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Discovery Exhibition: Using Spatial Treemaps in Local Authority Decision Making and Reporting

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ABSTRACT

At Leicestershire County Council we are using spatial treemaps to analyse labour markets and commuting behaviour. This novel visualization technique, presented at *InfoVis 2008*, has resulted in a number of insights and discoveries. Transport planners in our organization indicate that the graphics are effective and have advantages over alternatives. As researchers in the local authority we report upon using these graphics to inform decision makers and residents in the county's evidence base for sustainable transport planning.

Index Terms: H.4.10 [Information Systems]: Information systems applications—General;

1 INTRODUCTION

The UK Government has begun to realise the benefits of using Research & Information (R&I) in defining policy goals and everyday service delivery [1]. It has increasingly encouraged government agencies to find new ways of analysing and representing large data sets. Most attention has been focussed on Local Authorities – discrete administrative areas that provide local education, healthcare, transport and leisure facilities in the UK. Whilst these organisations collect vast amounts of data about their residents, data sets are often under utilised: the main barrier being a lack of appropriate accessible analytical methods and the expertise with which to use them in internal research teams.

Leicestershire is a rural authority in the heart of England with a population of around 690,000. The R&I Team at Leicestershire County Council (LCC) uses visualization extensively: employing and developing sophisticated and novel methods for analysis and communication. To do this effectively we (*Radburn*, *Beecham* in R&I @ LCC) have needed to develop strong working arrangements with specialists in the field. One particularly successful relationship has been with the *giCentre* at City University London (*Dykes*, *Wood* and *Slingsby*). Here we show how we at LCC have used two new visualization solutions developed at the giCentre to inform local transport planning in Leicestershire: *OD maps* and *spatial treemaps* – the former being a particular case of the latter.

2 PROJECT CONTEXT: TRANSPORT AND LABOUR IN LEICESTERSHIRE

The Environment & Transport department at LCC is currently developing a 15-year Local Transport Plan (LTP) to outline how the county's transport system can support local economic and social priorities. It is vital that a robust evidence base underpins the LTP. Since autumn 2009, our R&I Team has therefore been working closely with Environment & Transport to produce a comprehensive report [4] that assesses the evidence. This analyses and presents relevant data and is subsequently used by our transport planners to produce the LTP (Fig. 1). A particularly current objective for the LTP is to identify how the transport system can improve local economic performance. Spatial economists have argued that local authorities should focus on the way in which transport systems enable flexible labour [2]. In particular this means understanding the extent to which workers, and especially low-skilled workers, are able to take advantage of local employment opportunities, and whether geography acts as a friction or obstacle to these people in accessing jobs. For the LTP, we therefore wanted to better understand and represent the numbers of jobs and workers in the county and their spatial distributions. Crucially, we needed to identify parts of Leicestershire where, either through intense local competition or a lack of locally available opportunities, low-skilled workers were isolated from jobs or low-skilled jobs were distant from workers.

Figure 1: Delivering a Sustainable Transport System in Leicestershire [4] – cover. This 184-page evidence-base for sustainable transport planning makes use of innovative graphics throughout – including spatial treemaps showing multiple geographies and OD maps.

3 CASE STUDY: COMMUTING FLOWS

3.1 Visualization Need: Travel to Work

Initially we needed to show general spatial patterns of travel-to-work in Leicestershire. The data for daily commutes are very accessible – the 2001 Census contains origins and destinations of all workers and working residents in the county by output area (OA). However, standard means of representing these flows visually can become cluttered and confusing [6] (see Fig. 2).

3.2 Visualization Solution: OD Maps

OD maps are a new graphical technique developed by the giCentre [9] to overcome some of the problems associated with visualizing flows. In the OD map in Fig. 3, Leicestershire is first divided into a grid of 12×12 cells (as shown in Fig. 2). Each of these large cells is

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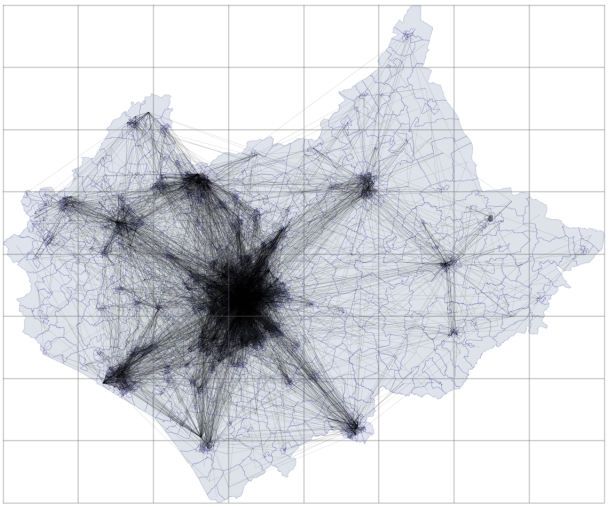


Figure 2: Flow map of commuting journeys within Leicestershire. See Fig. 3 for an *OD map* of these data.

also subdivided into a small version of the larger grid, resulting in 144 small multiple maps arranged spatially within the larger map. We colour the small maps according to where people have travelled from (where workers live) to the destination cell represented by the position of the small multiple in the larger map. This destination position (the workplace) is emphasised by a thicker border in the smaller maps. Effectively we have 144 destinations (12×12 grid squares) within Leicestershire and a map showing the residential areas from which workers have travelled. The darker the colour, the more people travelling to the cell represented by the position in the large map from the position in the small map. This is why the cells that refer to Leicester City (four cells highlighted with a grey box in Fig. 3) are mostly darker in colour – there are high numbers of people commuting to them from most parts of the county. It is also why grid cells towards the rural west have so little colour – since there are fewer employment opportunities, a relatively small number of workers commute in to these areas and usually over smaller distances (from neighbouring cells). The OD map is a spatial representation of a standard OD matrix with the advantage that it allows us to see the spatial patterns that are so essential to our context.

3.3 Discoveries... and Some Surprises

The OD map allowed us to discover quickly how labour market flows are spatially organised in Leicestershire. A cursory glance at the map showed us that Leicester City (highlighted with a box in Fig. 3) is the most important destination for residents across Leicestershire. Looking more closely, we could find particularly high flows from residential areas surrounding the city (coloured in deep red) and to the west of the county, but also substantial numbers commuting in from market towns within the county.

Despite the visual prominence of Leicester City, a number of exceptions can be easily spotted in the OD map. Significant numbers of workers commute in to towns in the north and north west of the county, a substantial business park south west of Leicester City and a market town towards the north east of Leicestershire. Importantly, this was something that our earlier attempts at visualization – drawing lines between points on a map using standard GIS software as in Fig. 2 – failed to make clear: a visualization discovery.

A significant insight was that the geography of labour market flows is very uneven. Workers travel to major employment opportunities from most and relatively disparate parts of the county – emphasizing the need for coordinated and sustainable transport planning. At the same time, however, we were able to identify other parts of the county that tend to exhibit more localised labour markets. That this was the case in rural areas (to the north east) was not a surprise – these areas generally offer few jobs. However, we could also identify relatively large employment centres to the far west, north-west and south of the county, which still draw a substantial portion of their workforce locally. These patterns were unknown and less expected. A completely unexpected pattern revealed by the OD map whilst obscured in the flow map was that workers travel significant distances up and down the county to access work – between locations in the north and south, but relatively few tend to commute across Leicestershire – from east to west or visa-versa (see Fig. 3). The strength of this pattern, evident across OD maps created at multiple resolutions, and its implications are still being explored.

The OD maps and analysis form an important part of the evidence base. We have not been able to present such details to our transport planners concurrently, geographically and at multiple scales using alternative methods.

4 Case Study: Labour Market Supply and Demand

4.1 Visualization Need: Mapping Leicestershire

We also needed to understand and communicate the scope of and spatial interactions between low-skilled jobs and workers in Leicestershire. Key requirements were to establish the size and the geography of labour market supply and demand. Representing the data on standard choropleth maps means that the more rural parts of Leicestershire, with larger areas but few workers and jobs, dominate the map. Patterns in urban areas are hidden and a sense of magnitude is lost. It was also important for us to show different geographies used in data collection and reporting in a single view – including district, electoral ward, output area (OA) or lower-level super output area (LSOA). Of these, our audience was most familiar with wards and districts – making it crucial that ward names could easily be located and labelled within districts.

4.2 Visualization Solution: Spatial Treemaps

Spatial treemaps were presented at *InfoVis 2008* [8] and use a two-dimensional geographic ordering to lay out nodes at all levels of a hierarchy. OD maps are a special case, but spatial treemaps also work particularly well with the hierarchical geographies typically used to record and represent data about the population [7].

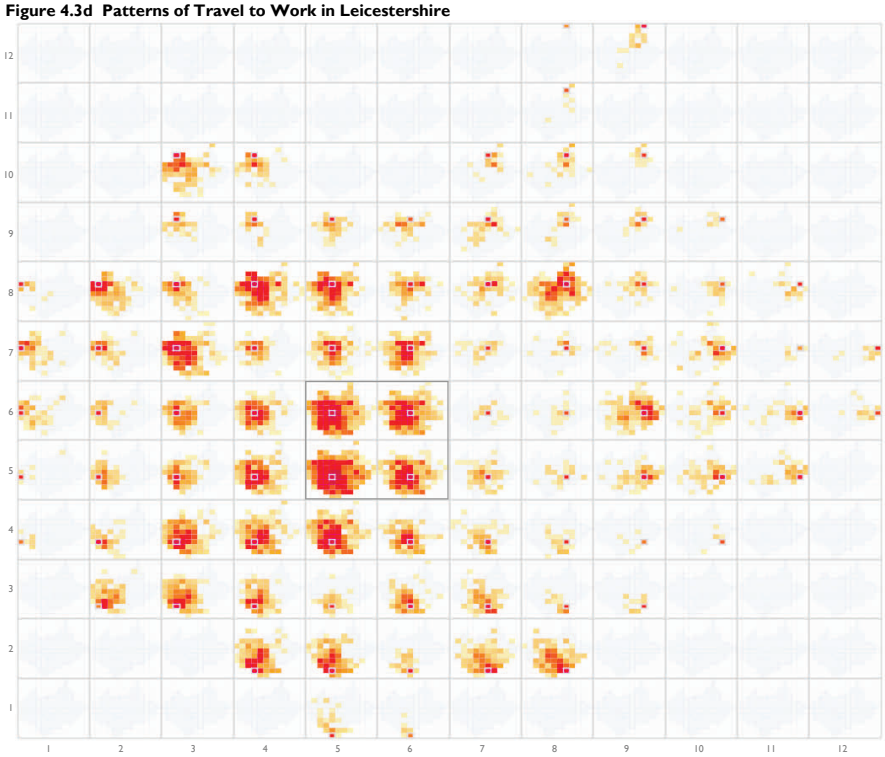
4.3 Discoveries... and Some Surprises

The spatial treemaps enabled us to understand and communicate the number and spatial concentration of jobs in the county. Sizing nodes at all levels of geography according to numbers of working residents, and making labels visible, meant we could use graphic space efficiently to consistently identify priority wards. Showing the size of labour markets gives greater spatial prominence to areas where people work – precisely what we are interested in here – and allows colour to be used to encode other key variables.

So by comparing across the graphics we could see, for instance, that a small number of wards in the county contained a large supply of jobs, a relatively small supply of workers, experienced high levels of in-commuting and little out-commuting and – based on our model of access to work – that businesses locating in these wards may find it difficult to recruit. The space-filling nature of the treemaps allowed us to neatly place maps close together for comparison and meant we could easily accompany the maps with text that described important patterns. Fig. 4 shows an example page from the DaSTS report [4] in which a spatial treemap is used in the context of analysis of distances travelled to workplace.

The treemaps did support our assumption that jobs in Leicestershire are spatially concentrated. However, by sizing them first by

Figure 4.3d Patterns of Travel to Work in Leicestershire



OD Maps (or Origin-Destination maps) are a new form of visual display to have come out of City University's giCentre. OD maps show connections between sets of origin and destination locations and here are used to display travel-to-work flows (from home to work). Drawing lines on a map between individual origins and destinations usually leads to a cluttered visual display and makes it very difficult to see patterns in a data set. Instead in an OD Map, Leicestershire is first divided into 12 grids, and each grid cell is then subdivided into a small copy of the larger grid. Within each larger cell, the destination (so the workplace) is emphasised by a thicker border and the other finer cells are coloured according to where people have travelled from (so where workers live). Effectively we have 144 destinations (12x12 grid squares) within Leicestershire and a map showing the residential areas from which workers have travelled. The darker the colour, the larger the number of people travelling from that cell.

This is why the cells which refer to Leicester City contain so much colour: there are high numbers of people commuting to them and from most parts of the county. It is also why larger grid cells towards the rural west have so little colour. Since there are fewer employment opportunities, a relatively small number commute and usually over smaller distances - so from neighbouring cells.

Source: Census, 2001
OD Map created by City University's giCentre. For a more detailed explanation see: http://www.soi.city.ac.uk/~jwo/odMaps/

Figure 3: OD map of Leicestershire showing origins of commuters by destination taken from '*Delivering a Sustainable Transport System in Leicestershire*' [4] – p.31. Four cells representing destinations in Leicester City are highlighted. See Fig. 2 for a *flow map* of these data.

jobs, and then by workers, we found that, rather than necessarily concentrating in urban areas, many rural parts of the county offer a significant number of jobs. Another insight derived through consideration of the spatial treemaps, was that there remains intense local competition for low-skilled jobs in the former industrial parts of the county, even when controlling for commuting.

Whilst these discoveries represent a considerable success, there were some limitations in our approach. We inevitably lost some sense of geography in using an abstract map. This was partly overcome by also representing the same data on a choropleth map. The fact that the transport planners and policy officers using these documents had a very good local knowledge of the geography of the county also helped here. We have also tried to limit the number of treemap layouts used – by maintaining a consistent aspect ratio and presenting a number of important data sets within these boundaries to help decision-makers learn and benefit from this new geography.

5 Impacts on User Community

The intention is to use this work in Leicestershire's LTP to help define priority wards in which public transport routes are evaluated. If interventions are successful, the analysis will have contributed to making labour markets more flexible, and so potentially increasing employment rates and boosting business competitiveness following an economic recession. Ultimate evidence of these kinds of impacts will not be available until the LTP is complete and operational, but these visualization solutions and discoveries are already having effect amongst the transportation planning teams to whom we provide information. Steve Rothwell, from our transport policy team states:

> *"Although they took a bit of effort at first, the graphics have been really useful and have helped us to highlight possible areas of intervention."*
>
> *"With the OD map, I felt I could genuinely get a sense of commuting patterns in Leicestershire. In the past we just had a matrix showing the number of journeys to work between our major towns and city – this missed some significant workplaces, and it was difficult to picture these commutes or see how they could impact on the road network."*
>
> *"The spatial treemaps were a nice way of presenting the different labour market indicators. It was weird seeing an abstract map of Leicestershire and getting round the fact that space was being used to show the number of workers or jobs in the county. Having the ward names visible was important, as we could flick back across the indicators to identify particular places. The R&I Team showed us the alternative – displaying the data on a traditional map. Because we wanted to compare between very small areas, it would have just been too difficult to spot those we were interested in."*

4.7 How far do workers travel to jobs (by car) in Leicestershire?

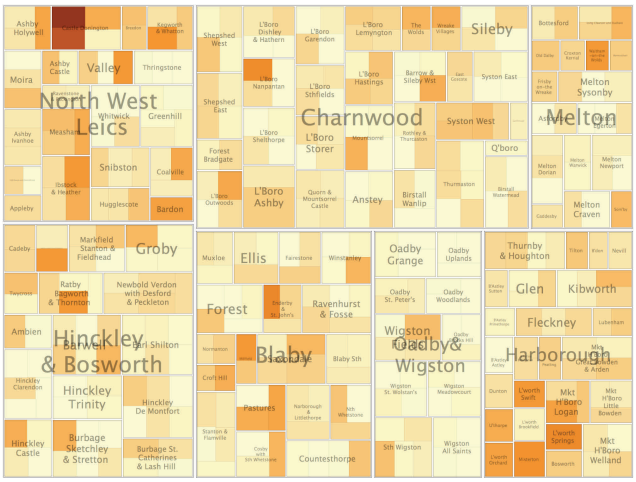
When we were using the OD map to describe overall travel-to-work flows in the county, we suggested that some labour market movements are more localised than others. We also (in section 4) said that, depending on the wages they offer and the number of other locally available opportunities, certain jobs will be able to attract workers over greater distances than others. This is something which the tree map in figure 4.7a starts to account for in Leicestershire. It shows the mean distance travelled to workplaces in the county by car. Due to data restrictions, it is only possible to show this information at Lower Super Output Area level.

Looking at the histogram (bottom right), there is some convergence in the mean distances workers drive to access jobs. For 65 percent of LSOAs the average distance travelled to workplaces by car is between 6 and 14 kilometres. However, and probably as expected, LSOAs containing the larger employment centres we identified earlier tend to attract workers over greater distances. This is particularly true of those in more peripheral parts of the county (for example Castle Donnington).

Key points (4.4-4.7)
Not all workers in the labour market can travel equally to access employment. When deciding on taking employment, an individual must weigh up, amongst other things, the wages they earn with the cost of travelling to work. Also crucial is the number of local jobs available to workers and the number of other workers with which they must compete. In Leicestershire, as in most other economic areas, jobs tend to be spatially concentrated. However, they are not always found in urban areas, and there is some concentration in the county's business parks.

Whether or not this is a problem for workers wishing to access employment and for businesses wanting to attract workers, depends on where workers live relative to these employment centres. This can be only understood by looking at both simultaneously.

Figure 4.7a Mean distance travelled to LSOA of workplace in Leicestershire by car



Source: Census, 2001

Figure 4.7b Mean travel distance by car to workplaces in Leicestershire's LSOAs

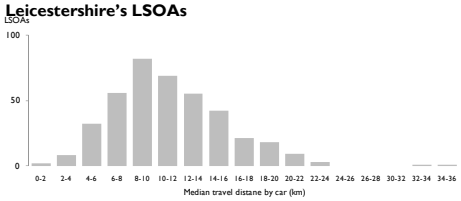


Figure 4: Spatial treemap taken from '*Delivering a Sustainable Transport System in Leicestershire*' [4] – p.36. Districts, wards and lower super output areas of Leicestershire are shown concurrently, sized by population and shaded by average distance travelled by workforce.

Furthermore, the introduction of these innovative techniques has had wider benefits within our organisation. It has given analysts access to methods with which to represent and communicate trends in large data sets and enabled the R&I Team to demonstrate why a central research unit should be working closely with other departments within the authority – such as Environment & Transport – to provide effective, appropriate and informed data analysis. These efforts, the associated discoveries and a genuine sense of 'added value' in terms of the analysis of data and communication of trends are helping to break down traditional silo work structures.

There is evidently room for more work, to embed these methods in the organisation and build them into workflows. There is also scope for adding interactive features to the representations to help with recognition, look-up and exploration. We are exploring some of these opportunities with the giCentre through funded projects to provide data to analysts [5] and citizens [3]. These include the development of an interactive transport map to visualize traffic speeds and volumes by time of day and day of week at high resolution.

Visualization will inevitably be used increasingly in analysis and decision-making to improve local services in one of the UK's leading local authorities on the back of the work reported here.

Acknowledgements

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