Activities, accessibility and mobility for individuals and households

D. Olaru, N. Smith & T. Ton
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

Abstract

Planning for accessibility is a complex task because myriad spatial and temporal ties mark individual mobility needs and patterns. This research uses activity spaces and travel time expenditure to indicate opportunities for participation and interaction, within specified transport and urban services environments. The analysis, conducted at individual and household levels, reveals significant differences across gender, age, employment, ethnic background and restricted mobility groups, as well as among households at various stages of their lifecycle.
Keywords: accessibility, mobility, life cycle, activity space, travel time.

1 Introduction

With an increasing proportion of the world's population living in urban areas efforts to improve the "liveability" of cities are important. To achieve such ends, transport planning seeks to increase accessibility to desired activities, goods and services for urban populations, without escalating the negative environmental and social impacts of growing motor vehicle traffic. This is a challenging task as complex spatial-temporal ties mark individual mobility patterns, accessibility needs which are reflected in activity scheduling and values of time.

It is helpful in this context to understand that, while there can be large variation in people's tastes and preferences, there are also similarities in access needs and mobility options between population groupings. In particular lifecycle stages affect both travel needs and options. For example, families with young children have to juggle their activities, and elderly people face mobility constraints. Equally, cultural background and gender can lead to specific access needs or limit mobility options.

This study investigates activity spaces (combining accessibility for whom and to what) and travel time across population groups at different stages of life cycle, with different ethnic background, and degrees of mobility restriction.

2 Activity spaces and factors affecting them

Significant work conducted in the previous decades has suggested that land-use (LU), characteristics can have measurable impacts on travel behaviour [2], [7], [15], [19]. Accessibility has been expressed via sets of measures of varied form and content which may help overcome myopia in planning – Harris [10].

Here we apply activity spaces as measures to investigate the relation between accessibility (e.g., [8], [13], [20]) and travel. The action/activity space concept is based on a broad determination of space-time behaviour. In this research we include all locations visited by a traveller, of which the traveller has personal experience, the so-called *repertoire* of individual's daily activities [5], [6], [17], [18]. The activity space is closely related to individual accessibility and reflects the satisfied needs of the individual within the space-time and budget constraints.

The activity space is an approximate measure of the size of the individual's mental map (locations known to him/her [3], [4]) correlated with the costs of accessing different opportunities. In this respect, it reflects all three processes influencing accessibilities: household scheduling of time-space budgets; the nature of the transport system, and the time-space organisation of accessed services - Church *et al.* [1], Harvey and Taylor [9]. The latter two elements represent urban form, features of the environment and quality of transport services, while the first reflects the socio-demographic characteristics of the individuals/households and their activity routines. Both work and non-work activities are included in the measure. The position of the centre of gravity of an activity space and the spread around it illustrate the degree of accessibility enjoyed by an individual, accounting for the importance of different locations in the household activities and available transport supply.

Household and individual characteristics might be expected to influence activity spaces in some of the following ways:

- Households with children may have more activities than those without children or other carer activities;
- Single-parent families may tend to have their travel closer to home than other households;
- Households with high income, located in the outer suburbs may be likely to have larger activity spaces than households in the city;
- Households without car may have their activity space reduced;
- Women may have reduced activity spaces, as a result of their "multiple roles and primary responsibilities for child care and domestic work, more constrained opportunities in paid employment and a much greater likelihood of being engaged in part time and/or casual employment, usually local" - Hine and Grieco [11];
- Older retired people may have smaller activity spaces than working age people.

3 Data sources and modelling techniques

To enhance our understanding of the mobility and accessibility needs of people at different lifecycle stages, this paper proposes a methodology which combines multivariate analysis and data visualisation. Using Sydney - an Australian city of some four million people and a multicultural population - as a case study, the paper will report on the application of the proposed methodology to pooled data, expanded to provide estimates for all Sydney households, from a household travel survey (HTS) 1997-2002.

Several measures may be used for activity space Schönfelder and Axhausen [18]. We applied the relatively simple derivation of an ellipse representing the part of the urban area visited by an individual or household on a certain day. The ellipse was calculated by the covariance matrix of all ordered activity locations of an individual/household [18].

The coordinates of the activity locations were weighted by the frequency of visits, deriving the centre of gravity (cg) of activities, which is at the centre of the ellipse. The dispersion of the activities as well as the standard distance from cg to all the activities was also determined. The area of the ellipse was analysed to illustrate the use of urban space. We compared this among individuals and households (between groups defined by gender, age, employment, car use, life cycle/household type) as well as intra-individual (weekday versus weekend).

Analysis of variance – AN(C)OVA modelling techniques where used to test a series of hypotheses formulated by the authors and presented in sections 3.1 and 3.2. These considered how activity spaces and travel time and distance were affected by socio-economic characteristics of individuals and households. At the individual level, the factors used in the model were: gender, language barrier, possession of driving license, stated restrictions in mobility, and employment status, with age and personal income as covariates. At the household level, the model included the type of household and household income as covariate.

3.1 Hypothesised individual level determinants for activity space and travel

Women: although women have entered the labour force in the last decades, an unequal distribution of child care and domestic activities between partners continues to put more time pressure on women. Consequently, women's travel arrangements must allow them to combine all the activities they need to perform. Differences in activity spaces and travel time expenditure are envisaged.

Main language: is related to mobility. Individuals not speaking English, in an English speaking environment, may need assistance when travelling outside the home. This could lead to differences in employment, reduced driver status (and vehicle ownership) for non-English speaking persons, travel over shorter distances, and smaller activity space, based around home.

Employment: many studies have found that full time employees (FT) tend to spend more time in travel than part time or unemployed people. We also expect noticeable differences in other labour status categories such as study, retirement, housekeeping or voluntary work.

Seniors: if dependent, are almost never leaving home; if independent, they make shorter distance and time trips, compared with working age adults. If engaged in community activities and family, their travel increases, especially during weekends. The quality of the neighbourhood, friendly for walking, providing essential amenities, is essential.

Youth: young people's freedom to travel is seldom restricted; they are likely to drive longer distances, especially during weekends. Chaining is not crucial for their time budget; they are expected to spend more time on travel (out-of-home activities) and to have larger activity spaces.

Car Availability: As Australia is a "car-reliant" society Hinde and Dixon [12], the car availability is expected to have high impact on the activity space. At the same time individuals who experience restrictions in mobility of different nature (physical, psychological, financial, circumstantial, etc.) are likely to limit their daily universe at the neighbourhood area, having significantly smaller activity spaces than the other un-restricted categories.

Finally, *Weekdays/Weekends*: During weekdays, there are two anchor points of daily mobility, home and work place; but during weekends most activities are for subsistence, shopping, recreation, frequently joint activities with family. It is therefore expected that activity spaces will indicate differences. Similarly, travel time expenditure is marked by the different routine weekday-weekends.

3.2 Hypothesised household level determinants for activity space and travel

Life cycle stages have impact on the activity space, mainly due to the different mobility needs of the households with different groupings, occupations and interests over a lifetime:

Individuals living by themselves, unless suffering disabilities including those associated with old age, have less restrictions and their potential activity space may be large; their travel time expenditure may be higher, mainly for commuting, as their daily schedule of activities are not dependent on anybody else's and thus less fragmented.

Families with school-age children: travel and drive more (particularly when trip chaining is involved), and the distance travelled for non-commuting is significantly higher than for other families; where they live does matter: more families with children are found in the outer suburbs. We also expect greater activity spaces for families with school children and more travel over weekends.

One Parent Families: are probably the most travel challenged category, as there is no possibility to negotiate the share of activities/responsibilities with anyone; when a car is not available, the activity space is small, mainly gravitation around home and workplace; a high number of trips per traveller (with chaining) is hypothesised, combined with a lower travel time as numerous activities need to be covered within the same time budget.

Senior families: are spatially and temporally more restricted, especially because difficulties associated with driving and physical abilities; they travel less and for different reasons than the other categories (health, entertainment). Distinctions must be made between independent, senior people, some still in the workforce and the senior families in need of personal care.

4 Findings

4.1 Individuals' activity space and travel

Table 1 presents averages for daily travel time and distance, distances between all activities to their centre of gravity, the position of the centre of gravity with respect to home location, and the activity space differentiated by gender, English speaking, driving licence, restricted mobility.

Table 1: ANOVA results based on 4 factors and 2 covariates.

Group	Period	Daily travel time (min)	Daily travel distance (km)	Standard distance (km)	D home-cg (km)	Activity space (km^2)
Males	Weekday	100	52	5.7	6.9	244
	Weekend	90	48	5.3	7.0	258
Females	Weekday	85	41	4.3	5.2	170
	Weekend	84	44	4.9	6.8	253
English-speaking	Weekday	94	48	5.2	6.2	224
	Weekend	86	48	5.3	7.2	266
Non-English	Weekday	91	44	4.9	5.9	192
	Weekend	87	44	5.0	6.7	246
Driving license	Weekday	94	49	5.3	6.4	222
	Weekend	89	49	5.3	7.2	268
No license	Weekday	79	29	3.2	3.8	114
	Weekend	73	30	3.7	5.1	185
Mobility restricted	Weekday	72	34	3.6	4.6	143
	Weekend	70	37	4.7	6.5	244
Un-restricted	Weekday	84	42	4.5	5.5	208
	Weekend	83	44	5.0	6.9	293

Table 2 makes the distinction among various labour statuses for the same variables of access and mobility. We built separate models for weekday and weekend. Due to space limitations, the detailed fit values and parameter estimates of multivariate tests have not been reported here. All main effects of the tested factors and covariates are statistically significant (p=0.000), but not their interactions.

The analysis results show:

Women Compared to Men: men travel further (11 km more during weekdays and 4 km more during weekends) than women, for longer periods of time (15 min in weekdays, respectively 6 min in weekends), and their weekday activity space is 1.4 times larger than for women. Women travel more around home, and for shorter time. On weekdays women use significantly more public transport (PT) and walk more than men. Their workplace is closer to home (10 km compared to 12 km for men) and their activity space is reduced (about 70% of men's). The smaller activity space may also be linked to the lack of availability of transport services to enable them to take opportunities beyond the local area.

Table 2: ANOVA results based on 1 factor and 2 covariates.

Group	Period	Daily travel time (min)	Daily travel distance (km)	Standard distance (km)	D home-cg (km)	Activity space (km^2)
Full-time	Weekday	105	55	6.3	7.6	259
	Weekend	97	52	5.7	7.5	304
Part-time	Weekday	87	46	4.6	5.3	192
	Weekend	85	46	4.9	6.9	230
Unemployed	Weekday	82	36	3.5	3.9	125
	Weekend	76	43	4.8	5.8	190
Student	Weekday	64	30	3.1	3.7	108
	Weekend	79	40	4.5	6.4	181
Pensioner	Weekday	72	31	3.3	4.2	152
	Weekend	72	35	4.1	5.7	217
Housekeeper	Weekday	73	36	3.3	3.9	139
	Weekend	75	43	4.9	6.6	222

Main Language Not English: Persons with a main language other than English have reduced activity spaces (85% of the English speaking population) and travel time as they face some interaction and integration problems. They are not as well represented in the labor force (30% of the non-English employees are full time, compared to almost 40% of native English speakers; 9% are involved in housekeeping activities, compared to only 5% of English speaking people). Their schedule is bound to house and children. During weekends, however, the common scheduling enables their families to access further facilities, and the language differences become minor.

Employment's positive impact on activity space and travel time expenditure found here is consistent with much research conducted previously. On a weekday, FT employees travel 18 min and 10 km more than the part-time employees and their activity spaces are 1/3 bigger. This is not surprising if we consider that they commute at 12 km compared to 8 km distance for part-time employees. The smallest activity space, travel distance and time corresponds to students, followed by pensioners, the unemployed, and housekeepers.

Age: People over 60 use less the car than the other age groups; public transport and walking are higher, although adequate infrastructure is not always in place. The high use of walking (27% of all trips) and PT (9%) reduces the travel distance to 32 km per day and activity spaces around their houses ($161km^2$). People younger than 20 years display similar activity spaces and mobility characteristics

Car Availability: The linkage between travel time expenditure and car use have been widely explored in the literature (e.g. Lu and Pas [14]) and in this study a positive relation is found between activity space and driving license readiness. It is useful for accessibility planning to note that the activity space for car drivers is almost twice as much as for captives of public or non-motorised transport. The relation holds for daily travel distance (20 km and 15 min more for car drivers) and it is extended over weekend.

The group with *restricted mobility* suffers for a variety of reasons (lack of driving license or car ownership, disabilities, etc.) and finds difficult accessing public transport services as well. Their activity space is 2/3 of the size of people without restrictions; they spend in average 12-13 min less than the un-restricted people in travel and at shorter distances.

Income & age: A positive, although not strong, relationship was found between activity spaces, travel time, and income for weekday mobility. The relation is less significant for weekend. The second covariate, age, had a significant negative impact on all variables for weekday, but not for weekend. The single interaction found in the models was between gender and license for weekdays.

Remarkably, the activity spaces increase for all categories during weekend, even if the travel time expenditure decreases. This may well be explained by the temporal spread of activities during weekends, avoiding the typical congestion situations at peaks during week. Gender and language group differences are not prominent during weekend activities.

4.2 Household activity space and travel

Table 3 presents the activity spaces and travel by household type.

Travel time expenditure is related to household characteristics and correlated with the activity space. Activity space includes the most attractive destinations household members can reach given the travel time. In development of a constant preferred travel time budget, increased accessibility may be translated in increased activity spaces as the individual/household pushes the borders of their daily universe of activities out further.

Families with Children: Although the families with children make the highest number of trips (double that of other couples and triple that of single people) and cover an extensive urban space, they do not spend the highest amount of time on travel (actually 18 min less than single person households and 10 min less than other families). This amount is reduced because of the interaction between family members and trip chaining. One member of the family may travel less by having somebody else travelling more, linked to the existing scheduled trips.

Couples without children: have a high car use that enables them to combine their paid work with leisure and other activities. They are able to reach destinations further (activity space 50% larger than single person households) and they have one of the largest travel time expenditure/person (80 min in weekdays, 75 during weekends).

Single Person Households: Young people have the highest travel time expenditure and distance and the senior people alone have the smallest activity spaces and travelled distance.

4.3 Spatial mapping

The aggregate mapping of activity spaces and travel time expenditure has shown two different tendencies/patterns:

Table 3: ANOVA results based on household structure.

Category	Period	Number of trips	Average trip time (min)	Daily trip time/ person (min)	Average trip distance (km)	Standard distance (km)	Acti-vity space (km^2)
Alone	Week day	5.7	19	88.4	7.6	4.1	187
	Week end	5.0	19	84.4	8.9	4.2	233
Couple	Week day	9.4	19	79.8	9.5	5.8	287
	Week end	8.1	21	74.9	10.7	5.3	309
Couple + children	Week day	17.7	18	70.0	9.3	6.1	265
	Week end	14.5	21	64.5	11.2	6.0	304
Sole parent + children	Week day	12.6	16	69.3	7.5	5.1	235
	Week end	9.7	20	67.3	9.7	5.4	336
Other	Week day	13.9	18	67.8	7.8	5.2	182
	Week-end	11.9	29	66.8	9.0	6.0	359

- for weekdays, distinguished by their strong commuting imprint, the activity spaces for "central" suburbs are significantly smaller than for outer suburbs, far from CBD; the quasi-radial disposition of the traffic zones with similar activity spaces is interrupted by a few exceptions of more self-contained areas;
- this clustering almost disappears for weekend activities, the areas with small activity spaces alternating with those of large urban expansion of activities; the activity spaces are larger during weekends; if during weekdays, the spatial repartition is talking about the shape and performance of transport services, during weekend the (public) transport services repartition is overtaken by scattering due to life and activity circumstances;

Similar mapping is observed for travel time expenditure and for activity spaces and travel time at the household level.

But some information is lost when data is collapsed. There is considerable variability for individuals and households with the same home travel zone, according to their socio-demographics. Mapping done for all these groups is helpful to overcome the main shortcoming of geographical access where all population in an area experience the same opportunities regardless their needs.

The study investigated an accessibility measure to characterise the prevailing conditions in urban areas accounting for the individual/household needs. There are multiple levels of interest considered – zonal, derived from socio-economic

characteristics (family structure, income, education, employment, language), and days of week. Activity space is one of those measures of exclusion we particularly examined and correlated with travel time expenditure.

This study found significant differences between groups defined by gender, mobility restricted, language, employment, and driving license after accounting for income and age.

Our research extended the ellipse derivation of activity spaces at the household level where interaction between members occurs. The family structure/stage of their life cycle is prominent in its influence on the extent of daily urban space used for activities.

5 Implications and future research

From the wide spectrum of implications for planning approaches from the results reported we consider the following relevant:

- Neighbourhood-level transport planning - In the outer suburban locations there are significant non-motorised trips and the pedestrian convenience is determinant of the mode choice; therefore, providing the opportunities within the home travel zone would facilitate the uptake of walking and cycling; also, appropriate PT provision may lessen the negative impact of the reduced physical and geographical accessibility some areas witness;
- Improving the land use mix would influence the chaining of activities and provide more opportunities for "tied-to-home" population groups;
- Where the socially isolated and low accessibility groups are, a better correlation of PT can accomplish much; where the groups with similar non-accessibility are clustered, the task of good fit between public transport schedules and vehicle types is easier [11]; Where the areas with similar access, or activity spaces are scattered, planning for smarter "reach and mobility" solutions is called for; most outer suburban residents have lower PT accessibility compared to the CBD; connecting car or walk/bike use with PT is essential for enhancing the access.

There are several limitations of the study the authors will address in the future:

- The activity space defined by ellipses is higher than the area of the convex polygon connecting all visited locations; even if the measure is correlated to the daily travelled distance and to the travel time expenditure, providing a useful indication of the opportunities for participation and interaction at the individual level, a minimum convex polygon may result in more accurate estimates of activity space [18];
- Currently the research covers most but not all households and uses simple lifecycle groupings. More detailed lifecycle analysis would be of value;
- Correlation between more traditional accessibility measures and the activity spaces is a topic worth investigating.

However, we believe the current study findings already show that if research ignores gender, age and life cycle stages in examining travellers and travel it may limit its usefulness for planning. Mapping accessibility needs and mobility patterns to the lifecycle and cultural mix of populations could allow planning

treatments to encompass such issues. This type of analysis has "triple bottom line" implications. It informs about various options likely to reduce motor vehicle use in different groups and more importantly, it can easily inform actions and policies to improve transport equity.

Acknowledgements

We thank the Transport and Population Data Centre in the NSW Department of Infrastructure Planning and Natural Resources for access to their Household Travel Survey data.

References

[1] Church, A., Frost, M., Sullivan, K., Transport and social exclusion in London, *Transport Policy*, **7**(3), pp. 195-205, 2001.
[2] Crane, R. & Crepeau, R., Does neighbourhood design influence travel?: A behavioural analysis of travel diary and GIS data, *Transp. Res.D* **3**, pp. 225-238, 1998.
[3] Dijst, M., Two-earner families and their action spaces: a case study of two Dutch communities, *GeoJournal*, **48**(3), pp. 195-206, 1999.
[4] Downs, S. & Stea, D., *Maps in mind: Reflections on Cognitive Mapping,* Harper & Row, New York, 1977.
[5] Gärling, T., Introduction-Conceptualizations of Human Environments, *Journal of Environmental Psychology*, **18**, pp. 69-73, 1998.
[6] Golledge, R.G. & Stimson, R.J., *Spatial behavior: A geographic perspective*, The Guildford Press, New York, 1997.
[7] Handy, S.L., Understanding the link between urban form and non-work travel behaviour, *Jour. of Planning Educ. and Res.*, **15**, pp. 183-198, 1996.
[8] Handy, S.L. & Niemeier, D.A., Measuring accessibility: An Exploration of Issues and alternatives, *Environ. and Planning* A, **29**, pp. 1175-1194, 1997.
[9] Harvey, A.S. & Taylor, M.E., Activity settings and travel behaviour: A social contact perspective, *Transportation*, **27**, pp. 53-73, 2000.
[10] Harris, B., Accessibility: Concepts and Applications, *Journal of Transportation and Statistics*, Sept/Dec, pp. 15-30, 2001.
[11] Hine, J. & Grieco, M., Scatters and clusters in time and space: implications for delivering integrated and inclusive transport, *Transp. Policy*, **10**, pp. 299-306, 2003.
[12] Hinde, S. & Dixon, J., Changing the obesogenic environment: insights from a cultural economy on car reliance, *Transp. Research D*, **10**, pp. 31-53, 2005.
[13] Kwan, M.P., Space-time and integral measures of individual accessibility: a comparative analysis using a point-based framework, *Geog. Analysis*, **30**, pp. 191-217, 1998.
[14] Lu, X. & Pas, E.I., Socio-demographics, activity participation and travel behaviour, *Transp. Research A*, **33**, pp. 1-18, 1999.

[15] Mackett, R., Land use transportation models for policy analysis, *Transportation Research Record 1466*, pp. 63-70, 1994.
[16] Mokhtarian, P.L. & Chen, C., TTB or not TTB, that is the question: a review and analysis of the empirical literature on travel time (and money) budgets, *Transportation Research Part A*, **38**, pp. 643-675, 2004.
[17] Schönfelder, S., Some notes on space, location, and travel behaviour, *1st Swiss Travel Research Conference*, Monte Verita, March 1-3, 2001.
[18] Schönfelder, S. & Axhausen, K.W., Activity spaces: measures of social exclusion, *Transport Policy*, **10**, pp. 273-286, 2003.
[19] Srinivasan, S. & Ferreira, J., Travel behaviour at the household level: understanding linkages with residential choice, *Transp. Res. D*, **7**, pp. 225-242, 2002.
[20] Weber, J., Individual accessibility and distance from major employment centres: An examination using space-time measures, *Jour. of Geog. Syst*, **5**, pp. 51-70, 2003.