The Travel Effects of Community Design

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1 Introduction

Although several studies can be found in the literature related to interactions between urban form and transportation, the influence of urban form on travel choices by considering micro-scale design attributes has not been properly investigated. This study aims to consider micro-scale attributes of urban form and their impacts upon travel choices made by individuals. Measuring such attributes objectively is relatively difficult, however combining field observations with GIS measurements from digital maps can be used to quantify such attributes. Disaggregate information related to the socio-demographics of the population and their travel patterns were predominantly obtained from two datasets: the 1999 Metropolitan Adelaide Household Travel Survey (MAHTS99) and the Australian Bureau of Statistics' (ABS) census data. Data on design issues are taken from available land use maps and an inventory field survey. Based on disaggregated measures, the micro-scale aspects of urban areas are characterised and then incorporated within models to estimate the travel choices made by residents in these areas to explore the causal relationships between urban form and travel patterns. A multinomial logit model was developed to find the impact of endogenous factors on the modal choices of residents and identify the cause of travel pattern differences between areas.

The ultimate goal of this paper is to test the hypothesis that pedestrian-oriented urban environments with high density, mixed land use and high quality urban design reduce mobility and car use and hence increase the market share of more sustainable modes of transport. For the purpose of this study, four neighbourhoods of metropolitan Adelaide were selected to reflect differences in morphological urban form and network types for the main street system. The selection was based on the literature on historic and more recent neighbourhood form. Two different forms were selected: the grid neighbourhood and the curvilinear neighbourhood.

The paper provides a review of background studies followed by a description of the approach taken for the study. The modelling process is then explained with a discussion of the outcomes from the models. The paper concludes with a reflection on the study and its outcomes and provides recommendations in considering urban form and design when promoting sustainable forms of travel.

2 Review of related studies

A large number of studies document the interactions between urban form and travel behaviour. The majority of these studies acknowledge relationships between some aspects of urban features and travel behaviour. In this way, density and a mixture of land uses (which are basically defined by zoning) have been the emphasis of investigations (Schimek 1996; Cervero and Kocklman 1997). Areas with higher density have been linked to higher public transport usage. In a transit-oriented planned area, this is also associated with higher shares of non-motorized modes of travel (Cervero and Gorham 1995). The areas with higher degrees of land use mix where diverse types of activities can be found have a higher potential to attract walking or bicycle trips. McNally and Kulkarni (1997) compared three types of neighbourhood development in Orange County, California: traditional, planned and hybrid. They found that trip frequency is lower than average in traditional neighbourhoods and higher than average in planned unit developments. Frequency of transit trips was also found to be higher in traditional neighbourhoods. On the other hand, frequency of walk/bicycle trips was found to be lower in planned developments. Friedman *et al* (1994) compared two types of communities: pre-war traditional communities versus standard post-war suburbs. They found that suburban areas were associated with higher rates of trip frequency as well as higher proportions of auto-driver trips. On the other hand, more walking and public transit use was found in traditional communities. Handy (1992) suggested that choosing an alternative mode depends strongly on the nature and range of travel choices available within a neighbourhood rather than on the ‘neighbourhood design’ (i.e. ‘new’ versus ‘old’).

Some researchers argue that higher density areas are usually associated with better public transport services as well as accommodating different social groups which all together make a denser area feasible for non-automobile travel activities (Kitamura et al. 1997). Density in fact does act as a proxy for several attributes that are difficult to quantify and thus represents their ambiguous associations with travel behaviour (Brunton and Brindle 1999). Certain degrees of density attract certain types of people, which would show their effects in travel patterns. Such critique may be true when density is investigated at an aggregated level. Giuliano and Dhiraj (1999) investigated travel trends and land use characteristics in both US and British cities and suggested that improved income, demographics and economics explain travel trends. Therefore, urban spatial characteristics have little impact on travel behaviour. The study by Giuliano and Dhiraj considered aggregated attributes and measures of land use and travel, failing to consider the finer characteristics of neighbourhoods (such as provisions for various forms of travel, neighbourhood character and its conduciveness for non-motorised forms of travel), the socio-demographics of the population (such as the difference in travel patterns of individuals and households), and the type of travel being undertaken.

Lack of comprehensive analysis, methodological weakness, and data limitations may affect any study in urban form-transportation interactions. As explained by Badoe and Miller (2000), analysing the real effects of urban form on travel behaviour requires a comprehensive approach that integrates the view of the problem within the overall transportation/land use interaction (which is critical to achieve) in order to first understand the nature of the interactions involved and then to generate useful analysis and forecasts based on this understanding. Cultural differences, public transport infrastructures, and many travel related attributes obviously are different in different geographical areas. However, one cannot rule out the possibility that the results of such studies may be correct in other similar cases.

Such study can benefit planners to rethink current spatial development patterns. The American *New Urbanism* programs, which have been successful in established communities in US recently, have been investigated by Australian planning authorities for consideration within design, infrastructure, and service initiatives. The *NSW SEPP 66* plan is one of valuable efforts made to achieve more sustainable future for Australian designed communities. The aim is to support sustainable transport (walking, cycling and public transport), reduce car use and create a compact liveable city (NSW Government 2001). Therefore, the planning objective should be to provide amenable spaces that encourage walking and cycling by keeping distances short and providing accessible continuous paths of travel. This is consistent with the direction being taken by Western Australian Planning Commission (2000) titled as the Liveable Neighbourhoods (LN) policies. Liveable Neighbourhoods aim to provide design codes to build liveable communities that have lower dependency on private vehicles and encourage sustainable energy usage. The guidelines discuss several physical elements of neighbourhoods such as street design, density and proximity to local centres and bus stops. Lack of density variations, large street blocks, and a limited number of local centres are of challenges for sustainability in recently developed suburbs. LN policies address these challenges through providing guidelines on the configuration of street layouts and blocks and the distribution of key amenities within a neighbourhood.

3 Research approach

The approach taken in this paper is to gather micro-scale land use, street network, and urban design data in a set of purposefully selected suburbs. This information is integrated within the socio-demographics of households (and individuals as trip makers) as well as their daily travel patterns collected in the 1999 Metropolitan Adelaide Household Travel Survey (MAHTS99). MAHTS99 was a two-day travel diary survey conducted by Transport SA that collected information related to the socio-economic and travel patterns of households. The face-to-face interview survey was conducted on 9000 randomly selected households within metropolitan Adelaide.

A strategy was followed to select study areas that represent different patterns of development in Adelaide. The case study suburbs were chosen via a primary investigation of different development patterns and for which a rich amount of information could be obtained. Although a systematic experiment was not used to select these areas, different aspects of urban characteristics as well as transport networks were considered. Four suburbs were selected in this research: Norwood, Unley, Para Hills and Golden Grove. Norwood and Unley are considerably different from the other two suburbs in their street design pattern, zoning, density and distance from the Adelaide Central Business District (CBD). The travel characteristics are also different with Norwood and Unley having lower vehicle ownership, higher share of walk/bicycle trips and public transport trips and lower proportions of car trips. These statistics show the diversity that exists among the chosen study suburbs ranging from the relatively high density, pedestrian-friendly inner neighbourhood of Norwood to the suburban, car-oriented neighbourhood of Golden Grove. Table 1 shows a brief comparison of the four neighbourhoods.

Within each study area, socio-economics significantly varied across households, permitting the examination of the relationship between socio-economic characteristics of households and their travel patterns. Each selected suburbs is divided into several Census Collection Districts (CCD) where each CCD on average covers around 30 hectares and contains approximately 500 residents (ABS 2001). Site observations were conducted at each of the four suburbs to obtain micro-scale measurements of street characteristics including street design, presence and quality of sidewalks and bicycle lanes, speed limits and other traffic calming means, street width and volume of traffic. These observations were analysed within an inventory evaluation system to compare different streets in terms of their design efficiency for pedestrians and cyclists (Soltani and Allan 2004). The survey results were combined with the South Australian Digital Cadastral Data Base (DCDB) land use data, ABS census data and information from the MAHTS99 database to create a single database (detailed later in this paper) for further analysis and model development.

In this study, modal choice is used to represent travel behaviour. A multinomial logit model to estimate mode choice was developed and used to evaluate the effects of community design variables. Model coefficients show the importance and strengths of urban factors and their ability to improve the explanatory power of behavioural models. Based on the modelling outcomes, the potential influence of urban design on travel choices is discussed and directions for further research are provided.

Table 1 Differences in urban form features and travel characteristics for case study areas.

Measure	Norwood	Unley	Para Hills	Golden Grove
Street Network Pattern	Grid	Grid	Curved	Curved
Average Distance from Adelaide's CBD (km)	3.049	2.370	14.335	18.513
Topography	Flat	Flat	Hilly	Hilly
Bus Lines	Two lines	Three lines	Two lines	Two lines
Residential Net Density (pp/ha)	53.8	43.8	30.2	47.2
Employment Density (jobs/ha)	13.31	13.10	7.32	8.03
Area (acre)	2.206	1.461	5.575	5.381
Vehicle ownership (vehicle per household)	1.19	1.37	1.67	1.59
Work travel made by car (percent)	77	75	87	85
Non-work travel made by car (percent)	71	74	86	89

(Source: MAHTS99 and DCDB)

4 Measures of Community Design

The research covers four neighbourhoods in both inner and suburban areas of metropolitan Adelaide. A total of 15 comparative spatial indicators were developed to quantify community design characteristics. For statistical purposes, these indicators should be independent from each other to reduce the risk of collinearity and facilitate the interpretation of results. For calculation purposes, this study investigates attributes of urban form at a local level by considering the CCD as the level of spatial resolution since it offers the finest level of detail of community design attributes.

In Table 2, the definitions of these factors are presented. These measures together represent the physical character of a residential neighbourhood and are assumed to be relatively independent from each other. Density was measured using two single indicators: residential gross density and employment density. The land use entropy index (LUM) is used as a measure of land use mix (Cervero and Kockleman 1998). Regional accessibility to workplaces were calculated using a gravity-based formula. Travel distances between origins and destinations were calculated using *ArcView* GIS on the current transport network system. The distances were based on the best path –(least cost) assuming that trip makers follow such paths. For trips made within a zone, distance was calculated by multiplying travel time by the average travel speed for different modes of travel (see Table 3).

Table 2: community design measures.

Variable Name	Definition
Residential Density	Residential gross density: number of residents per developed residential area
Employment Density	Employment Density: number of jobs per developed area
LUM	Land Use Mix (mean entropy for land use categories within a CCD area) on a 0-1 scale
Accessibility to Workplaces	The sum of all job opportunities in a zone weighted by distance
Proximity to Shopping Complex	Proximity to shopping complex as average distance to closest shopping centre weighted by number of dwelling units
Proximity to Education Centres	Proximity to schools & education centres as average distance to closet school weighted by number of dwelling units
Cul de sac	Ratio of cul-de-sacs vs. cul-de-sacs and intersections on a 0-1 scale
SSA	Street Space Allocation: total length of streets per developed area
WPDI	Walking Permeability Distance Index: ratio of actual network distance between an origin and a destination versus straightline distance between them
MBA	Median block area (ha)
Diversity in Parcel Size	Diversity in parcel size: standard deviation of parcels
PEF	Pedestrian Environment Factor ranged between 0 and 9
CEF	Cyclist Environment Factor ranged between 0 and 9
Bus Coverage	Coverage of bus routes: percentage of area which is covered by 200m buffer of bus routes
Open Space Availability	Open space availability: percentage of area denoted to parks, playgrounds and ovals

Proximity indices for two key amenities: shopping centres and education centres and schools were calculated as the median distance between them and all residential units within a neighbourhood area weighted by the number of dwelling units. To consider the permeability of each residential neighbourhood, four different indicators were developed: the proportion of cul-de-sacs and dead-end streets; street space allocation as a proportion of the total centreline distances of streets in each area; the walkability index (WPDI) calculated by dividing the direct distance between an origin and destination by the actual network distance between them and average of urban block area (MBA). The standard deviation of parcels (DPA) is employed to show the diversity of parcels in each neighbourhood.
The results from the field observation survey (which was undertaken for 110 streets) are summarised in two measures: Pedestrian Environment Factor (PEF) and Cyclists Environment Factor (CEF). The percentage of neighbourhood area covered by metropolitan public bus route buffers was also calculated to consider the availability of public transport

services. The covered area is the area within 0.2 km of local bus routes, where pedestrian connections to transit areas are available from the surrounding area. The percentage of open spaces including parks, playgrounds, and ovals was also included.

5 Modelling

The multinomial logit model estimates the likelihood of choosing a mode of travel by a household member. This model uses socio-demographic and economical features of the sample households (and individuals) as exogenous variables along with the measures of community design. For the purpose of analysis, the individual is considered as the unit of analysis to achieve more accurate outcomes. the mode choice by individuals who participated in the MAHTS99 survey was modelled to represent the travel patterns made by individuals. Four mode alternatives were modelled:

- Car driver: available to adult members with a driver's licence from households that own at least one vehicle;
- Car passenger: available to all individuals;
- Walking/cycling: available to all individuals;
- Metro-ticket public bus: available to all individuals.

The sample data contains 1842 trip records taken from MAHTS99 database to represent travel undertaken by individuals who resided in one of the four case study areas. The distribution of the use of these modes for the sample is 57%, 24%, 16%, and 3% respectively. Two alternative specific attributes were calculated for non-chosen alternatives, these were travel time and the number of stops. Travel time was calculated using travel distance assuming constant average speed for different modes by dividing the distance travelled by the speed of the mode alternative for every trip. Travel speeds for different modes of travel within metropolitan Adelaide were considered as detailed in Table 3.

Table 3: Average speeds for modes of travel.

Mode of travel	Average speed(km/h)
Car	46.4
Walk	4.25
Bicycle	8 (female) or 11 (male)
Public Transport (Bus, Train, Tram)	23

(Source: Primerano 2004)

Number of stops for each trip for different alternatives was calculated using a similar method detailed by Primerano (2004).

6 Modelling results

The modal choice model, including values of Alternative Specific Constants (ASCs), values of attribute coefficients and their significance are detailed in Table 4. Generally, the analysis shows the complexity of the potential interaction between spatial attributes and modal choice. The adjusted ρ^2 value is strong with a value of 0.72 (compared to the model with no coefficients). The *t-statistics* in the modal choice model are all above the threshold values of ±1.96 (95 percent confidence) showing that all ASCs and the coefficient estimates of attributes are all significant. The coefficients of the alternative specific attributes are all the expected sign and are significant. Car Passenger was taken as the referent alternative here.

The results of modeling modal choice can be summarised as follows:

- Travel time has a negative coefficient indicating that the higher the values of this attribute the lower the utility. This means that the greater the travel time the lower the benefit to the user. This finding is consistent with Crane and Creapue (1998) showing the importance of travel cost factor in a behavioural model.

- The number of stops made has a positive sign indicating that the more stops an individual can fit into the trip the greater the benefit to that individual.
- With the importance of household income, as the income increased the likelihood to choose to travel as an alone driver, by public transport and walk/ride a bicycle increased. The highest positive influence of the household income was for the drive alone alternative. However with higher income, people were next willing to travel by public transport, then walk and then be a car passenger.

Car driving appears as the most popular modal choice (with a share of 56 % in the MAHTS99 data) and appears influenced by community design factors as well as socio-demographics. Individuals in households with a greater number of residents were less likely to drive a car alone, probably because of the possibility to share rides among household members. The result may also imply that the increase in household size may require greater essentials such as food, clothing and housing, thus reduce the amount of financial resources for expenditures on car use (Lerman and Ben-Akiva 1985). An individual being a licensed driver had the greatest positive influence on drive alone mode.

Living in an area with higher (employment) density resulted in car usage as a driver to be less likely which may be due to individuals being reluctant to travel due to the limitations of parking or traffic congestion. The finding is consistent with previous empirical research. The residents of denser areas tended to have fewer car use presumably due to higher auto level of service (because of congestion problems, parking limitations, etc) associated with denser areas (Bhat and Koppelman 1993) and more availability of other modal choices i.e. walking; cycling or public transport. Another reason could be that they did not need to drive since they may have been close to work. This choice of mode was more favorable for an individual resided far from the CBD. The greater the distance to shopping centres, the more likely an individual drove alone.

An increase in walking/cycling trips with decreasing levels of WPDI value (higher walkability) could certainly demonstrate the importance of connectivity and permeability of street networks.

Weekday trips were less likely to be done by walking/cycling. Walking/cycling is a favorable choice for home-based non-work trips including shopping, recreation, educational and personal business trips.

Females were less likely to catch public transport for their trips. They were more likely to be car passengers. Licensed car drivers were less likely to use public transport. Adults living alone were more likely to use public transport than those of other household types. On the other hand, students were less likely to take public transport but more likely to be taken as a car passenger.

Some urban attributes (like LUM) could not be proven to be useful to relate urban form to travel patterns. This might be due to the small sample size and low variation through the sample. Further research needs to consider a larger sample with larger variations.

Table 4: Modal choice model.

Variable name, Alternative	Coefficients	t-statistics
Alternative Specific Constants		
Car Drive Alone (DA)	-1.854	-2.37
Public Transport (PT)	-7.774	-7.111
Walk/Bicycle (WB)	-2.312	-3.044
Alternative Specific Attributes		
Travel Time (min)	-2.450	-10.235
Number of Stops	1.283	15.819
Observation Specific Attributes		
Household Income, DA	0.511e-04	6.239
Household Income, PT	0.428e-04	5.732
Household Income, WB	0.329e-04	4.392
Car License, DA	5.994	5.911
Car License, PT	0.664	2.363
Number of members, DA	-0.501	-4.651
Distance to CBD, DA	0.701e-04	2.123
Employment Density, DA	-0.138	-3.329
Proximity to Shopping, DA	0.762e-03	2.520
Female, PT	-0.710	-4.006
Student, PT	-0.895	-3.062
Adult living alone , PT	0.592	2.115
Weekday, WB	-0.673	-3.407
WPDI, WB	-0.264	-0.729

Adjusted ρ^2 Value (No Coefficients) = 0.717; χ^2 [17] = 2449.610; No. of observations = 1842

(Note: e+nn or e-nn represents multiply by 10 to + or –nn power.)

7 Summary

This study examined the effects of community design variables on travel behavior using data collected from four diverse neighborhoods in metropolitan Adelaide. The data collected for this study forms a rich basis from which these types of effects can be explored. This paper has reported the results of initial analyses of this database. The findings show the importance of detailed community design features in influencing travel behaviour that are qualitative and mostly absent from the literature of land use/transportation interactions. Apart from socio-economic specifications of the individuals (and households) such as household type, number of members, household income, and some attributes relating to daily activities, some design attributes of community also need to be considered. In other words, for those who would like to make active choices, neighbourhood design can limit their options. The low-density, single use, large-area zoning usually found in suburban landscapes further limits residents' ability to walk or cycle for daily transportation. Local networks where permeability and connectivity are high induce higher shares of walking/cycling travel. Local density and closer proximity to shopping places encourages choices of sustainable modes of travel. Furthermore, suburban development away from major activity centres results in higher private car use, thus decreasing the use of other modes. Overall, the findings of this study could be used to compare three key spatial issues in community design: dispersal versus concentration, high versus low density, and segregated versus integrated land use patterns. This can help provide the strategic framework for community planning and design.

8 Further Research

One limitation of this study is its concentration on specific suburbs. It can be critiqued that by only considering the four suburbs, the results can be inferred to those suburbs. The suburban developments of the Adelaide metropolitan are nearly homogeneously populated. In order to control (as much as possible) the influence of non-design-related factors, it was necessary to compare these suburbs with suburbs of similar socio-demographic characteristics. The approach followed in this study, in fact, can be developed to expand the research to consider more neighbourhoods and hopefully create a model that can be more generally applied. It would be interesting to use the equations from the model and derive the modal split for each of the case study suburbs and compare the results. Then the urban form characteristics of each suburb can be used to explain the results.

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