Why Travel Longer? Investigating the Influence of Suburbanisation and Land Use Consideration on Distance Travelled

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1 Introduction

There is considerable current interest in the effects of urban form and land use characteristics on the travel activities made by people. The underlying assumption is that these built environment characteristics have an important influence on making shorter travel and a person's willingness to travel by public transport, ridesharing, walking or bicycling - modes other than driving alone. A moderate set of strategies has been proposed or implemented by both federal and state governments in South Australia (SA). For instance, Planning SA (2000) has made a connection between transport choice and urban design with providing a detailed set of guidelines covering micro-scale urban form attributes that may impact people in choosing their mode of travel. However, relatively little empirical work has been done to evaluate the real effects of land use and development strategies on travel behaviour.

For this project, an integrated database of built environment characteristics in GIS and travel characteristics was developed for a sample of specific residential locations in the metropolitan Adelaide. The case study areas selected for this study represent a range of development paradigms in Adelaide: two inner old garden-city model suburbs, Norwood (1853) and Unley (1871) and two outer modern suburbs, Para Hills (1974) as early modern, and Golden Grove (1980s — 90s) as late modern developed in last decade. The integrated database was constructed by adding land use and site information, developed through field observation and a particular household travel survey of 324 households conducted in early 2005 within four case study suburbs. The survey collected data included information about personal travel characteristics, socio-economic demographic characteristics and the respondents' attitudes on their neighbourhood area. This integrated database was then analysed to explore the interactions that may exist between social, land use, urban design characteristics, and distance travelled by the sample individuals. The primary objective was to develop conclusions about the combined impacts of land use and physical development strategies on residents' travel behaviour.

This paper is organised as follows: the first section, reviews some previous empirical studies in the topic of the interaction between built environments and travel characteristics. The second section of this paper describes the methodological approach applied, including the specific data collection and modelling procedures. Findings of the statistical analyses are presented in the third section. The effects of various exogenous factors for work and non-work activities on distance travelled were examined separately. Also, two distinct groups: inner suburbs versus outer suburbs were compared together. The final section concludes.

2 Review of past studies

There is a vast amount of literature from around the world on the impacts of urban form on travel characteristics. Much of the work has originated in either North America or Western Europe. The majority of these researches conclude that urban form characteristics, ranging from regional to local in scale, have an effect on travel patterns and consequently the environmental impacts of transport such as emissions. Full reviews of the literature have been undertaken by Crane (2000); Stead and Marshall (2001); Badoe and Miller (2000) and Handy (1996).

This review here includes only empirical studies. The empirical studies are real examples and rely on fewer assumptions than simulation works. Also they are more understandable and applicable for planning and policy making because of including various urban form factors (Stead and Marshall 2001).

Most past studies attempt to find out the influence of urban form factors on more than one response variable. Also they tend to focus on the relative significance of the explanatory variables on travel behaviour. It is more difficult to extract the different effects of urban form variables on different travel response variables. The four response variable categories summarise the foci of most of the studies in this field are included trip frequency; modal split; distance travelled (vehicle kilometres travelled); and energy consumption/emissions.

2.1 Comparative studies

Development pattern is effectively a composite variable (or a set of variables) which is used to characterise areas of cities that are relatively homogenous to a range of attributes. These attributes could be including the age of development (e.g. pre-war or post-war), the style of development (e.g. traditional, conventional) and the street network design (e.g. grid or curvilinear). Figure 1 provides an example:

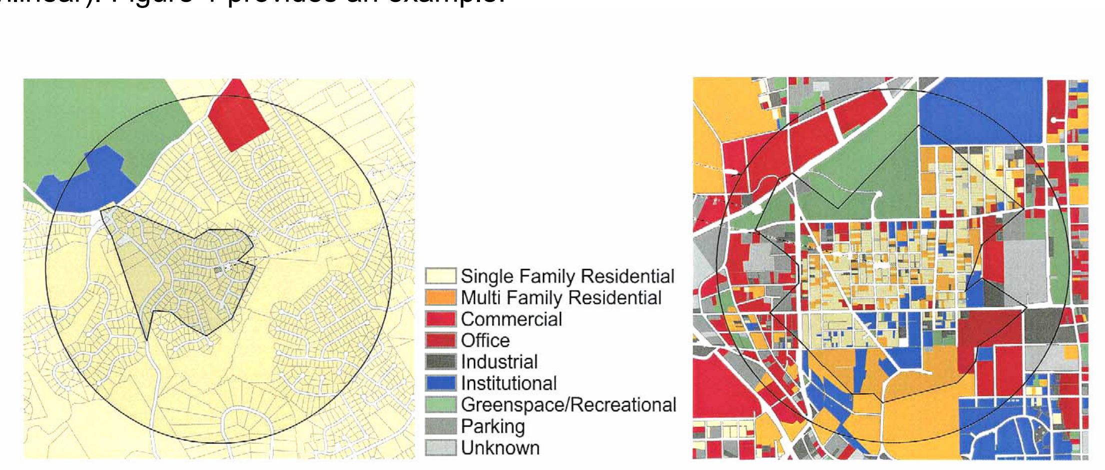

Figure 1: Comparing two neighbourhood development paradigms: disconnected segregated neighbourhood (left) versus connected mixed use neighbourhood (right) (primary idea from Frank , Andresen et al (2004))

The reason to choosing this approach is that neighbourhood design features need to be considered as a balance of attributes. Otherwise considering them individually may not present a significant effect on travel behaviour. For instance, the analysis of four neighbourhoods in the San Francisco Bay Area found no evidence that individual residential design elements have an effect on travel behaviour, rather neighbourhood design as a whole is an important determinant of whether residents perceive walking as an option and affects pedestrians activity in a community (Handy 1993). Handy believed that in different areas, different types of design elements may be appropriate or fit into the neighbourhood environment differently. However, the importance of comprehensive design rather than identifying a specific design element works in all places. Furthermore, it is difficult to sort out the effects of land use mix and urban design because they are strongly correlated with density. Thus some studies tested the effects of density, diversity, and design, all together on travel behaviour.

Table 1 details some of comparative studies based on the 'development pattern' type. From the studies summarised in this table, it can be claimed that suburban dispersed neighbourhoods generate a higher trip rates; higher share of car use; lower non-motorised travel; higher vehicle kilometres travelled (VKT) and greater energy use/emissions comparing to traditional compact suburbs with more pedestrian-friendly environments.

However, this ruling is not explicit to make a generalisation for other geographical areas. In fact, the relationship between urban form and travel behaviour is more complex than it may seem on the surface. It is sometimes difficult to distinguish between suburban and traditional suburbs. In fact, if suburban development encompasses pedestrian-friendly elements such as coordinated urban design, and close proximity to facilities then there will be not much difference between two development paradigms. In such case, it might be better to discover the impacts of individual elements of physical form on travel behaviour. This would help to find out the relative importance of variations between neighbourhoods as well as variations within neighbourhoods. On the other hand, the presence of non-physical factors such as socio-economics or personal attitudes may work better to influence travel patterns. Moreover, the impact of regional factors such as regional accessibility to job may significantly contribute to change travel patterns. Therefore, it is required to conduct an analytical investigation taking into account most potential factors to find out the real impact of physical features in affecting travel behaviour.

2.2 Travel distance studies

The estimation of travel distance from urban form has received generally little attention in the literature, most attention having been given to estimating travel distance from travel-related factors. However, a number of studies can be found on discovering the association of land use variables and travel cost factors such as travel time and distance. White (1988) empirically demonstrated that, given the distribution of workplaces and residences, households and workers locate to minimise commuting. Small and Song (1992) showed that White's results are dependent on the degree of disaggregating of origin and destination zones. When zones are finely disaggregated, they show that about two-thirds of all commuting in Los Angeles is surplus.

Schwanen, Dieleman et al. (2002) using multivariate multilevel regressions showed that workers living in decentralised regions commute longer than residents of centralised and self-contained region. In addition, commuting distance is affected inversely by job density in the area. Redmond and Mokhtarian (2001) did a similar study using data from randomly-selected households in three neighbourhoods of the San Francisco Bay Area. These areas were chosen to represent the diverse lifestyles, land use patterns, and mobility options. And once again, the suburban explanatory variable was highly significant. As indicated in studies of land use and travel and, in particular, travel patterns associated with suburban development, commutes tended to be longer for those living in suburbs.

Naess (2000) using multivariate analysis of the influence of various urban form variables on the total distance travelled discovered that residential location was a significant factor in commuting behaviour. The location of the dwelling relative to the town centre of the study area (Danish Frederikshavn) was the factor that exerts the strongest influence on both the total distance travelled during the week of investigation, and the travel distance by car. The proportions of distance travelled by car and by non-motorised modes were also clearly influenced by the distance from the residence to the urban centre. The accessibility to workplaces and various types of facilities was strongly related to whether the residence had a central or peripheral metropolitan. Thus, the location of the residence relative to the town centre emerged as a key factor influencing a range of urban structural factors at a more detailed level, all of which influences the residents' need for transportation: accessibility to workplaces, local administration, shopping opportunities, leisure activities and schools.

Table 1: Studies comparing neighbourhood development designs

Source, Location	Development Patterns and Attributes		Key Findings
(Friedman, Gordon et al. 1994), San Francisco, US	'Standard neighbourhood' -developed since the early 1950's -hierarchy of roads -concentrated facilities -segregated land use	'Traditional neighbourhood' developed before 1940 - mixed-use and close proximity of residential area to non-residential land uses - grid network	-Standard neighbourhoods generated a 25% higher average number of trips - Traditional neighbourhoods generated a lower proportion of car trips but higher transit and other modes
(Moudon, Hess et al. 1997), Washington DC, US	'Urban neighbourhood' higher density mixed use	'Suburban neighbourhood' lower density dispersed development	- Volume of pedestrian traffic to neighbourhood commercial centre was higher in urban than suburban neighbourhoods
(PBQD (Parsons Brinckerhoff Quade & Douglas 1996), San Francisco Bay Area, US	Traditional neighbourhoods	Non-traditional neighbourhoods	- Density is the most significant physical factor in explaining modal choice; -The residents of traditional neighbourhoods were more interested in no auto-based modes for non-work trips ; - There was not any explicit relation between urban variables and mode choices for non-work trips.
(Cervero and Gorham 1995), San Francisco, US	'Car neighbourhood'	'Transit neighbourhood'	- Transit neighbourhoods showed a higher transit use - The mode split depends on the character of both neighbourhood and its larger region
(Handy 1992) Austin, US	'Pre-WWII/high local accessibility' -Rectilinear grid network - Smaller blocks and more intersections - More direct routes - Traditional downtown area	'Post-WWII/low local accessibility' - Curve and irregular network more cul-de-sacs - Very few connections to arterial roads - Car oriented commercial centres	- For travel characteristics, the variation between the neighbourhoods was significantly greater than the variation within neighbourhoods - Not any effect on strolling activity by neighbourhood type - The regional context played an important role in influencing modal split
(McNally and Kulkarni 1997), Orange County, US[1]	'Traditional Neighbourhood Design (TND)' - grid street network - high density	'Planned Unit Development' (PUD) - circuitous street network with cul-de-sacs, segregated use	- PUD generated 30% higher trips per household
(Rutherford, McCormack et al. 1996), Seattle, US	'Mixed use suburb'	'Homogenous suburb'	- The residents of mixed use suburbs travelled fewer personal kilometres than people living in non-mixed use suburbs. - Walk share is higher in mixed use suburbs
(Perkins 2002), Adelaide	City 'compact' infill development	'Sprawl' fringe development	- The choice of infill development over fringe development produced more significant energy savings than the combination of a number of other demand reduction measures
(Diepen and Voogd 2001), Netherlands	'Inner city'	'Oouter city'(traditionally built / sustainable built)	- Households in both outer suburbs have a higher energy-intensive travel activity than households in the inner city suburbs. - The distinction of outer city neighbourhoods into traditionally and sustainable built ones does not generate remarkable differences.
(Leslie, Saelens et al. 2005), Adelaide	'High walkable neighbourhood' higher intersection density higher dwelling density higher land use mix	'Low walkable neighbourhood' lower intersection density lower dwelling density lower land use mix	- Residents from neighbourhoods with different characteristics do perceive environment differently. - The different direction for the neighbourhood-based differences in aesthetics is likely to be attributable to the low-walkable area having a much 'bushier' and hillier topography, with more trees, shrubs and open green spaces as well as scenic views, than did the high-walkable area.

[1] The authors also identified a third, hybrid category of neighbourhood. The list of attributes given is a summary of a longer list of network, land use, and design variables.

Solmon and Mokhtarian (1997) incorporated land use related factors as explanatory variables, in addition to the traditional demographic factors and attitudes. Linear regression models were developed for the dependent variables. Commute speed was the only objective mobility variable that was significant in the final model. Higher commuting speeds indicated physical access to a freeway. Thus, this variable was likely to serve as a general supply-side indicator. It was interesting that the explanatory power of this variable was so strong, even when controlling for a suburban residential location, suggesting that the same mechanism was at work regardless of neighbourhood type. The significance of this variable clearly illustrated the connection between travel and land use.

Kockelman (1998) through regressing travel distance with measures of urban form in San Francisco, found that the number of choices a trip-maker has increases with the distance travelled. The evidence suggests that people travel further than they need to; this may very well be because they wish to expand their choice set of activity sites and thereby increase the expected 'quality' of the activity they do engage in, at their chosen sites. For example, while one probably will travel only to the closest of a very specific activity type (such as eating out at a fast-food restaurant), one will not often travel to the closest dining establishment. The author suggested that as long as the marginal value of travel time plus the monetary cost of travel remains below the marginal value of increased opportunities brought about by travelling further, people can be expected to lengthen their journeys.

Gordon, Richardson et al. (1991) argue that individual households prefer to avoid the time penalties caused by the extensive congestion in mono-centric urban areas by systematically changing their job or residence. This residential and workplace changing provides them opportunities to travel shorter distance or make use of less congested routes. In addition, employment centre seek ways to escape the disadvantages of high-density locations such as congestion; high land values, and limited choices for spatial expansion. In aggregate, the dispersal of activities across the metropolitan area leads to decline in travel distances and time. This study limited the influence of metropolitan structure on travel distance to the impact of mono-centrism and poly-centrism, thus the importance of other dimensions of spatial structure such as population and employment density were ignored. This neglect has been found in other studies e.g. Giuliano and Small (1993) resulted in claim that travel distance and time cannot be explained by the distribution of housing and jobs alone.

This short review of literature serves to illustrate that the effects of spatial patterns on travel distance are not undisputed. However, the role of several potentially important factors, such as the degree of centralisation needs to be investigated further. In addition, local accessibility to local workplaces and facilities should be given similar attention as regional accessibility.

3 Methodology and data used

Four residential suburbs of metropolitan Adelaide were chosen for this study: Norwood, Unley, located in inner ring approximately three kilometres from the CBD. Golden Grove and Para Hills as outer city fringe suburbs are at 18 and 23 kilometres from Adelaide city centre respectively. The neighbourhoods are divided into traditional (built in the mid 1800s near the city centre), early-modern (built soon after World War II near the urban fringe) and late-modern (built in the past two decades near the urban fringe).

A range of differences in urban form characteristics can be found among these two sets of developments. Norwood and Unley as typical traditionally designed neighbourhoods have a mix of land uses, residential, office, shopping, civic uses, and entertainment, within easy walking distance of home. On the other hand, suburban developed areas: Golden Grove and Para Hills lack heterogeneous land uses. The density of population and activities of these suburbs are lower than those of Norwood and Unley. The styles of housing area dominated single-family houses with back yards, land-escaped gardens and parking spaces.

Stead and Marshall (2001) claimed that many past urban form-travel studies contain weaknesses in methodology and data used. Studies often fail to explore interactions at the disaggregated neighbourhood level. Also some lack taking into account socially important factors such as household size or structure. For addressing such shortcomings, some improvements have been made in this study included: using GIS for capturing disaggregated elements of urban form; incorporating other important factors such as household/individual preferences and attitudes and also incorporating the overall structure of city region surrounded the neighbourhood by regional measures.

It is tried to take a disaggregated approach: in terms of urban form opertionalising, a Census Collection District (CCD)-as defined in 2001 Census data (Australian Bureau of Statistics (ABS) 2001)- is suggested as spatial unit of analysis. Thus all local urban form measures were taken in CCD level. Using GIS facilitates work with more precision and efficiency. The spatial data come from South Australian's Digital Cadastral Data Base (DCDB). In case, GIS maps were not up to dated or apparent, an on-screen digitising method used to enter new features or edit current spatial features.

The original mail-back survey (HTS2005) consisted of 1500 addresses but only 324 valid addresses. The response rate is about 21% based on the valid returned questionnaire only. This response rate is considered well for a survey of this length, since the response rate for a survey administered to the general population is typically 10–40% (Sommer and Sommer 1997). Additionally, the comparison of sample characteristics to population characteristics, based on the 2001 Australian Census, showed a reasonable distribution.

Trip distances were calculated using *ArcView GIS* and the *Network Analyst* extension. It was assumed that a trip maker made a rational decision and followed the path with the lowest cost. For the purpose of calculation, the central node of the relevant CCD of the suburb's polygon was considered as the point where the trip originated or finished. This method has had its specific bias because of the above assumption. In fact, all trips which are started from the same CCD have the same starting location. This is also true for destination points. Regardless of this bias, it is the most practical way and it provides an acceptable level of accuracy. For those trips which are started and finished at the same CCD, the average travel speed is applied. The travel time was multiplied by the average travel speed depending on the mode of travel for calculating the travel distance. The average travel speed which has been used here was provided by Primerano (2004) for different modes of travel in metropolitan Adelaide as below: car (46.4 km/h); public transport (23 km/h); walk (4.25 km/h) and bicycle (8 km/h for female and 11 km/h for male).

Trip distances depend on the location of activity centres and trip purposes as well for each suburb. In Figure 2, it is shown that the average trip distances include work trips and non-work trips to different areas. The average trip length for both work and non-work activities are clearly longer in Golden Grove (18.5 km) and Para Hills (11.0 km) than for Unley (5.3 km) and Norwood (5.7 km). There was also a difference between work and non-work trips. The average length of work trips for all four suburbs (11.2 km) was approximately 12% longer than the average trip lengths of non-work trips (9.2 km). In Para Hills (13.6 km) and Golden Grove (18.9 km), work trips were much longer than Unley (5.7 km) and Norwood (6.7 km). In fact, Golden Grove had the longest trip length for work trips and Unley had the lowest figure. For non-work trips (including shopping, social/recreation, education, and medical): Golden Grove had the highest number (16.3 km), followed by Para Hills (10.1 km). It was followed by Unley (5.4 km) and then Norwood (5.0 km). Again, Golden Grove had the longest non-work trips. There seems to be a huge difference between Para Hills and Golden Grove, but this may simply reflect the fact that Golden Grove is 5 km further out from the city centre. On the other hand, Norwood had the lowest average trip length for non-work trips.

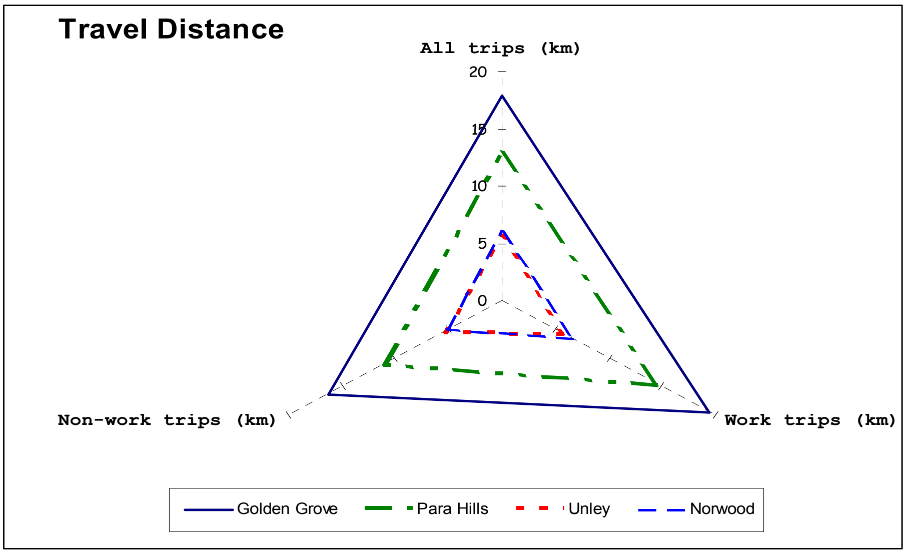

Figure 2: The average trip distances of four case study areas.

The travel behaviour among the four case suburbs is markedly different, as the two outer suburbs are more car- dependent. Here are a number of facts about these areas extracted from HTS2005:

- Norwood has the highest share of short trips with length of less than 1 km (approximately 10%). A proportion of trips started and finished in the same suburb as the residential suburb of the trip maker. These trips can be called as “local trips”. Higher proportion of local trips represents the higher capability of neighbourhood to support its residents for daily requirements. Norwood had the highest percentage of local trips as the residents of Norwood found a quarter of their necessities inside their neighbourhood. For Unley, this figure was 20%. Golden Grove and Para Hills had lower figures: 17% and 13% respectively.

- Car usage either as single occupant or shared ride is the dominant mode in each of the four cases: 60.7% and 60.5% of trips taken by car in Norwood and Unley respectively. The figures are 81.3% and 76.2% for Para Hills and Golden Grove respectively. 31.1% and 27.6% trips made by the residents of Norwood and Unley respectively were on foot or by bicycle, compared to 11.1% and 8.5% in Para Hills and Golden Grove respectively. 4.2% and 10.9% were by public transport in Norwood and Unley respectively, compared to 6.1% and 9.3% in Para Hills and Golden Grove respectively. Around 3.9% and 1.0% of trips by the sampled adult’s resident in Norwood and Unley respectively were made by other modes of travel whereas in Para Hills and Golden Grove, 1.5% and 6.0% of trips respectively were made by other modes.

- Norwood and Unley residents have higher trip generation (for Norwood and Unley were 3.7% and 3.5% which are higher than those of Para Hills and Golden Grove: 3.3%).

- The vehicle ownership rate per household for the residents of Norwood (1.2 vehicles/dwelling) and Unley (1.4 vehicles/dwelling) are lower than those of Golden Grove (1.6 vehicles/dwelling) and Para Hills (1.7 vehicles/dwelling).

4 Modelling distance travelled

It is assumed that total distance travelled is to be influenced by three main factors or groups of factors: socio-economic; environmental (urban form) and level of service. This implies that the amount of distance travelled by the individual will depend on his/her own socio-economic status (income, occupation, age and gender), and on that of the individual's household (overall household income, household size and structure), but also on external factors to the household. Location of the home, relative to the sources of supply of the activities from which the travel in question is a derived demand is likely to be of great importance. Local and regional urban form variables give an approximate indicator of likely availability of facilities for which travel may be undertaken. Level of service provides a degree of convenience to achieve the desired facility. It is a combined effect of mode availability, accessibility to the mode, and the characteristics of the mode such as frequency, speed, cost, comfort and so on. For different modes it would vary.

The Figure 3 provides an overview of a conceptual model showing the elements that play a part in travel behaviour and how the various factors are hypothesised to affect one another. It is assumed that the spatial structure can have both direct effect and several indirect effects on mobility and the length of travel. First, the spatial characteristics affect the individual and household characteristics of a certain neighbourhoods. For example, car ownership level of households is closely related to the spatial attributes of certain neighbourhoods, although this claim will be not tested here. A neighbourhood that has been designed in a specific pattern could attract residents who would be less likely to live there. Second, spatial characteristics have an indirect effect on travel pattern included distance travelled. Furthermore, there are interrelationships between dimensions of a trip such as purpose, time and distance. Aggregated impacts of travel behaviour influence the environment, society and public health issues.

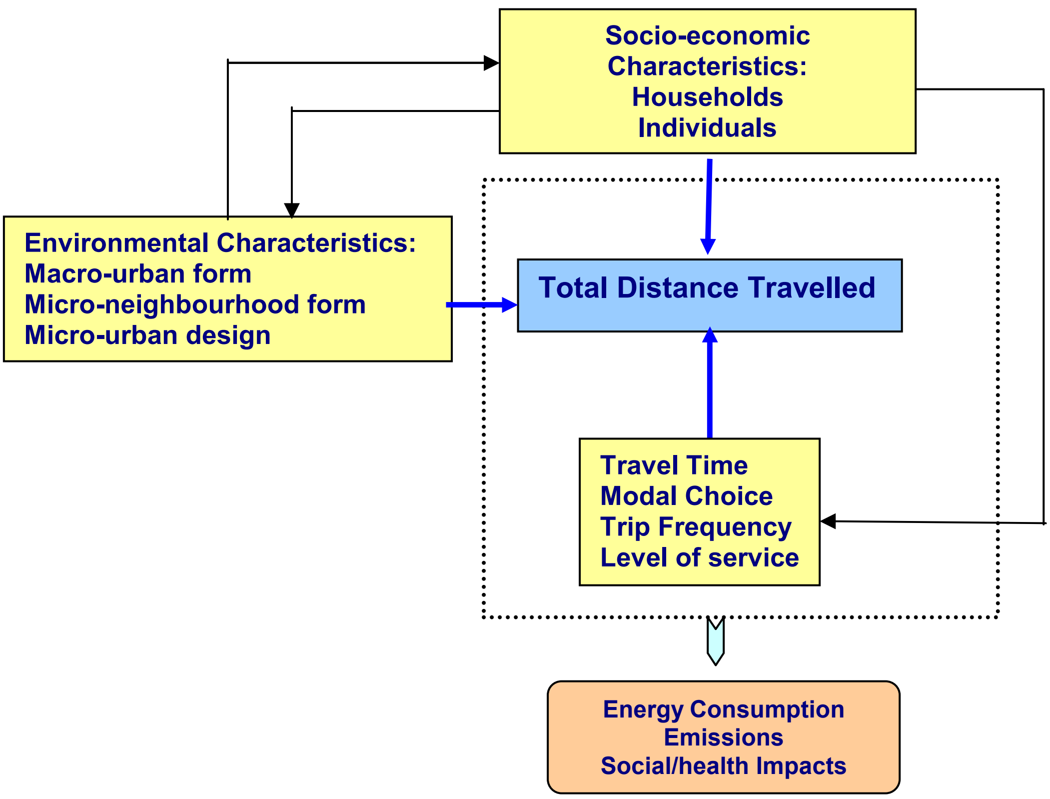

Figure 3: The conceptual model of travel distance modelling.

Conceptually, the issue of travel distance modelling can be considered as trying to answer the question of how many kilometres will be travelled by an individual trip-maker. A number of methods have been developed over the years to study travel distance as one aspect of travel behaviour. These include the use of simple or multivariate regressions at an aggregated level (zonal or regional) or disaggregated level (individual or household). Another approach is based on the use of discrete choice models such as the nested logit or probit models which deal with destination (distance) choice. While the use of discrete choice models is closely associated with newer research approaches (e.g. activity based analysis), regression models remain for the most part the state of current practice. The selection between the two approaches is based on data availability and performance circumstances. In the present study, regression modelling is adopted for the analysis.

For a given distance category (total or purpose), trips were combined across the metropolitan region to obtain a measure of distance as a log of distances, the natural logarithm of one plus the total number of distances in the category. One kilometre was added to each total so that when zero kilometres were actually travelled in a given category, the log transformation would return the value zero (=ln(1)) rather than ∞(=ln(0)). The natural logarithm of the sum of the kilometres was chosen after trying several other transformations. This transformation expresses the diminishing marginal impact of distance, reducing the impact of longer distances. If ordinary distances are used, respondents with very long trips exert a stronger influence, and the estimated travel distances increase by about 50 km in the centre as well as in the peripheral areas (Mokhtarian and Salmon 2001).

The distance travelled by an individual is summed by every trip record in one day. Note trip records with length over 65 km were excluded from the data set. This could control for out of State's trips and rural travel.

Numerous candidate measures of the built environment were available as exogenous factors for the analysis, but, through correlation explanatory analysis, some were found better than others in terms of their lower potential risk of colinearity and statistical significant association. These include (Table 2):

Table 2: The List of Urban Form Factors Included in the Models

Variable Name, Unit	Definition
Distance to CBD, km	The average network distance from the centriod of district to the Adelaide's CBD (Victoria Square)
Distance to Shopping Centre, km	The average distance between local shopping centres and all residential units within a neighbourhood area weighted by the number of dwelling units
Distance to Workplace, dummy	Reported categorical distance between sample household and workplace of the respondent adult
Employment Density, people per hectare	Jobs per developed area within a district area
Lot Size, squared metre	The average size of allotments within a district area
Quality of the Walking Environment	This composite measure environment quality for walking represents the quality of the built environment in terms of physical activity options (sidewalks, pavement quality), safety (low traffic, safe for walking, street lighting), and attractiveness (appearance, building setback, variety in housing styles, landscape). The value for this measure was obtained through a field observation survey- more information is in Soltani and Allan (2004)
Route Directness	The route directness index was calculated by dividing the direct distance between an origin and destination by the actual network distance between them

Six regression models are being developed and compared for evaluating the built environment features for different travel purposes. The regression models for each of the selected geographic areas were estimated by a least-squares procedure so that only high correlated factors with dependent variables entered the equation (with a coefficient significant at a 95 percent confidence level). The models, including value of constant and attribute coefficients and their significance are detailed in Table 3. Model coefficients show the importance and strengths of urban factors and their ability to improve the explanatory power of behavioural models. All analyses were done by LIMDEP Version 7.0 (Greene 1998). The adjusted R^2 value is good with a values ranging between 0.62 (for work trips in outer suburbs) and 0.77 (for work trips in four suburbs). The t-statistics in the model are all above the threshold values of ±1.96 (95 percent confidence) showing that all coefficient estimates of attributes are all significant. The coefficients of the attributes are all the expected sign. Total distance travelled (natural logarithm transform) by an individual for work (or/and non-work) purpose per day was taken as the dependent variable here.

5 Findings from travel distance modelling

The coefficients of the regression equations detailed in Table 3 show that the daily distance travelled by an individual can be explained by travel attributes; socio-economics and urban form characteristics.

Consistent with expectations, travel attributes included travel time; frequency and the share of motorised travel (by private vehicle, taxi, pool-car or public transport) had significant strong impacts on the total distance travelled by an individual within one day. Travel time has a positive coefficient indicating that the greater the average travel time to reaching destinations, the higher the total distance travelled by an individual. This finding is consistent with Crane and Crepeau (1998) showing the importance of travel time as a cost factor in a behavioural model. Furthermore, time plays a central role when deciding whether to engage in an activity. The main consequence of the time constraint for the modelling of non-work trips is that making a trip of one kind reduces the time to make a trip of another kind. A theoretical treatment of the time constraint issue can be found in Jara-Diaz (1998). The higher the frequency of activities, the further the total distance travelled. The greater the share of motorised travel, the further the total distance travelled. If an individual makes a work trip it is more likely to increase his/her non-work travel distance probably because a part of individuals do their non-work activities e.g. shopping in areas closer to their job than home. Golob and Wissen (1989) using data from a Dutch national survey showed that the distance by one mode (car-driver) is affected by the distance travelled by other modes (public transport); future travel distance (at time T_2) can be explained by former travel distance attributes (at time T_1).

Households living farther from a local shopping complex tended to travel further (for inner suburbs). In fact, local accessibility does help to reduce the length of journeys to nearby facilities, which is consistent with the British study by Farthing, Winter et al (1996). Individuals living in districts with higher street quality in inner suburbs had longer non-work trip distances. This may even be perceived as a positive rather than negative expenditure of time if undertaken for exercise for example.

The farther a job is from the home, the longer the distance to work: when job is located 5 km away from home has greater impact on travel distance than when it is between 2 and 5 km as is expected. The distance travelled to a workplace also increased the total distance taken for non-work purposes (for outer suburbs). These results could reflect the tendency for those living in denser inner suburbs with higher levels of mixed land-use to be relatively close to jobs, especially CBD jobs. They might also reflect the influences of residential self-selection, wherein those placing a high value on urban amenities and who want to economise on commuting look for neighbourhoods that area mixed use in character and reasonably close to their jobs.

Table 3: Total Distance Travelled by an Individual for Work and Non-work

	Work, Four Suburbs		Work, Inner Suburbs		Work, Outer Suburbs		Non-Work, Four Suburbs		Non-Work, Inner Suburbs		Non-Work, Outer Suburbs	
Variable Name	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat	Coeff.	t-Stat
Constant	-.626	-1.992	.504	2.531	-1.117	-2.536	-.305	-2.121	1.764	3.546	1.613	3.324
Avg. work trip duration (min)	1.291	9.281	1.272	6.964	1.259	6.093						
Avg. non-work trip duration (min)							1.711	10.029	1.572	7.023	1.558	6.826
Number of work trips	.475	13.979	.498	11.488	.386	6.998						
Number of non-work trips							.367	17.295	.347	13.382	.349	12.848
Share of motorised work trips	5.871	2.708	.579	4.663	.995	3.257						
Share of motorised non-work trips							1.042	10.822	.949	8.282	.911	8.116
Made a work trip on that day dummy											.214	2.284
Average distance to shopping (km)							.521	7.172				
Quality of the walking environment									.225	2.337		
Distance to job between 2 – 5 km dummy			.201	1.962	-.419	-1.979						
Distance to job longer than 5 km dummy			.392	3.212	.277	2.590					.223	2.078
Employment density (pp/ha)			-.161	-2.644								
Distance to CBD (km)	.755e-01	6.731										
Route directness			-.195	-1.987								
Average lot size (squared metre)	.272	2.850										
No of vehicles	-.114	-2.652			-.143	-2.534						
No of workers in household											-.109	-2.203
Single adult living with kids/adults dummy							.219	2.882				
Family with kids/adults dummy									.192	1.968		
Age over 76 dummy									-.220	-2.877		
Median weekly rent (Aus$)									.291e-02	2.048	.346	2.445
Management or professional job dummy			-3.062	-3.272					-3.803	-3.839		
Well educated people dummy					8.856	3.597						
Income between $1000-1500 dummy	.169	2.140										
Income between $1500-2000 dummy									.151	2.006		
Income more than $2000 dummy							.271	2.074				
No of Cases, R-Square	**172, 0.77**		**88, 0.76**		**84, 0.62**		**268, 0.68**		**143. 0.67**		**125, 0.66**	

When a job is located in a relatively close proximity, between 2 and 5 km from home, it is less likely a longer trip will be made. Since most workers in the two outer suburbs work far from home (the average journey to work distance for Golden Grove and Para Hills are 18 and 14 km respectively), the workplaces in 2-5 km dummy has a negative association with total kilometres travelled. This important result confirms that while urban form continuous measures are advantaged because of more robust and easy transferability to other urban setting, however, it is important to understand the non-linearity that may be inherent in such variables (Krizek 2003). For example, Frank and Pivo (1994) suggested that residential density need to exceed eight housing units per acre before it can be expected significant modal shifts from single occupant vehicle to transit use. More investigation is required to find thresholds out using more accurate urban form measures.

Having higher employment density in the immediate neighbourhood was associated with shorter distance travelled. Living farther from the Adelaide CBD is associated with longer kilometres travelled for work purpose. One reason is that employment has remained quite centralised in metropolitan Adelaide despite the overall trend to suburbanisation of jobs:"… 39 per cent of all jobs held by females in 1991 were still located in the CBD and inner suburbs, compared with 33 per cent for males" (Forster 1999). In other words, the CBD is the largest employment centre, with one third of Adelaide's jobs, and strong employment in the professional, office and service works. Other employment centres of smaller scale also exist in the south, north and northwest parts of Adelaide. One advantage of inner suburbs: Norwood and Unley is better access to employment centres in the CBD. Baker (1997) suggested that the increasing number of employees in the CBD is contributing to the continuing demand for terraces and town housing in inner Adelaide. On the other hand, in metropolitan Adelaide, the number of local jobs available relative to the resident labour force is relatively low, thus workers may find it difficult to find a job near their residential location. This low job ratio may result in a large average commute distance and time and related to this, lower shares of non-motorised modes. However, this finding recommend that employment or residential relocation may serve as a means for households to travel shorter, but it often functions as a last option when other strategies have proven insufficient. The reason for this reluctance to relocate is that substantial costs are involved in changing jobs and particularly the place of residence, not only for the worker but also his/her family.

The other significant factor to decrease the length of travel was route directness. The impact of this variable may thus be a mixture of some local urban fabric factors to ease the movement through the area. In contrast, the larger the average size of allotments, the longer the distance travelled for work. The size of allotment could play a proxy role for other physical form variables which were not considered in the model. More research is needed to examine how this factor influences trip distance, and consider how the effect on trip costs influence trip generation and other characteristics of travel behaviour.

The other group of variables revealed their importance in the travel distance models was socio-economic characteristics. Travel distances tend to be shorter for those living in households owning a greater number of vehicles having or more adult workers (only in outer suburbs), since a part of necessary daily trips can be made by other members of households. Those living in households keeping children were likely to travel further, all else being equal, possibly due to mobility requirements for their children. the study by Rosenbloom and Burns (1993) showed that both mothers and fathers make a significant number of trips solely for children, with mothers making the majority of these trips for children up to 17 years old. The aged living in inner suburbs were less likely to travel further for non-work purposes such as shopping or recreation. Also, census districts with higher median housing rent were associated with great distances travelled for non-work either in inner or outer suburbs.

The modelling also showed that occupation type had a strong influence on travel distances, those working in inner city, in management or professional jobs travelled shorter either for work or non-work purposes. In fact, those working in central areas close to the CBD have been found to choose residential locations that allow them to shorten commuting. In contrast, well-educated workers in outer suburbs have a significantly huge part in making long travels for work. They probably need to travel further to reach their professional workplaces. Household income level were strongly associated with total travel distance but in two different ways. For non-work purposes, individuals from high and very high-income groups travelled further as the income increased. On the other hand, for work purposes, individuals from low-income households travelled further as the income increased. This difference may represent that travelling further for non-work trips by high-income groups due to have more fun at leisure time, but travelling further for work by low income groups made due to have more opportunity to job. For instance, a carer has two jobs far from each other needs to travel further than a registered nurse works in one job but with higher income. In contrast, the registered nurse would probably travel further for non-work destinations.

6 Conclusions and further investigation

While exclusionary zoning and market forces have tended to segregate activities and lengthen trips, bringing origin and destinations closer together is associated to decrease daily kilometres travelled for work and non-work activities. Better urban form would locate workplaces and activities linked as trip productions and attractions are as close together as possible.

This study is a primary step in Australian context with applying a disaggregated approach; considerable additional analysis is possible and is encouraged. The results would help to identify practical means to incorporate built environment aspects in local demand travel forecasting systems, to better understanding of the connection between urban form and travel behaviour. This study also may serve to assist other practitioners in Adelaide in their efforts to address the issue of induce travel, and to present better solutions for sustainability concerns.

The results showed that urban form works to discourage making longer trips and further travels especially with motorised modes of transport. However, it is important to say that improving access to more travel choices does not routinely result to less car use. Some people take their own transport due to their attitudes and perceptions. They drive because they believe in it and they want it regardless of cost, time and other constraints. In a unique study that looked at the association between land use, transportation and attitudes , it was found that personal attitudes is a strong predictor of travel behaviour, perhaps stronger than land use characteristics (Kitamura, Mokhtarian et al. 1997). While this research did not consider individuals' attitudes directly, personal attitudes may potential influence travel decisions. What this research suggests is providing more alternatives and improving the self-containment of the residential suburbs are necessary conditions which should be given more attention in policy and planning.

The fact that residents of inner suburbs, Norwood and Unley spend more time being actively in their neighbourhood may also be resulted from stronger sens of community and higher neighbourhood cohesion which are explaining by many non-physical factors not sole urban design features. Intuitively, spending more time out-doors, in turn, cause an increase in social communication and social cohesion over time, and perhaps as a result reinforce increased physical activity.

Only four suburbs have been studied and a modest survey response rate has been obtained, so theses results are not necessarily generalisable unless they are replicated in other contexts and for populations with different socioeconomic attributes. A low variation between urban form variables in geographical areas, due to small sample size, plus lesser variation within suburbs makes the urban form measures less insensate to detect the effect of urban form on travel choices.

Information was collected only about the urban form of the sample sites. Such kind of information should be gathered from the characteristics of destinations of daily commuting. Similarly, data on the destination of midday travel, trip chaining, or other related topics were not included, while the attraction of those trips made outside of the origin suburbs are important as well.

7 References

Australian Bureau of Statistics (ABS) (2001). Census of Population and Housing: Journey to Work datasheets. Australia.

Badoe, D. A. and E. J. Miller (2000). "Transportation-land-use interaction: empirical findings in North America, and their implications for modeling." Transportation Research Part D **vol. 5**: 235-263.

Baker, E. (1997). Gentrication and gender effects in North Adelaide. Department of Geographical and Environmental Studies, University of Adelaide.

Cervero, R. and R. Gorham (1995). "Commuting in Transit Versus Automobile Neighborhoods." Journal of American Planning Association(61): 210-225.

Crane, R. (2000). "The influence of urban form on travel: An interpretive review." Journal of Planning Literature **15**(1): 3-22.

Crane, R. and R. Crepeau (1998). "Does Neighbourhood Design Influence Travel? A Behavioural Analysis of Travel Diary and GIS Data." Transport Research Digest **3**(4): 225-238.

Diepen, A. V. and H. Voogd (2001). "Sustainability and planning: does urban form matter?" International Journal of Sustainable Development **4**(1).

Farthing, S., T. Winter, et al. (1996). Travel behaviour and local accessibility to services and facilities. The Compact City. M. Jenks, and E. Burton, K. Williams. Oxford, Oxford University Press: 181-189.

Forster, C. (1999). Australian Cities: Continuity and Change. Melbourne, Oxford University Press.

Frank, L. and G. Pivo (1994). "The impacts of mixed use and density on the utilization of three modes of travel: the single occupant vehicle, transit and walking." Transportation Research Record **1466**: 44-52.

Frank , L. D., M. A. Andresen, et al. (2004). "Obesity Relationships with Community Design, Physical Activity, and Time Spent in Cars." American Journal of Preventive Medicine **27**(2): 87–96.

Friedman, B., S. Gordon, et al. (1994). "Effect of neotraditional neighbourhood design on travel characteristics." Transport Research Record **1466**: 63-70.

Giuliano, G. and K. A. Small (1993). "Is the journey to work explained by urban structure?" Urban Studies **30**: 1485-1500.

Golob, T. F. and L. V. Wissen (1989). "A joint household travel distance generation and car ownership model." Transportation Research B **23B**(6): 471-491.

Gordon, P., H. W. Richardson, et al. (1991). "The Commuting Paradox Evidence from the Top Twenty." Journal of the American Planning Association **57**(4): 416-420.

Greene , W. H. (1998). LIMDEP Version 7.0 : User's Manual. Sydney, Econometric Software, Inc.

Handy, S. (1992). "How land use patterns affect travel patterns." Council of Planning Librarians, Chicago.

Handy, S. (1993). "Regional versus local accessibility: neo-traditional development and its implications for non-work travel." Built Environments **18**(4): 256-267.

Handy, S. (1996). "Understanding the link between urban form and non work travel behaviour." Journal of Planning Education and Research **15**: 183-198.

Jara-Diaz , S. R. (1998). Time and income in travel choice: towards a microeconomic activity-based theoretical framework. Theoretical Foundations of Travel Choice Modelling. T. Garling, T. Laitila and K. Westin. Oxford, Pergamon: 1-30.

Kitamura, R., P. L. Mokhtarian, et al. (1997). "A micro-analysis of land use and travel in five neighbourhoods in the San Francisco Bay Area." Transportation **24**: 125-158.
Kockelman, K. M. (1998). A Utility-Theory-Consistent System-of-Demand-Equations Approach to Household Travel Choice. Department of Civil and Environmental Engineering, University of California at Berkeley. **PhD**.
Krizek, K. J. (2003). Operationalizing neighbourhood accessibility for land use-travel behaviour research and regional modelling. Minneapolis, University of Minneapolis.
Leslie, E., B. Saelens, et al. (2005). "Residents' perceptions of walkability attributes in objectively different neighbourhoods: a pilot study." Health & Place **11**: 227–236.
McNally, M. G. and A. Kulkarni (1997). "Assessment of Influence of Land Use - Transportation System on Travel Behaviour." Transportation Research Record **1607**: 105-115.
Mokhtarian, P. L. and I. Salmon (2001). "How derived is the demand for travel? Some conceptual and measurement considerations." Transportation Research Part A **35**: 695-719.
Mokhtarian, P. L. and I. Salomon (1997). "Modelling the Desire to Telecommute: The Importance of Attitudinal Factors in Behavioural Models." Transportation Research A **31**(1): 35-50.
Moudon, A. V., P. M. Hess, et al. (1997). "Effects of Site Design on Pedestrian Travel in Mixed-Use, Medium-Density Environments." Transportation Research Record **1578**: 48-55.
Naess, P. (2000). Residential location and transport in a small Danish town: a contribution to the discussion on the influence of land use on travel behaviour. Transport and tourism in sociology and geography, Roskilde.
PBQD (Parsons Brinckerhoff Quade & Douglas, I., et al) , (1996). Transit and Urban Form. Transit Cooperative Research Program Report. Washington, DC, Transportation Research Board.
Perkins, A. (2002). The influence of urban form on life cycle transport and housing energy and greenhouse gas emissions. Planning. Adelaide, University of South Australia.
Planning SA (2000). Transport Choice and Urban Design: Design Issues for Accessible Neighbourhoods. Adelaide, Government of South Australia.
Primerano, F. (2004). Development of Accessibility Measures for Transport and Urban Planning. Transport Systems Centre. Adelaide, University of South Australia. **PhD**.
Redmond, L. S. and P. L. Mokhtarian (2001). "The positive utility of the commute: Modelling ideal commute time and relative desired commute amount." Transportation **28**(2): 179-205.
Rosenbloom, S. and E. Burns (1993). "Why working women drive alone: Implications of the travel reduction programs." Transportation Research Record **1459**: 39-45.
Rutherford, G. S., E. McCormack, et al. (1996). Travel Impacts of Urban Form: Implications from an Analysis of Two Seattle Area Travel Diaries. the Travel Improvement Program Conference on Urban Design, Telecommuting and Travel Behaviour, Williamsburg VA.
Schwanen, T., F. M. Dieleman, et al. (2002). The Impact of Metropolitan Structure on Commute Behaviour in the Netherlands. A Multilevel Approach The Fifth Symposium of the International Urban Planning and Environment Association, Oxford.
Small, K. and S. Song (1992). "Wasteful Commuting: A Resolution." The Journal of Political Economy **100**(4): 888-898.
Soltani, A. and A. Allan (2004). The Impacts of Urban Form on Travel: A Comparative Study of Four Suburbs of Metropolitan Adelaide. 27th Australian Transport Research Forum, Adelaide.
Sommer, B. and R. Sommer (1997). A Practical Guide to Behavioural Research: Tools and Techniques. New York, NY., Oxford University Press.
Stead, D. and S. Marshall (2001). "The Relationships between Urban Form and Travel Patterns. An International Review and Evaluation." EJTIR **1**(2).
White, M., J, (1988). "Location choice and commuting behaviour in cities with decentralized employment." Journal of Urban Economics **24**: 129-152.