



23rd Australasian Transport Research Forum
Perth, Western Australia. 29 September – 1 October 1999

Towards a Theory of Suburban Form and Travel Mode Use

George Pund

PhD Candidate, Graduate School of Management, Macquarie University, New South Wales

Abstract

One set of travel demand management techniques aimed at reducing the use of private cars emphasise suburban planning. This involves planning suburbs within which people are encouraged by the form of local urban development to walk, cycle, or use public transport.

Research shows that the form of suburban areas does affect travel mode use. However, researchers study different aspects of suburban form, using several methods and yielding varying results. This makes developing successful practices difficult. Understanding (through research) the ways that suburban form affects the mode of travel is vital for the development of planning practice and travel demand management techniques. Disaggregate analysis is particularly useful. Unfortunately, only a small number of studies use this analysis.

I review the theoretical approach and the findings of research using disaggregate analysis. The research suggests the ways that suburban form affects travel mode use are: accessibility affecting travel choice; trip costs and benefits; choice of residential location; and attitudes. Other research suggests that urban form impacts on the level of service that a bus operator is able to viably provide. Suburban form affects bus service supply and the attractiveness of bus services as a mode of travel. The research reviewed also identifies factors other than suburban form that affect mode use.

The complexity of the concept of urban form and of the travel behaviour of people means that there is an array of factors involved. The ways that suburban form affects mode use identified by researchers, are varied but not contradictory. They integrate easily into a theory of mode use that includes suburban form. This theory will guide further research. In this way, it supports more effective travel demand management techniques for urban planners.

Contact Author

George Pund
21 Boronia Avenue
Epping NSW 2121

Phone: +61 2 9876 2608
e-mail: allgeoje@one.net.au

Fax: +61 2 9876 5894

Introduction

There is now wide acceptance of the necessity for travel demand management (Austroads 1995; Road and Traffic Authority of NSW 1994). Generally, the aim of travel demand management is reduction in the proportion of travel by car. Certain urban planning practices now compose one set of accepted travel demand management techniques (Austroads 1995; Banister 1994a; Breheny 1993).

In North America, a significant number of public transportation and local planning authorities have adopted "transit-oriented guidelines" for suburban planning (Cervero 1993). In Australia, government departments in two states recommend certain suburban planning practices for reducing car dependence (Morris 1997). Documents produced under the Building Better Cities Program (Kaufman and Morris 1995), the *Australian Model Code for Residential Development* (Department of Housing and Regional Development 1995) and *Cities for Tomorrow* (AUSTROADS 1998) rely on the effect of urban form on mode use.

Research shows that there is an association between suburban form and mode use, but the results are inconsistent in strength and nature (Cervero 1993; Handy 1997; 1996a; 1992; Transit Cooperative Research Program 1995). This has not always prompted caution. Rather, the interest in local urban planning as a means of controlling car use leads as Breheny (1994) states to:

'Half-formed, but attractive, research findings... hastily adopted by practitioners and politicians as the basis for policy.'

Boarnet and Sarmiento (1996) suggest an appropriate alternative response:

'The idea that land use policy can influence travel behaviour stems from the observation that the two variables are typically correlated... Yet the attempt to move from observed relationships between land use and travel to policy tools requires a deeper understanding.'

Establishing what the research actually shows is fundamental to developing successful travel demand management techniques. As a contribution to this task, I review the theoretical approach and findings of research into how the urban form of suburban areas affects people's mode of travel. I synthesise these results into a theory of suburban form and mode use.

I review eight empirical studies identified in a search of transport planning and urban planning literature over the last decade or so. The results suggest five different ways by which suburban form may affect mode use. Suburban form affects mode use through: accessibility influencing travel choices (Hanson and Schwab 1987; Handy 1996b; 1996c; 1993); trip costs and benefits (Crane and Crepeau 1998); residential location choice (Boarnet and Sarmiento 1996); and people's attitudes (Kitamura Mokhtarian & Laidet 1997). Other research suggests that urban form impacts on the level of service that a bus operator is able to viably provide, affecting the use of bus services as a mode of travel (Fleming and Pund 1994).

Theory

In the last ten years there have been several reviews collating research into the effect of urban form on travel activity (Cervero 1993; Handy 1992; Transit Cooperative Research Program 1995; Steiner 1994). Reviews generally concentrate on the results of research, compiling considerable evidence supporting the contention that urban form affects travel activity.

Recent studies (Crane and Crepeau 1998; Handy 1996a) report deficiencies with the methods employed in previous research. However, the theoretical position tested in a study may still provide a useful insight, even if the method employed in its testing is deficient. The theoretical positions require further study with refined methods.

A theory or (competing) theories of urban form and travel mode use will identify the ways in which urban form affects travel activity. Valid research findings support or demand refinement of the theory or theories, which in turn provide crucial questions for further investigation. Such a theory is critical in developing travel demand management techniques.

Definitions: Urban form and travel activity

Managing travel demand requires a better understanding of the relationship between transport use and urban areas. This means a focus on urban form over the previous narrower focus on land use. The following definitions of urban form show concern for capturing the complexity of interaction between aspects of urban areas.

'Urban form is the shape and configuration of the physical characteristics of a town or city. It includes the bulk, height and density of buildings; patterns of roads and railway lines; parks and watercourses; and the built edges of a city.' (Urban Design Advisory Service 1998).

Urban form refers to the type and location of land uses, connections between these uses, circulation and layout. It also includes urban design which is concerned with the environment (urban spaces) created by buildings and other structures and how these affect the people who use them (adapted from Handy 1997).

These attempts to capture complexity result in a degree of ambiguity. Consequently, measuring urban form in a practical way for research projects is difficult. The measures used seem simplistic against the complexity of the concept. Research studies consider only a small number of aspects of urban form.

Travel activity includes the 'decision' to use a particular mode and the earlier and more fundamental decision to undertake travel. The studies reviewed show that considering mode use as a later and somewhat separate decision is valid. In this paper, I focus on the mode of transport used. I use the term 'travel activity' where studies deal with more than mode use.

Method

Disaggregate analysis measures individual and household characteristics. This level of analysis allows exploration of the ways by which urban form may affect people's travel activity (Banister 1994b; Crane and Crepeau 1998; Handy 1997; 1996; Steiner 1994). By contrast aggregate analysis measures characteristics for a zone or city or other sizeable urban area. It shows the relationship between characteristics but not how this relationship occurs or the way individuals behave (Banister 1994b; Handy 1997; 1996a; Hanson & Schwab 1987).

The bulk of the research on urban form and travel activity involves aggregate analysis (Handy 1992). Handy's conclusion (1997) reflects the weight of this aggregate analysis:

'For the most part research to-date demonstrates correlations between travel patterns and characteristics of urban form, with urban form accounting for a limited by statistically significant share of the variation in travel patterns. But it has shed very little light on the behaviour underlying these correlations and thus on causal relationships...'

Getting the best travel demand management results from urban planning practices requires research that shows how urban form impacts on people's travel activity. To this end I concentrate on disaggregate empirical studies at the neighbourhood and suburban level. However, I also introduce some research that used aggregated data but also suggested a way that urban form affects use of bus services.

How suburban form affects mode use

Accessibility affecting travel choice

Handy (1996b) used discrete choice theory to study the relationship between suburban form and travel behaviour. Urban form affects the range of choices (types of destinations and modes of transportation), and the quality of choices (cost and comfort of travel and the quality of the activity at destinations) available to an individual. Handy uses the concept of accessibility to evaluate the choices provided by suburban form. The accessibility of a place is both the range and quality of activities at locations around the place and the ease of reaching these locations. In particular the ease of reaching locations depends on the connectivity afforded by the transport system (Handy 1993).

Handy (1996b; 1993) compared walking and car usage (but not public transport use) for non-work travel to the local town centre and to the regional centre, for four suburban communities in San Francisco.

In the later analysis of the data from this study, Handy (1996b) tested four hypotheses. High levels of accessibility are associated with shorter travel distances. High levels of accessibility are associated with greater variety in destinations chosen by residents.

Greater accessibility is associated with more frequent travel. Higher use of non-motorised modes of travel is associated with greater accessibility. After accounting for household type and income the results were significant and in support of the four hypotheses.

Handy (1996b) concludes that urban form does make a difference to whether a person perceives walking (from the trip origin) as an option. Pedestrian-oriented features such as short distances, lack of barriers such as arterial roads and certain types of establishments such as restaurants are conducive to walking. Residents value a greater range of choice, but this results in more travel. How much this increased travel occurs by walking depends on the other choices available, both locations (and the range and quality of activities) and the distances to activities and the experience of accessing them.

A further study of walking in six suburbs in Austin Texas (Handy 1996c) confirmed that the choices made depend on the benefits and costs of available alternatives.

A study of accessibility by Hanson and Schwab (1987) found similar results. They re-examined earlier work by Hanson (1982) in Uppsala Sweden investigating whether a person's accessibility to activity sites affects their travel behaviour. The accessibility of a location depends on the distribution of surrounding potential activity sites. This is a narrower definition than that used by Handy. Hanson and Schwab did not consider the connectivity of the transport system, or the quality of activities at activity sites.

The accessibility measures included aspects of the urban form of the areas where respondents lived and worked. The measures were the radial distance to activity sites, the exact location of activity sites and the density of activity sites around the household or workplace. The researchers controlled for sex and employment status of the respondents and the availability of cars to each individual.

Using household travel survey data, the researchers found a relatively weak relationship between an individual's accessibility level and their travel behaviour. This was contrary to what was expected. Socio-demographic variables (sex, car availability and employment) are more influential than spatial/environmental factors in affecting overall travel patterns. Nevertheless, high accessibility levels are associated with higher proportions of travel by non-motorised means, lower levels of automobile use, reduced travel distances for certain discretionary trip purposes (eg shopping and restaurants), and destinations within a more confined area.

Overall, accessibility has a greater impact on mode use and travel distance than it does on discretionary trip frequency. This suggests that higher density settlement with a mixture of land uses restricts the spatial range of travel and increases the choice of non-motorised modes.

The studies above involving the concept of accessibility to construct hypotheses produced similar results. Accessibility had a significant effect on mode use. High accessibility afforded by suburban form is associated with a higher proportion of travel by non-car modes.

Hanson and Schwab conclude that socio-demographic variables, not accessibility affects trip frequency. Handy found a positive relationship between accessibility and trip frequency. Handy's work shows that increasing accessibility to reduce car use may be illusory. It could induce an overall increase in travel including more car use as well as more non-car use. Crane (1996) found similar results to Handy in a simulation study based on micro-economic theory. The other results between studies using the concept of accessibility are consistent.

Different definitions of accessibility may explain the different results about trip frequency. For Handy accessibility includes an evaluation of the connectivity of the transport network. If it is easier to move around rather than just closer in radial distance, this may affect trip frequency. This shows that accessibility like urban form is a complex concept that is difficult to define for research purposes

Trip costs and benefits

Crane and Crepeau (1998) employed travel diary records of non-work trips in San Diego County, California to study mode use and suburban form. Aerial photographs and site visits established the characteristics of the road network around the household (0.8 km radius) where trips originated. Census data gave measures of household characteristics for the actual households completing the travel diaries.

Initial investigation of the data involved dividing neighbourhoods into 'grid-like', 'cul-de-sac' and 'mixed' road network patterns. The comparison of average trip characteristics between grid-like and cul-de-sac road networks showed that trips originating in culs-de-sac were on average shorter in duration, had a higher average speed and were of longer average distance than those originating in areas of grid street networks. Differences in the mean number of car trips and walking trips per household in the two neighbourhood types were not significant.

Crane and Crepeau state that a simple comparison of averages is incomplete. The number of trips undertaken result from decisions to maximise the benefits of moving location (travel), for purposes reflecting the characteristics of the person. Decisions are subject to the constraints of travel costs. Benefits and costs are products of trip lengths, modes, trip purposes, individual characteristics, and available time.

In regard to mode use, maximising the benefits of travel involves considering the positive attributes of the available modes, within the constraints of trip length and available time. The hypothesis is that the road network layout affects the relative costs or benefits between each of the different modes. For example, a grid layout might promote the use of walking by shortening the trip distance thereby reducing its cost.

Crane and Crepeau found that neighbourhood street pattern did not have any significant effect on the use of cars or walking, when controlling for land uses, urban density around the trip origin, trip length and characteristics of the person undertaking the travel.

Importantly Crane and Crepeau point out that other urban areas may reveal contrary data. They conclude that their study indicates the need for careful attention to the particular circumstances of each suburban area.

This study concerns one aspect of urban form – the suburban road layout. There is no analysis of the other aspects of urban form. The grid-like layouts and the cul-de-sac layouts of San Diego County may not be sufficiently different to affect travel behaviour. The findings do not refute the claim that suburban form affects mode use.

The study provides an insight into the decision making process people may use in 'choosing' a particular mode for a particular trip. However, other approaches (explained below) challenge the assumptions underlying the micro-economic approach used by Crane and Crepeau.

Bus service levels

Fleming and Pund (1994) suggest that urban form affects the quality of bus services in suburban areas. Ensuring that all people have a bus service within acceptable walking distance and operating at a good frequency, determines the number of bus routes required. Therefore, the road layout and the degree of accessibility it affords, defines the number of bus routes and the minimum level of resources that an operator must use to provide service. They contend that modern suburban planning generally acts to increase bus travel distance, reducing efficiency and with it bus service frequency.

The researchers compared the bus service network provided and the patronage levels achieved by the same bus service operator in three suburban areas (Blacktown, Campbelltown and Mt Druitt) in outer western Sydney. The bus operator applied the same operating policies to each of the areas. The three areas are similar in terms of population density, population age profile, car ownership and in the percentage mode use of public transport for the journey to work.

The average number of passengers per bus departing the bus-rail interchange in the afternoon peak period was substantially lower in Campbelltown (27 passengers/bus) compared to Blacktown (42 passengers/bus) and Mt Druitt (44 passengers/bus). A similar pattern occurred in off-peak patronage. The total number of people living within an acceptable walking distance of each bus route and the average for each route kilometre showed the same relationship. In Campbelltown the ratio of the route distance to the straight line distance at 4 km from the bus-rail interchange was 1.98:1. In Blacktown the ratio was 1.27:1 and in Mount Druitt 1.50:1.

The researchers suggest that the urban form of Campbelltown, particularly the road layout requires relatively more bus routes to maintain acceptable walking distance for residents to bus services. This led to lower frequency services. The bus routes in Campbelltown are also relatively indirect. Consequently, the use of bus services in Campbelltown in comparison to the other areas is also significantly less.

While this study aggregates data it suggests (while not proving), a way by which urban form affects travel mode use. Suburban form affects the level of bus services that a bus operator can provide while maintaining economic viability. The level of service provided is a critical factor in whether people use the bus transport. Research by Massot (1994) shows the positive relationship between frequency and use.

Residential location approach

Boarnet and Sarmiento (1996) ask whether the effect of suburban form on travel behaviour is actually due to people who are predisposed toward certain travel behaviours choosing to live in suburbs that support their travel behaviour.

The researchers investigated non-work travel recorded in travel diaries by residents of Greater Los Angeles. They modelled both non-work trip frequency and non-work distance travelled as a function of individual socio-demographic variables and suburban form near the respondent's home.

An alternate model substituted residential location choice for suburban form variables in order to test how well this explained travel activity. Residential location was seen as a function of workplace location; preferences towards commuting; preferences about non-work travel; preferences about residential area amenity; and land use characteristics. The suburban form variables were: population density; proportion of streets in a grid layout; and measures of retail, service and total employment. The suburban form variables reflected the approach of increasing density and encouraging mixed use development suggested as the solution to car dependency.

The researchers evaluated the capacity of the models to explain the non-work travel frequency and mode use of respondents. Suburban form variables were rarely statistically significant when considered directly with non-work travel (frequency and mode use). The residential location variables gave statistically significant relationships with non-work travel. Boarnet and Sarmiento conclude that suburban form is a factor in choice of residential location, which is determined in part by desired travel behaviour. People who value non-car travel will locate in suburban areas where they can undertake travel by non-car modes.

Boarnet and Sarmiento suggest caution interpreting the results of their study. There was a bias in sampling. The people studied lived in a heavily car dependent area of the Greater Los Angeles region. They were predominantly employed in business centres, earned middle incomes and therefore were heavily reliant on automobiles. Suburban form may have little effect on travel mode use in urban areas with little non-car transport and amongst people heavily dependent on car travel. In these areas personal preference is likely to be a more obviously present.

There is a more fundamental question about the conclusion reached by the researchers. They assume that attitudes are set. They do not consider whether living in a location with a suburban form that encourages travel by non-car modes causes change in attitudes. Information about previous residential location and travel behaviour would strengthen the validity of their conclusion.

Nevertheless, the study suggests a logical and plausible way that suburban form affects mode use. A person's preference for certain travel behaviours inclines them to choose a residential location (with a certain suburban form) enabling travel using desired modes.

Attitudes approach

Kitamura, Mokhtarian and Laidet (1997) collected demographic, socio-economic, land use, street network and public transport information on five San Francisco Bay Area neighbourhoods. They found that demographic and socio-economic factors determined the amount of travel undertaken. However, use of non-car modes was strongly associated with suburban form characteristics – higher density, more mixed-use development, accessibility to activities and non-car transport services and facilities.

Next the researchers assessed whether the apparent association between neighbourhood characteristics (including suburban form variables) and travel is generated by attitudinal factors. The neighbourhood characteristics measured were: mixed use development; density; pedestrian and bicycle facilities; housing choice; accessibility to activities and public transport; and perceptions of neighbourhood quality. The researchers asked respondents 39 attitude questions relating to: private vehicles; ride sharing; public transport; urban transport; time; environment; housing; and the economy.

The researchers found that attitudes correspond to experience and therefore reflect the neighbourhood characteristics of where people live. There was a clear association between attitudes and travel patterns which was stronger and perhaps more direct than the association of neighbourhood characteristics with mode use and travel activity.

The researchers conclude that policies directed at altering suburban form such as promoting higher densities and mixed uses may not alter travel patterns significantly unless attitudes (particularly to car travel) are also changed. They rightly recognise that they have not researched the development of attitudes in relation to suburban form. This is also a fundamental aspect missing in the residential location approach. Kitamura, Mokhtarian and Laidet suggest that further research to answer questions such as: how are attitudes formed; how they interact with travel experience; how they relate to choice of residential and job location, housing unit and vehicle ownership; how observed associations between attitudes and neighbourhood characteristics are formed; and how attitudes can be affected by suburban form.

Towards a theory of suburban form and travel mode use

Each of the above studies on the effect of suburban form on travel activity investigates a different aspect of suburban form. Is integration into a theory of how suburban form affects mode of travel, possible?

There are some contradictory results, with two studies (Boarnet and Sarmiento and Crane and Crepeau) suggesting that urban form has no effect on mode use. However,

both sets of authors admit that their findings may be different in other urban areas. The method of both these studies is limited by the narrow way that urban form is measured. Handy (1997) sees this as a general reason for the variance in results between studies.

The first point in favour of an integrated theory is that all studies accept and provide further evidence for the connection between travel activity and social, economic and demographic characteristics. In general, the studies see travel activity involving decisions about whether to travel (trip generation or frequency) and then decisions about mode use. Results show that social, economic and demographic characteristics strongly affect travel frequency, but with other factors also affecting mode use.

A theory of how suburban form affects the mode of travel must place considerable weight on social, economic and demographic characteristics of people both affecting mode use and interacting with other factors. This is the common point of entry to the theoretical position of each. The five approaches fall into two main categories: where urban form affects the range and quality of options for travel by modes; and where urban form affects mode use through positive attitudes towards, and therefore propensity to use specific modes.

Integrating the accessibility, benefits and costs and bus service levels approaches

There is a common base in economic theory with the costs and benefits approach used by Crane and Crepeau and Handy's use of discrete choice theory. Crane and Crepeau use a standard micro-economic conception of travel activity. It assumes that travel involves a rational decision with all factors measured in a common unit, which is time or distance. In discrete choice theory as used by Handy, travel activity involves rational decisions between possible choices on the basis of the costs and benefits afforded by those choices. In both approaches, suburban form brings costs and benefits to the decision of which mode to use.

A point of difference between Crane and Crepeau on the one hand and Handy and Hanson and Schwab on the other, is that Crane and Crepeau focus on one suburban form factor (suburban road layout), while the other two studies take a more general view of suburban form. The difference in results may follow from the scale of analysis. Nevertheless, all three studies identify the same way in which suburban form may affect mode use. Suburban form through the distance to activities, the nature of the activities available, the alternative means of accessing activities, etc, affects the range and quality of available choices (options) to use alternative modes of travel. This affects decisions about the relative use of the available modes.

The study by Fleming and Pund is in line with this conception. Suburban form affects the level of bus service provided. The level of service is a critical element in people deciding whether bus travel is the more attractive mode. Suburban form affects the range and quality of available choices.

Integration of the residential location and attitudes approaches

The residential location and the attitudes approaches both conclude that the association of attitudes with mode use was stronger and perhaps more direct than the association between mode use and suburban form.

Boarnet and Sarmiento do not record the same significant effect of suburban form on mode use that Kitamura Mokhtarian and Laidet find. The likely reason for this difference is (the previously identified) bias in the data used by Boarnet and Sarmiento. The other difference is that Kitamura Mokhtarian and Laidet are cautious about drawing conclusions about the interaction of people's attitudes and suburban form. Both studies find a relationship between attitudes and suburban form variables.

Boarnet and Sarmiento are definite about the way that suburban form affects travel behaviour. They conclude that suburban form is a factor in choice of residential location. People with positive attitudes to non-car travel will locate in suburban areas where they can undertake travel in the way they desire. Other research supports this position (Prevedouros 1992).

Boarnet and Sarmiento view the interaction between attitudes and the environment as linear, from attitudes to behaviour. Kitamura Mokhtarian and Laidet identify the possibility that the environment may also affect people's attitudes and behaviour. Not only may people move to areas with suburban form that parallel their attitudes, but also living in an area with a particular suburban form could change their attitudes. The mutual dependence of attitudes towards travel and travel behaviour were suggested by research in the late 1970's (Dobson et al 1978; Tardiff 1977).

The two studies reviewed indicate a way that suburban form affects mode use through people's attitudes, but do not provide detail of how this precisely occurs. Nevertheless, this is a useful insight. A review of other research on travel attitudes and travel behaviour, not specifically concerned with suburban form may assist in providing the detail of how this occurs.

Developing a theory

In general between the eight studies reviewed there are three consistent theoretical positions on the way that suburban form may affect mode use. The first is that the social, demographic and economic characteristics of individuals affects travel activity relatively independently of suburban form. The second is that suburban form affects the range and quality of choices about alternative modes of travel and in the context of rational decision making the relative use of travel modes. The final position is that suburban form provides opportunity for, or constrains behaviour generated by attitudes about travel.

Are any of these three theoretical positions necessarily contradictory with each other? Social, economic and demographic factors are central to travel activity. These factors

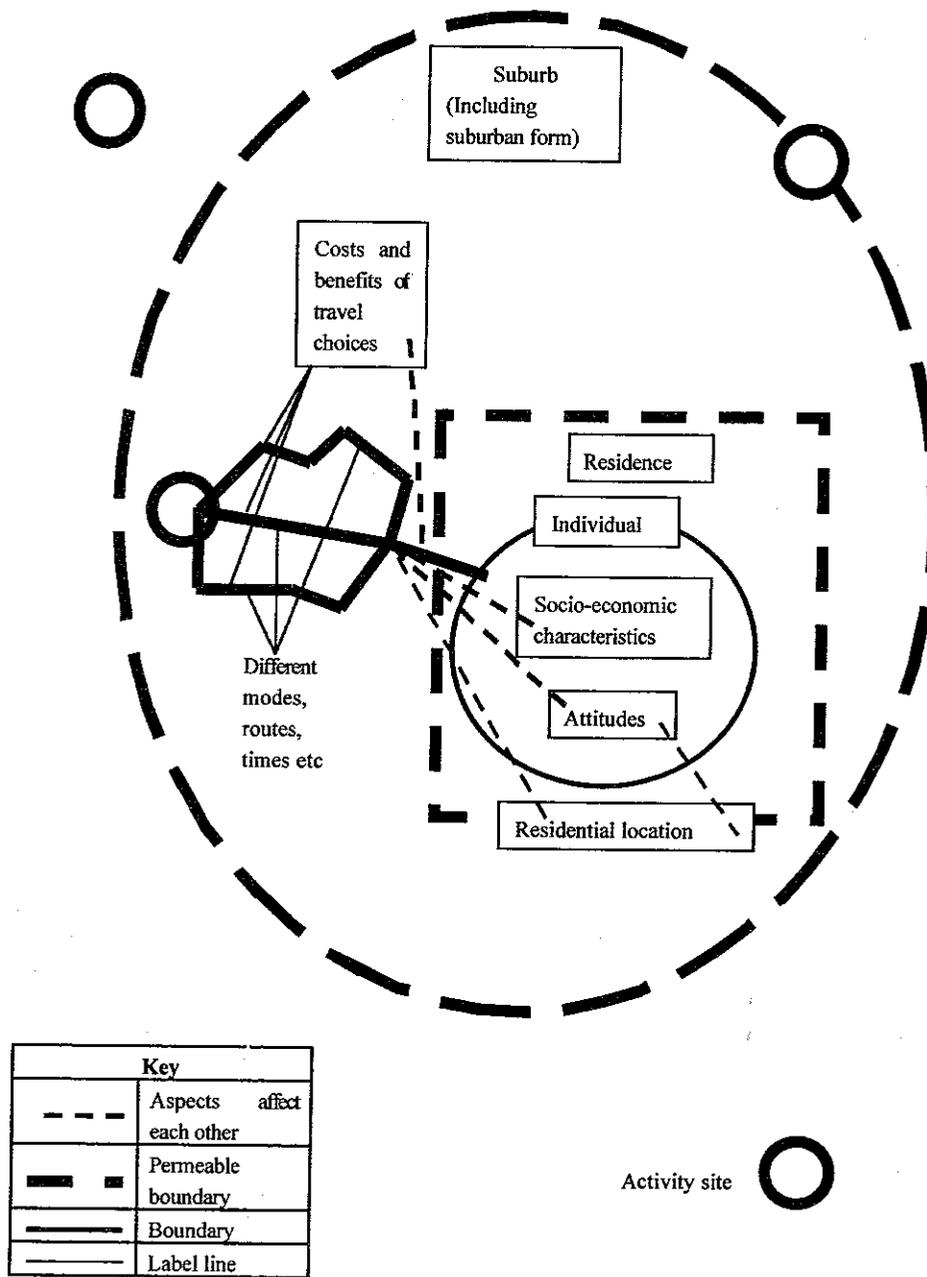
have a major effect in the generation of people's attitudes to mode use. Similarly, they affect the range and quality of choices available to a person and the judgements made about mode use afforded by suburban form. There is no difficulty in suggesting a relationship between social, economic and demographic factors and the choices for travel by different modes afforded by suburban form, as well as attitudes to mode use.

There is a potential contradiction between the choice position and the attitudes position. The choice position sees travel as a derived demand and the travel undertaken depends on the activity first and then on the evaluation of costs and benefits of travel. The attitude position diminishes the concentration on rationalism as the basis of decision making. It questions the use of terms such as choice and decision making. Behaviour may be less consciously rational.

There are also strong similarities. Both positions see suburban form as the environment and therefore somewhat independent of mode use behaviour which is a function of the individual. This common view of human behaviour allows integrations of the two positions. The theory of urban form and mode use is represented in **Figure 1**. Mode use may be both a result of a rational process of weighing options and/or a less conscious reaction in line with attitudes held. Most often it is likely to be both. Whatever combination of these two processes leads to mode use behaviour, that behaviour will be undertaken by individuals with certain social, economic and demographic characteristics, which will affect that behaviour.

A major benefit of this synthesis of theoretical positions is that it precludes physical determinism. Suburban form does not cause a person's mode use. Suburban form provides opportunities and constrains mode use, but it does not define behaviour. Behaviour is a characteristic of people not of the urban environment.

A theory attempting to deal with the complexity of mode use behaviour must also take account of the interdependence of the factors. While mode use is a consequence of attitudes so will the behaviours made possible through the suburban form affect attitudes held.



Source: major refinement of Frank and Pivo (1994)

Figure 1. Theory of Suburban Form and Travel Mode Use

Further research and guidance for practitioners

These steps towards a theory show the ways that suburban form may affect travel mode use. It is not possible at this stage to apply weights to the relative strengths of these ways. Although there are research results that suggest attitudes more strongly affects mode use than suburban form alone (Kitamura Mokhtarian and Laidet 1997). The interaction between the aspects has not been appreciated let alone researched (Handy 1997; 1996a).

The definition of suburban form and the way that it is measured remains a particular difficulty for further research. This is one aspect of the theory requiring further development.

Accessibility like urban form is a complex concept that is difficult to define for research purposes. This raises difficulties in using accessibility as a concept to define the range and quality of choices afforded by suburban form

There are also other theoretical positions on travel activity that could be included in the theory. Handy (1997; 1996a) mentions the activity based approach which examines travel behaviour in the context of the activities that people undertake in their daily lives. Within the bounds of my study, I found no research using this approach to suburban form and mode use was found.

The theory is useful in guiding further research and in the development of travel demand management techniques. There is great interest in techniques based on urban planning for altering suburban form and increasing non-car mode use. However, techniques that aim to change attitudes about travel by different modes should also receive prominence

Finally, the theory shows the complexity of the processes that lead to people's travel mode use. Simplistic paradigms that rely on the general application of some set of physical characteristic in suburban areas to manage travel demand will fail, because they do not deal with the complexity of the interactions leading to the way people behave

References

- AUSTROADS (1998) *Cities for tomorrow: Integrating land use, transport and the environment - Resource document and better practice manual* Sydney: AUSTROADS
- AUSTROADS (1995) *Travel demand management guidelines* Sydney: AUSTROADS
- Banister, D (1994a) Reducing the need to travel through planning *Town Planning Review* 65 (4), 349-354
- Banister, D (1994b) *Transport planning: In the UK, USA and Europe* London: E&FN Spon

- Boarnet, M G & Sarmiento, S (1996) Can land use policy really affect travel behaviour? A study of the link between non-work travel and land use characteristics *The University of California Transportation Center Paper* 235
<http://socrates.berkeley.edu/~uctc/papers.html>
- Breheny, M (1994) Transport planning, energy and development: Improving our understanding of the basic relationship pp 89-95 of Bannister D (ed) *Transport and urban development* London: E&FN Spon
- Breheny, M 1993 Planning the sustainable city region *Town and Country Planning* 29(4):71-75
- Cervero, R (1993) *Transit-Supportive Development in the United States: experience and prospects* Washington DC: Federal Transit Administration
- Crane, R and Crepeau, R (1998) Does neighbourhood design influence travel?: a behavioral analysis of travel diary and GIS data *Transportation Research Part D Transport and Environment* 3 (4), 225-238
- Crane, R (1996) Cars and drivers in the new suburbs: Linking access to travel in neotraditional planning *Journal of the American Planning Association* 61 (1), 51-61
- Department of Housing and Regional Development (1995) *Australian Model Code for Residential Development* Canberra: Department of Housing and Regional Development
- Dobson, R, Dunbar, F, Smith, C J, Reibstein, D and Lovelock, C (1978) Structural models for the analysis of traveler attitude - behavior relationships *Transportation* 7, 351-363
- Fleming, R and Pund, G (1994) The impact of the planning of urban areas on the use and attractiveness of local bus services pp265-282 of *Proceedings 17th Australian Road Research Board Conference Part 7* Melbourne: Australian Road Research Board
- Frank, I D and Pivo, G (1994) Impacts of mixed use and density on utilization of three modes of travel: Single-occupant vehicle, transit, and walking *Transportation Research Record* 1466:44-52.
- Handy, S (1997) *Travel behavior - land use interactions: an overview and assessment of the research* unpublished, Austin: School of Architecture University of Texas at Austin
- Handy, S (1996a) Methodologies for exploring the link between urban form and travel behavior *Transportation Research D* 1 (2), 151-165
- Handy S (1996b) Understanding the link between urban form and nonwork travel behavior *Journal of Planning Education and Research* 15, 183-198.

Handy, S (1996c) Urban form and pedestrian choice: Study of Austin neighbourhoods *Transport Research Record* 1552, 135-144

Handy, S (1993) Regional versus local accessibility: Implications for nonwork travel *The University of California Transportation Center*
<http://socrates.berkeley.edu/~uctc/papers.html>, 11 Jan 1998

Hanson, S and Schwab, M (1987) Accessibility and intraurban travel *Environment and Planning A* 19, 735-748

Hanson S (1982) The determinants of daily travel-activity patterns: relative location and sociodemographic factors *Urban geography* 3 (3), 179-202

Kaufman, C and Morris, W (1995) Transit supportive urban design in National Capital Planning Authority *Transit Supportive Development - Benefits and Possibilities* Occasional Paper Series Paper 1 Canberra: National Capital Planning Authority

Kitamura, R Mokhtarian, P and Laidet, L (1997) A micro-analysis of land use and travel in five neighbourhoods in the San Francisco Bay Area *Transportation* 24, 125-158

Massot, M (1994) Sensitivity of public transport demand to the level of transport services in French cities with underground *Transport Reviews* 149 (2), 135-149.

Morris W (1997) Sustainable growth management and new urbanism - new directions for planning in the post-industrial economy *The changing agenda for planning NSW Division annual conference - Conference papers RAPI NSW Division* Armidale NSW: RAPI NSW

Prevedouros, P D (1992) Associations of personality characteristics with transport behavior and residence location decisions *Transportation Research A* 26A, (5), 381-391

Roads and Traffic Authority of NSW (1994) *State Road Network Strategy: technical Report for Public Discussion* Sydney: RIA

Steiner, R L (1994) Residential density and travel patterns: review of the literature *Transportation Research Record* 1466, 37-43

Tardiff, I (1977) Causal inferences involving transportation attitudes and behavior *Transport Research* 11, 397-404

Transit Cooperative Research Program (1995) An evaluation of the relationships between the transit and urban form *Research Results Digest Number 7* Washington USA: Transportation Research Board

Urban Design Advisory Service (1998) *Urban form: An urban design approach for understanding the urban form of regional centres* Sydney: Department of Urban Affairs and Planning