THE LAND USE AND TRANSPORT RELATIONSHIP IN PERIPHERAL AREAS: POLICY INTEGRATION BASED ON CASE STUDIES

Henar Salas-Olmedo. University of Cantabria (Spain). salasmh@unican.es

Soledad Nogués. University of Cantabria (Spain). noguess@unican.es

ABSTRACT

The land use and transport relationship has been largely discussed in both directions. Most empirical research projects have taken metropolitan and central areas as case study areas, where more and more transport infrastructures have been built and where transport management is now the key issue to satisfy travel demand. In fact, there is a general agreement that transport infrastructure shape land use patterns, but they do not necessarily generate an increased rate of development. Peripheral areas within developed countries share some trends, although at a different scale and intensity, with central areas, such as sprawl processes, but they also have some particularities, namely large spatial imbalances, low development and accessibility rates and so on. Consequently, they require an independent approach both in the analysis phase (because of the different behaviour of variables throughout the territory) and in the policy suggestion phase (because of spatial dissimilarities, weaker transport system, socioeconomic and financial difficulties, etc.).

In the first section of this paper, we briefly describe the state of the art of the land use and transport relationship with particular reference to peripheral areas; we perform a short review of the numerous tools which have been developed to tackle spatial analysis; and we establish the criteria to choose the case studies, which are Doncaster and Lincoln areas in the United Kingdom. Section 2 deals with the analysis of their internal accessibility and residence-to-work flows, using tools from the graph theory mainly. We complement the analysis with some indicators of city-size distribution and sprawl based on population and land use data to set the basis for particular land use and transport policy suggestions for this kind of areas. Finally, we summarize the main findings of our research regarding the differences in the spatial pattern and daily mobility of a motorway-connected peripheral area and a motorway-free one.

Keywords: LUT policies, peripheral areas, land use, transport planning

1. INTRODUCTION

1.1. Land use and transport

Transport is an element that provides structure, which is fundamental in the configuration of the territory. On the one hand, it is a factor in the localization of the population and its activities and a link that permits the connection of settlements. On the other hand, it is the result of the spatial distribution of land uses.

Interest in studying the relationship between transport and land use was first laid down in the work of Von Thünen (1862), Weber (1929) an Christaller (1933) , among others, who considered transport costs an important factor in the localization of activities with the resulting increase in the value of the land. Nevertheless, the most significant precedent was demonstrated by the body of work by Cervero (1991) and Banister and Lichfield (1995) and the work of Mitchell and Rapkin, who introduced accessibility as a decisive element in the distribution of land uses. These authors place much emphasis in the existence of a reciprocal cause and effect relationship between transport and land uses, stating that:

> 'A changing land use pattern will generate the need for additional physical channels of movement and new or changed traffic facilities will in turn encourage change in the existing distribution of establishments' (Mitchell and Rapkin, 1954: 133).

For this reason they set down the need to develop coordinated planning of transport and land use policies.

This widely accepted reciprocal relationship shows a deep and temporal dissymmetry which creates spatial imbalance, and it is noted that, in the words of Mackett (1993) changes in land uses produce practically immediate alterations in the transport system, while modifications to the transport system result in spatial changes in the long term.

This said, despite the recognition of the existence of a state of interdependency between both, the 1990's saw the start of discussion as to the weakening of this relationship. In North America, at a moment in which this phenomenon appears to be patent due to the ubiquity of accessibility, Giulano (1995) proposed the theory of abandoning the coordination of transport and land use and regional policies. In Europe, Banister and Lichfield (1995) among others, considered transport infrastructures as a secondary factor in the decisions of firm location in developed economies. On this very subject, Wegener (1995) picking up the "land use transport feedback cycle", points out that although it is clear that transport infrastructures influence the evolution of territory, what turns out to be extremely tricky to discern is to what extent the changes produced are due to the infrastructure itself and to what measure they are due to the interaction of many other factors. Furthermore, as Lawless and Dabinett (1995) underline, the effects of infrastructures depend also on exogenic influences, such as

economic, social and institutional conditions. It can be said therefore that there is a general consensus on the correlation between construction of a new transport link and changes in land uses, which does not necessarily imply a relation of causality, an aspect that is still under debate among researchers (Boarnet and Chalermpong, 2001; Chi et al. (2006); Baum-Snow, 2007; Funderburg et al., 2010).

In short, although the debate has not been completely cleared up, it is possible to draw certain conclusions on the state of the question: On the one hand, it appears that the prediction of the Urban Systems Research and Engineering (1976: 22):

> 'The first highway in an area may have substantial local effects, but the twentieth one will probably have much less',

can be corroborated, which is to say, that the impacts tend to diminish with the greater the density of the communication network upon which the new link is laid down, since the increase in accessibility is lesser. This idea coincides with the greater strength of the land use-transport relationship which is deduced from the studies carried out between 1950 and 1970 in the USA (Chi et al., 2006) and the later weakening proposed by Giuliano (1995). Elsewhere, it is necessary to bear in mind the concurrence of multiple factors that mitigate for or favour territorial changes.

It is possible to think, therefore, about a different behaviour in the land use-transport relationship of peripheral areas with respect to central areas, bearing in mind their differentiating characteristics. On a European level, the periphery is characterized by its having common and interrelated conditions from the socio-economic and territorial viewpoint, which makes development and regional competitiveness difficult (Krugman, 1995; Barro and Sala, 2004).

From the economic point of view they show marginalization and subordination with respect to decision centres, economic development and innovation, with a fragile productive system, which is barely dynamic and dependent on the exterior, aspects that have some bearing on deficient levels of income and welfare. Peripherality is linked at the same time to the weakness of human resources, and shows in general terms regressive demographic behaviour, with notable processes of aging and loss of population, which normally includes the youngest and most qualified. All this affects the spatial distribution of the population and economic activities, and in consequence it generates imbalances in the spatial system, characterized by a weak and polarized urban network.

These distinctive features of the most underprivileged areas make development difficult. In addition, the frequent lack of transport infrastructures has commonly been held as a main obstacle to progress if these areas. However, despite their importance, their construction has not always had the expected effects. On the one hand, certain studies, such as those carried out by Holl (2004) on the construction of a network of motorways in Portugal, show that there is a relationship between transport infrastructures and localization of economic activities, equalling their role to that of agglomeration economies. On the other hand, we find peripheral

areas in which, as Baudelle and Guy (2004) point out, the difference in the provision of infrastructures with respect to central areas has increased, areas that have been for some time asking for investments in transport arguing that they will benefit the socio-economic progress, but in which quality transport infrastructures are not capable of generating development on their own. Moreover, the axis of transport localized in isolated areas that do not have the support of measures have little or no impact (tunnel effect) or may even favour the migration of the population and resources outside the area (pump effect), just as the European Commission warned (1999).

Therefore, we can deduce that the impact of transport infrastructures does not only differ according to whether we are dealing with a central or peripheral area, but also according to its degree of socio and economical and spatial marginalization. A fundamental factor for a transport infrastructure to have an effect on the territory on which it is situated, is, as Parsons Brinckerhoff Quade & Douglas (1998) explain, the increase of accessibility that it provides. That is to say, the impact will not be very high in areas that already possess a high degree of accessibility (central areas), nor where accessibility is very low and a single communication link is constructed (very peripheral areas). However the impact will be larger in those areas where the network has been substantially improved by virtue of their already possessing a transport network thus permitting a certain amount of development and broadening connections that already exist.

Furthermore, the intensity and extension of the impacts depends on other factors, such as regional economic development, the level of technology, and in particular the development of telecommunications, institutional policy, social conditions, characteristics of the environment or the availability of other infrastructures and services.

In turn, within the peripheral region it is common to find a higher density of high capacity transport infrastructures around the central city or town of the region. In this situation, the zones that gain in terms of greater accessibility are the peri-urban areas, which are those that experience a greater increase in population and economic activities. This growth, boosted by the transport network and zoning policies, among other factors, took place from the 1970s onwards following a disperse model, where urban uses developed extensively with a low density of occupation.

1.2. Quantitative measures of spatial analysis

A wide range of fields have tackled the introduction of the spatial perspective in the analysis of urban issues, the most remarkable ones being those coming from spatial economists, geographers, statisticians and their co-authored works. Most of these tools have been widely applied in spatial analysis of mainly metropolitan areas at different scales, from the national, or even international, level to the regional, local or infra-local scale. The widespread employment of GIS technologies has favoured the use of complex tests and, particularly, it has enabled the use of more disaggregated data and the elaboration of local analysis.

In the following table we show the proposed classification, in which we combine a first level of classification of the indicators, according to whether their result consists of a value of reference for the entire region (global spatial analysis) or whether it is a new value for each element analysed (local spatial analysis), along with one or two lower levels where tools are grouped together in terms of the subject and /or type of analysis, attempting in this way to pool the groups most commonly accepted. Nevertheless, our objective is not to produce a definitive categorization, but rather a scheme that can be useful for explaining the different types of tools available for territorial analysis on a sub-regional scale.

Table I – Spatial Analysis Tools

GLOBAL	**LOCAL**
Thematic indicators	
Functional specialisation tests Sprawl statistics	
Analysis of the regional urban system	Analysis of the role of urban settlements
Distribution of settlements in order of demographic size Measures of primacy Regional connectivity	Central places and catchment areas Functional centrality Connectivity of settlements
Global spatial analysis	Local spatial analysis
Centrality Dispersion Randomness Topological – qualitative analysis of areas	 Density Randomness Local analysis of qualitative maps
Spatial statistics	Local spatial statistics
Global spatial autocorrelation	 Geographically weighted regression Local spatial autocorrelation AMOEBA

Source: personal compilation.

Global territorial analysis can be approached from the following perspectives:

1. Thematic indicators: these offer a first general vision of the area of study presenting a synthesis of the principal statistical and cartographical variables through functional specialisation tests (geographical association, Gibbs-Martin index, Gini coefficient, etc.) and through the evaluation of the sprawl process (urban density, residential use efficiency, and many others).

2. Indicators of the distribution of the urban system: their function is to help set up the urban structure of the study area through population analysis (city-size distribution primacy measures), and the way in which the different settlements relate (graph theory).

3. Global spatial analysis: offers indicators that permit an easy temporary comparison or one between regions and which counts on the specific disposition of the elements in the territory (mean centre, standard deviational ellipse, nearest neighbour, k-function, fractal dimension).

4. Spatial statistics: this compiles more complex tools that take into account the spatial dependency of the observations. We include here the indicators of global spatial autocorrelation such as Moran's I, Geary, G(d), join-count statistics…

In addition to the global analysis, there are several tools for an in-depth analysis of local conditions:

1. Analysis of the role of urban settlements: we study the role that each of the main urban areas (catchment areas, functional centrality) in the regional system and the relationships they generate between each other (graph theory).

2. Spatial analysis: by means of methods based on moving windows that offer data giving average density for each point based on surrounding observations (kernel density, local k-function). In the case of qualitative maps, the shape of the resulting polygons (composition and configuration tests) is analysed.

3. Local spatial statistics: this offers a series of indicators that allows the detection of the spatial association between variables or the localization of groups of similar or dissimilar values (geographically weighted regression, Anselin local Moran's I, Gi*, AMOEBA, etc.).

1.3. The selection of the study areas

We approach the study of two areas that share a peripheral position but are located in a different country enabling us to have the chance to see what other academics and local and regional agents are doing, and which therefore provides a wider framework for the analysis and conclusions to be derived.

Firstly, we have checked over a hundred different tests that deal with the distribution and characterisation of population, land use and the urban system, taking as a case study a peripheral region in Spain in order to compare the results of each test or tool. This case study area is the Autonomous Region of Cantabria, on the north coast of Spain, for which we have plenty of data available and a deep qualitative knowledge of the territorial system, allowing us to easily understand and interpret the quantitative results.

Once we have tested this broad selection of measures, our aim is to use the acquired knowledge to analyse another area so we can learn how others work and make some comparisons that will finally provide us with a better understanding of the relationship between transport and the spatial pattern of land uses.

We have chosen two peripheral study areas in the United Kingdom (one containing a motorway crossing and another with a trunk road crossing) in order to try to isolate the impact of highways from other factors. The Metropolitan Borough of Doncaster and Lincoln Policy Area have been chosen based on these criteria:

1. They are on a peripheral location at a national, or European, scale: both areas had been included in EU Objectives 0 or 1 because of their lower level of development. Naturally, there are many other areas that fulfil this requirement, but these two cities are at a reasonable distance from Sheffield Hallam University, where we have found support to gather data and make some fieldwork.

2. They are broadly located in the same part of the country, and at the same time they are far enough away so that development in one area does not constrain development in the other.

3. Both of them contain a crossroad, which has been a factor for having a catchment area that is larger than the strict city boundaries.

4. Only in one of them does this crossroad consist of motorways (Doncaster), whereas in the other case they are just trunk roads (Lincoln).

5. However, according to major socio-economic data and some local agents that were interviewed, Doncaster does not look a more dynamic area than Lincoln, thus there is a challenge to understand the real impact that highways have on the territory.

We agree that highways do not necessarily provide further development, but does this mean that they have no influence at all? We analyse the spatial distribution of urban land uses by evaluating the relationships between the place of residence and work and some complimentary data.

2. ANALYSIS OF THE STUDY AREAS IN UK

2.1. Data source and tool considerations

Apart from the vast literature review of tools to measure the spatial dimension, the criteria for the selection of a set of tools upon which to base the analysis, must also consider the data availability for each particular study area, in terms of thematic characteristics, time span and spatial scale and degree of aggregation. In general terms, more complex tools are able to provide better results with fewer limitations, but they need a large amount of the most disaggregated and spatially continuous data to be effective.

Data sources

In the case of our British study areas, Doncaster Metropolitan Borough (DMB) and Lincoln Policy Area (LPA), we have retrieved population data from the Census at different levels of disaggregation and land use maps from the Centre for Ecology & Hydrology and the European Environment Agency. We also have a cartography base of roads and administrative boundaries from the Digimap - Ordnance Survey, Masterplan Transport and UK Borders collections available at the Edina platform. After a deep analysis of these data

sources, we conclude that thematic diversity and spatial or grain scale, on the one hand, and time span on the other hand, are inversely related.

Table II – Data source characteristics

Data source	Advantages	Disadvantages
Origin-destination matrix. Output Areas (OAs), Wards, Census 2001. National Statistics.	Residence to work mobility patterns at a local scale	Data aggregated at the ward level does not permit settlement to settlement analysis; and OAs are too small to analyse significant flows
	Residence and job place based data	Data is only available for a single date (year 2001)
Key statistics. Output Areas, Wards, Postcode sector, Urban areas and Settlements. 1981-2001.	Great diversity of thematic data	Boundaries change over time
	Better spatial match of population data by urban area or settlement	Most disaggregated data is only available for year 2001
		Not all the settlements mapped in OSM50 cartography are registered
		Settlements below 1,500 inhabitants only have data for year 2001
Land use maps (1990 by the Centre for Ecology & Hydrology and CLC2000 by the EEA)	Exact spatial location and characteristics of different land use areas	1990 and 2000 land use maps have been made with a different methodology, which does not allow comparison over time. CLC2006 land use map is not still available for the United Kingdom

Source: personal compilation.

Accordingly, it is necessary to look for a balance between an in-depth research of a single variable through time, such as local spatial autocorrelation of the most disaggregated and with the oldest registries variable (i.e. resident population); and the analysis of spatial relationships in a single (and most recent) point-spot.

With the detection of land use and transport relationships to suggest measures to improve the sustainability of the urban system being the main goal of this paper, we decided to deal with the second approach and focus on residence-to-work flows using some other variables such as resident population and land use as complementary data. We also use previous research in the area and some interviews with local and regional agents to endorse our findings.

Tools selection

Considering accessibility as a key factor to understand the impact of highways on the spatial pattern of population and activities, we use some tools from the Graph theory for a mixed analysis of accessibility and the location of residential and job places. This concept, first described by Euler in 1735, has centred the interest of remarkable academics related to human geography like Nystuen and Dacey (1961), Haggett et al. (1977) or Gutiérrez Puebla (1985, 1987). These authors have developed some procedures in which they introduce a

thematic variable to an origin-destination matrix to extract some relationships between settlements in order to provide a better understanding of the urban system. Among them, we have chosen the *multiple linkage analysis* and their derived dispersion tests (Holmes and Haggett, 1975; Haggett et al. 1977) because, although its elaboration and result are more complex, it assumes a lower simplification of the reality by analysing all the significant flows for each node.

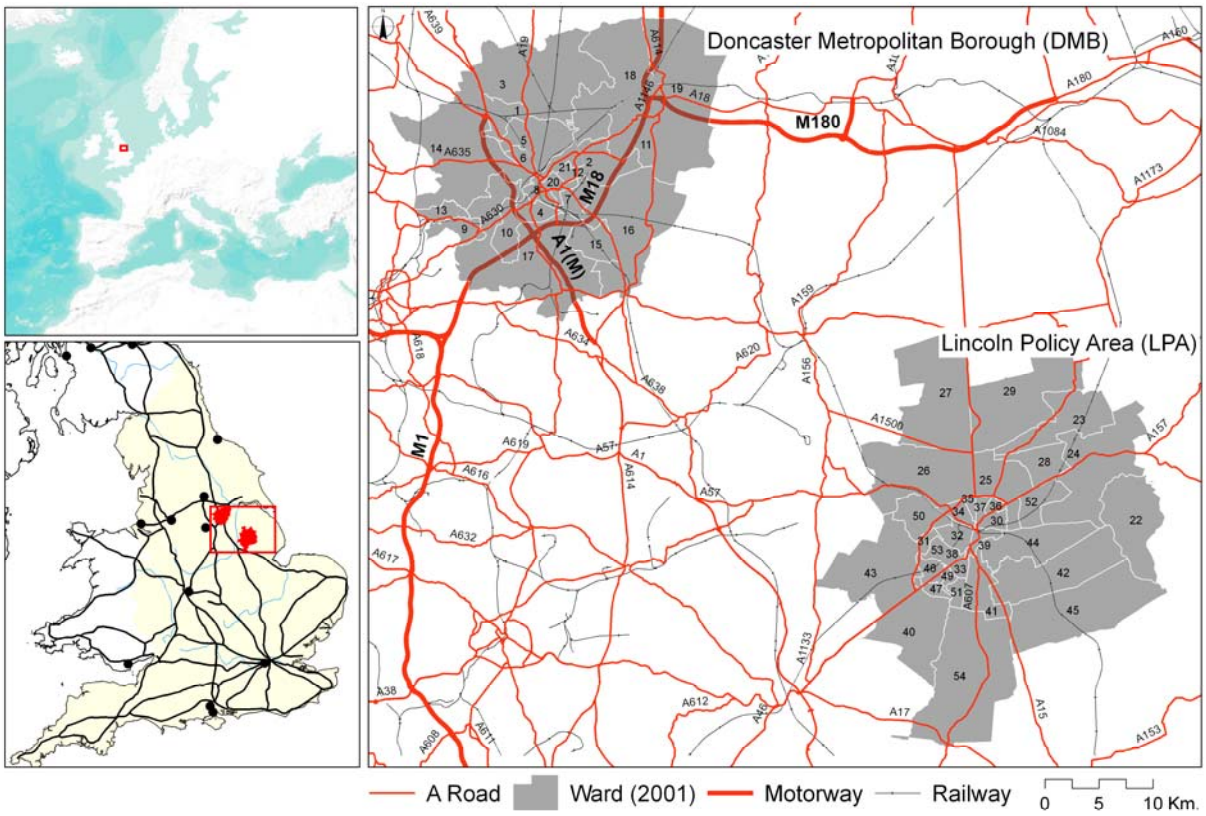
Apart from the multiple linkage analysis applied to the origin-destination matrix of place of residence and work at the ward level (National Statistics, 2001), we complement the accessibility approach with some tests that evaluate the dispersion or centrality of the urban and road network system such as Köning and Shimbel tests (modified from the description by Haggett et. al, 1977 in order to measure time and distance instead of the amount of links) and Mackenzie's centrality indexes (Mackenzie, 1966; Moreno Jiménez, 1980); the relative dispersion Δ'(G) test (Gutiérrez Puebla, 1987); or the rate of people living and working in the same ward.

We complement this kind of mobility analysis with data related to land use from the Corine Land Cover and population data both at the ward and settlement scale using some tests designed to measure the centrality of the urban system (Marshall, 1997), and the degree of sprawl with some residence or job-based tests like the job decentralization and dissimilarity tests (modified from Stoll (2005) to fit ward aggregated data); resident and workers relationships test by Wassmer (2000); and some tests based on land use maps from Kasanko et al. (2006) and Simón Rojo and Hernández Aja (2008).

2.2. Background of DMB and LPA

The cities of Doncaster and Lincoln are broadly in the same part of England, placed within the centre of the country. As can be seen in figure 1, Doncaster (within the Yorkshire and the Humber region) is located more to the centre and North, and Lincoln (included in the East Midlands region) is nearer the Eastern coast.

Despite their different socioeconomic background and spatial context, Doncaster being located in a coalfield and industrial area and strongly related to coal mining, and Lincoln surrounded by a rural area and related to heavy and mechanical manufacturing and the food and drink industry, both are clear crossroads that have now the challenge of regeneration after the severe coal and industry crisis.



Source: Personal compilation from Masterplan Transport, OSM50 and UK Borders. © Crown Copyright/database right 2007. An Ordnance Survey/EDINA supplied service.

DMB: 1: Adwick; 2: Armthorpe; 3: Askern; 4: Balby; 5: Bentley Central; 6: Bentley North Road; 7: Bessacarr; 8: Central; 9: Conisbrough; 10: Edlington and Warmsworth; 11: Hatfield; 12: Intake; 13: Mexborough; 14: Richmond; 15: Rossington; 16: South East; 17: Southern Parks; 18: Stainforth; 19: Thorne; 20: Town Field; 21: Wheatley.

LPA: 22: Bardney; 23: Dunholme; 24: Fiskerton; 25: Nettleham; 26: Saxilby; 27: Scampton; 28: Sudbrooke; 29: Welton; 30: Abbey; 31: Birchwood; 32: Boultham; 33: Bracebridge; 34: Carholme; 35: Castle; 36: Glebe; 37: Minster; 38: Moorland; 39: Park; 40: Bassingham; 41: Bracebridge Heath and Waddington East; 42: Branston and Mere; 43: Eagle and North Scarle; 44: Heighington and Washingborough; 45: Metheringham; 46: North Hykeham Memorial; 47: North Hykeham Mill; 48: North Hykeham Moor; 49: North Hykeham Witham; 50: Skellingthorpe; 51: Waddington West; 52: Cherry Willingham; 53: Hartsholme; 54: Cliff Villages; 55: North Hykeham Forum.

Figure 1 – Location of the study areas

Doncaster Metropolitan Borough (DMB)

The first study area comprises the whole Metropolitan Borough of Doncaster (DMB), which is one of the sub-regional centres of the Yorkshire and the Humber Region, with the larger cities of Leeds and Sheffield being the two main centres of the whole Region.

DMB covers over 56,000 hectares distributed in 21 wards of different sizes. The intersection between motorways M18 (Southwest - Northeast) and A1 (M) (North - South) falls within its boundaries, to the south of the main urban area. In addition, M180 connects to the M18 at the North-East border. According to the Principal Transport Planner of Doncaster, the annual number of vehicle kilometres driven within Doncaster is the highest in South Yorkshire.

It has a population of 286,866 persons (Census, 2001), which means a density of 5.2 persons per hectare. Therefore, although the density is higher than the regional average, it is the lowest value of the sub-area. According to ONS, mid-year population data, population has decreased from 1981 to 2000 in a lesser extent than the rest of the sub-area, increasing since then with the exception of the year 2001. However, this increase is considerably lower than the average of the region and sub-area.

According to the *Local Development Framework (LDF) Annual Monitoring Report* (2006), the settlement hierarchy of the Borough has three ranks, Doncaster being the main urban area. Surrounding the city of Doncaster, which is located in the centre of the Borough, there are 12 market and coalfield towns, where Thorne, to the North-East, and Mexborough, to the South-West, play a more significant role. Finally, about 50 villages (some of them with a recent commuter character) stand out within the rural landscape.

At present, the socio-economic background can still be seen through the labour force structure, since manufacturing, construction and transport & communications employ more people than the national average. However, as in the rest of the country, employment in public administration, education & health and distribution, hotels & restaurants is more than 50 per cent of the whole labour force.

As a consequence of the economic slump, the unemployment rate of DMB (4.20 per cent in 2001) is the highest in the sub-area (albeit only slightly higher than the second highest rate), and it is higher than the regional average.

Lincoln Policy Area (LPA)

Contrary to Doncaster, the administrative boundaries of the City of Lincoln include strictly the city centre and the very near surroundings, having a surface of only 3,343 hectares. However, in accordance with the Lincoln Policy Area, stated in the *Draft East Midlands Plan, RSS 8* (2006), the City of Lincoln Council does not cover the main catchment area of Lincoln. Therefore, some wards have been added in order to plan the future development of the city centre and its closer surroundings. Journeys to work and shopping, public transport and housing development have been the key ward selection factors.

The wards involved in the Lincoln Policy Area are those corresponding to the whole City of Lincoln, 9 wards of West Lindsey and 15 wards belonging to North Kesteven.

The total area (72,332 hectares) is larger, but still comparable, than the DMB case study, and contains a population of 164,443 persons, according to the 2001 Census. Therefore, these data lead to a population density of 2.27 persons per hectare. According to the ONS mid-year population data, Lincoln has growth about 12 per cent (over the regional average and twice the national average) during the last 25 years, with a small decrease in the middle 90's and, on the contrary, with a quicker pattern of increase since 2002. North Kesteven has a stronger pattern of growth, particularly since 1998, whereas in West Lindsey, whose average increase is below the regional average, higher increase begins in 2000.

The settlement pattern is based on the City of Lincoln as the main urban area. Very close to it to the South-West, North Hykeman is the second-range settlement, with a considerable service and employment role. Apart from that, several villages fulfil the settlement hierarchy of the area, acting like both dormitory sites and local service and employment centres. These villages include, according to the *Draft East Midlands Plan*, Saxilby, Nettleham and Welton in West Lindsey, and Bracebridge Heath, Skellingthorpe, Waddington, Washingborough and Branston in North Kesteven.

Lincoln Policy Area is, by far, the largest concentration of services, employment and housing of Lincolnshire, spreading its shopping catchment area beyond its boundaries. Services and tourism are the main activities of Lincoln, whereas the main contribution of rural areas is the provision of open spaces facilities, such as parks and green areas.

Since 1978, when manufacturing employed about 35 per cent of the labour force, this sector has declined, leaving redundant developed land along rail and water ways, and employing less that 20 per cent nowadays, according to the Official labour market statistics. On the contrary, the increase of the service sector has allowed the general increase of jobs in the area. Most of these jobs are concentrated in the city centre and nearest surroundings, which make Lincoln a job centre where about 45 per cent of the workforce lives outside the city boundaries.

Despite the peripheral location of Lincoln within the national framework and the lack of motorways, the role of road transport and communications is taken into account in the development of Lincoln as one of the five Principal Urban Areas of the East Midlands. In fact, A46 and A15 trunk roads intersect in Lincoln and it is a crossroad for three more A roads: A158, coming from the East; A57, from the West and A 607, from the South.

2.3. Results

Accessibility has been established as a key factor in the relationship between transport and land use, therefore our analysis starts by evaluating the differences in internal accessibility between the motorway connected area (DMB) and the area containing a trunk road crossing (LPA), and also the different accessibility pattern of DMB with and without motorway.

Modified Köning and Shimbel tests have been applied to estimate the minimum time required to travel to the furthest ward and the minimum time to travel to all the wards in the area respectively. They confirmed the higher accessibility of each central area, which is coincident to the city centre in both study areas, and, once related to the total area, they also show a higher level of accessibility in DMB. The accessibility analysis of DMB with and without motorways shows similar global values, but a different spatial pattern: the central area loses relative accessibility with the motorway in favour of the northwest part of the Borough and, secondary, along the A1(M).

The presence of motorways A1(M) and M18 in DMB particularly benefit wards outside the city centre, and on the opposite side of the motorway, in accessibility terms. The reduction in travelling time is higher in the north area, but according to origin-destination data between place of residence and place of work, the rate of people living and working in the same ward is lower along the A1(M), especially in wards with fewer jobs. The larger amount of jobs of Thorne and Hatfield, close to the M18 & M180 junction towards the northeast, allows a higher rate of people to live and work in the same ward, thus presenting a reduced mobility between wards.

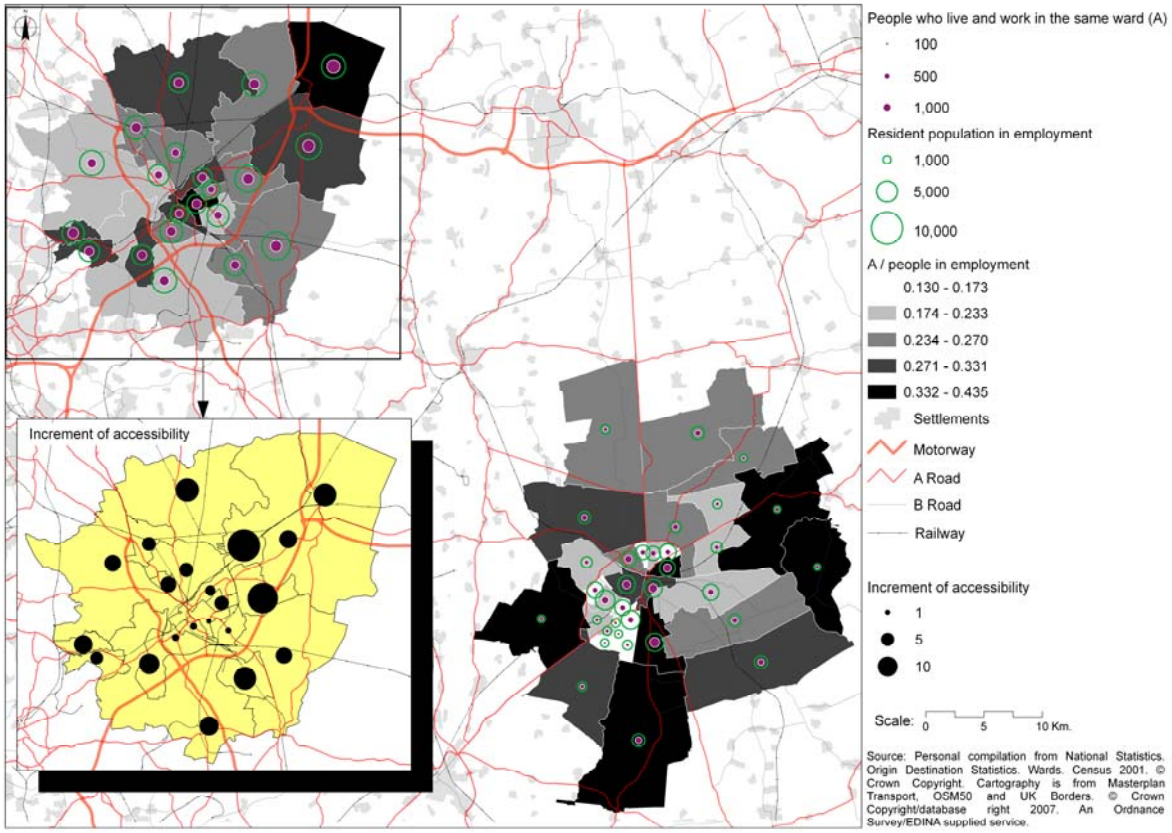


Figure 2 – Relationship between place of residence and work in DMB and LPA; and difference in accessibility in DMB with and without motorways (Shimbel test in minutes)

In contrast, LPA wards with fewer jobs and further away from the city centre have a higher rate of people living and working in the same ward, probably evidencing a certain degree of isolation, whereas the highest mobility values are obtained mainly by the small wards located in the immediately southwest boundary of the central urban area.

Continuing with the analysis of accessibility to job places and the mobility of the working population, we have applied Mackenzie's centrality index (Mackenzie, 1966) taking as input every flow of over 50 people between the ward of residence and the ward of work for DMB and LPA separately.

Figure 3 below shows the highest degree of centralization of LPA in the city centre and a middle degree of centralization in the very close surroundings inside the western ring road. The rest of the LPA wards have almost no centrality at all. On the contrary, the centralization

gradient of DMB is much softer, with lower values in Doncaster city centre than Lincoln's and higher values in Doncaster's hinterland than Lincoln's. Centrality is almost fully associated to the city centre in LPA whereas several wards further away from Doncaster city centre have a middle centrality value. Coalfields have had a great influence on the spatial distribution of job centres, and also other factors, like the concentration of transport infrastructures, have an influence on the less decentralized spatial pattern of job centres in 2001 (some twenty years after the closure of coalfields and the severe shortage this process caused in the regional economy).

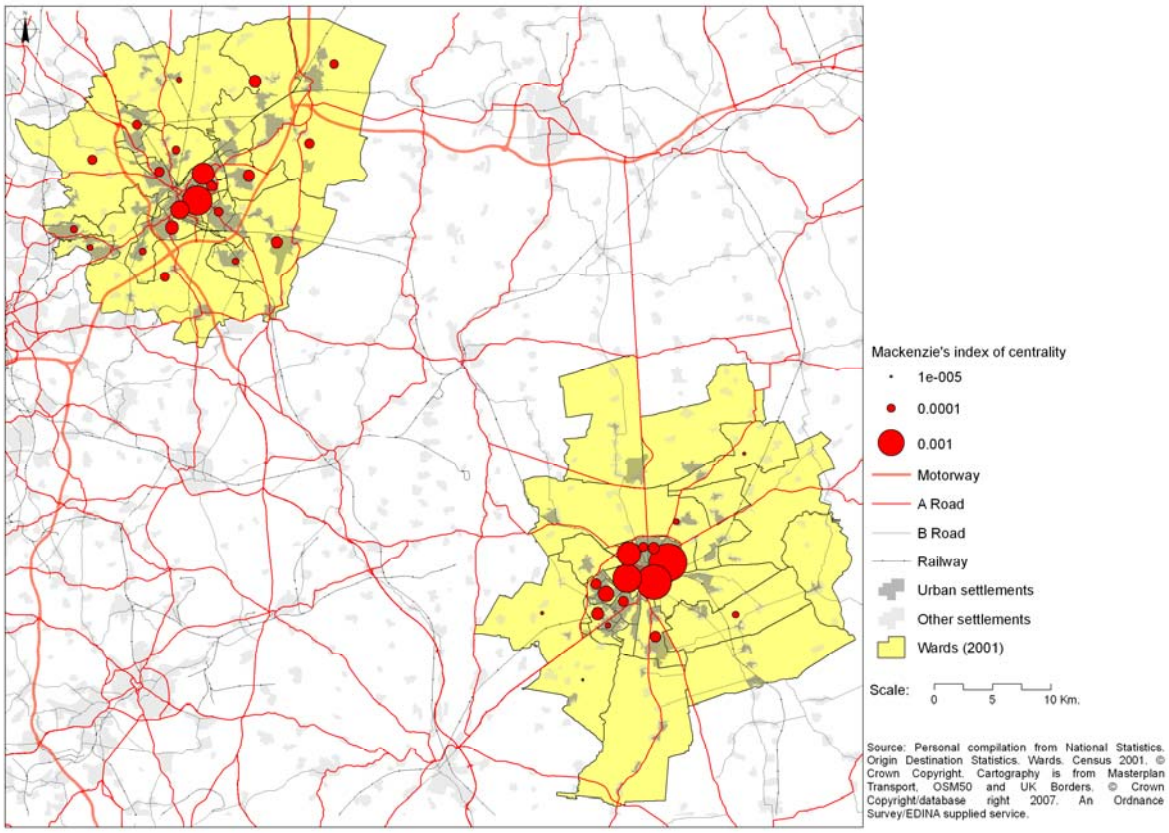


Figure 3 – Mackenzie's index of centrality

For a better understanding of the direction and intensity of residence-to-work flows we applied the multiple linkage analysis on the same data, which is shown in figure 4. The main relationships are from the periphery to the central area in both case study areas. The graph also reveals some flows between non-central wards and the importance of the NE-SW axis in DMB, where M18 motorway runs parallel to the A18 road and the railway. Most job centres are within the north quadrant drawn by the A1(M) & M18 motorways. Outside this quadrant, the axis continues towards Sheffield (about 30 km. away to the southwest) following the A630 road instead of the M18 motorway, although the latter provides a 21% reduction in time travelled.

Centralization in Lincoln is higher in relation to the size of its hinterland. There is only one significant job centre outside the limits of the city centre and the northwest ring road. The area remains quite isolated from near towns like Newark-on-Trent, which is only 30 km. away

to the southwest. Only Metheringham, railway connected, has links with the outer area. Flows between non central wards are scarce but they exist in the southern surrounding of the city centre, being Scarle and Waddington West the two job centres outside the city centre. Stoll's job decentralization test also suggests higher centralization in LPA (1.175) than in DMB (0.429).

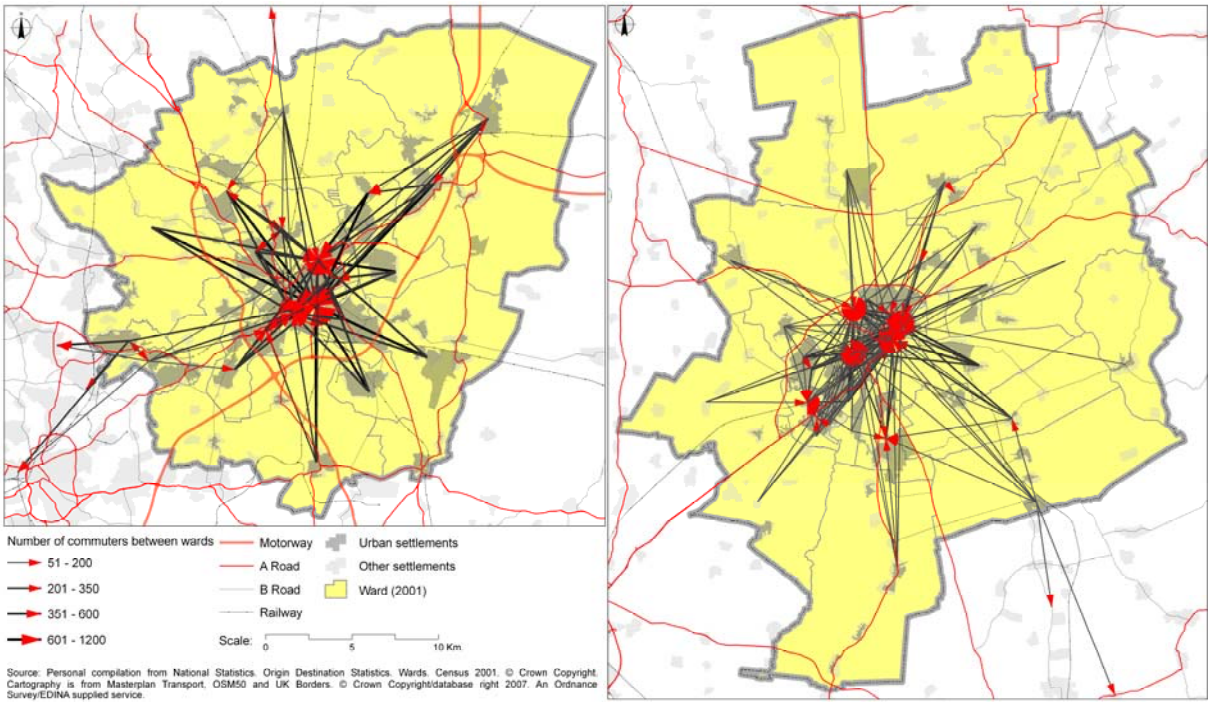


Figure 4 – Multiple linkage analysis

In fact, the relative dispersion Δ'(G) test confirms the greater dispersion of DMB's residence to workplace flows (Δ'(DMB) = 3.813) compared to those in LPA (Δ'(LAP) = 2.448).

Complementary data and tests have been conducted to confirm the different spatial pattern of population, activities and urban system. The CLC 2000 land use map highlights the higher degree of centralization of residential and industrial and commercial units in LPA; the decentralization of industrial and commercial units in DMB; and the relationship between artificial land uses and the NE-SW transport axis.

Resident population data computed by settlement shows that the urban system of LPA is quite similar to Marshall's Gini-constant model, and differs a lot from the rank-size rule. Gini-constant model was specifically designed for the regional analysis of urban systems with a large population gap between the most populated settlement and the rest of them. DMB also shows a better fit to Marshall's model, but, as shown in Table II below; its dissimilarity index is higher than LPA's. Rank-size rule, which performs better when the population slope is gentler, also supports the higher centralization on LPA, with its dissimilarity index almost 50% lower in DMB than in LPA.

Table II – Settlement population accordingly to Gini-constant and Rank-size rule prorated values

Settlement (DMB)	**Residents (2001)**	**Prorated G-C model**	**Prorated R-S rule**	**Settlement (LPA)**	**Residents (2001)**	**Prorated G-C model**	**Prorated R-S rule**
Doncaster Urban Area	127 851	151 859	74 975	Lincoln Urban Area	104 221	103 469	40 773
Hatfield / Stainforth	20 232	26 066	37 487	Heighington / Washingborough	6 274	11 433	20 386
Bessacarr	19 803	15 270	24 992	Welton/Dunholme	5 502	6 348	13 591
Thorne / Moorends	16 338	11 054	18 744	Bracebridge Heath	4 530	4 466	10 193
Conisbrough	15 361	8 765	14 995	Branston	3 797	3 473	8 155
Mexborough	14 750	7 313	12 496	Saxilby	3 660	2 855	6 795
New Rossington	13 255	6 303	10 711	Cherry Willingham / Reepham	3 555	2 432	5 825
Adwick le Street	10 507	5 557	9 372	Nettleham	3 514	2 123	5 097
Carcroft	8 397	4 982	8 331	Metheringham	3 384	1 887	4 530
Askern	5 434	4 523	7 497	Skellingthorpe	3 340	1 700	4 077
Tickhill	5 112	4 149	6 816	Navenby / Wellingore	2 385	1 549	3 707
Finningley	4 048	3 836	6 248	Sudbrooke	1 604	1 424	3 398
Bawtry	3 775	3 571	5 767	Bardney	1 440	1 318	3 136
Norton (Doncaster)	2 111	3 344	5 355	Bassingham	1 308	1 228	2 912
Branton	2 074	3 146	4 998	Scothern	892	1 150	2 718
Campsall	1 997	2 972	4 686	Ingham	857	1 082	2 548
Barnburgh	1 979	2 818	4 410	Fiskerton	830	1 022	2 398
Auckley	1 839	2 681	4 165	Dunston	694	968	2 265
Moorland Prison	1 482	2 558	3 946	Potterhanworth	648	920	2 146
Wadworth	1 229	2 446	3 749	Skampton Airfield	648	877	2 039
Toll Bar	971	2 345	3 570	Welbourn	646	838	1 942
Braithwell	804	2 252	3 408	RAF Nocton	622	803	1 853
Fishlake	628	2 167	3 260	Harmston	453	770	1 773
				Thorpe on the Hill (North Kesteven)	398	740	1 699
				Leadenham	385	713	1 631
Total	279 977	279 977	279 977	Total	155 587	155 587	155 587
Gini coefficient	0.707			Gini coefficient	0.801		
Dissimilarity model		**29.615**	**42.320**	**Dissimilarity model**		**11.332**	**81.560**

Source: own work from National Statistics. Key Statistics. Urban Areas and Settlements. Census 2001. © Crown Copyright.

Finally, we have approached the evaluation of the sprawl using some straightforward tests related to resident and jobs location. According to Jaret et al. (2009), positive values of sprawl in these tests are correlated to other sprawl dimensions like poor street connectivity or scarce mixture of land uses, thus they can be used in absence of the data required by most complex tests of sprawl developed by Galster et al. (2001) and Ewing et al. (2002).

The results of the analysis carried out up to now suggest that DMB is more sprawled than LPA, which is more centralized and whose local policy has largely promote the compact city. Table III shows that Kasanko et al.'s (2006) ratio of built-up and un-built areas supports this

hypothesis as also does Stoll's (2005) job decentralization test and Wassmer's (2000) resident and workers relationship.

Table III – Tests of sprawl

	DMB	LPA
Ratio of built-up and un-built areas	17.503	9.047
Ratio of continuous residential areas	1.413	0.800
Land consumption efficiency - primary test	838.306	945.682
Land consumption efficiency - secondary test	346.873	397.917
Job decentralization	1.175	0.429
Resident and workers relationship	2.56065E-11	3.20722E-11
Dissimilarity index	0.270	0.350
Primacy index	0.694	0.865
Dispersion index Δ(G)	4.100	4.531
Relative dispersión index Δ'(G)	3.813	2.448

Source: own work from National Statistics. Key Statistics. Urban Areas and Settlements and Origin-Destination Statistics. Wards. Census 2001. © Crown Copyright and EEA. CLC2000. European Environment Agency.

Conversely, some other sprawl tests –like Kasanko et al.'s (2006) ratio of continuous residential area, Stolls's (2005) dissimilarity index, and both primary and secondary land use efficiency tests developed by Simón Rojo and Hernández Aja (2008)–, suggest a higher degree of sprawl in LPA. Nevertheless, previous in-depth research about approved planning applications in years 1981, 1991 and 2001, in which residential use is analysed at the local level with regard to the type of dwelling and related to existing dwellings and number and type of commercial deals (Salas-Olmedo et al., 2009), confirms the more compact development of LPA compared to DMB. Therefore, we attach the different results of sprawl tests to data limitations of disaggregation and time span that may be solved with further research and the accessibility to new data with the publication of the 2011 Census in a few years.

3. DIAGNOSIS AND PROPOSALS

We recognise that there are other factors affecting the spatial pattern of these areas, such as the traditional location and complexity of towns, rural settlements and economic resources, and urban functions as well; and the convenience of an in-depth analysis of changes over time that current data availability does not permit. Nevertheless, the closure of coalfields, which is the main decentralization source of DMB, some twenty years ago; and the high level of centralization of Lincoln, even though in these twenty years decentralization has been the general trend in western countries, indicates that both transport infrastructures and local policy play a key role in land use distribution.

The results of the analysis above and the interviews that we made to some local and regional agents bring to light some of the strengths of each area, and also some issues for which we have some suggestions to secure more sustainable areas.

Among the strengths we highlight are the capacity of Lincoln to diversify its economy, traditionally rural and tourist-oriented, with the development of industrial land and the

achievement of its own university, and the commitment of the Local Authority for a compact, middle density and mixed-use city with a large presence of local firms. In addition, Doncaster Council is aware of its strategic location in the transport network and some settlements outside the city centre have been able to maintain their status as job centres.

However, there are some issues that can be improved. We have detected that in DMB the presence of a motorway and the absence of an urban settlement attracts more residents than job centres, thus there is more daily mobility between wards. Considering the higher mobility pattern of wards closer to the ring road in LPA, a similar situation might take place there if a motorway is built and no complementary measures are taken. In addition, the weak urban system of LPA may affect the impact of a hypothetical motorway because settlements that are less populated and with fewer and less diversified economic activities can become more isolated (because of the so-called tunnel effect) or they can become attractive for mainly uniquely residential use, thus incrementing the distance travelled to work.

The results of our analysis together with our knowledge of our Spanish study area and a significant literature review permits the outline of some measures related to land use, transport and institutional co-operation that should be applied to improve current sustainability, that should specially be taken in account if a motorway is eventually built crossing a peripheral area like LPA.

As the land use and transport relationship is the focus of our research, we centre our attention on measures to reduce daily travel. Indeed, this approach will be helpful to solve some of the priorities expressed by the respective Local Authorities of DMB and LPA, such as planning to adapt to climate change, access to services and facilities by public transport, walking and cycling, or congestion reduction (Communities and Local Government, 2010).

Consequently with our analysis and the above-mentioned priorities, one of the main targets to achieve is to bring households and workplaces individually closer. With this we mean not only encouraging mixed land use development, which is an obvious first step that local urban planners already contemplate, but introducing new measures so that individuals consider distance to work as a prime factor when choosing the place of residence. The current social situation, in which more than one person works outside home in each household, makes it difficult to tackle this approach, but on the other hand, communication technologies act as a counterbalance, since more *white collars* can work from home at least some days of the week, as also does high quality public transport. The role of public transport is thus essential if other members of the household do not work so close.

There are many ways in which the public administration can influence decision making, but attention should be paid to look for a combination that does not affect long term mobility of workers: the objective is to facilitate workers to find a suitable home near their workplaces, which does not necessarily imply taking distance to workplace as a favouring factor for resident population in a job selection process, thus reducing the permeability between areas and the transfer of knowledge. In Spain, resident population has the priority to access social housing in each municipality, which -although it is not a direct constraint to mobility-, together

with the high social value of house property, clearly discourages people from changing their residence according to their place of work.

At the same time, it is broadly accepted nowadays that centre to periphery relationships are not the most suitable pattern for improving territorial cohesion (an issue explicitly mentioned in the recent Treaty of Lisbon). Instead, polycentric systems based on economically diversified and sensible compact cities (Llop et. al, 2007) are called upon to provide a balanced territory.

Consequently with the above-mentioned ideas, our case study areas face two main challenges: creating workplaces in peripheral wards (DMB's mainly resident wards and LPA's least populated ones) and reducing daily mobility. The former requires economic measures to increment the attractiveness of these wards for firm location, whereas the latter, on which we focus, needs three different kinds of measures that should be applied within a common framework: improving the public transport, reducing the need to travel, and enhancing co-operation between and within all public and private agents.

Measures to improve public transport and encourage people to use it

This is a particular difficult task for less populated areas like LPA, since high quality public transport (in terms of frequency, cost, time, new vehicles and customer information) requires a minimum number of faithful users to be feasible, whereas customers require a high quality public transport before becoming faithful users. In addition, a number of academics (see Marshall and Banister, 2007) agree that in order to reduce the use of the car, thus encouraging the use of public transport, it is also compulsory to increment the cost of the use of the car with higher fuel taxes, parking restrictions/pricing and/or toll roads.

However, the latter kind of measures needs to be carefully considered specifically in peripheral areas, where a feasible public transport system is particularly difficult to achieve. Indeed, in DMB, which has clearly more chances of securing a suitable system of public transport than LPA, the Principal Transport Planner is considering the introduction of a flexible local bus service because current public transport is not time competitive with the car.

Complementary measures, like individual journey advice to households, live information availability with the use of communication technologies, competitive fares to faithful or group users, and so on have to be implemented for people to change from private car to public transport.

Given the great abundance of literature about these topics (see for example, WBCSD, 2001; Bonsall et al., 2004; Banister, 2007; Macário et al., 2007; Cognilio and Prota, 2008), we better focus on measures on how to reduce the need to travel.

Measures to reduce the need to travel

The previous kind of measures tend to minimize the use of the car but one of the main obstacles is that if people have to move from one place to another, they prefer to use the car because they can save time (especially if they link several destinations together) and money, particularly if more than one person travels in each vehicle. Therefore, the great challenge is to reduce the need to travel for which measures in the following directions should be implemented:

Measures to improve the design of the urban land to encourage walking and cycling and create vibrant neighbourhoods: this includes plot size, which should be adapted to create towns of human (instead of car) scale; street design (pavement, cycle lanes, and pedestrian areas); and building design to achieve sensible densities and to incorporate compatible uses like residence and retail, public facilities, offices and so on, particularly in corridors connecting walking routes between residence and workplaces. It is important to involve local people and firms to prevent small cities from becoming 'serial replicas' (Griffiths, 1998; Tallon, 2010) in which the same firms perform a similar city landscape.

Measures to favour a closer location of residence and workplace in each household: this can be done through a reduction of taxes for those living and working within a walking distance (usually the equivalent to 15-20 minutes); public support for workers to rent a house near their respective workplace, and to sell and buy if they want to move to a closer location; fares reduction in public transport for other members of the household; promotion of the advantages of reducing car dependency in daily mobility, and so on. The achievement of this goal implies a higher likelihood of getting a liveable and compact settlement, thus reducing sprawl if changes are applied on existing urban areas. It can be also helpful favouring compact development by introducing charges to low density areas (and/or a reduction of taxes in compact areas) in compensation for the higher maintenance and management costs of facilities, social services and public transport per person or per spatial unit.

Complementary measures to promote relationships between settlements: attention should be paid to prevent that the reduction of the need to travel to work or study implies a reduction of the opportunities to interact with other neighbourhoods or settlements. Indeed, the objective is to reduce the need to travel on a daily basis so that people may have more free time for other activities, including leisure time that can be employed in travelling to other places without a fixed timetable (thus reducing peak hour congestion) and with less time pressure, thus improving public transport competitiveness. Some measures to consider are the promotion of local firms and activities to a wider catchment area; fostering trade shows and workshops; fitting shop, activity and public transport frequency and timetables; providing suitable delivery services and public transport connection between all the settlements, etc.

Enhancing co-operation

All the previous sets of measures need co-operation in order to succeed. Co-operation and co-ordination of diverse interests is needed at all levels: horizontally and vertically within the

public administration, social and economic agents; and also between these different institutions. Here we just outline the main obstacles to overcome, such as pointing out the need for long term planning out to politicians, which requires previous agreement of the general public; strengthening the share of information between public bodies and with the rest of the society (which is not so easy in view of our own and others experience (i.e. Smyth, 1995)) and finding win-to-win relationships among all the agents, i.e. sensible densities provide higher incomes to the Council, greater business opportunities to firms, more shop options for customers, easier public transport management, less travelling expenses for residents.

In-depth analysis of institutional co-operation issues can be found in Rietveld and Stough (2007) and, focusing on the United Kingdom experience, in Tallon (2010).

4. CONCLUSIONS AND FURTHER RESEARCH

This paper, unlike many articles about land use and transport, is not intended to prove or disprove a relationship between the provision of transport infrastructure and economic development. Instead, we seek to detect if the spatial distribution of population and activities is affected by transport infrastructures, and particularly by the presence of motorways in peripheral areas, with the objective of providing measures to improve the spatial layout of urban activities.

From the analysis of the comparison between the two different peripheral areas that set up our case study, we have reached some specific conclusions about their accessibility and daily mobility; land use pattern; and land use and transport measures that would ease their mobility pattern.

In terms of accessibility, our main findings point out that the increment of internal accessibility provided by the motorway is not evenly distributed within the study area. Areas inside the region with fewer trunk roads get the highest internal accessibility increment, followed by the surroundings of the motorway. The relative accessibility of the central area in relation to its hinterland is now lower, since it is here where accessibility increases the least. However, accessibility and centrality, as capacity to attract workers, is more evenly distributed in the motorway-connected area.

Mobility patterns based on residence to work flows indicate that peripheral to centre flows are dominant with and without motorways, although they are more dispersed in the motorway connected area. This is far more significant in small settlements, where the motorway attracts far more population than firms, thus increasing daily mobility. We have also found that there are more job relationships with other cities in the motorway connected area.

With regard to differences in land use pattern, although further research is needed, we have detected higher decentralization of population and activities and a higher degree of sprawl throughout the whole study area in the motorway-connected area.

Given this situation, measures should be taken to bring individual households and workplaces together through economic measures and land-use and transport policies, to include the improvement of urban design and public support to reward people living close to their jobs, as well as high quality public transport and other complementary measures to promote not-daily-based relationships between settlements.

Apart from the consideration of other factors influencing the spatial pattern of these areas, such as socioeconomic development or the role and functions of the main city and the urban network, institutional co-ordination and co-operation at all levels and an improved management of communities' participation is essential to success.

Additionally, further research is needed related to both the case study areas and the suggested measures that should be applied. An in-depth analysis of the study area with the most disaggregated data available will help in the understanding of local particularities, whereas a long term analysis may benefit the identification of relationships of causality. In relation to the measures that have been suggested, further research is needed on how to implement them in small or medium sized towns in peripheral areas.

ACKNOWLEDGEMENTS

This paper has its origin in the research project titled "Development of a method of evaluation of the effects of road networks on the socioeconomic integration, territory and mobility for peripheral areas, application to the Northwest Spanish Arc", 2007-2010 (TRA 2007-66750), which is financed under the Means of Transport Section of the R&D National Programme of the Ministry of Education and Science of Spain.

Henar Salas-Olmedo is supported by a Predoctoral Research Staff in Training period Programme grant of the University of Cantabria, jointly funded by the Government of Cantabria.

The authors would like to thank the support given by the Centre for Regional Social and Economic Research (CRESR) at Sheffield Hallam University, and to the people who were interviewed.

REFERENCES

Banister, D. (2007). Sustainable transport: challenges and opportunities. Transportmetrica, 3, 2, 91-106.

Banister, D. and N. Lichfield (1995). The key issues in transport and urban development. In: Transport and Urban Development (D. Banister, ed.), pp.1-16. E & FN Spon, London.

Barro, R. J. and X. Sala i Martin (2004). Economic Growth. MIT Press, Cambridge.

Baudelle, G. and C. Guy (2004). The peripheral areas of Western Europe and EU regional policy: prospective scenarios. Europe at the margins: EU regional policy, peripherality and rurality. Available at: http://www.regional-studies-assoc.ac.uk/events/150404papers.asp.

Baum-Snow, N. (2007). Did highways cause suburbanization? Quarterly Journal of Economics, 122, 775-805.

Boarnet, M. G. and S. Chalermpong (2001). New highways, house prices, and urban development: a case study of toll roads in Orange County, CA. Housing Policy Debate, 12, 3, 575-605.

Bonsall, P., J. Beale, N. Paulley and A. Pedler (2004). Evaluating problems, priorities and solutions for road travel: the differing perspectives of users and service providers. Proc. European Transport Conference, Strasbourg.

Cervero, R. (1991). Congestion relief: the land use alternative. J. Planning Education and Research, 10, 2, 119-129.

Chi, G., P. R. Voss, and S. C. Deller (2006). Rethinking highway effects on population change, Public Works Management Policy, 11, 18-32.

Christaller, W. (1933). Central Places in Southern Germany. Translated from Die Zentralen Orte in Süddeutschland (originally published by Jena in 1933) by C. W. Baskin (1966). Prentice-Hall, Englewood Cliffs New Jersey.

Coniglio, N.D. and F. Prota (2008). Human capital accumulation and migration in a peripheral EU region: the case of Basilicata. Papers in Regional Science, 87, 1, 77-95.

Euler, L. (1735). Solutio problematis ad geometriam situs pertinentis (The solution of a problem relating to the geometry of position). Academy of St. Petesbourg.

European Commission (1999). European Spatial Development Perspective. Towards Balanced and Sustainable Development of the Territory of the European Union. Luxembourg: Office for Official Publications of the European Communities.

Ewing, R., R. Pendall and D. Chen (2002). Measuring Sprawl and Its Impact. Smart Growth America, Washington D. C.

Funderburg, R.G., H. Nixon, M. G. Boarnet, and G. Ferguson (2010). New highways and land use change: Results from a quasi-experimental research design. Transportation Research Part A: Policy and Practice, 44, 2, 76-98.

Galster, G., R. Hanson, M. R. Ratcliffe, H. Wolman, S. Coleman, J. and Freihage, (2001). Wrestling sprawl to the ground: Defining and measuring an elusive concept. Housing Policy Debate, 12, 681-717.

Giuliano, G. (1995). The weakening transportation-land use connection. Access, 6, p. 3-11.

Griffiths, T. (1998). Making sameness: place marketing and the new urban entrepreneurialism. In: Cities, Economic Competition and Urban Policy (N. Oatley ed.), pp. 41-57. Paul Chapman, London.

Gutiérrez Puebla, J. (1985). El análisis simple de ligazones. Anales de Geografía de la Universidad Complutense, 5, 49-70.

Gutiérrez Puebla, J. (1987). Spatial structures of networks flows: a graph theoretical approach. Transport Research B, 21B, 6, 489-502.

Haggett, P., A. D. Cliff, and A. Frey (1977). Locational Methods. Locational Analysis in Human Geography. Second Edition. Volumes I and II. Edward Arnold, Bristol.

Holl, A. (2004). Transport infrastructure, agglomeration economies and firm birth: empirical evidence from Portugal. Journal of Regional Science, 44, 4, 693-712.

Holmes, J.H. and P. Haggett (1975). Graph theory interpretation of flow matrices: a note on maximization procedures for identifying significant links. University of Queensland.

Jaret, C., R. Ghadge, L.W. Reid, and R.M. Adelman (2009). The measurement of suburban sprawl: An evaluation. City & Community, 8, 1, 65-84.

Kasanko, M. J. I., Barredo, C. Lavalle, N. McCormick, L. Demicheli, V. Sagris and A. Brezger (2006). Are European cities becoming dispersed? A comparative analysis of 15 European urban areas. Landscape and Urban Planning, 77, 111-130.

Krugman, P.R. (1995). Development, Geography, and Economic Theory. MIT Press, Cambridge.

Lawless, P. and G. Dabinett (1995). Urban regeneration and transport investment: a research agenda. Environment and Planning A., 27, 1029-1048.

Llop, C., A. Calvo and M. Marincioni (2007). Motions and logic of intervention in the contemporaneous territorial project of the urban areas. In: L'explosion de la ciudad: transformaciones territoriales en las regions urbanas de la Europa Meridional = The explosion of the city: territorial transformations in the South Europe urban regions (A.F. Arellano, coord.), pp. 354-362. Ministerio de Vivienda, Madrid.

Macário, R., D. Carvalho and J. Fermisson (2005). Achieving Sustainable Transport and Land use with Integrated Policies. In: Urban Transport XI. Urban Transport and the Environment in the 21st century (C.A. Brebbia, L.C Wadhwa, eds.), Vol. 77, pp. 351-360. WIT transactions on the built environment, Algarve, Portugal.

MacKenzie, K. D. (1966). Structural centrality of communications networks. Psychometrika, 31, 17-25.

Mackett, R. L. (1993). Structure of linkages between transport and land use. Transportation Research B, 27B, 3, p. 189-206.

Marshall, J. U. (1997). Beyond the rank-size rule: a new descriptive model of city sizes. Urban Geography, 18, 1, 36-55.

Marshall, S. and D. Banister (2007) (Eds.). Land Use and Transport. Elsevier Ltd., Amsterdam, London.

Mitchell, R. B. and C. Rapkin (1954). Urban traffic. A function of land use. Columbio University Press, New Yok.

Moreno Jiménez, A. (1980). Jerarquía de núcleos y áreas funcionales: análisis de redes de flujos. Estudios Geográficos, 161, 413-445.

Nystuen, J.D. and M. F. Dacey (1961). A graph theory interpretation of nodal region. Papers of the Regional Science Association, 7, 29-42.

Parsons Brinckerhoff Quade & Douglas (1998). Land use impacts of transportation: a guidebook. National Academy Press, Washington.

Rietveld, P. and R. R. Stough (2007). Institutions and sustainable transport: regulatory reform in advanced economies. Edward Elgar, Cheltenham.

Salas-Olmedo, H., S. Nogués and E. González-González (2009). Land Use Changes Associated To Highways". In: Proceedings of the 14th HKSTS International Conference. Transportation and Geography. (D. Wang and S-M. Li, eds.), vol. 2, pp. 971-980. Hong Kong Society of Transportation Studies, Hong Kong.

Simón Rojo, M. and A. Hernández Aja (2008). Relaciones entre el cambio de modelo urbano-territorial y consumo de suelo en los municipios españoles. In: I Congreso Urbanismo y Ordenación del Territorio "Ciudad y Territorio" (Colegio de Ingenieros de Caminos, Canales y Puertos, ed.) CD-ROM, pp. 1-19. Colegio de Ingenieros de Caminos, Canales y Puertos, Bilbao.

Smyth, A.W. (1995). The development of long-term land use guidelines and public transport strategy for Belfast: lessons for medium-sized cities. Proc. Instn Civ. Engrs. Transp., 111, 213-224.

Stoll, M.A. (2005). Job sprawl and the spatial mismatch between blacks and jobs. The Brookings Institution, Washington, DC.

Tallon, A. (2010). Urban Regeneration in the UK. Routledge, Oxon.

Urban Systems Research and Engineering (1976). The Growth Shapers. The Land Use Impacts of Infrastructure Investments. Council of Environment Quality, Washington.

Von Thünen, J. H. (1966). The Isolated State. Pergamon Press, Oxford.

Wassmer, R. W. (2000). Urban Sprawl in a U.S. Metropolitan Area: Ways to Measure and a Comparison of the Sacramento Area to Similar Metropolitan Areas in California and the U.S. Lincoln Institute of Land Policy. Working Paper WP00RW1.

WBCSD (2001). Mobility 2001. World mobility at the end of the twentieth century and its sustainability, World Business Council for Sustainable Development. Massachusetts Institute of Technology and Charles River Associated Incorporated, Cambridge (MA).

Weber, A. (1929). Alfred Weber's theory of the location industries. English Edition. Chicago: University of Chicago Press, Chicago.

Wegener, M. (1995) Accessibility and development impacts. In: Transport and Urban Development (D. Banister, ed.), pp.157-161. E & FN Spon, London.