0.24)	0.34 (0.30)	0.17 (0.18)	0.47 (0.31)	0.07 (0.11)	0.03 (0.07)	0.02 (0.09)
Noise around the neighbourhood	55.5 (7.9)	60.6 (6.2)	60.2 (4.6)	63.4 (6.2)	49.6 (4.3)	54.4 (5.1)	45.0 (5.4)

Figure 1: Location of clusters



The clusters found can be organized in a sequence of decreasing levels of private transport job accessibility. The first cluster, which corresponds almost exactly to the city of Lisbon, is the centre of the metropolitan area, with the highest private transport job accessibility and relative public transport job accessibility and the lowest public transport time to urban facilities. On the other hand, the concentration of employment, activities and transport links is also reflected in high values for the indicators of community severance and noise exposures for pedestrians walking around their neighbourhood.

The areas surrounding Lisbon and with fast motorway access to this city are classified as 'suburbs. These areas have levels of private transport job accessibility, relative public transport accessibility and time to urban facilities that are clearly better than the average of the metropolitan area but considerably worse than in Lisbon. This cluster is located almost totally in the North Bank, confirming the role of the River Tejo in the creation of accessibility differentials between the South and North corridors of access to Lisbon. Despite the differences in accessibility between Lisbon and suburbs, both clusters have similar average values in exposures to noise of pedestrians walking around their neighbourhood, which suggests that the suburbs bear a disproportionate share of the costs of the transport system, when comparing with their share on benefits.

The cluster with the third highest average level of private transport job accessibility is the most relevant for the analysis of transport in terms of social justice, as it is characterized by conditions which contradict the expected pattern of pedestrian mobility increasing with the decrease of accessibility as we move from more crowded to less dense areas. The districts in this cluster are close to motorways and as such have higher than average private transport accessibility indices; however, they have below-average levels of relative provision of public transport and higher than average public times to facilities. Furthermore, they show the highest exposures to noise and the highest indices of community severance. This cluster is labelled “multiple disadvantage” as it aggregates the districts in which the incidence of transport negative effects occurs alongside the insufficiency of public transport to provide services comparable to the private transport options. The cluster includes a series of small agglomerations to the Northeast of Lisbon, located in a narrow strip between national-level road and rail infrastructure which do not always serve the local populations. This geographic context explains the poor scores of these areas in terms of community severance, exposure to noise and public transport accessibility to jobs and facilities. Overall, the multiple disadvantage cluster is more numerous in 2001, incorporating areas which were previously classified as semi-rural.

A fourth cluster is labelled “independent” as it is formed by the municipality capitals and other major towns with economic and employment dynamics that are partially autonomous from the influence of Lisbon. These areas have the second best average index of access to urban facilities and a relatively good index of public transport provision, similar to that of the more central areas in the suburbs cluster. Community severance and pedestrian noise exposures are also lower than average. It should be noticed that some areas in the Northwest corridor moved from this cluster to the “suburbs” cluster in the period 1991-2001, which is explained by the higher accessibility levels that followed the construction of a new motorway and by the associated increase in noise exposures.

The two remaining clusters (“semi-rural” and “rural”) contain the less urbanized areas in the AML and have the lowest levels of private transport job accessibility and relative public transport job accessibility and the highest public transport time to urban facilities. On the other hand, community severance and noise exposures are clearly below average. These two clusters merge in a 5-cluster solution, as the major differences between them are their degree of dissimilarity to the other clusters. It is salient, however, that the noise exposures in the “semi-rural” cluster are higher than in the predominantly urban areas of the independent cluster. This is explained by the fact that population agglomerations in the semi-rural cluster tend to be located along national and regional roads with relatively high traffic levels.

4. Cluster characterization (socio-economic structure and mobility-based indicators)

In this section, the clusters found above are next characterized in terms of the socio-economic structure of their populations and of the mobility-based indicators of accessibility and environmental quality.

We evaluate the socio-economic structure of an enumeration district in terms of three variables. These variables are linear combinations of a series of census variables and were obtained by a previous factor analysis. "Age" is associated with age of both population and buildings. "Qualifications" is associated with variables measuring educational and professional qualifications and with other variables linked to socio-economic status, such as large and large and owner-occupied dwellings, values of rents and mortgage payments. "Urbanization" is related to dwellings per building and proportion of non exclusively-residential buildings.

The characterization of clusters in terms of these three variables is presented in the top part of **Table 2**. The table shows that the central part of the metropolitan area has a predominantly elderly population and that the most isolated areas (the rural cluster) and the cluster of “multiple disadvantage” areas have populations with qualifications below the mean of the metropolitan area. The comparison of the clusters in the two periods also indicate the ageing of the population in small centres (the independent cluster) and a shift in the relative concentration of low-qualified populations from the semi-rural and rural areas to the other clusters. The averages of the urbanization variable also indicate the intensification of urbanization in all clusters.

It should be noted that in most cases, the variability of the variables inside each cluster is similar to the variability in the whole study area (standard deviation close to 1), although their distributions are centred around different mean values. The greatest variability in terms of qualifications occurs in the Lisbon and suburban clusters, which may be related to socio-economic spatial segregation within these clusters. The question is especially relevant as in these clusters the community severance and the pedestrian noise around the neighbourhood indices vary from values just above standards to some of the highest values in the whole AML, as seen if we compare mean and standard deviation of these indices in these clusters.

Table 2: Characterization of clusters (means and standard deviations)

	1991						2001					
	Lis	**Sub**	**MDis**	**Ind**	**SRur**	**Rur**	**Lis**	**Sub**	**MDis**	**Ind**	**SRur**	**Rur**
Age	0.77 (0.92)	-0.26 (0.70)	-0.49 (0.72)	-0.40 (0.78)	-0.54 (0.64)	-0.34 (0.57)	0.78 (0.98)	-0.26 (0.85)	-0.51 (0.78)	-0.17 (0.90)	-0.48 (0.74)	-0.31 (0.69)
Qualification	0.29 (0.92)	0.09 (1.09)	-0.13 (0.90)	-0.04 (0.82)	-0.01 (0.84)	-0.37 (0.62)	0.15 (1.04)	-0.11 (0.93)	-0.17 (0.86)	-0.10 (0.81)	0.00 (0.91)	-0.17 (0.86)
Urbanization	1.01 (0.89)	0.80 (1.02)	0.34 (1.09)	0.43 (0.98)	-0.22 (0.90)	-0.89 (0.55)	1.09 (1.00)	0.90 (1.00)	0.48 (1.12)	0.46 (0.98)	-0.14 (0.82)	-0.72 (0.59)
Time to work	18.5 (3.7)	23.5 (3.8)	26.7 (4.9)	24.5 (5.5)	26.3 (5.7)	25 (6.0)	17.7 (3.2)	22.5 (3.4)	23.3 (4.0)	22.1 (4.3)	23.6 (4.1)	26.3 (4.7)
Effect of mode	1.72 (0.22)	1.76 (0.30)	1.80 (0.30)	1.78 (0.25)	1.79 (0.33)	1.66 (0.42)	1.60 (0.22)	1.64 (0.23)	1.62 (0.27)	1.60 (0.22)	1.61 (0.31)	1.55 (0.35)
Effect of congestion	1.08 (0.04)	1.12 (0.07)	1.08 (0.05)	1.06 (0.04)	1.05 (0.04)	1.02 (0.02)	1.09 (0.06)	1.12 (0.06)	1.10 (0.06)	1.09 (0.06)	1.08 (0.05)	1.06 (0.05)
Noise on way to work	55.4 (4.5)	56.5 (4.1)	57.5 (4.5)	52.0 (3.2)	51.0 (3.1)	47.3 (2.8)	56.8 (3.9)	55.6 (3.6)	55.5 (4.7)	51.6 (2.7)	50.8 (3.0)	48.2 (2.4)

It is also revealing to examine the averages and within-cluster variability of the mobility-based indicators inside each cluster, in order to investigate whether patterns of transport disadvantage that depend on where people live are different from patterns of disadvantage that depend on decisions on destination and transport mode.

The cluster identified as “multiple disadvantage” has the highest average time to work in 1991 and the highest average time in non-rural clusters in 2001. This disadvantage is linked to the disadvantage in terms of public transport job accessibility, as the cluster fares relatively well in terms of private transport job accessibility. The variability in times to work is also small when comparing both with the variability of private transport accessibility in this cluster or with the variability of times to work in clusters with similar or higher mean values of time to work. Times to work decreased in all clusters in the period of concern, except in the rural cluster. This result may be linked to the increase of the proportion of high-qualified populations in these areas, commuting to more distant destinations.

The effects of modal choice showed a tendency to decrease from 1991 to 2001, while the effects of congestion increased in all clusters. Both effects are especially marked in the suburbs. These results show that the advantage of the suburbs in terms of potential accessibility many not be fully realized due to the "modal mismatch" and to the effects of congestion.

The inter-cluster differences in average exposures to noise are less marked for the case of noise on the way to work than for the case of noise around the neighbourhood. In addition, these differences do not follow the same order and are not proportional as differences in mobility, with clusters with very different accessibility levels having comparable exposures on the way to work, as there is only a 5 dB (A) gap between Lisbon and the areas classified as semi-rural. The choice of daily destinations and modes of transport for workers have therefore a significant impact on the spatial distribution of exposures to noise for workers, which neutralizes in part the correlation between this indicator and the exposure to noise around the neighbourhood (which is due to the fact that part of the journey to work on foot is made around the neighbourhood). The results show that noise exposures for workers and non-workers follow different spatial patterns, and as such an equity analysis should analyse separately the two dimensions.

5. Discussion and conclusions

The results show there is a clear distinction between different sub-sets of the AML in terms of potential and actual indices of accessibility and pedestrian exposure to environmental nuisances. These distinctions are broadly related with the position of each region in relation with the centre of the metropolitan area, with accessibility decreasing and environmental quality increasing as we move towards less central areas. However, there are 'hotspots' of multiple transport-related disadvantages, which tend to have low-qualified populations. Due to their high relative concentration in the main centre, elderly populations are also disproportionately affected by community severance and exposure to noise. The association of transport disadvantages with populations at risk of social exclusion indicates that more emphasis should be put on locally-based interventions and on public participation methods in the definition of strategies for urban transport planning.

The analysis also suggests that potential advantages in terms of accessibility or environmental quality may not correspond to actual advantages when we account for the individuals' patterns of daily mobility. The improvement of private transport accessibility may therefore not benefit the populations served, if these populations rely on public transport or if congestion limits the benefits brought by road infrastructure.

At a methodological level, the cluster procedure is a useful method to divide the study area into homogeneous sub-sets based on their conditions in terms of different indicators related to transport and can be used to develop hypothesis on the spatial variability of statistical associations between those indicators and socio-economic factors.

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