USING GIS TECHNIQUES TO MODEL THE CHANGES IN URBAN COMMUTING PATTERNS FOR THE SOUTH EAST QUEENSLAND REGION

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ABSTRACT

Using journey to work (JTW) data derived from the 1996 and 2006 censuses, this paper explores changes in commuting dynamics in the South East Queensland (SEQ) region. Our focus is concerned with the geographic patterning of commuting distance across the SEQ region and to identify any changes in such patterning over the decade to 2006. To achieve this advanced GIS methods were employed to calculate the average commuting distance and the degree of self-containment (i.e. people living and working within the same area) for the local areas. Through a quantitative analysis of SEQ JTW patterns over time, we link the results to the current planning debates regarding urban spatial policies aimed at reducing commuting distances. Specific attention is given to: whether job-housing balanced development has an effect on reducing commuting distance between 1996 and 2006. Results indicated that the spatial patterns of commuting had a limited change over the 10 years period; and the change in commuting distance did not present a strong relationship to the change in jobs-housing ratio across the region.

1. INTRODUCTION

Commuting constitutes a typical daily activity for most, placing ever changing demands on our transportation systems. Commuting has been attributed to the sub-optimal performance of transportation systems (Horner, 2004). As our cities grow the nature of this growth, in terms of the spatial dimension has significant implications for travel patterns. Congestion has become a reality in cities around the world and we must seek solutions to alleviate these problems. Developing an understanding of the basic relationship of the worker’s residence to their locale of work, its variation across a given region and time and how this differs according to industry sector, mode and gender are central to the search for solutions to the problem.

The commute has an inherent spatial component comprising an origin or home location and a destination, the workplace. Geographical Information Systems (GISs) have a potentially large role to play in the analysis and visualization of commuting data permitting more in-depth studies to be undertaken. The ability to integrate multiple data sources such as road networks and their associated capacities permits more advanced measures of movement between home and workplace to be incorporated rather than using a simple Euclidean distance between two travel zones. In addition, the application of exploratory spatial data analysis such as Local Indicators of Spatial Association (LISA) (Anselin 1995) allows the spatial arrangement of urban form and land use in conjunction with commuting behavior to investigate the existence of local clusters. Finally, their powerful visualization and data manipulation capabilities permit commuting data to be visually explored to uncover spatial patterns and trends.

Whereas GIS-based techniques have been applied to analyze and visualize urban commuting (see for example, Cervero (1988); Wachs et al (1993); Wang (2000); Horner and Murray (2003); Sakanishi (2006); Sultanta and Weber (2007) very little research has applied spatial techniques that are capable of tracking change in the spatial nature of commuting. This paper redresses the gap in the research by applying advanced GIS and statistical methods to analyze disaggregate JTW data for two census periods (1996 and 2006) to identify changes in the spatial dynamics of intra-urban commuter behavior. Our focus is on the geographic pattern of commuting distance and commuting flows across the South East Queensland region (SEQ) region. Further, this paper explores the relationship between these
spatial-temporal variations and changing urban spatial structure. Our specific attention is given to: (1) whether job-housing balanced development patterns had an effect on reducing commuting distance between 1996 and 2006?

The remainder of the paper is structured as follows: The following section describes the study area and data. GIS techniques used to model travel distance and jobs-housing balance using JTW data are explained. The results are then provided, examining the effect of jobs-housing balance on commuting distance in the SEQ region, based on the results of JTW analysis. Major findings are summarised, limitations highlighted, and needs for future research outlined.

2. THE STUDY AREA AND DATA

2.1 The Study Area

South East Queensland (SEQ) is the one of the fastest-growing metropolitan regions in Australia. Historically, the region has experienced dispersed, low-density urban development coupled with spatially-uneven distribution of industries and population settlements (Spearritt, 2009). The region comprises three major urban centres including Brisbane, Gold Coast and Sunshine Coast along with Ipswich to the west of Brisbane. Due to its multi-centric urban structure, the region has developed a complex pattern of JTW movements and economic interactions. With fast population and economic growth, a significant problem for planning is to anticipate sustainable transport outcomes in SEQ. In 2005, the Queensland State Government passed legislation to implement a new regional growth management plan for the SEQ region (Office of Urban Management 2005). This incorporates an urban consolidation strategy and seeks to achieve a regionally-balanced urban structure to support the population and the economic growth and the transportation demand.

2.2 Journey to Work Datasets

The data used in this research are the JTW flow datasets obtained from the Australian Census for 1996 and 2006. We use the JTW data for 1996 and 2006 because they provide a good opportunity to overlook the social and economic change over the recent 10 years period in the SEQ region. There are three types of information contained in the JTW data used in this study: GIS coverages for both the origin and destination zones for all trips, and the JTW (origin-destination) matrix. The JTW matrix simply comprises one column and one row, specifically a destination code and an origin code and the total number of people travelling between each origin and destination. Specifically, the compiled JTW matrices for 1996 and 2006 for the SEQ region contained 300 origin zones (using the boundary of statistical local areas for year 2006), but each year contained a different number of destination zones. For example, there were 558 destination zones for year 1996 and 627 destination zones for year 2006, for the same region. The reason for this is that the spatial configuration (e.g. shape and size) of destination zones were independently defined for each census year by the Queensland Department of Transport based on the flow of people.

3. METHODOLOGY

3.1 Spatial integration of JTW data sets

The major difficulty in the analysis of changes in JTW flows between 1996 and 2006 are the changes in destination zones of JTW data over that period (an example of the spatial inconsistency is illustrated in Figure 1). As such, this has raised a crucial analytical issue of how these independent zonal structures can be spatially integrated into a single, consistent set of geographical units.
To overcome this problem, we applied an area interpolation technique to transform the spatial data from the zones supplied by the ABS to a new set of spatial units which are consistent between 1996 and 2006. We used 2006 Statistical Local Areas (SLAs) as the new destination zones (consistent to the origin zones) and applied an areal weighted proportioning method to transform the spatial data. The technique assumes homogenous spatial data (in this case – the number of JTW trips) for old destination zones. The data estimation for the new destination zones was based on the degree of spatial overlap with known data for the previous destination zones. This technique proved challenging as the areal calculation for the large spatial matrix data was computationally intensive. The outputs are new JTW matrices (300 rows by 300 columns) for year 1996 and 2006, reporting the number of people commuting from an origin zone (SLA) to a destination zone (SLA) within the SEQ region.

We then evaluated the error of area interpolation procedure by examining the consistency between the estimated SLA values and the sum of their constitute destination zone values in the original dataset for 1996 and 2006 respectively, and the results reported an overall very low interpolation error, on average smaller than 0.1%.

3.2 Modelling the Distance of Commuting

Based on the information on the origin and destination of JTW flows, we calculated the average commuting distance for each SLA. In order to identify variations in peoples’ commuting behaviour for local areas, the commuting distance is calculated based on SLA of residence (trip origins). The road network data was applied to calculate the network travel distance between origin and destination.

Because SLAs are a relatively large geographical unit (especially SLAs for rural areas), the measure of JTW distance between the centroid of each SLA was not appropriate to represent the multiple route choices for all commuters within the SLA. Therefore, we randomly generated 10 points within each SLA and each point was used as the single departing location and arrival location of the travel. The use of this method permits more advanced measures of movement of commuters on the road between multiple home locations and workplaces. Then the point-to-point based travel distances were summarized within the SLA to give an average SLA-SLA travel distance. The SLA-SLA commuting distance was then multiplied by the number of commuting trips between each origin-destination pair (provided by JTW data), and the total travel distance for all commuting trips for every single SLA (including all destinations) was calculated. Then the average commuting distance for each SLA was obtained based on the total number of commuters in a SLA.

The results of the average commuting distance across SLAs for year 1996 and year 2006 are provided in Figure 2 (a) and (b). This shows that the commuting distance tends to be shorter among workers who live closer to central city areas (e.g. Brisbane metropolitan area, Gold Coast and Toowoomba City), whilst longer commutes (mainly cross-suburban travel) tend to be for workers in the middle and outer suburbs. Therefore, the regional trend is that the travel distance increases as residences are separated further from the city centre. The further one’s home is from a city centre, the longer one’s commute tends to be.
The result also reveals the local difference in average commuting distance between 1996 and 2006. In general, there was minor change in average JTW distance between 1996 (15.75 km) and 2006 (15.95 km). There were an increased number of commuters travelling shorter distances to work (less than 10 km) by 2006, but the distance of travel for commuters in the middle range (e.g. 10 to 30 km) slightly increased. The number of commuters with very long commutes (30 km or more) remained stable between 1996 and 2006.

The areas with significant change in commuting distance are highlighted in Figures 3 and 4. Figure 3 shows that over time a decrease in average commute distance occurred at the Brisbane port (Eagle Farm), along the Brisbane to Ipswich corridor, and most Gold Coast suburbs. The possible reasons include fast urban growth and employment decentralisation, which have introduced increasing numbers of employment opportunities into these areas. People living in these areas tend to find work locally, travelling relatively shorter distances. In Figure 4, the areas with an increased commuting distance were highlighted as the central city areas (Brisbane CBD, coastal areas of Gold Coast city) and some outer suburbs (e.g. Caboolture and Beaudesert). Tentatively, the significant increase in reverse commuting from the city could be driven by decentralized employment towards outer urban areas. And new residents in emerging peri-urban locations such as Beaudesert are often reliant on employment well outside their local area, perhaps explaining increasing general commute distances for such SLAs.

### 3.3 Measuring the Jobs-Housing Balance

Jobs-housing balance refers to the spatial relationship between the number of jobs and housing units within a given geographical area (Wang, 2009). The jobs-housing balance has been largely acknowledged as a planning tool to reduce travel demand.
Framework for Growth Management (Queensland Regional Coordination Committee and Queensland Dept. of Housing Local Government and Planning 1995) introduced a jobs-housing balanced strategy to promote compact growth and self-contained urban settlement patterns. The inclusion of jobs-housing balance analysis in this research allows us to examine the effects of such land use policies in changing the JTW pattern in SEQ.

In this study, we applied a modified floating catchment approach (Peng, 1997) to measure the jobs-housing ratio. Firstly, a network distance buffer of 12km was created for each zone (which is below the average commuting distance for the whole study region of ~15 km). All jobs within 12km were regarded as ‘local’ to the SLA. This is based on the assumption that the majority of people would like to commute 12km to work or less. The number of jobs and resident workers that lay within each buffer area was then summed, and the ratio of the total number of jobs to the total number of working residents was calculated for each SLA. The resulting map of the jobs-housing ratio for 2006 is shown in Figure 5. The map presents a clear pattern that the higher jobs-housing ratio is concentrated near the CBD and sub-regional centres. A further discussion of the pattern of jobs-housing ratio is provided in Section 5. The jobs-housing ratio for 1996 showed a very similar pattern as that presented for 2006, except for a higher job-housing ratio in the central urban areas. This means that the entire region was not significantly restructured over the period of 10 years, and most areas experienced both population and employment growth and therefore retained a similar jobs-housing ratio.

![Figure 5. Distribution of the ratio of accessible jobs per resident for 2006 (within 12 km travel) (the insets highlight the ratio of jobs per resident for Brisbane and Gold Coast)](image)

4. DISCUSSION

The main question this paper attempts to address is whether the jobs-housing balance has reduced the average commuting distance between 1996 and 2006 in the SEQ region. Based on the results of the modelled jobs-housing ratio and commuting distances, we analysed the relationship between the two urban processes.

First by plotting the average commuting distance against the job-housing ratio for 1996 and 2006, respectively (see Figures 8 and 9). Both figures highlight that the jobs-housing ratio for many SLAs in the study region are largely imbalanced (e.g. JHB < 0.5 or JHB >1.5) and that only a small number of areas (5% of total SLAs) have roughly an equal number of resident and employment (JHB ~ 1). The commuters living in the housing-rich and job-poor areas (e.g. JHB < 0.5; 15% of total SLAs) on average have a longer and more dispersed commuting pattern. The average commuting distance for housing-poor and job-rich areas (JHB > 1.5) tend to be shorter and less dispersed (31% of total SLAs). People living in a job-housing balanced area (JHB ~ 1) commute for a longer distance than the people in the housing-poor and job-rich areas. Therefore, at a regional level the average travel distance is negatively related to the job-housing ratio and the pattern of relationship is very consistent between 1996 and 2006).
Next, we plotted the changes in average commuting distance (at the SLA level) against the changes in jobs-housing ratio between 1996 and 2006 to explore the interaction between the two processes. Figure 10 shows that most SLAs are highly clustered within the centre of the graph suggesting no clear regional relationship between the change in commuting distance and the change in jobs-housing ratio. This relationship was expected to be positive, based on the hypothesis that people tend to travel shorter distances for work because of the increased local employment opportunity. Figure 10 also revealed that the changing jobs-housing ratio had a very different effect on average commuting distances in local areas (SLAs). The changing jobs-housing ratio had an unevenly positive effect on commuting distances in 167 SLAs, and a negative effect in 133 SLAs.

These findings support the commonly held views of much of the existing literature in the area that the co-location of employment and population did not have a significant effect on reducing commuting distance (Wachs et al., 1993; Peng, 1997; and Wang, 2000). However, this may relate to the type of urban restructuring experienced in SEQ between 1996 and 2006. The region has not been restructured around transit-oriented developments and strong clustering of employment into centres. Instead, development has been more laissez-faire and dispersed, reflecting weaknesses in planning, redressed in the more recent SEQ Regional Plan (Office of Urban Management 2005).

Our results indicate that despite the increased local employment opportunities, people’s decisions on employment location and commuting choices appear to be very different across the region. This can be affected by some factors related to the human capital and local land-use. For example, it may be that there are major mis-matches in employment in specific SLAs or sub-regions according to the industry-type of employment and the skills and occupation of workers. This could be resolved by investigating the relationships between commuting patterns in conjunction with social and spatial factors such as industry types, worker’s skills and occupations, and household socio-economic status to derive a more in-depth understanding of the spatial and temporal variations in commuting.

Further, this analysis has been limited to analysis of jobs-housing access based solely on the road network, and on shortest path, not more realistic travel routes on the road network. Given the increasing importance of public transport in the travel task within SEQ (Queensland Transport 2005:25) further insights may be gained by exploring how jobs-housing balance may be affected by further refining
accessibility based on travel times (not distances) on the road network, and on the public transport network.

5. CONCLUSION

This paper has investigated JTW dynamics in the SEQ region based on spatial analysis of 1996 and 2006 JTW data. It has focused on geographic patterns of commuting and travel distances. In addition, the changes of such patterns over the decade to 2006 were investigated in order to identify variations in urban commuting behaviour.

In order to compare the JTW datasets for 1996 and 2006, an area interpolation technique was employed to transform two data sets (1996 and 2006 JTW matrices) into consistent geographical units. This method provides new opportunities to examine spatial and temporal changes in urban form and commuting patterns and therefore contribute to the body of literature in urban transportation research. Secondly, we applied a GIS-based network analysis to compute the average travel distance between the origin-destination traffic zones. This method accounts for all possible routes between randomly generated points in order to give more advanced measures of the effects of multiple residential locations, workplace and road choices on the resulting travel distances. Thirdly, we used a modified floating catchment method to measure the jobs-housing ratio using JTW data. The method is novel because it took into account all accessible jobs within a 12 km travelling catchment area (by travelling on the real road network) which provided a better estimate of the spatial relationship between housing and employment. Both these GIS techniques are found to be useful tools to model the spatial dynamics of commuting from the complex JTW datasets.

Through the application of advanced GIS-based techniques, firstly, we revealed the spatial-temporal changes in commuting distance across the region. The results show that at the SLA level, the average commuting distance increased for commuters who live in the central city areas from 1996 to 2006, whilst the commuting distance decreased for people living in the Brisbane port, the western corridor of Brisbane, and the Gold Coast, during the period. Secondly, through the analysis of the relationships between commuting distance and jobs-housing ratio, we found that the pattern of change in commuting distances did not seem to be correlated to the change in jobs-housing ratio over the 10-year period. The commuters showed very different travel behaviours in response to the changes in employment in the local areas. This finding is consistent with previous research which emphasises that in addition to urban land use structure there are other socio-economic factors playing an important role in determining the JTW pattern. The development of urban policies needs to focus on both urban land use and urban social-spatial structure to ensure transport outcomes.

While the techniques presented in this study are applicable to model the spatial patterns of commuting, there remains a number areas that will form a focus for future research. First, a more advanced area interpolation technique can be applied to spatially integrate the JTW matrices to better account for spatial heterogeneity of commuting flow within traffic zones (for example, using an multi-class dasymetric method with digital cadastral data) (Li et al., 2007). Second, in the application of local spatial statistics such as Local Indicators of Spatial Association (LISA) (Anselin, 1995) to explore local correlations between urban land use and commuting behaviour. Third, a more disaggregated JTW analysis may be used to explore how JTW patterns differs according to industry sector, travel mode and gender across the region.

REFERENCE


