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Sustainable Australia: Containing Travel in Master Planned Estates

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ABSTRACT

Low density suburban development and excessive use of automobiles are associated with serious urban and environmental problems. These problems include traffic congestion, longer commuting times, high automobile dependency, air and water pollution, and increased depletion of natural resources. Master planned development suggests itself as a possible palliative for the ills of low density and high travel. The following study examines the patterns and dynamics of movement in a selection of master planned estates in Australia. The study develops new approaches for assessing the containment of travel within planned development. Its key aim is to clarify and map the relationships between trip generation and urban form and structure. The initial conceptual framework of the paper is developed in a review of literature related to urban form and travel behaviour. These concepts are tested empirically in a pilot study of suburban travel activity in master planned estates. A geographical information systems methodology is used to determine regional journey-to-work patterns and travel containment rates. Factors that influence self-containment patterns are estimated with a regression model. This research is a useful preliminary examination of travel self-containment in Australian master planned estates.

INTRODUCTION

The relationship between urban form and travel behaviour has been of substantial interest to urban researchers (see Handy 1995; Ewing et al. 1996; Miller and Ibrahim 1998; Crane 2000; Cervero 2001). The link between land use patterns and travel demand is, however, complicated by the varying socio-economic and travel preference factors associated with different land uses (Stead et al. 2000). According to Stead (2001: 499) “the variation in socio-economic characteristics increases the difficulty in establishing the precise relationship between land use characteristics and travel patterns, and adds complexity to the comparison of travel patterns in different areas.”

The key aim of this research is to investigate the dynamics of travel self-containment by exploring and mapping the relationships between urban form, urban structure and trip generation. The notion of ‘travel self-containment’ is used by urban scholars to describe the spatial travel patterns of residents within a given locality. Empirically, it is the proportion of trips that are internal to the locality, relative to all trips made by residents (Cervero 1995; Healy and O'Connor 2001). A high rate of travel self-containment indicates a set of land use and transport conditions able to satisfy

much of local resident need(s) without recourse to multiple external journeys involving dispersed destinations. Local travel reduces automobile use, adding to the environmental sustainability of a region.

Our study is focused on Australian master planned estates (MPEs). To date there has been limited international consideration of travel in MPEs. The research that does exist does not explicitly address the issue of self-containment. In Australia there has been no empirical research into any aspect of travel in MPEs.

The ambition of master planning, as its name suggests, is considerable. Its conceptual vision extends to all aspects of development (Gwyther 2005). Its spatial ambit is the entire project site. The idea of master planning dates back to Ebenezer Howard's Garden City concept of the 1880s (Gwyther 2003). A developing practice in North America since the 1960s, master planning has, in the last 15 years, made its mark in Australia. MPEs or master planned communities (MPCs) are large-scale developments whose essential features are a definable boundary; a consistent, but not necessarily uniform, character; and overall control during the phasing and build-out process by a single development entity (Schmitz and Bookout 1998; Minnery and Bajracharya 1999). Such planned communities generally contain a wide range of residential and non-residential land uses, open space, and public services and facilities. MPEs tend to be low density and suburban in character. Of late, however, there has been a slight shift towards mixed densities, with some estates including areas of medium and high density development.

MPEs are becoming the dominant form of urban expansion in Australia, replacing traditional regulatory subdivisions (Blair et al. 2003). Historically, many MPEs offered limited residential products. The newer estates, however, are offering more varied options developed with better design principles that allow open space preservation, integration of land uses to reduce auto trips, walkable pedestrian networks, and architectural details that foster social interaction (Schmitz and Bookout 1998; Cowley and Spillette 2000).

MPEs have attracted the attention of international scholars interested in the links between urban form and generated travel behaviour (e.g., Gordon and Richardson 1989; Breheny 1992; Newman and Kenworthy 1992; Cervero 1995). Few empirical studies, however, have been completed into MPEs' travel behaviour patterns (e.g., Ewing et al. 1993; Cervero 1995). In Australia, while a number of scholars have investigated MPEs, they have largely concentrated on the physical, environmental and social issues of such developments, rather than travel patterns (see Forsyth 1997; Minnery and Bajracharya 1999; Gwyther 2002; Wood 2002; Blair et al. 2003; Bosman 2003; Dodson and Berry 2003; Gwyther 2005).

MPEs often claim to provide a strong sense of community identity, traffic and property safety, and to promote self-containment of travel within their region. They purport to conserve non-renewable energy sources and to reduce high levels of vehicular movement (Commonwealth of Australia 1995). It is also their aim to use available infrastructure and land more efficiently and, with higher density development, to increase resource and transport efficiencies (Blair et al. 2003).

Information about local self-containment rates for Australian suburbs is scant. To date there has been no research into the travel self-containment rates of master planned residential communities in Australia.

This study investigates a set of locational, design and social variables, associated with self-containment and internal trip capture, in selected Australian MPCs. The objectives of the research are:

- to define local area travel containment;
- to test the definition with a geographical information system (GIS) empirical analysis of suburban localities - using Australian Bureau of Statistics (ABS) Census journey to work (JTW) data for MPEs;
- to identify the relationship between land use characteristics, household socio-economic profiles and travel preferences in MPEs.

The research investigates three primary questions:

- How can urban scholars measure self-containment?
- What are the local area (travel) self-containment characteristics of Australian MPEs?
- What factors influence the travel self-containment in Australian MPEs?

The methodology is threefold. First, the paper reviews existing literature on suburban travel patterns and self-containment and reports on the major conclusions of this scholarship. The paper then analyses journey to work (JTW) travel patterns as revealed by ABS Census data and measures local travel containment rates. Finally, a statistical regression analysis is used to estimate factors affecting local trip generation patterns (i.e., self-containment).

The rest of this paper is structured as follows. Section Two introduces the empirical model used in the pilot study to address the second and third research questions. A regression model estimates the factors affecting self-containment patterns in Australian MPEs. Section Four concludes with the research's overall findings and identifies opportunities for future research into MPEs in Australia and internationally.

EMPIRICAL STUDY

The empirical goal of the pilot study is to map and explore the relationships between urban form, urban structure and trip generation patterns to better understand the sustainable options of urban development. The empirical section of our investigation is presented in six parts. First, we discuss research design. We then introduce the case study MPEs. Next, we discuss sources of empirical data and their limitations. Fourth, we analyse regional JTW data using a GIS-based methodology and present the preliminary travel patterns. The heart of the empirical study is an 'ordinary least squares' (OLS) statistical regression model of factors presumed to influence travel self-containment. Factors found to be inadequate are discarded and a final model is estimated. We conclude by discussing the research findings, including data and methodological limitations, and identifying opportunities for future research.

Research Design

Preceding section of this paper reviewed previous research on the relation between urban form, urban structure and trip generation patterns. In this section we discuss methods to analyse JTW travel patterns, measuring (travel) self-containment, and means of determining the influence of various urban variables on internal trip-capture rates.

GIS-based analysis is increasingly used in land use and transportation research (Crane and Crepeau 1998). Its biggest advantage is it allows spatial and non-spatial attributes of the urban built environment, including their populations, to be relatively easily defined, quantified and manipulated (Cervero and Duncan 2003). This study employs a GIS-based spatial analysis to define local area travel containment values and measure internal trip capture rates for MPEs. The basic input into the analysis is journey to work (JTW) data from the ABS Census (Figure 1).

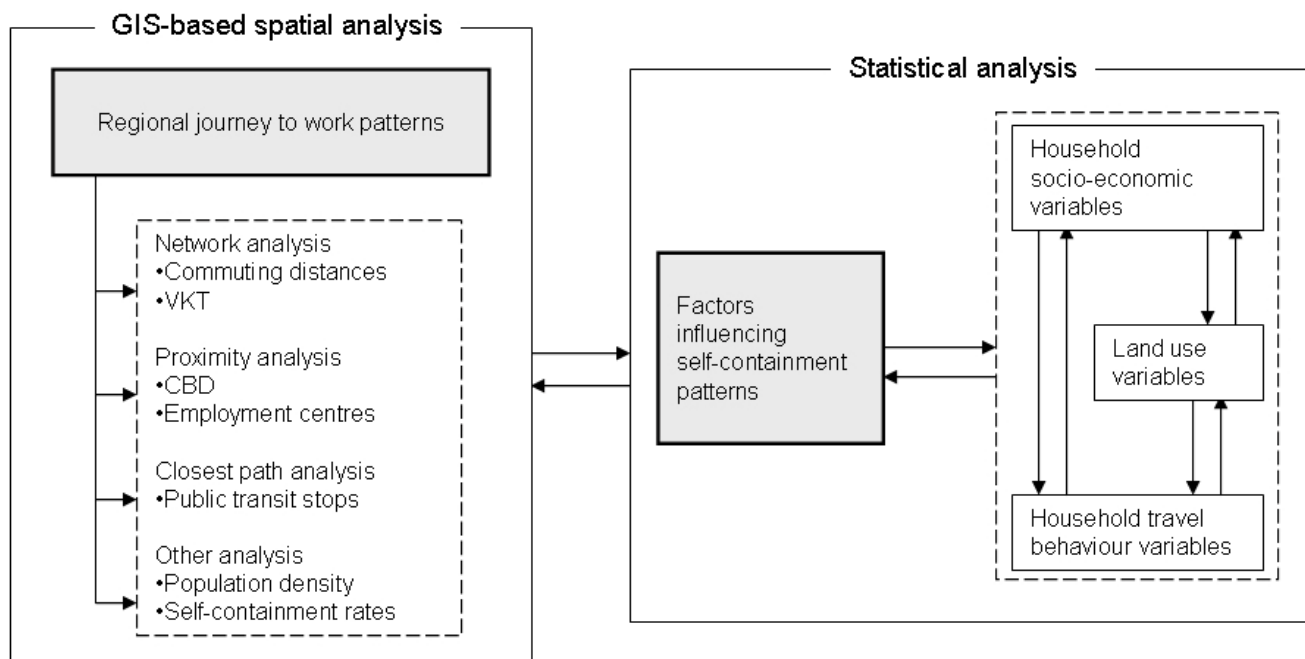


Figure 1: Model for analysing JTW and self-containment patterns

JTW patterns have been the focus of much research on the relationship between urban form and travel behaviour. Many scholars have used JTW data to investigate the links between job access, work place location, and commuting trips (see Giuliano and Small 1993; Cervero and Gorham 1995; Forrest 1996; Naess and Sandberg 1996; Levinson 1998; Ong and Blumenberg 1998; Healy and O'Connor 2001). In this research JTW data is used to measure commuting distances and travel self-containment rates for a selection of Australian MPEs. The restriction of the analysis solely to home-to-work trips is driven by pragmatic considerations of data availability and relative ease of manipulation. While it is desirable for research into self-containment to investigate trip-capture rates for non-work trips, such as shopping and recreation journeys, such data is difficult to obtain to a statistically valid sample size. The lack of prior travel containment research in Australia means there is little, if any, existing data to draw upon. For a pilot study such as this, the JTW Census is an available and easily accessible, albeit limited, data source.

Crane (2000) categorises methods of analysis of urban form and travel under three headings: Simulations, descriptive studies, and multivariate analysis. Simulations are based on either: (i) entirely hypothetical situations, and thus succeed or fail depending on the validity of their assumptions, or (ii) on more complex combinations of assumed and manifest behaviours. Descriptive studies restrict themselves wholly to observable data. Multivariate analysis— usually some form of linear regression – is a framework able to span a large number of variables, expressed in numbers, representing a complex net of relationships (Crane 2000). It is common to much research into the link between urban form and travel patterns (e.g., Cervero and Gorham 1995; Cervero 1996; Kitamura et al. 1997; Boarnet and Sarmiento 1998; Stead 2001; Dieleman et al. 2002; Krizek 2003; Schwanen et al. 2004).

When the relevant data is available, multivariate regression analysis permits the identification of key socioeconomic and land use characteristics associated with travel behaviour. We believe multivariate statistical analysis to be the most suitable technique for our study because it:

- processes observed as well as hypothetical behaviour;
- assigns weights (i.e. rude quality) to causal relations until now only described;
- has the capacity for multi-linear complexity.

Ewing et al. (1994), Cervero and Kockelman (1997) and Stead et al. (2000) all produce evidence to suggest household demographic and socio-economic attributes, as well as the characteristics of residential environments, have a strong effect on travel patterns. Dodson (2003) finds the age of residential areas likely to impact on access to employment.

To measure ‘travel self-containment level’ (dependent variable) we selected a set of empirical land use, travel and household characteristics as independent variables to represent it (Table 1, below). In defining the set we included variables considered to affect the pattern of travel and variables demonstrated by the literature to possess trip generation effect (See Southworth and Owens 1993; Cervero and Gorham 1995; Cervero and Kockelman 1997; Hess et al. 1999; Krizek 2003). The Census data narrowly confined the definitional possibilities of variables. In the absence of superior data, however, this constraint is unavoidable.

Table 1: Regression analysis variables used in this study

Land Use Variables	Household Socio-economic Variables	Household Travel Behaviour Variables
Population density	Income level	Travel method
Age of estate	Employment level	Proximity to employment centres
Proximity to CBD	Education level	Commuting distance
Proximity to public transport	Car ownership	Vehicle Kilometres Travelled

Note: Dependent Variable is ‘travel self containment level’

Case Studies and Datasets

Data and data gathering constraints restricted our case study to the following six MPEs (Figure 2):

- Forest Lake (Queensland),
- Golden Grove (South Australia),
- Caroline Springs (Victoria)
- Roxburgh Park (Victoria)
- Harrington Park (New South Wales)
- Garden Gates (New South Wales).

The study MPEs were selected such that each had: (i) been established before 2000; and (ii) had achieved a take-up ratio of at least 50 per cent by the March 2001 Census. Some of the salient characteristics of these MPEs are identified in Table 2, below.

The 2001 Census of Population and Housing, as well as 2001 Census boundaries and 2001 Census ‘Detailed Study Area’ Journey-To-Work data, were obtained from the ABS. Detailed Study Areas have been created by State transport agencies and comprise destination zones (DZNs) that aggregate to statistical local areas (SLAs). The core data was JTW detail collected at the level of the Census collection district (CD). DZN boundaries were provided by NSW Department of Transport – Transport Data Centre, VIC roads – Road System Management, QLD Department of Transport – Strategy and Planning Services, and Transport SA. Road and rail networks were derived from MapInfo Street Pro road network database for Australia.



Figure 2: Location of the case studies

Table 2: The salient characteristics of the MPEs

	Harrington Park, NSW	Garden Gates, NSW	Caroline Springs, VIC	Roxburgh Park, VIC	Forest Lake, QLD	Golden Grove, SA
Developer	Hassell	Landcom	Delfin Lend Lease	VicUrban	Delfin Lend Lease	Delfin Lend Lease
Population (persons)	3027	3829	5356	9487	15062	26029
Population density (person/hectare)	8.9	6.5	7.9	18.1	11.8	18.2
Commencement of occupation (year)	1994	1991	1999	1992	1991	1986
Full-time employment level (%)	36.9	35.9	39.6	30.4	33.0	32.9
Higher education level (%)	8.6	4.4	8.5	6.4	6.5	6.8
Household weekly income level (\$)	1,500-1,999	1,500-1,999	800-999	800-999	1,000-1,199	1,000-1,199
Car ownership per dwelling	1.9	1.9	1.9	1.7	1.6	1.8
Motor vehicle use in JTW (%)	88.2	86.4	90.0	89.8	46.5	46.5
Proximity to CBD (km)	57	56	25	26	21	22
Proximity to public transit - train station (km)	9	5	6	5	7	8
Proximity to employment centres (km)	45	44	33	26	24	12
Average commuting distance (km)	23	22	16	13	12	13
Daily journey to work VKT (km)	21510	24926	9428	7732	82838	8390
Travel self containment rate (%)	13.8	8.9	3.0	4.4	11.1	11.8

Note: Figures presented in this table are based on year 2001

Regional Journey to Work Patterns

This study estimates travel self-containment values with a GIS-based model used in conjunction with spatial statistical techniques. Detailed JTW data is the primary input of the model. The dataset records each employed person’s usual residence (origin) and workplace (destination). Residential location is identified at the level of the CD – variable areas with boundaries determined such that each CD contains approximately 200 households. Workplace destination is specified at the level of the DZN.

GIS software was used to link JTW data with DZN boundaries and determine the number of work trips undertaken between each MPE census district and each JTW destination zone. The calculation required CD and DZN ‘centroids’ be imputed as the origin and destination, respectively, of a representative journey. This journey was notional traced on the road and public transport network(s) to yield a travel route distance. Each CD-DZN route distance was then multiplied by the number of recorded trips, to calculate a residence-to-work VKT. Total VKT was calculated by doubling the number of trips, to account for return journeys from work. The results of this analysis are provided in Figures 3 and 4.

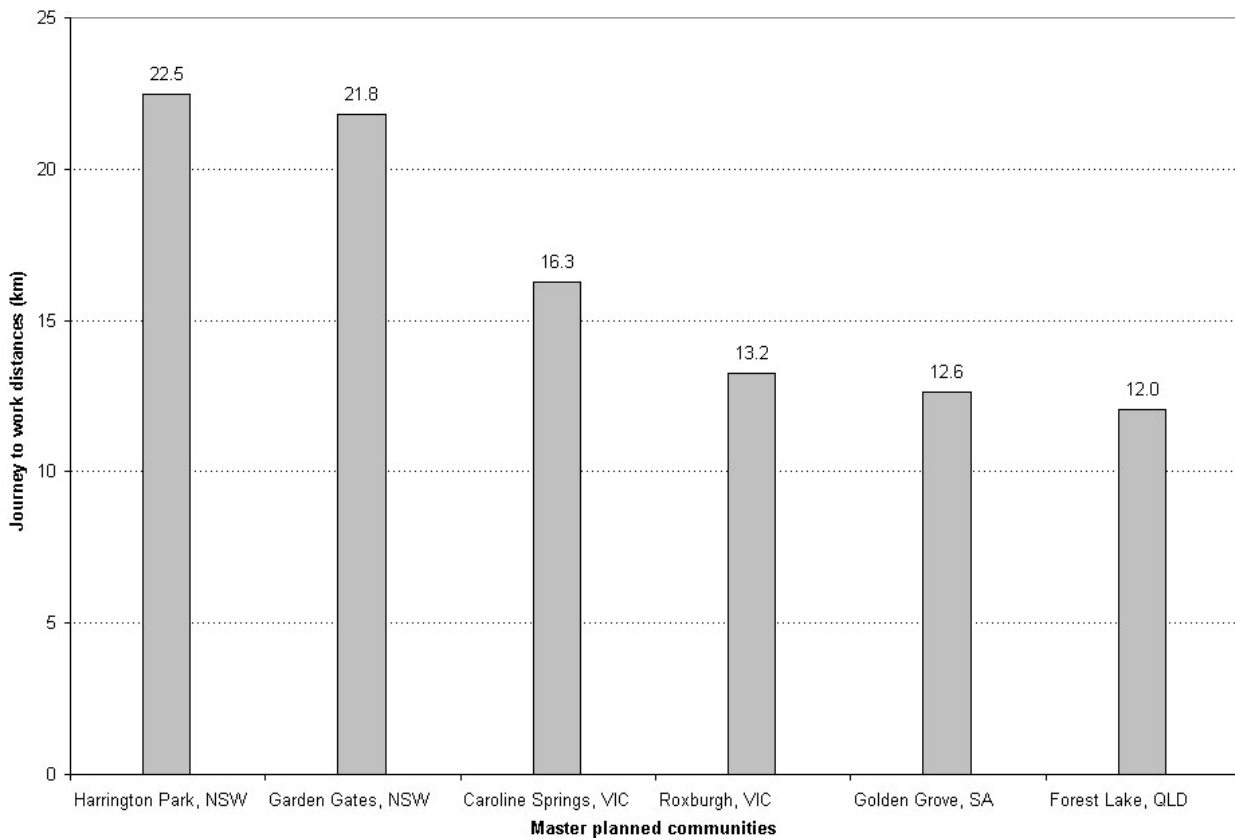


Figure 3: Average commuting distances

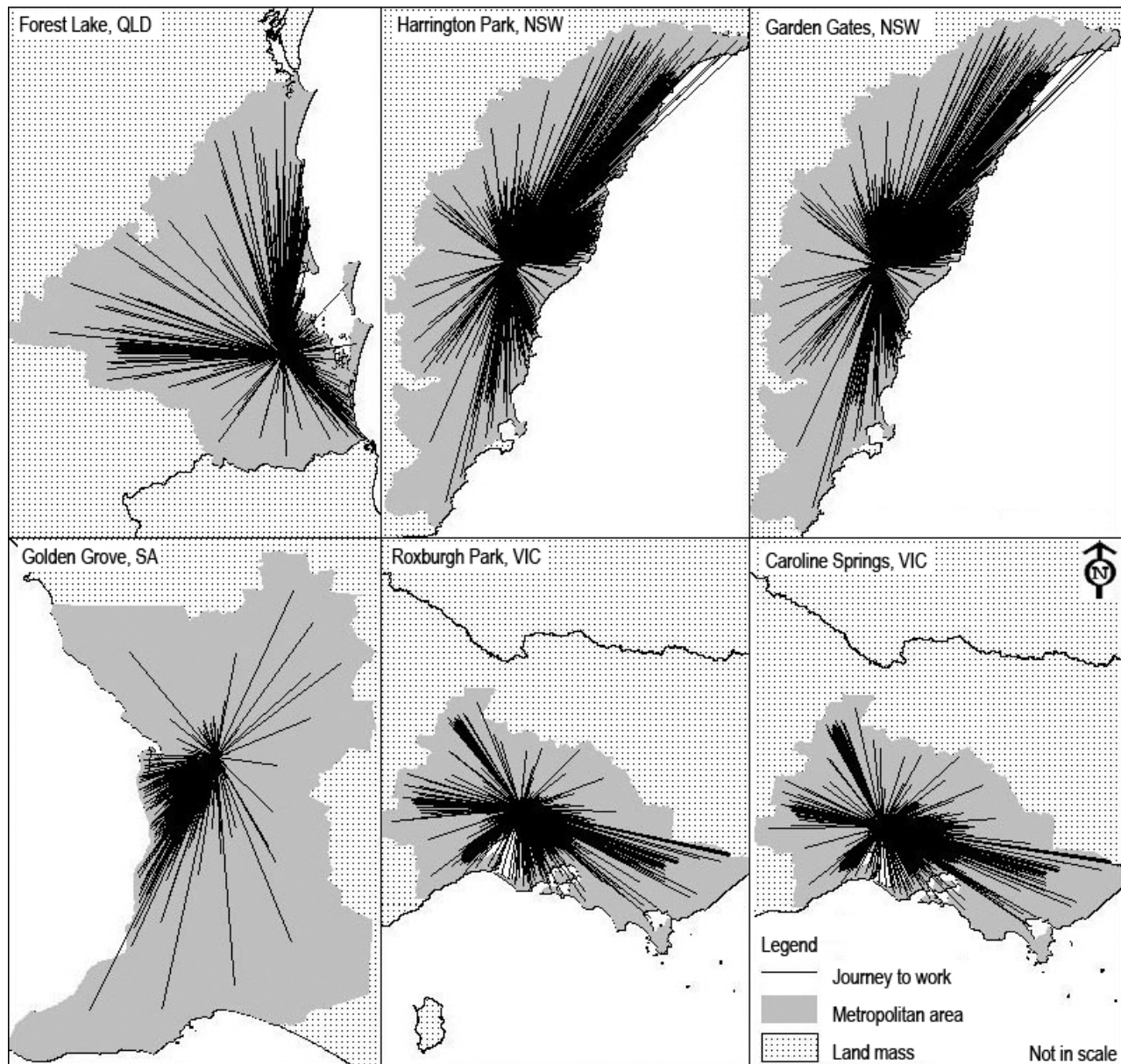


Figure 4: Distribution of work trips

The next task of the study was to measure the travel self-containment values for MPEs. Work trips from each CD to each DZN were calculated. The ratio of work trips to DZNs within each CD relative to work trips to DZNs external to each CD provides the self-containment ratio for each CD (Figure 5 and 6).

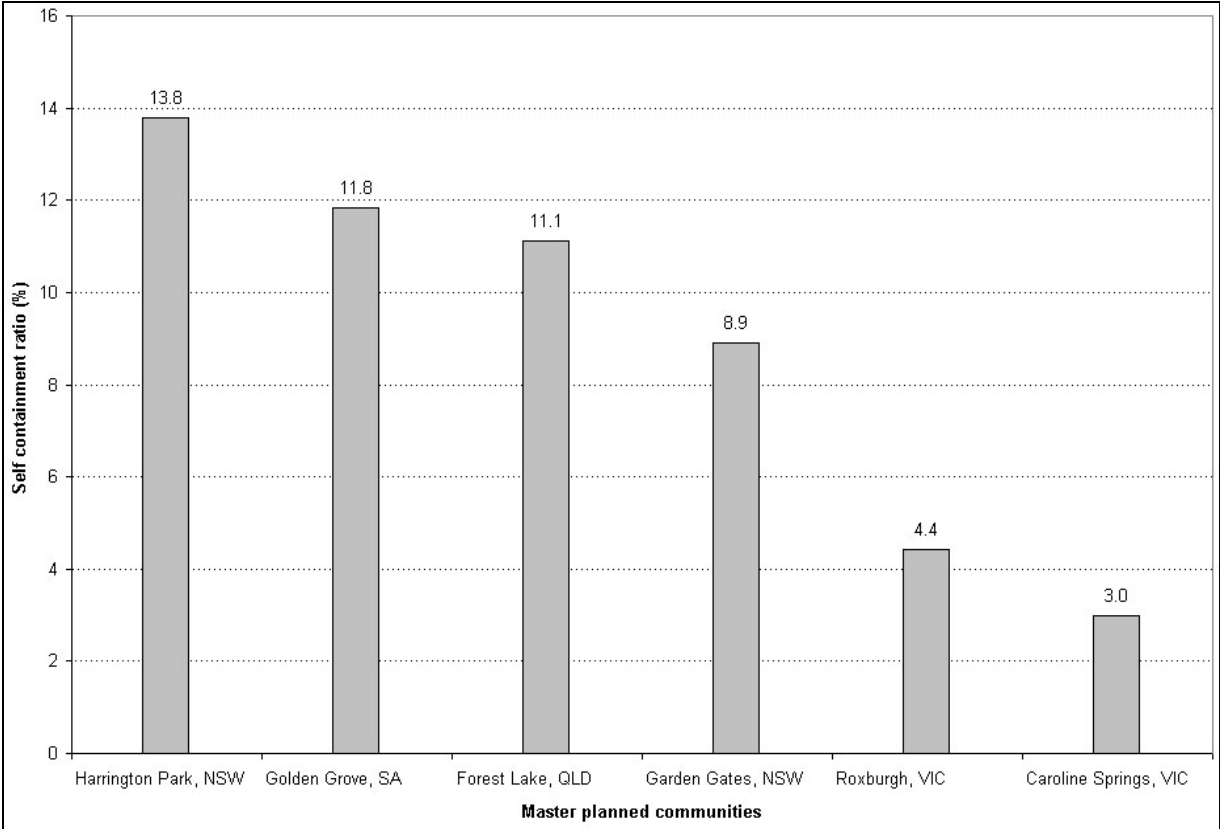


Figure 5: Travel self-containment rates

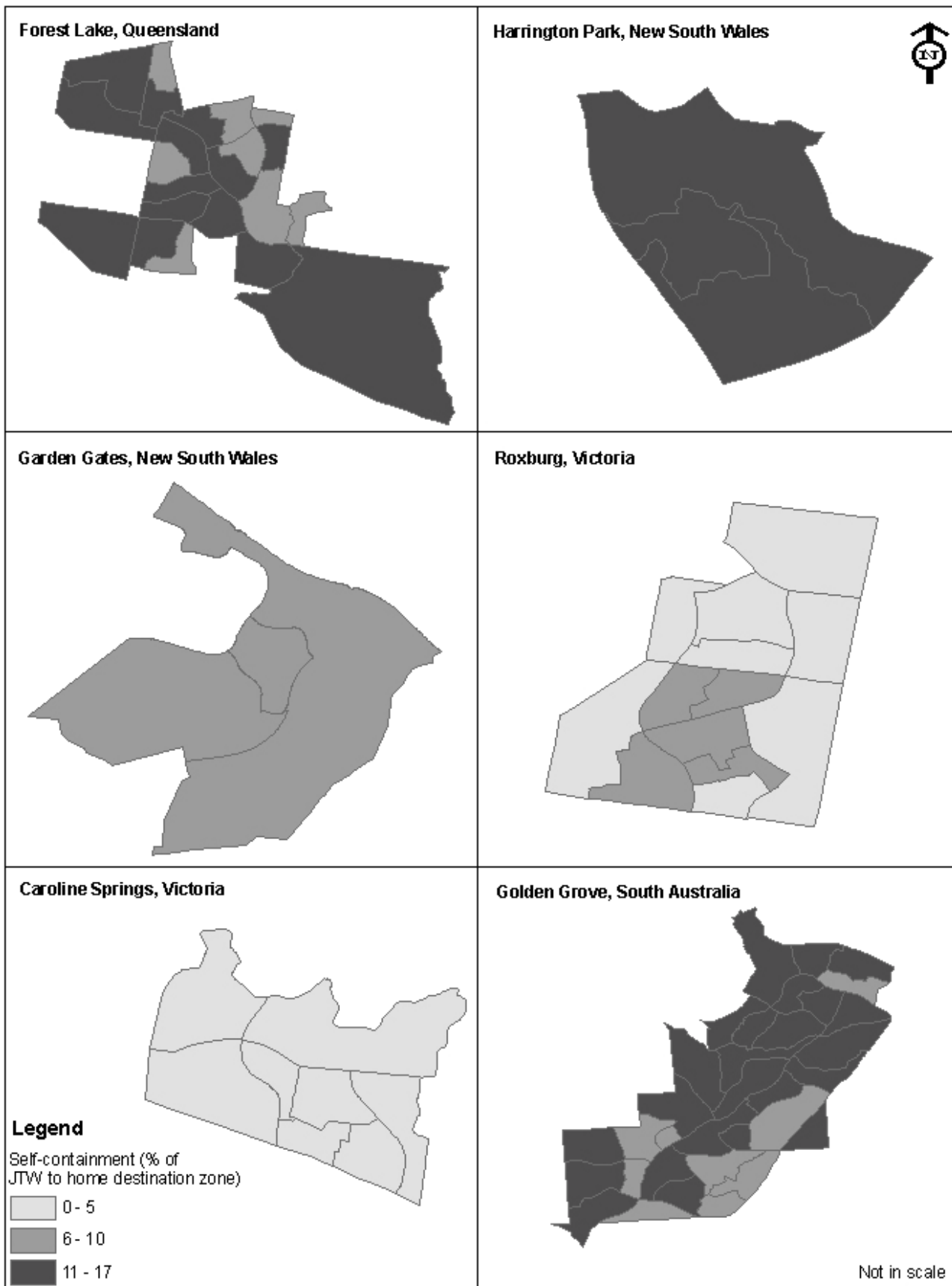


Figure 6: Census CD level travel self-containment rates

The model also included several proximity analyses that measured distances from the MPE CD centroids to such land use and transport features as the metropolitan CBD, regional employment centres and rail stations. The model, using road and/or rail networks, calculated actual rather than Euclidean distances. Figure 7 shows, as an example, the results from Sydney’s Harrington Park

MPE. It visually defines the proximity of the MPE to the Sydney CBD and regional employment centres. The regional employment centres were, in all cases, selected as the destinations of elevated numbers of MPE work trips.

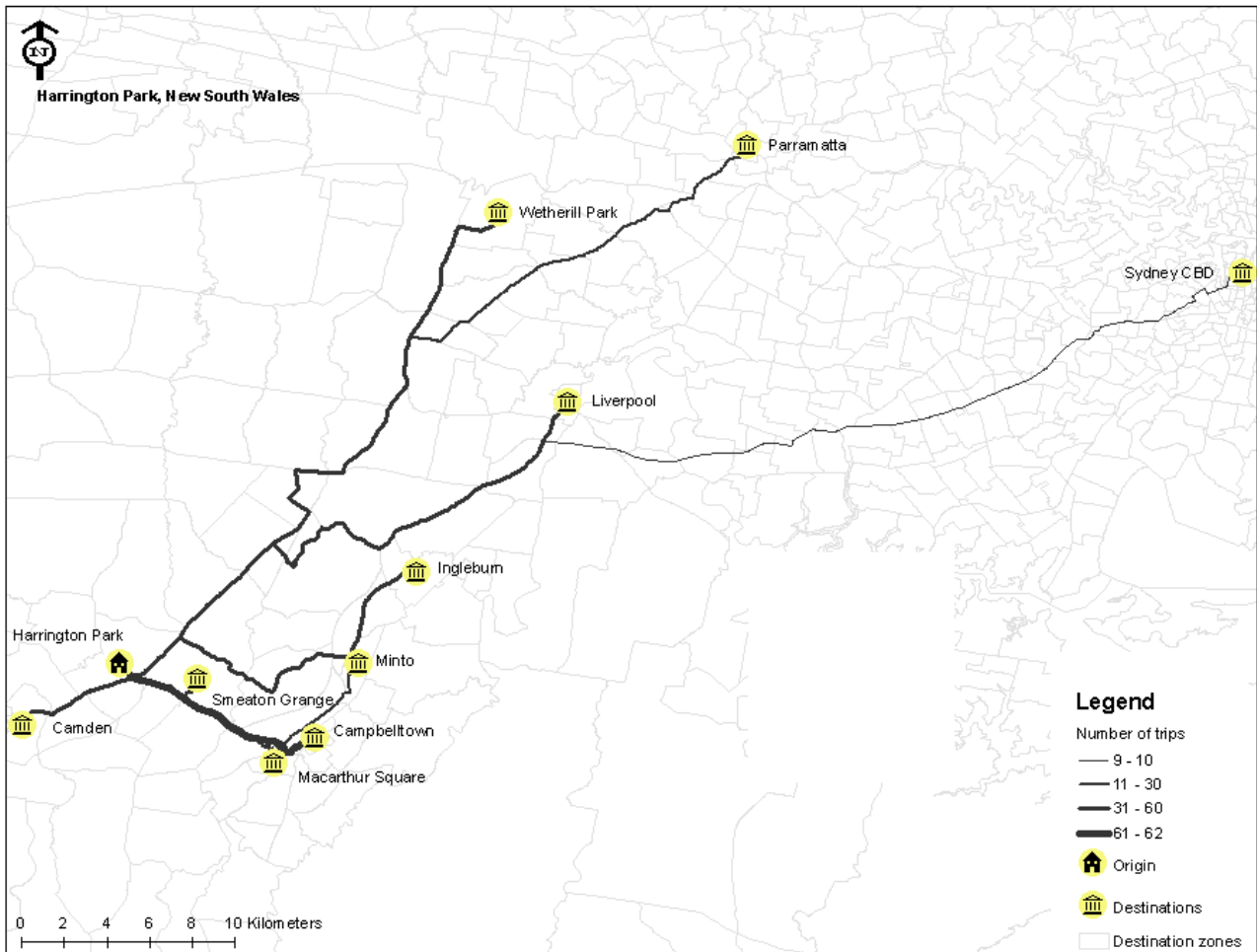


Figure 7: Proximity to CBD and regional employment centres

Accessibility and the quality and frequency of public transit services are major factors in commuter modal choice (Litman 2001, 2003). To measure public transport access we determined network distance(s) from each MPE CD to the nearest public transit node(s). Unfortunately we could only measure for rail transport. Difficulty in obtaining up-to-date bus, tram and ferry routes, including stop locations and service timetables, precluded accessibility measurement for other public transport modes. Over the case study set distance to nearest rail station varies between five and nine kilometres (Table 2). In Figure 8 the Forest Lake example typifies the ‘shortest path’ analysis used to gauge public transport access.

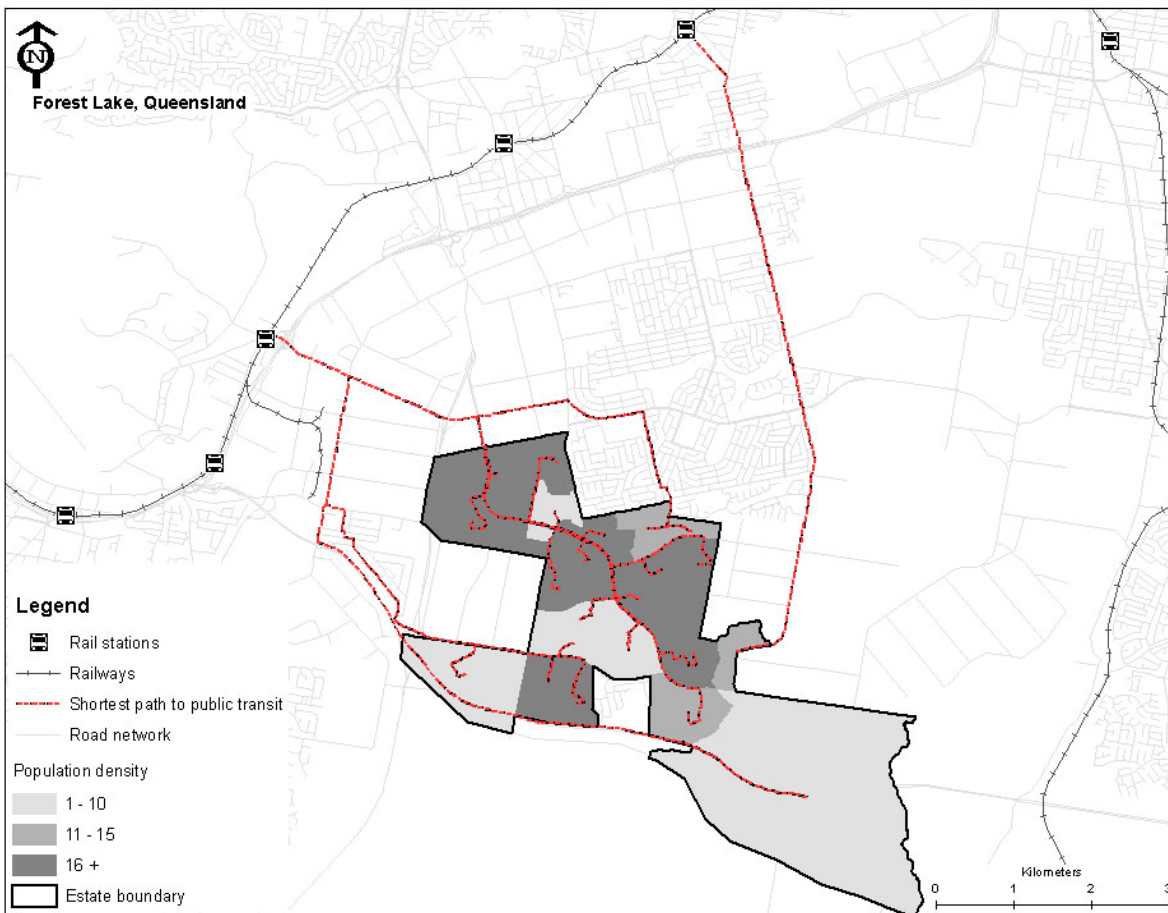


Figure 8: Proximity to public transport

Factors Influencing Self-Containment Patterns

The final stage of the project sought to identify the major demographic, land use and socio-economic factors that affect travel self-containment in MPEs. The tool of analysis was multivariate linear regression. With self-containment defined as the dependent variable it was regressed against 12 independent variables in an OLS analysis using SPSS software. The basic spatial unit of the model was the CD. There were, in total, 82 Census CDs from six different MPEs. Having 82 statistical observations enabled us to use up to eight concurrent independent variables in a single regression analysis. The selection of these variables was based on both the literature review, which identified likely factors contributing to self-containment variance, as well as pragmatic imperatives associated with data availability. The selected variables included attributes of land use, household demography, socio-economic profile and travel behaviour. The dependent variable (self-containment) and the independent variables, their formal definitions as well as their mean and standard deviations derived from 82 observations, are listed in Table 3, below.

The regression equation consists of three types of independent variables. They are: (a) land use; (b) household socio-economic; and (c) travel behaviour. The variable sets were entered in the regression both separately and together and their variance in relation to the dependent variable calculated. The adjusted R squared (R^2) values are recorded in Table 4. The R^2 value reflects the proportion of the variance in travel self-containment accounted for by the regression model. The higher the R^2 value the better the “explanation” of the pattern of the dependent variable by the multi-linear pattern of the independent variables. Results in Table 4 show socio-economic variables to be the least effective of the three variable sets in explaining self containment. Travel behaviour, specified in JTW and proximity measurements, had the greatest explanatory power, exceeding that of land use variables. When all variable sets were included in the model the explanatory effect was maximised. The suggestion is self-containment is best explained as a function of a combination of the variable categories.

Table 3: Definitions, means and standard deviations of variables

Variables	Definition	Mean	Standard Deviation	Observations
Self-containment (<i>DV</i>)	Percentage of work trips occurring into home destination zone(s)	9.56	4.57	82
Population Density (<i>IV</i>)	Number of people per hectare	18.11	13.32	82
Age of Estate (<i>IV</i>)	Years since first residents moved into the MPC	14.96	4.01	82
Proximity to CBD (<i>IV</i>)	Kilometre distance to central business district	24.30	8.98	82
Proximity to public transport (<i>IV</i>)	Kilometre distance to nearest rail station	6.83	1.55	82
Income level (<i>IV</i>)	Mean weekly household income in dollars	1079	211	82
Employment level (<i>IV</i>)	Percentage of full-time employed people	34.03	4.04	82
Education level (<i>IV</i>)	Percentage of people with bachelor or post-graduate degree	9.13	8.55	82
Car ownership (<i>IV</i>)	Average car ownership per dwelling	1.72	0.15	82
Travel method (<i>IV</i>)	Percentage of motor vehicle use in work trips	60.56	20.20	82
Proximity to employment centres (<i>IV</i>)	Average kilometre distance to five most travelled employment centres from each CD	8.17	5.13	82
Commuting distance (<i>IV</i>)	Average kilometre distance of commuting	11.81	4.403	82
Vehicle Kilometres Travelled (<i>IV</i>)	Vehicle kilometres travelled to and from work	8428	5364	82

*DV: Dependent variable**IV: Independent variable*

Table 4: Results of Regression Analysis of MPE Travel Characteristics

Independent Variables	Column A: Land Use Variables only		Column B: Socio-economic Variables only		Column C: Travel Behaviour Variables only		Column D: All Variables	
	Coefficient	Significance	Coefficient	Significance	Coefficient	Significance	Coefficient	Significance
Population Density	0.004	0.889	–	–	–	–	0.012	0.541
Age of estate	0.603	0.000	–	–	–	–	0.151	0.325
Proximity to CBD	0.063	0.175	–	–	–	–	0.384	0.000
Proximity to public transport	0.794	0.008	–	–	–	–	0.084	0.685
Income level	–	–	0.008	0.032	–	–	-0.004	0.107
Employment level	–	–	-0.493	0.001	–	–	-0.140	0.101
Education level	–	–	0.130	0.022	–	–	0.016	0.629
Car ownership	–	–	-5.379	0.226	–	–	11.830	0.000
Travel method	–	–	–	–	-0.170	0.000	-0.200	0.000
Proximity to employment centres	–	–	–	–	-0.212	0.002	0.026	0.734
Commuting distance	–	–	–	–	0.012	0.945	-0.219	0.190
Vehicle Kilometres Travelled	–	–	–	–	0.000	0.096	0.000	0.158
Constant	-6.503	0.007	25.875	0.000	19.839	0.000	1.232	0.830
Number of observations		82		82		82		82
R-squared		0.450		0.147		0.597		0.805
F statistics		17.566		4.484		30.952		28.802
Probability		0.000		0.003		0.000		0.000

Note: Coefficients that are significant at the 5 per cent level are shown in bold.

When all the independent variables were included in the regression analysis, the adjusted R^2 value was 0.805. Within this 80 percent account of the variation of the dependent variable, the regression identified five sets of highly correlated variable pairs. These pairs were:

- proximity to CBD and commuting distance;
- income level and car ownership;
- travel method and age of estate;
- VKT and proximity to CBD; and
- commuting distance and VKT.

A very close match between two variables suggests one variable is a substitute (or repeat) of the other. After careful inspection of the correlated pairs, and testing of the model to balance the minimisation of the number of independent variables (i.e., simplicity of explanation) with the maximization of R^2 (breadth of explanation) only proximity to CBD, income level and travel method were retained from the above list. These three were included with population density, proximity to public transport, level of employment, level of education and proximity to employment centres to give an eight dimensional model (see Table 5, below). Of these dimensions travel method and employment level were negatively associated with self-containment. The rest contributed positively to local travel containment. The R^2 value for our final model was 0.735.

In sum our regression model explains almost three-quarter of the total variance in self-containment. Collinearity checks were performed to find out whether, within the final dimension set, some of the independent variables were totally predicted by other independent variables. Some correlation was apparent but the problem was not substantive. Similarly, the standard errors were low enough relative to the coefficients to suggest the variables were, at the level of statistical significance, singularly as well as jointly independent. In short, none of the independent variables can be construed as a linear combination of the others.

In statistical analysis the level of significance measures the likelihood that the result would occur as a result of random chance. A significance level of <0.05 indicates there is a ninety-five per cent possibility the result is not due to random chance. Using a five per cent ($p<.05$) significance level for the model, it was found:

- for each kilometre increase in the distance from the MPE to the CBD, the self-containment rate increased by 0.186 per cent;
 - for each dollar increase in mean weekly household income, self-containment rate goes up by 0.004 per cent;
 - for each percentage increase in full-time employment, the self-containment declines by 0.245 per cent; and
 - for each percentage increase in motor vehicle use for the JTW, self-containment rate goes down by 0.196 per cent. (see Table 5, below, Coefficient B).
- At the ten per cent ($p<.10$) level of significance:
- for each percentage increase in bachelor and post-grad degrees, self-containment rate goes up by 0.059 per cent (Table 5, Coefficient B).

Table 5: OLS Regression model for travel self-containment

Independent Variables	Coefficient - B	Significance
Population Density	0.001	0.960
Proximity to CBD	0.186	0.000
Proximity to public transport	0.108	0.625
Income level	0.004	0.019
Employment level	-0.245	0.006
Education level	0.059	0.090
Travel method	-0.196	0.000
Proximity to employment centres	-0.077	0.242
Constant	20.043	0.000
Number of observations	82	
R-squared	0.735	
F statistics	29.138	
Probability	0.000	

Note: Coefficients that are significant at the 5 per cent level are shown in bold & at the 10 per cent level are shown in italic.

Research Findings and Future Directions

The first conclusion to be drawn from our study is that in terms of journey-to-work patterns MPEs are not as self-contained as many commentators claim. Harrington Park has the highest JTW self-containment rate of our sample with only 13.8 percent capture. The retention rate declines to a very low 3 percent in Caroline Springs. Overall, the travel containment findings in our research are markedly lower than those of Newton et al (1997).

As MPEs locate on metropolitan fringes, and at greater distance from the CBD, they become more dependent for employment on local and regional activity centres. CBD dependency declines. This positive correlation between self-containment and distance from CBD is apparent from the results presented above. Harrington Park is the clearest example. Located most distant from its CBD it has the highest self-containment rate of all the case studies. At the other end of the scale Forest Lake, most closely situated relative to its metropolitan CBD, has the third lowest self-containment rate (see Table 2).

Travel self-containment values appear to increase in conjunction with the affluence of MPE households. Harrington Park has both the highest income level and the highest self-containment rate. Caroline Springs is its mirror reverse. It combines the lowest self-containment rate with the lowest income level. These findings unambiguously illustrate a positive statistical correlation. Garden Gates confirms the relationship. It is home to a relatively high level income population and manifests an elevated JTW retention pattern.

MPEs with a relatively greater number of retirees and part-time workers generate less external work trips compared to settlements with high full-time employment participation rates. It can be reasonably suggested that residents in full-time employment are likely to travel further to access full-time work opportunities thus depressing the locality's self-containment rate. Moreover, MPEs do not, typically, contain manufacturing industries. Rather, the service sector is the usual major proximate employer. This sector requires disproportionately high levels of part-time and casual workers. Caroline Springs and Golden Grove illustrate the negative correlation between full-time

employment and self-containment. Caroline Springs has the lowest self-containment rate and the highest full-time employment ratio among all MPEs. Golden Grove has the second highest self-containment and the second lowest full-time employment ratio.

MPEs with fewer car dependent residents appear to be proportional more self-contained and more sustainable. Caroline Springs and Golden Grove again demonstrate this (negative) relation. Caroline Springs has the lowest self-containment rate and the highest car dependency rate (for work trips), whereas Golden Grove has the second highest self-containment rate and the second lowest rate of car dependency in our study.

Education appears to be a significant factor in the self-containment of the MPE work commute. It is hypothesised as education levels increase white-collar jobs proximate to the estates are readily taken up such residents. In short white-collar workers seem to have more choice in their job market. What is certain is the greater the education status in an MPE the shorter the commute times and distances. Our results show Roxburgh Park to have the second lowest higher degree ratio and the second lowest travel self-containment rate, while Harrington Park has both the highest education level and self-containment rate.

Finally, our study shows self-containment decreases as the proportion of car-dependent work journeys increases. In sum estates poorly connected to regional employment concentrations via the public transport system generate higher levels of external and automobile travel.

The findings presented above are, as far as we are aware, the only analysis and assessment of MPE travel relationships in Australia. They should be of considerable interest to scholars, policy makers and planners. The results are preliminary, and as we discuss below, limited by methodological expedience. Nonetheless, the study has exposed important relationships in contemporary urbanism, the understanding of which would greatly benefit from further research.

Limitations of the Study

It is important to acknowledge the major conceptual and methodological limitations of the study. The lack of accurate, comprehensive data is the most serious constraint. This lack restricted of analysis to a comparatively small number of factors (12). The consequent model of travel self-containment is coarse. In future studies, we hope to include a larger number of variables by obtaining comprehensive travel data via direct surveys of MPE residents. Such data will permit not only more wide-ranging analysis but analysis at different geographical scales - such as the neighbourhood, the sub-region and the region.

Our pilot study, limited in case studies and observations, allows for only a preliminary explanation of self-containment patterns. More methodologically sophisticated research should enable the complexity of urban land use, demographic profile and travel behaviour to be drawn out in greater detail.

It is also important to note our OLS regression does not take spatial dependency and weight into account. Spatial weighting according to Stetzer (1982:571) represents “a priori knowledge of the strength of the relationships between all pairs of places in the spatial system.” Sophisticated spatial statistical analysis requires the specification of spatial weight matrices to capture the pattern of dependence across observed space (see Getis and Ord 1992; Anselin and Bera 1995; Getis 1995; Anselin 2002; Mitchell and Bill 2004; Mitchell and Bill 2005). Future research should include spatial statistical techniques able to account for spatial dependence and weightings.

Non-work trip generation, to supplement work travel patterns, is a key additional dimension to be included in further MPE research. Giuliano (1991) and Giuliano and Small (1993) claim work-

housing balance does not by itself effectively promote travel self-containment. They argue for an additional spatial balance between home and other destination(s) travel. Richardson and Gordon (1989) found non-working trips account for approximately three-quarters of all trips in large American metropolitan areas. The European research of Salomon et al. (1993) supports this finding. The most important non-work travel flows are for shopping, recreation and education. The fact that, in face of its known inadequacy, job-housing balance remains the most common index of travel self-containment reflects the ongoing difficulties of collecting reliable non-work trip data (Cervero 1995).

Despite the above limitations we are keen to develop a GIS-based decision support tool for local government. Its prime use would be in development assessment. It would depend on substantial prior analysis at a scale many times greater than that presented in this study, yet it would need to be user-friendly. Its task would be to identify problems and highlight opportunities in the development of MPEs. Its challenge would be to improve the design of sustainable urban forms, and both the quality and the efficiency of Government assessment.

We note that the MPEs examined in this study were selected as examples of recent practice in the Australian development context. The planning processes by which these estates were developed and the elements they incorporate may be at substantial variance with the principles of comprehensive master planning identified in the literature on balanced and sustainable communities. Further research is therefore imperative to better comprehend the links between scholarly prescriptions for sustainable development practices and the actual outcomes achieved within Australian MPEs.

CONCLUSION

This study arose from a concern about the sustainability of urban development. Literature review found a substantial body of empirical research evidence linking land use and travel patterns. Most of the literature and research, however, draws from North America and Europe. As such most of it is perhaps tangential to the patterns of urbanisation found in Australia. In short a simple application of borrowed concepts, methods and findings to the Australian context is inappropriate. Our pilot study is a start in developing a specifically Australian understanding of land use, travel and urban sustainability. More research is clearly needed.

The literature review suggests urban design philosophies that emphasise local-scale integration of residential and other compatible land uses are important in the development of less automobile reliant suburban communities. More specifically this requires the integration of land use and transportation planning, and a conceptual shift from the goal of mobility to the goal accessibility. Increasing the densities and compactness of cities would support the provision of public transit and non-motorised forms of transportation. There remains, however, considerable debate over the worth of such policy in Australia (Troy 1996; Newman and Kenworthy 1999; Mees 2000).

The first part of our empirical study, focused on sub-regional JTW patterns, required we develop and apply a GIS methodology to measure local area travel self-containment values. GIS, state-of-the-art technology, is extremely productive and able to generate quick and accurate results. However, as always, the accuracy of output(s) is dependent on the quality of input data. The imperfections of our data render our conclusions tentative. Nevertheless, we have been able to broadly map a research way forward. A clearer understanding of suburban travel behaviour and the impact of MPEs is in sight.

The second part of the empirical study examined the factors that influence self-containment patterns in MPEs. Analysis finds travel preference and behaviour to account for the greatest proportion of

the variance in self-containment. The most important single factors influencing travel patterns in MPEs, identified by our analysis, are:

- Distance to CBD,
- Work travel mode,
- Employment level,
- Income level,
- Education level.

These findings are preliminary and should be verified by further research.

Despite the many limitations of the study its model of urban form and travel behaviour is a useful starting point for a systematic and detailed analysis of self-containment in Australian MPEs. We anticipate continuing our work in this area. We believe it can benefit both scholarly and policy understandings of contemporary urban forms. The most important criteria, however, is it plays its part in the construction of a sustainable Australia.

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