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Investigating the changes in journey to work patterns for South East Queensland – a GIS based approach

Authors: Tiebei Li[i], Jonathan Corcoran[ii], Matthew Burke[i]

[i] Urban Research Program, Griffith University
[ii] School of Geography, Planning and Environmental Management The University of Queensland

Email for correspondence: t.li@griffith.edu.au

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 and flow (i.e. the number of people travelling from region *i* to region *j*) 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 firstly 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, and secondly to map the distribution of commuting flows. 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: (1) whether job-housing balanced development has an effect on reducing commuting distance between 1996 and 2006; and (2) identifying the most salient changes in commuting flows over the decade. 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

The investigation of the spatial patterning of the journey to work (JTW) has become an important area in urban geographical research. This is largely driven by an increased dispersion of population and economic activities in major Australian cities and growing pressures on urban infrastructure, transport costs and the environment (Newman, 2000; Galster, 2001; Newman, 2000; Wolman et al., 2002). JTW patterns have changed substantially over recent decades. With fast population growth and metropolitan decentralisation of employment, the traditional mono-centric commuting pattern has been gradually replaced by complex cross-suburban home-workplace interactions (O’Connor, 1992; Gipps et al., 1997). The changing JTW structure has led to continuous growth in car travel and greenhouse emissions (Gipps et al., 1997, Mees et al., 2007). Despite decentralisation, congestion remains a problem in Australian cities, for which no easy solutions have been found. 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 are central to the search for such solutions.

Over the decades, a number of studies have investigated the dynamics of JTW. Horner (2004) categorises the range of geographical studies into areas focussing on urban commuting and sustainability, urban commuting and land use, which he sub-divides into studies investigating jobs-housing balance, excess commuting and accessibility. Many of these studies particularly focus on how urban form and structure interplay with commuting behaviour. For example, Cervero and Wu (1988) investigated JTW dynamics in American cities and found that commuting distance increased with the decentralisation of employment. Other researchers have focused on commuting dynamics in relation to jobs-housing balance (for example, Wachs et al., 1993; Peng, 1997; and Wang, 2000) finding that the co-location of employment and population in American cities had a significant effect on reducing commuting time but not commuting distance. Aguilera (2005) studied the commuting patterns in three major French metropolitan areas and concluded that development of inter-suburban commuting increased both travel distance and car use. Titheridge and Hall (2006) analysed JTW patterns for South East England suggesting that new growth centres may result in an increased car use but not necessarily longer commute distances.

Exploring spatial JTW patterns is not a particularly active area of Australian research. Gipps et al (1997) provided a comprehensive study on the change in employment, urban structure and commuting patterns from 1981 to 1991. Mees et al (2007) investigated JTW patterns in five Australian cities between 1976 and 2006 with a focus on the change in travel mode at the metropolitan scale. Rickwood and Glazebrook (2009) more recently used a spatially disaggregated approach to examine the relationship between urban structure and travel mode for JTW. These research efforts have successfully revealed key characteristics of JTW (for example, the change in travel mode over time), but very few outputs have been produced for understanding JTW dynamics in a spatial context (e.g. commuting distance and flows). Understanding the spatial dynamics of commuting is vital for both transport and metropolitan planners. The spatial patterns of JTW need to be clearly defined to provide information for planning for transport infrastructure and urban policy making to reduce negative transport impacts (e.g. congestion, greenhouse gas emissions and excessive travel times).

GIS technologies created new opportunities for conducting urban commuting studies (Horner, 2004). Various GIS-based techniques have been applied to analyze and visualize urban commuting (see for example, Wang, 2000; Horner and Murray, 2003; Sakanishi, 2006; Sultana and Weber, 2007) yet very little Australian research has applied spatial techniques to track change in the spatial nature of commuting.

This paper redresses this research gap 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 for the South East Queensland region (SEQ). Our focus is on the geographic pattern of commuting distance and commuting flows across the 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? And, (2) identifying the most salient changes in urban commuting flows during that period.

The remainder of the paper is structured as follows: The following section comprises a review of GIS-based studies of commuting. The study area and data is described. GIS techniques used to model travel distance, travel flow 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. GIS-based studies of changes in JTW over time

The geography of urban commute in essence consists of the study of people's home location in relation to their locale of work coupled with the route and distance travelled between each. The application of GIS to study the spatial dynamics of commuting has been applied in a variety of instances (see for example, Thériault et al, 1999; Wang, 2000; O'Kelly and Lee, 2005; Sakanishi, 2006; Horner, 2007; Sultana and Weber, 2007; Killer and Axhausen, 2009).

GIS-based studies that have investigated changes in commuter behaviour over time are relatively sparse. Horner (2007) investigated urban form and commuting change in Tallahasse, Florida between 1990 and 2000. Using both global and local measures of land use and commute change, the results suggest that urban structure was relatively stable over the 10 year study period, in addition to a strong continuing relationship between land use and commute patterns. Vandersmissen et al., (2003) analysed changes in urban form and commuting time for Québec City between 1977 and 1996. Using disaggregate travel survey data based upon a sample of approximately 20,000 households the study performed various GIS operations to visualize and model JTW data. Their findings indicated that despite significant decentralisation in Québec City's jobs and housing, commuting distances have increased for males and decreased for females (when controlling for mode of travel and key social factors). Christopher et al., (1995) used US household travel surveys to explore changes in the direction of travel for 9 counties in the Chicago area between 1970 and 1990. They categorise the direction travel into 4 distinct types (towards the CBD, away from the CBD, neighborhood trips and local trips) for each of the 9 counties and perform the same summations for both census periods. Results indicated that directional biases (for each of the 9 counties) have changed little over the 20 year study period despite significant changes in land use and travel behavior, such as increases in car ownership, regional growth and significant decentralisation. Although the study does not explicitly utilize GIS-based techniques outputs from the analysis are represented cartographically. Wachs et al., (1993) focused on a single employer (Kaiser Permanente, based in Southern California) and tracked changes in the home and work locations for a total of 1,500 employees over a 6 year period. They found no significant changes in trip length, despite growth in the local work force contributing to an increase in local traffic congestion. An early work provided by Mogridge (1979) who investigated the changing spatial patterns in the JTW in London between 1966 and 1971. The results based on the Euclidean distance analysis between traffic zones showed an increase in commuting lengths over the periods.

These studies demonstrated that it is possible to compare JTW patterns over time, even at quite disaggregate scales, if one has access to satisfactory data and the skills to prepare and manipulate it into a meaningful comparison.

3. The study area and data

3.1. 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.

3.2. Journey to work datasets

The data used in this research are the JTW flow datasets obtained from the Australian Census for 1996 and 2006. 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.

3.3. Road network data

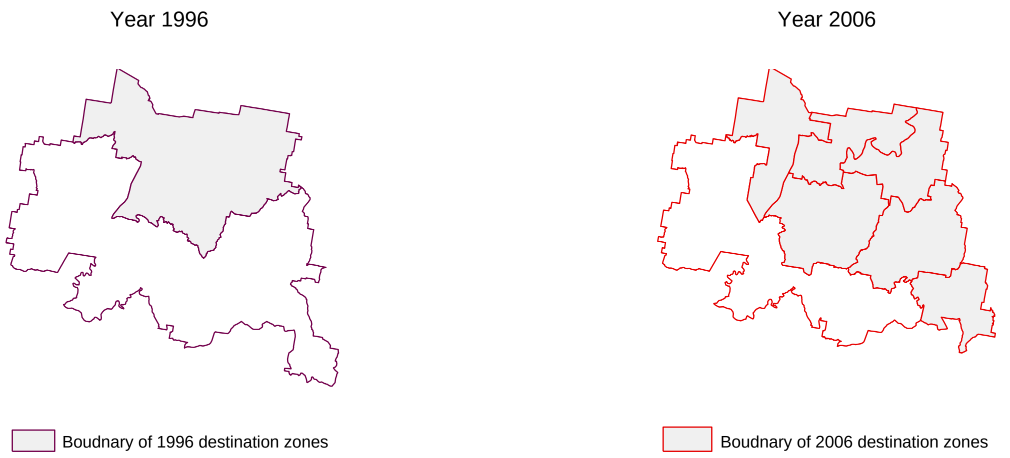
Road network data for Queensland was used to represent road networks for commuter movement. The geographic coverage of the road networks included the whole SEQ region. All commuters travel on the road networks were not restricted to specific road types or traffic nodes. In this study, the year 2006 road network was used to model commuting trips for both 1996 and 2006. The purpose is to purely explore the relationship between land-use change and commuting patterns across the period.

4. Methodology

4.1. 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.

Figure 1: The spatial units of destination zones for year 1996 and 2006, which constitute the same sub-area.



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. SLAs were selected within which the previous destination zones were appropriately nested from various locations across SEQ, to test the aggregation accuracy. For example, the SLA '*Crow'Nest'* contains 4 previous destination zones, and the estimated SLA value was expected to be equal to the sum of travel value for those 4 destination zones. We applied the evaluation procedure to the output datasets for 1996 and 2006, and the results reported an overall very low aggregation error, on average smaller than 0.1%.

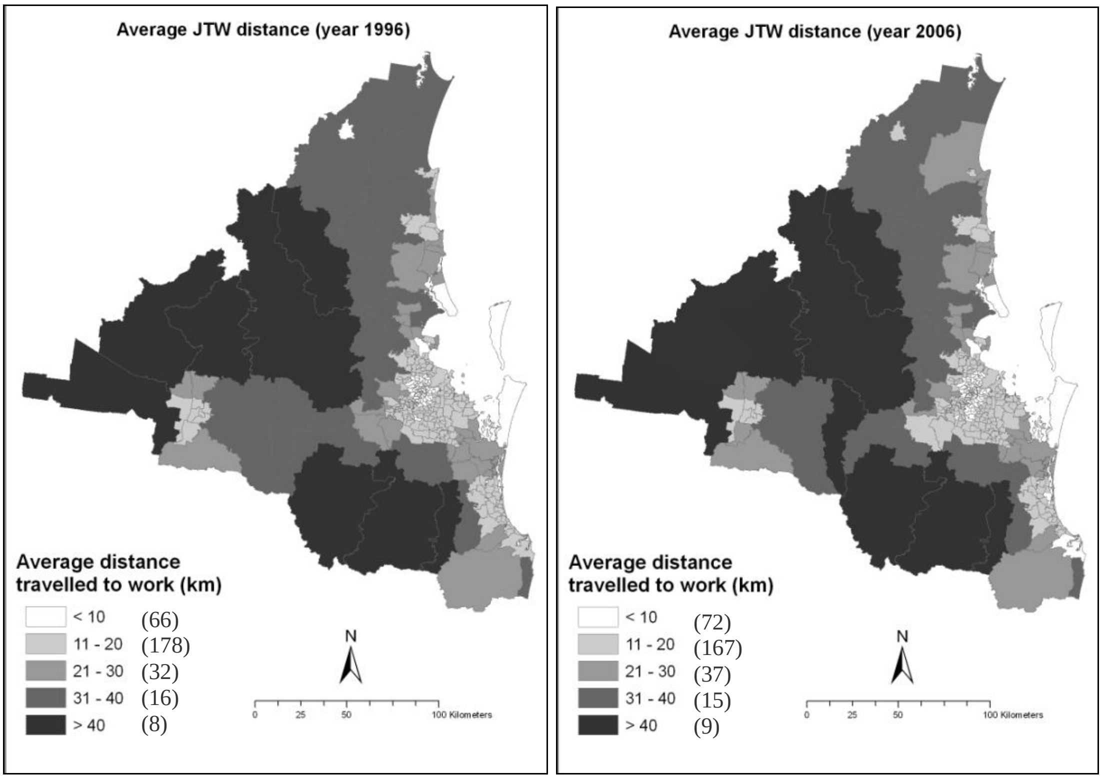
4.2. Modelling the distance of commuting

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.

Figure 2 (a) and (b): Average distance of JTW for year 1996 and year 2006 (numbers in the bracket are the count of SLAs in that distance class)



(a) (b)

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.

Figure 3: SLAs where the average commuting distance decreased by 1km or more between 1996 and 2006

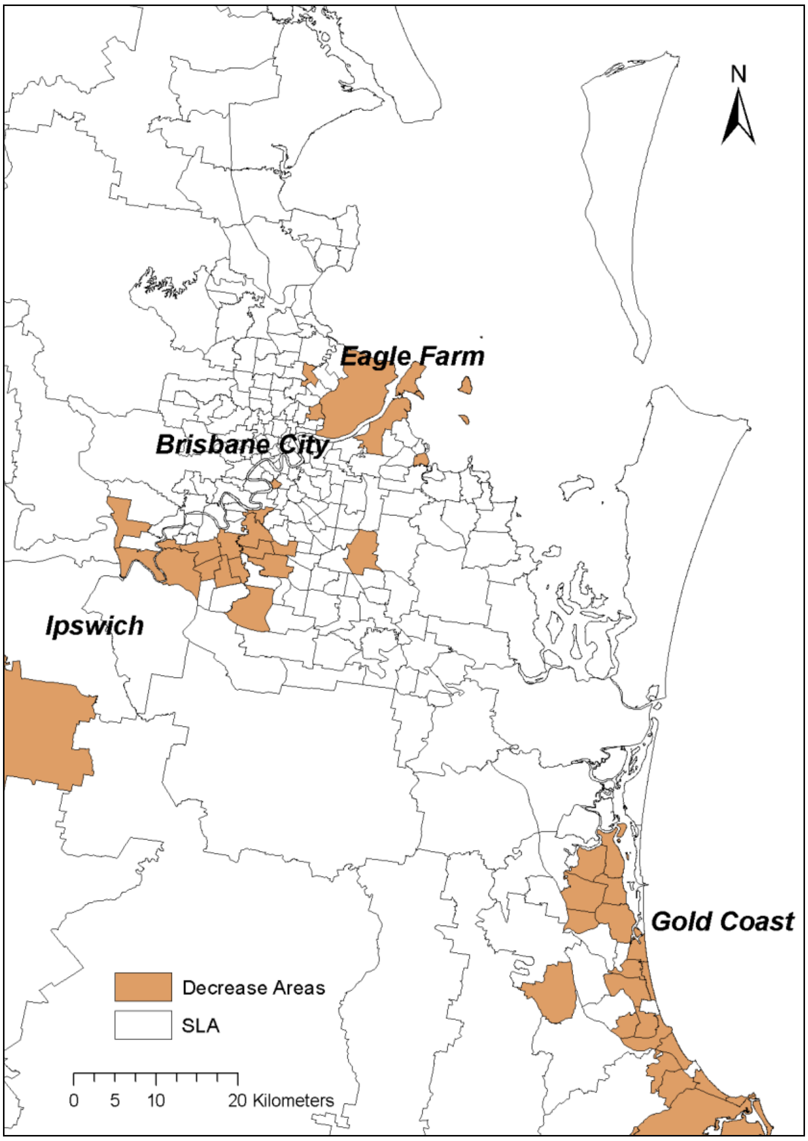
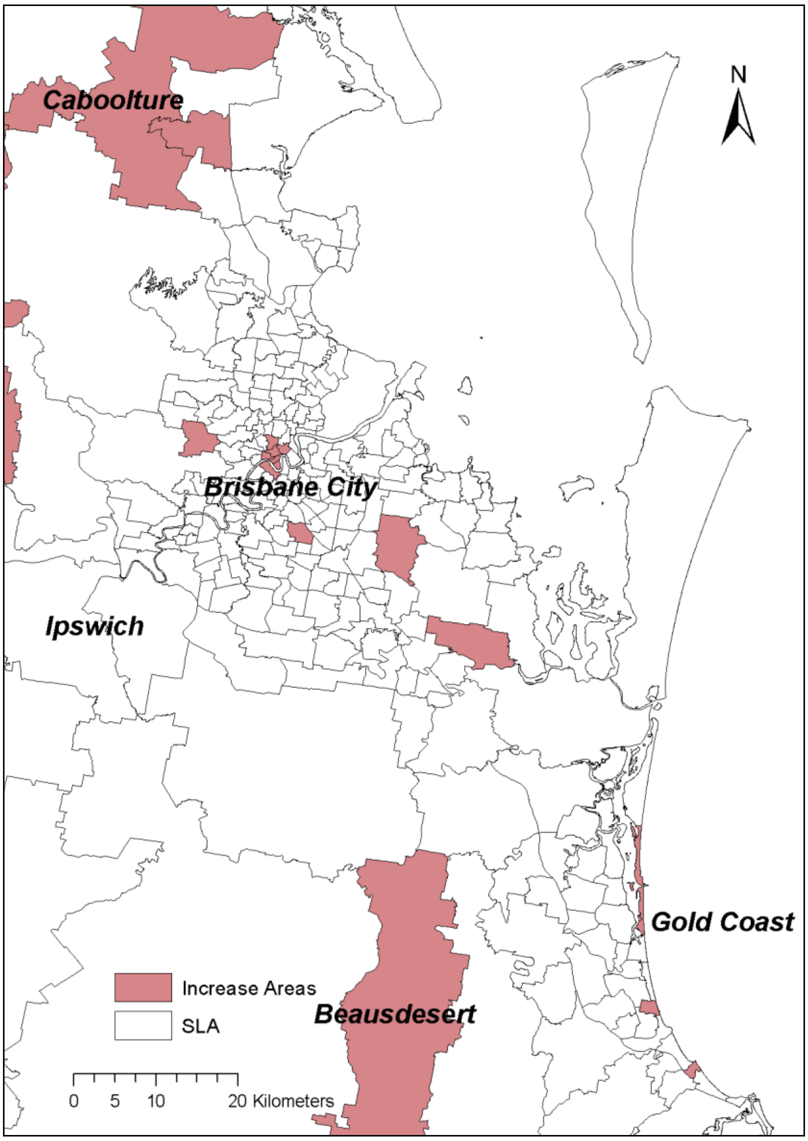


Figure 4: SLAs where the average commuting distance increased by 2km or more between 1996 and 2006



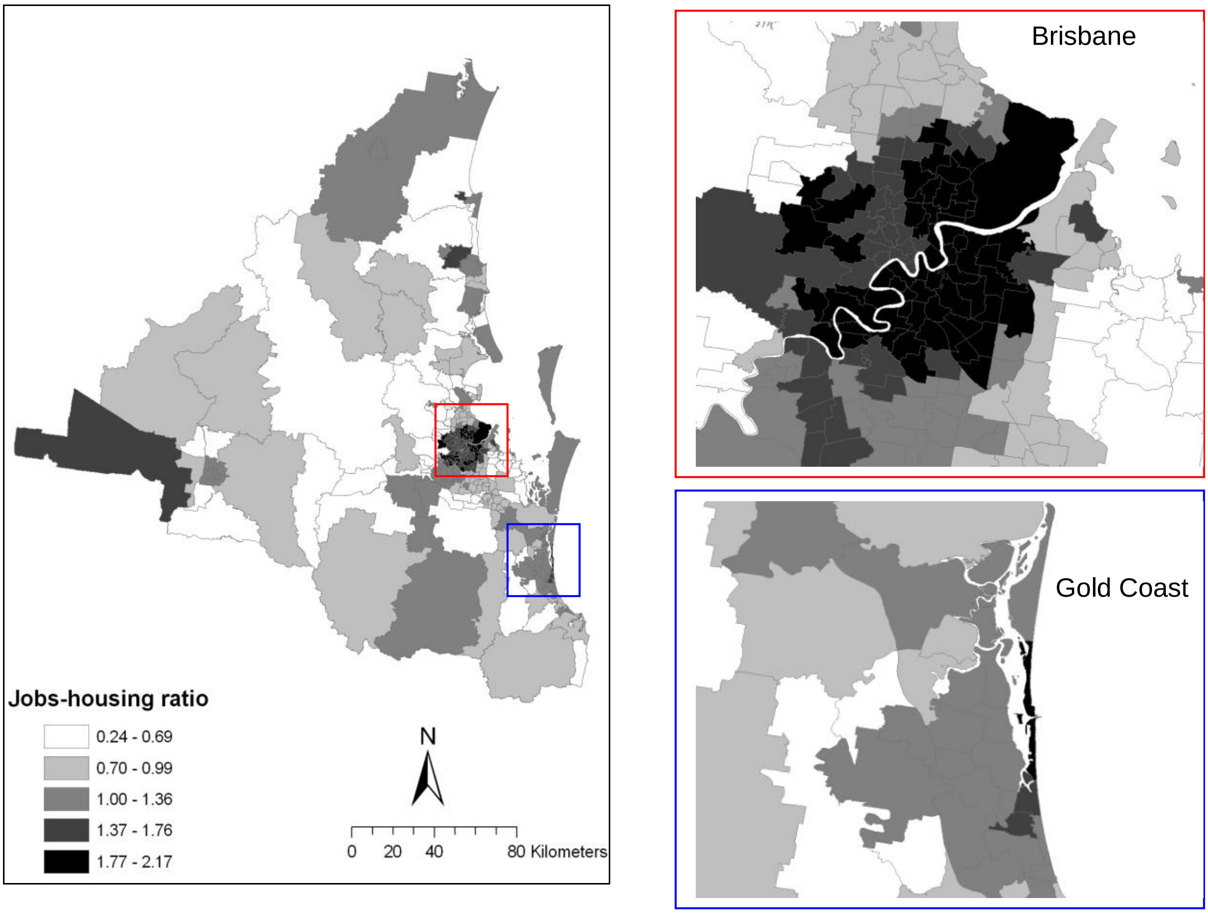
4.3. Measuring the jobs-housing balance

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. The *South East Queensland Regional 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.

The traditional measure of a job-housing ratio is often based on a single administrative boundary such as a local government area, calculating the proportion of jobs per resident. The limitation of this single location approach is that it poorly accounts for the short commuting trips within a larger area, and the interactions between that area and surrounding locations. Further, small areas, such as zones within the inner city, may have an internal job-housing ratio that suggests they have a mismatch, yet residents there may have very short commutes to nearby employment centres. In response, researchers have employed floating catchment areas to measure job-housing ratios (Peng, 1997). However, those floating catchment areas are often defined by the buffered area of each traffic zone. The catchment of households and jobs are often affected by the size and shape of the spatial unit.

In this study, we applied a modified floating catchment approach 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 high light the ratio of jobs per resident for Brisbane and Gold Coast)



4.4 Modelling commuting flows

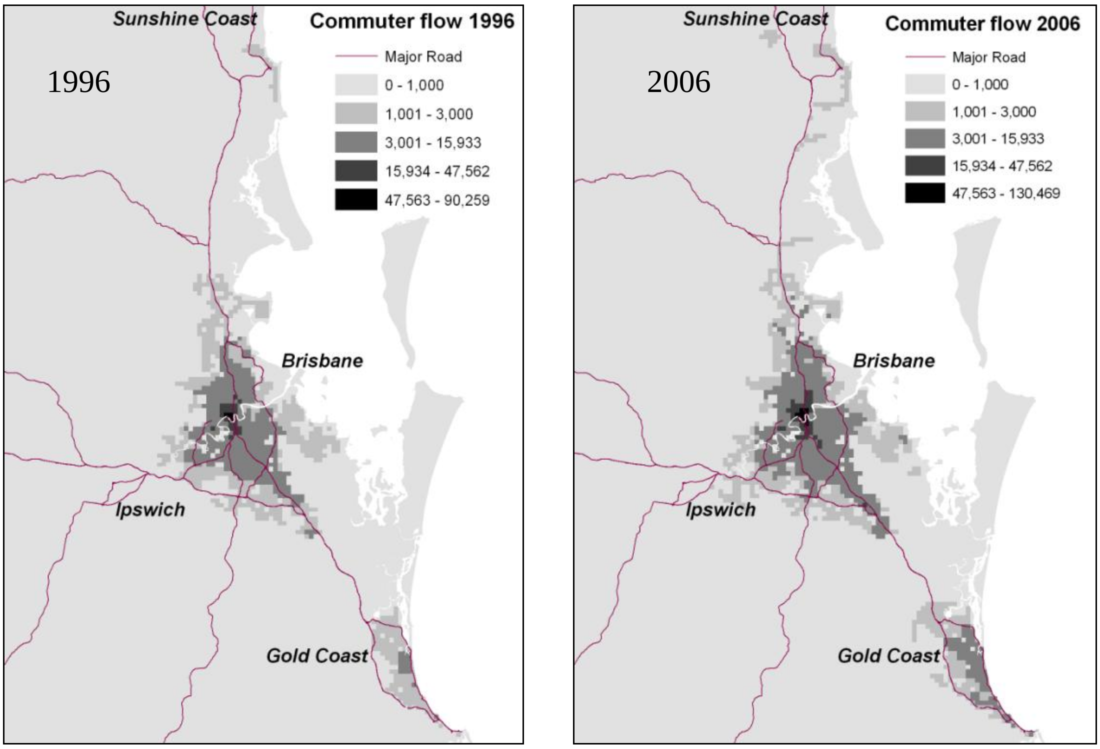
Another spatial issue we investigated was the geographical change in commuting flows across the SEQ region. The GIS-based network modelling (previously described) was also used to model the distribution of traffic flows through the road networks.

First, we calculated the shortest route for commuting travel between each origin and destination, assigning all trips to the shortest routes possible. Because the commuting flows on the shortest routes are highly overlapping, many road segments were shared. All shortest paths carrying traffic flows were then overlapped with SLA boundaries, and total commuting flows were summed for each individual SLA based on the total number of commuters passing through, originating, and ending in that SLA.

Next, because the spatial unit for SLAs is too coarse to represent the spatial distribution of the commuting flows, we transformed the total number of commuting flows from SLAs to 1km by 1km grid cells across the study area. A *binary dasymetric mapping* method (Langford and Fisher, 1996; Li et al, 2007) was applied to spatially disaggregate the data. The binary dasymetric method assumes that the number of travellers is uniformly distributed inside some part of a SLA (in this case, the grid cells that intersect with the road networks) and the remaining parts of the zone (non-road areas) necessarily have a zero commuting flow value.

The maps of spatially disaggregated commuter flows for year 1996 and 2006 are illustrated by Figure 6 (a) and (b). At the regional level, the highest commuting flows are concentrated in the central Brisbane area, extending north and south through the transport networks. The 1996 data showed the commuting flow stretching to the southern areas; and this tendency was found to be more significant in 2006. The increased commuting flow across the north-south corridor may have been caused by rapid urban expansion and new population settlements, especially in the southern suburbs of Brisbane, which generated increased commuting trips towards Brisbane. A similar pattern of commuting development was also found in the Gold Coast City area, where commutes spread considerably towards the north and south areas of the city along the coast.

Figure 6 (a) and (b): The distribution of commuting flows for year 1996 and year 2006 (by 1k by 1k grid cells)



(a) (b)

Figure 7: Changes in commuting flows between 1996 and 2006 (by 1k by 1k grid cells)

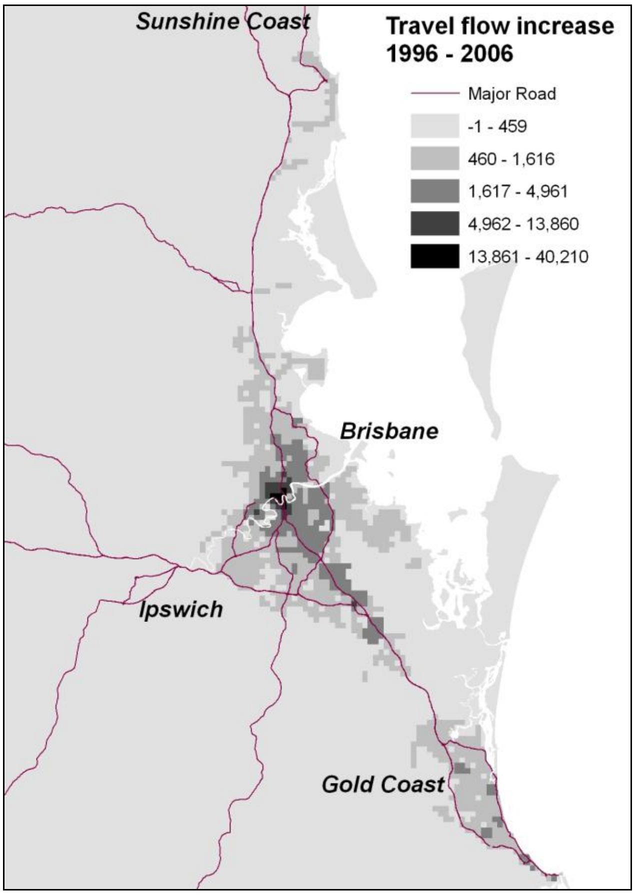


Figure 7 maps the changes in commuting flows between 1996 and 2006. The main findings are:

1) The central Brisbane area has experienced the highest growth in commuting flows. This was not only driven by an increase in inbound commuters but also the increased cross-suburban traffic that passes through the central Brisbane area.

2) The most significant growth in commuting was found along the transport corridor between Brisbane and Gold Coast. The major growth areas along this corridor include Logan City and Beenleigh. The clustering effect of commuting growth indicates that in addition to increased commuting interactions towards Brisbane, some increased internal commuting has also developed in these areas.

3) The change in commuting flows between Ipswich and Brisbane was not significant over time. This result can be supported by the research findings of Corcoran et al. (2008) in that Ipswich City was the most self-contained local labour market within the sub-region, where outward commuting movement was found to be minimal.

5. 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 $\approx$ 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 $\approx$ 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).

Figure 8: scatter plot of average commuting distance and job-housing ratio for 1996

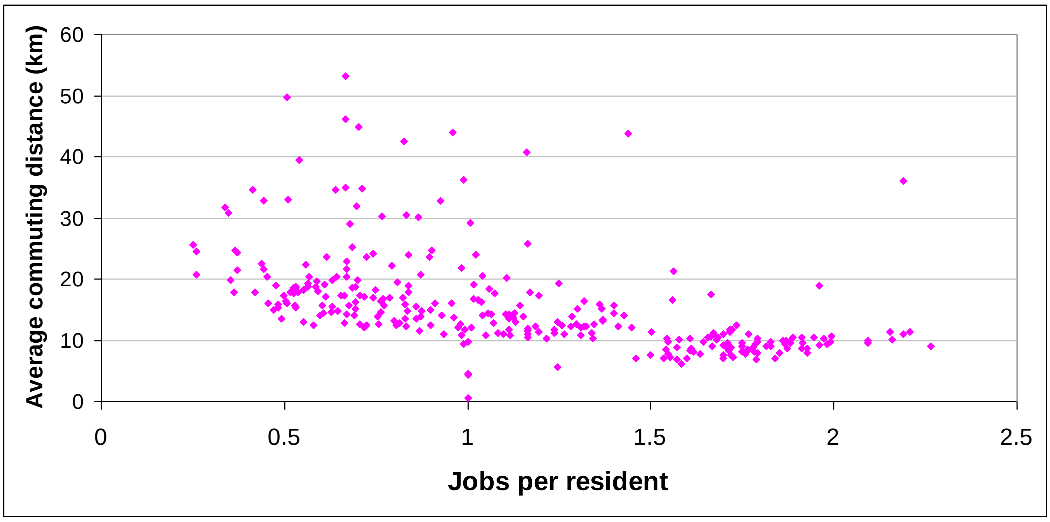
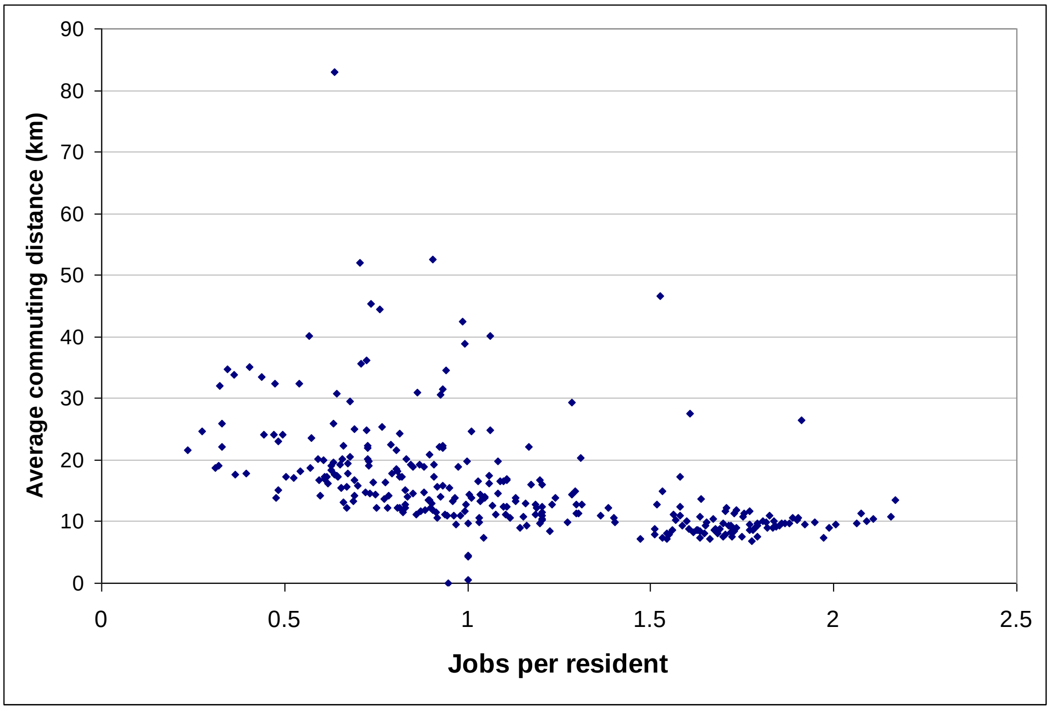
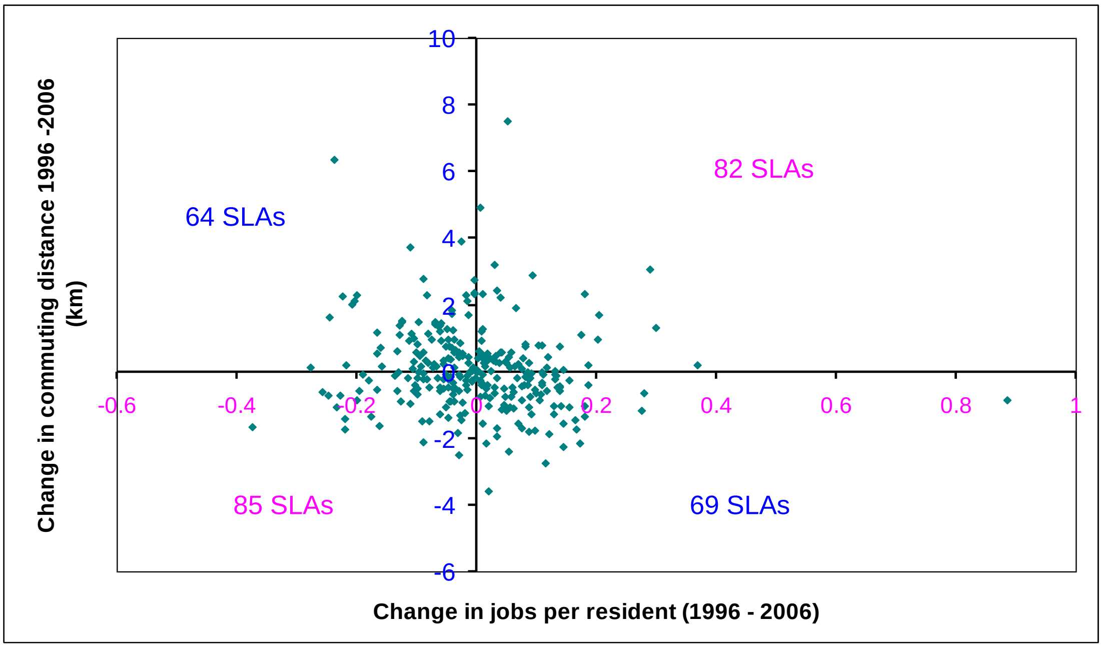


Figure 9: scatter plot of average commuting distance and job-housing ratio for 2006



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.

Figure 10: scatter plot of change in jobs-housing ratio and change in average commuting distance between 1996 and 2006



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.

6. 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, travel distances and commuting flows. 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 that are independent of the two original and inconsistent zonal structures. 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. The GIS network modelling is also used to model the distribution of traffic flows through road networks. The procedure calculated the number of trips travelling on every road (network link) to estimate a traffic map. The result is spatially disaggregated at 1km by 1 km grid cells. Thirdly, we applied 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, a regional trend was also detected for commuting flows. Over time, the significant growth in traffic flow spread towards the northern suburbs and more so towards the Brisbane-Gold Coast corridor. The central Brisbane area remained as a core traffic area. Thirdly, 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.

This research has focused on the spatial-temporal changes in JTW patterns. While the techniques presented 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) (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. Finally, exploring access based on travel times on the road network, and access via the public transport network, may provide a deeper understanding of the geographical and temporal variations of JTW across the region.

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