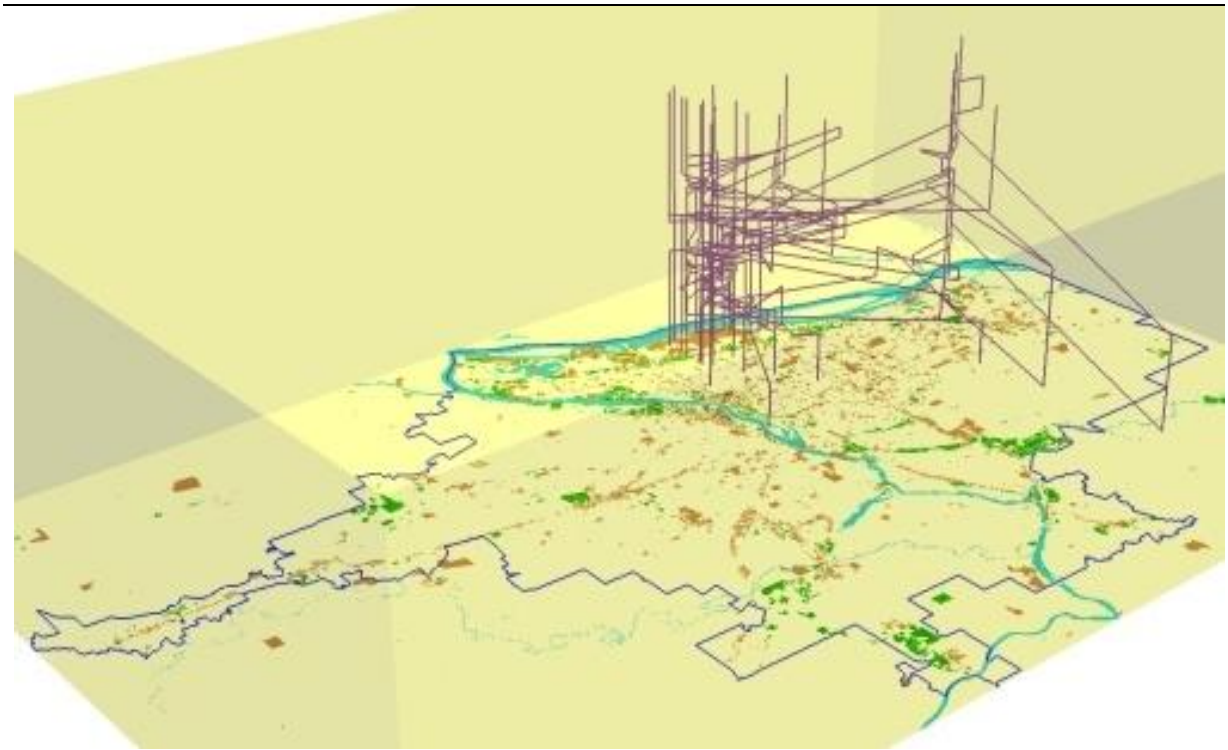

This figure shows the space-time paths of African-American women in the Portland Activity-Travel Survey (Oregon, 1994-95) dataset. It shows that the activity spaces of these women are more restricted than individuals of other gender/ethnic groups in the sample (Kwan).

Netting action and activity space/time: are our methods keeping pace with evolving behaviour patterns?

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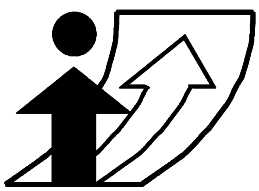

Moving through nets:
The physical and social dimensions of travel

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Netting action and activity space/time: are our methods keeping pace with evolving behaviour patterns?

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Abstract

With the evolution of in-depth methods, researchers are now increasingly equipped to capture and analyse spatio-temporal behaviour and underlying decision processes, using a variety of computer-aided and manual methods. In this paper, several theoretical frameworks for emergent behaviour are briefly reviewed as background to a discussion of leading-edge issues, including the links between personal accessibility and gender, health and land-use, and the social and equity impacts of new information technologies. The focus of the paper is on the adequacy of advances in data collection to deal with the complexity of behaviour in time and space, including cyberspace. It is argued that much remains to be done to ensure that such data collection and analysis techniques are adaptable to a full range of subpopulations, including some that are sometimes difficult to recruit for in-depth travel behaviour studies, such as low-income or immigrant groups. It is concluded that the current advances in modelling require, at least at the specification stage, multi-method data designs that yield relatively holistic descriptions of how people perceive the temporal, spatial and cyberspatial attributes of potential activities, and how they interact with others to organise them. Three examples of such multi-method approaches are described from recent and ongoing methodological and empirical research in Quebec City and Portland, Oregon.

Keywords

Activity, space-time, cyberspace, accessibility, equity, decision processes, microdata, survey methods, GPS, GIS, modelling, International Conference on Travel Behaviour Research, IATBR

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1. Introduction

In the 1970s, notions such as spatio-temporal "prisms", action space, and activity space led many travel behaviour researchers to question the adequacy of travel-oriented data collection and analysis methods, a debate that continues to this day. At first gaming-simulation and other in-depth techniques responded to a need for a more holistic observation of interdependencies within and beyond the household. However, the connection with travel modelling was initially tenuous. Many useful lessons led to the growth of the activity-based tradition, which by the 1990s had reached out to "mainstream" household travel surveys and models. More recently, the merger of new methods from time-use and spatial behaviour research has rekindled the debate.

The central focus of this paper is "moving beyond the mainstream" – bringing together from current research new insights about gathering data on decision processes and not just outcomes, in order to address issues of social equity and accessibility, to examine the role of social networks, and to begin to understand how perceptions and household interdependencies affect individual travel behaviour. Spatial and temporal activity patterns are arguably more variable and less anchored than they were 30 years ago. In the North American context this is often related to employment – there is usually more than one employee in a two-headed household; employment is becoming less stable and more flexible; and increasing numbers of individuals hold second jobs. This reality encourages researchers to reinforce the temporal dimension of action and activity zones. This is particularly relevant to our understanding of the perceived realistic opportunity set, incorporating such issues as interpersonal commitments or the self-imposed limits that may result from perceptions about personal security. Also relevant to broadening our understanding of action and activity space/time is incorporating the ways in which technology, notably the use of cell phones and the Internet, increases opportunity sets, by aiding activity scheduling or by offering new kinds of human interaction in wider cyber net communities. Drawing examples from their work and others, the authors argue the value of "going the extra mile" in data collection on activities, travel and underlying decision processes, notably by including interdependencies and respondent perception and cognition. We see this as indispensable to developing models that better address changing behaviour and emerging issues, and to represent the behaviour of women and a full range of subpopulations, including those who are difficult to engage in research, such as some low-income and immigrant groups.

The paper begins with conceptual frameworks that address activity space/time, and then focuses on the extent to which our data collection (and modelling) techniques are keeping pace with measuring accessibility and equity issues for the purposes of guiding policy makers in their decision making. The main perspective of this paper is the measurement and representation of changing behaviour in time and space, including cyberspace. It is argued that much remains to be done to ensure that such data collection and analysis techniques are adaptable to a full range of subpopulations. We believe that the current advances in modelling require, at least at the specification stage, an "ecumenical" approach to data collection – multi-method data designs that yield relatively holistic descriptions of how people perceive the temporal, spatial and cyberspatial attributes of potential activities, and how they interact with others to organise them.

Three examples of such multi-method approaches are described from recent and ongoing methodological and empirical research. The first of these is a package developed for a panel study of 300 Quebec City households: using in-depth interviews and diary instruments, it traces approaches to organising household activities and travel and then engages respondents in interpreting revealed patterns, including perceived levels of spatial and temporal fixity of each activity undertaken during seven days. The second consists of a quantitative and qualitative analysis of non-work related activities of low-income women, also in Quebec City: data collection methodologies include revealed behaviour questionnaires, focus-group discussions, map exercises to follow up the focus group, GIS-based analysis, and the use of large OD data sets to benchmark focus group data. The third example is drawn from GIS-based 3D geovisualization and geocomputation to analyse activity-travel diary data collected in Portland, Oregon, and from research on individual activities and "travel" in cyberspace.

We conclude with a summary of the prerequisites for working through the complexities of modelling social equity and accessibility issues, and some priorities for the work ahead.

2. Conceptual frameworks that address activity space/time

2.1 Evolving Notions of Travel Behaviour

Transportation planners have traditionally addressed access by observing people's daily movement patterns within cities, developing calibrated models using data from the observed behaviour, and using the models to forecast future travel. These models were designed to es-

timate travel demand within urban centres by analyzing the impacts of travel congestion, transportation infrastructure changes, changing transit fares, and land-use changes on travel behaviour. Because the maximum demand for transportation typically occurs during the time people travel to and from work, attention was typically given to the work trip, and the location of jobs and workers. However, as congestion levels within the transportation network increased and concern was raised about energy use, emissions, safety, and transportation demand management, attention was paid to the behaviour of the individual traveller within the transportation system.

Early attempts to model travel behaviour were based on an approach to urban travel demand forecasting that conceptualized trips within the urban area by a model system, (e.g. Pas, 1984; Stopher & Meyburg, 1975). The urban area was divided into traffic zones, and the models sought first to replicate existing vehicular volumes on the road system and to use these patterns to forecast future travel. Data for the calibration of the models came from household travel surveys, observations of traffic volumes, and measurements of existing capacity. Land-use was mostly treated exogenously.

Focusing on the need to measure the effects of land use development on accessibility, Hansen (1959) pioneered the gravity model. Gravity based accessibility models have a long history (Ingram, 1971; Morris, Dumble, & Wigan, 1979; Handy & Niemeier, 1997). Accessibility at a location, defined by a zone or single point, which is usually the home, is assumed to be directly proportional to the attractiveness or magnitude of the activity and inversely proportional to some measure of distance. Although there are a variety of different forms, the model is valuable as a measure of place accessibility, but has several limitations when measuring individual accessibility (Kwan, 1998). The model does not support the analysis of trips that are sequential in nature (multipurpose, trip-chaining), nor does its mathematical integral form allow for the analysis of spatio-temporal constraints that can render activities unreachable.

The paradigm shift from a trip-based framework to an activity-based framework, starting during the mid-1970s, opened up new avenues for researchers to better understand and address the human behaviour elements that drive travel. Much of this was driven by a need to better understand the complex and multiple-faceted factors affecting accessibility within an urban environment. Accessibility, in a broad sense, focuses on the needs and desires of individuals to engage in activities at various locations at different times. This section briefly reviews the theoretical foundations for the study of spatio-temporal behaviour and its evolution along with demographic, economic, cultural, public policy and technological changes.

2.2 Theoretical Foundations

2.2.1 Activity based framework

The foundation of the activity-based framework was developed through the North American research of Chapin (1974), an urban planner who focused on human behaviour patterns with a transportation focus, and Hägerstrand and the Lund University group, who used a time geographic approach (1970). Chapin developed the theory that travel behaviour patterns are a result of individuals traversing space and time to satisfy needs and wants. Hägerstrand dealt with human behaviour patterns by focusing on the imposed constraints of traversing space and time.

Chapin (1974) states there are two fundamental components that must be in place in order for an individual to engage in an activity. First, the individual must desire to engage in the activity, and second, the opportunity or means to engage in the activity must exist. The desire to engage in an activity reflects the level of importance the individual assigns to the activity. The opportunity to engage in the activity encompasses the quality of the activity and the spatial/temporal context, such as distance and opportunity costs. Equally important are the means to engage in the activity, reflecting the availability of affordable transportation and entitlement, the right to use the service.

Hägerstrand (1970) conceptualizes the human-activity space by applying the concept of a life path. From birth to death an individual follows a path that is shaped by constraints that serve to promote or inhibit human interactions. The set of potential human interactions are constrained by the individual (*capability constraints*) due to biological needs and/or the tools available to the individual, e.g. a private vehicle, and by the need to coordinate joint activities (*coupling constraints*), e.g. childcare drop-off. Constraints are also imposed by the culture or society, which limits access to locations in space and time (*authority constraints*), e.g. the opening hours of the shopping centre.

To date, the majority of activity-modelling research has relied on the utility maximization framework (Jones, Dix, Clarke, & Heggie, 1983; Kitamura & Kermanshah, 1983; Ben-Akiva & Lerman, 1985; Wen & Koppelman, 2000). McFadden's Discrete Choice Model (1974), which is based on this framework, was developed to provided a better understanding of human behaviour and its effects on travel. However, utility maximization has proven to be limited in its ability to represent underlying behavioural processes that shape accessibility and influence travel and influence travel (Axhausen & Gärling, 1992; Garling, 1998; Doherty &

Miller, 2000). Gärling (1998) argues that the framework is not an adequate description of how people make decisions, because people may use principles other than utility to make decisions, and may use different principles in different circumstances. Moreover preferences can be inconsistent, change over time, and be influenced by other factors. In addition, critics point out the fact that activity decisions may conflict, and utility theory, as classically applied, fails to account for hierarchies of choices made that are often part of a larger plan (Miller, 2002), for example, the set of activities and travel needed to prepare for a dinner party. However, developments in econometrics, such as recent structural equation models (Golob, 2000) and hybrid choice models (Ben-Akiva and Walker, 2002) are responding to at least part of the challenges from the activity-based perspective.

2.2.2 Disaggregate views of space-time accessibility

Recent advances in Geographic Information Systems (GIS) are now allowing researchers to better process microdata and to address some of the complexities of individuals and household decision processes that affect accessibility. Disaggregate space-time accessibility measures were developed on the above-mentioned time-geographic framework of Hägerstrand (1970). This framework conceives individuals' activities and travel as continuous daily trajectories in three-dimensional space-time, where the paths are the result of a range of personal and social constraints, including the limits on mobility resulting from the available transport technology and the biological need for resting time. The mobility allowed by a particular set of constraints, facing an individual, can be described in the form of a space-time prism, which can be represented as a potential path area (PPA) through projecting the three-dimensional prism onto two-dimensional geographic space (Dijst and Vidakovic 2000; Dijst et al. 2002; Lenntorp 1976, 1978). A potential path area is the geographic area that can be reached within the space-time constraints established by an individual's fixed activities. It is the area that an individual can physically reach after one fixed activity ends, while still arriving in time for the next fixed activity.

The approach offered by space-time measures - coupled with the geocomputational ability of GIS and individual-level activity-travel data - has potential for overcoming many limitations of travel demand models. This is not just because the use of GIS may greatly enhance our ability to represent real-world complexities (e.g. complexities of the structure of urban human activity-travel behaviour). Rather, with GIS and increasingly available disaggregate data, highly refined space-time measures of individual accessibility can be operationalized, and the conceptualization and modelling framework are no longer conditioned by *a priori* schema of areal or zonal units. The latter is particularly significant because analytical results in studies

involving areal units such as census tracts or traffic analysis zones are affected by the modifiable areal unit problem (MAUP). The disaggregate spatial framework of space-time measures is a useful way for overcoming its effect.

Concepts of space-time accessibility based on individual-level data have been widely implemented within vector and raster GIS (Forer and Huisman 2000; Kim and Kwan 2003; Kwan 1998, 1999a; Miller 1999; O'Sullivan et al. 2000; Weber 2001, 2003; Weber and Kwan 2002, 2003), creating a resurgence of interest in these concepts. Recent studies using disaggregate space-time accessibility measures have yielded important results about individual differences in accessibility and the effect of the temporal attributes of the urban environment. For example, Kwan (1998) has shown that space-time measures produced different spatial patterns when compared to conventional measures based on gravity models. Gender differences become more evident when applying space-time measures than conventional methods. This suggests that space-time measures have the ability to capture certain types of differences among individuals, such as the effect of space-time constraints on individual accessibility.

Recent research on space-time measures has also shown that individual accessibility is affected by facility opening hours and variable travel speeds at different times of the day and in different parts of the city. Weber and Kwan (2002), for instance, examine the effect of travel time variations and facility opening hours on individual accessibility using a variety of data. The results show that link-specific travel times produce very uneven accessibility patterns, with access to services and employment varying considerably within the study area. The time of day that activities were carried out has also been shown to have an effect on accessibility. Evening congestion sharply reduced individuals' access throughout the city. The effect of this congestion on mobility is highly uneven spatially. Further, the use of business hours to limit access to opportunities at certain times of the day illustrates a problem that non-temporally restricted accessibility measures produce inflated values when these opportunities are treated as if they were available at all times of the day. It is not just that incorporating time reduces apparent accessibility, but that it also produces a very different, and perhaps unexpected, geography of accessibility (Weber and Kwan 2002).

2.2.3 Social psychological perspectives on spatio-temporal behaviour

Other research traditions have approached spatio-temporal behaviour in terms of the relationship that an individual builds with space-time as s/he perceives it. Simply comparing socio-demographic groups, such as by age and sex, has not proven very fruitful, but the concept of

"lifestyle" allows a clearer description of the environmental context in which each form of daily mobility occurs. However, while decision-making processes are often associated with specific lifestyles, the way lifestyles are linked to activity and travel decisions is difficult to distinguish from broad behavioural rules. The lifestyle perspective offers only a limited explanation of spatial behaviour. As an alternative, a social psychological understanding of an individual's relation to space permits a more accurate appreciation of the dynamics of behavioural change in a given day or week (e.g. Gärling et al, 1986). This recognises dynamic, decision-making processes that depend on their specific and limited spatio-temporal context. On the other hand, broad behavioural rules depend on a stable social and geographic context that helps define a lifestyle.

Studies in environmental psychology suggest that attachment to places or spatial representations of cities, the most stable factors in space/individual relationships, strongly affect the definition of lifestyle. However, some theoretical perspectives (e.g. Dewey and Bentley, 1949) have long seen the individual and its environment as mutually defined, enabling more emphasis on the environmental situation. According to this perspective, the decision-making processes related to daily mobility are a product of the relation between the individual, defined by his/her lifestyle, and the spatio-temporal constraints of the moment. It is thus important to study both temporal and spatial fixity as viewed by individuals, households and other personal networks.

For their part, behavioural rules are closely linked to the value system of the individual. Whereas some research has attempted to analyse behavioural rules from the perspective of behavioural intentions and attitudes related to mobility, Ramadier et al (2002) propose eliciting these rules by studying *social representations* of daily mobility. Nevertheless, there is no such thing as a global social representation of mobility. The significance of a trip, in almost all cases, depends on the activity served. For this reason it is important to distinguish each representation according to categories of activity that are related to particular spatial behaviours, in order to compare lifestyles on the same basis.

These theoretical perspectives from social psychology suggest that the relationship between the individual and space/time is a powerful way to reveal *both* behavioural rules and decision processes linked to spatial mobility. This relationship allows us to move beyond the mere description of spatial behaviour and attempt to understand the dynamic aspects of the observed phenomena.

There is clearly much overlap in the understanding of spatio-temporal behaviour represented by the three theoretical perspectives discussed in this section. Each of them addresses the notion that an individual acts within bounds that are feasible and acceptable. They differ in the extent to which behaviour is best understood by the observation of behavioural outcomes versus the investigation of how the set of opportunities in time and space are perceived and how decisions are made. In section 4, we view data collection in this light, but first we examine the efforts of researchers to understand the full range of accessibility issues.

3. Keeping pace with what's important

As researchers become more focused on understanding the extent to which interconnected factors of policy, land-use forms, and human behaviour define activity and action space, the question becomes: what should we be measuring? What are some of the more important accessibility issues that modellers should be addressing to provide guidance to policy makers in making their decisions? To date, there has been an exhaustive amount of research on the effects of modal choice on accessibility. However, how well do we understand the effects of gender, socio-economic status, culture, technology, and the quality of the destination on travel time, activity space, and the decision to travel? As researchers, are we able to reach the disadvantaged, such as low-income groups and some immigrants, and include their behaviour in models? This section highlights some of the more important issues the authors believe should be addressed by developing creative data gathering and modelling techniques.

Most of our preoccupations concern the equity of accessibility and the inclusiveness of data collection. Often when transportation and sustainability studies are undertaken to evaluate equity issues, the focus is on the use of the roadway system, congestion, and parking policies. In other words, who pays and how much do they pay? To a much lesser degree do these studies directly address social equity issues of the transportation disadvantaged. Who are the transportation disadvantaged? Denmark (1998) characterizes this group as people who "due to poverty, disability, frailty, or other conditions have found their mobility increasingly restricted as the shift to automobile dependencies continues unabated." His definition points to individuals who have become socially excluded due to transportation policies that favour wealthier travellers, i.e. auto users, who have the ability to pay; land use policies; and housing policies that have systematically isolated the urban poor from regional labour markets. A concentration of urban poverty in the US has created a culture of "not working" (Wilson, 1987) where youth do not have access to jobs nor do they see esteemed family members and friends taking part in the labour market. Clearly, policy interventions to improve the quality of

life for socially excluded groups cannot concern transportation alone, but must be accompanied by land use, housing, social welfare, and technology solutions.

3.1 Social and Equity Impacts of ICT

What are some of the promising impacts of ICT (information and communication technologies) on addressing social and equity issues of travel behaviour? Mokhtarian (2003) provides a literature review of a number of relationships that can exist between physical travel and telecommunications. Her review suggests that even though incomplete, the empirical evidence suggests that complementarity is more prevalent than substitution. With the boom in mass telecommunications, including mobile cell phones, e-mail, internet, and fax machines, allowing individuals to increasingly interact without physically moving in space, there was an expectation that travel would decrease or be eliminated in some cases (US DOT, 1993). Researchers looked to the increasing trends of businesses embracing new interaction modes of tele-working and teleconferencing, more shopping via the internet, and educational institutions using the internet as a research tool and as a course provider. However, several studies have shown the ICT impact to have stimulated more travel due to an increasing need for face-to-face interactions and for the delivery of internet purchased merchandise (Salomon, 1986; Couclelis, 1999). At another level ICT, mostly in the form of mobile cell phone use, assists individual travellers to rearrange, change, or add to their schedules in a real-time fashion.

Focusing on the effects of urban space on employment, Shen (1998) developed an accessibility measure based on a gravity model to measure both travel and tele-working opportunities in the Boston Metropolitan area. Levels of tele-working were predicted for the year 2005 based on 1990 data. Results of his simulation give little hope of decreasing the negative effects of distance for low-income households, but showed a tremendous benefit to wealthy suburban communities. The study is valuable in that it sought to address the impacts of ICT for the transportation disadvantaged, by incorporating a measure of future tele-working opportunities. However, the study has several limitations including the method used to forecast tele-working, the emphasis on one mode (auto), and the use of an aggregate model to address individual accessibility.

In another study which uses time-use data within an activity-setting framework, the impacts of social contact on the travel behaviour of a representative sample of individuals from Canada, Norway, and Sweden are analyzed (Harvey & Taylor, 2000). They found that [pg. 53] "there is a tendency for persons with low social interaction to travel more. It is argued that individuals need, or want, social contact and if they cannot find it at the workplace, they will

seek it elsewhere thus generating travel." Even though this study does not directly deal with issues of social exclusion, their methodology could help establish the links between a lack of social interaction and the negative impacts of high levels of joblessness and urban decay in many U.S. urban centres. The effects of social exclusion have a negative impact on sustaining the social and economic well-being of a community. An interesting future study might address the degree to which vehicle-less low-income households can maintain healthy and meaningful networks within the community and outside the community.

3.2 Gender and Accessibility

Recent studies have shown that there are considerable differences in travel behaviour and activity patterns between men and women (e.g. Hanson and Pratt 1995). Ignoring these gender differences may lead to policy measures that not only ignore women's travel needs but also aggravate the difficulties they face in their daily lives (e.g. Rosenbloom and Burns 1993). An important issue is that a substantial proportion of women's travel consists of multi-purpose and multi-stop trip chains, and this characteristic of women's travel often renders travel demand models problematic. An example is the extension of the work trip in order to access essential facilities such as childcare centres. Since many women with children need the automobile in order to be able to undertake linked trips and to meet specific travel needs of their children, sustainable transport measures or travel demand management policies that aim at reducing car use in general may seriously affect the possibility for them to fulfil their household responsibilities.

Further, conventional models often ignore the role of individual time-budget and space-time constraints in women's lives. As women often face specific sets of space-time constraints imposed by the space-time fixity of their obligatory activities, their accessibility is constituted in the sequential unfolding of these activities (Pirie 1979). In other words, women's individual accessibility is determined more by the number of opportunities that are within reach given their particular life situation and adaptive capacity, instead of by the number of opportunities that are located close to their home or workplace. Women's access to jobs and urban opportunities is determined more by their space-time constraints in everyday life than by factors such as travel mobility or relative location to opportunities (Palm 1981; Hanson and Pratt 1990). Further, those constraints associated with socially ascribed gender roles tend to be spatially and temporally more binding for women than for men (Pickup 1984, 1985; Tivers 1985; Kwan 1999a,b).

3.3 Health and Accessibility

Understanding how transportation and land-use patterns facilitate or inhibit access to health services and opportunities for exercise is vital to addressing the societal needs of today. Unlike public health experts who have had a long history in analyzing the effects of distance on healthcare accessibility, transportation researchers are just beginning to seriously address the link between health and urban land-use form. This recent focus in the U.S. is partially due to the heightened attention the media has given to blaming urban sprawl and the lack of pedestrian friendly neighbourhoods for contributing to the increase in the number of Americans who are physical inactive, which seem to be resulting in an epidemic of obesity (Moore, 2003). A recent USA Today article points out that even though health professionals are calling for Americans to exercise more by simply walking, the reality in many neighbourhoods is that people cannot walk owing to the lack of sidewalks, the impermeability of many suburban layouts, and the location mismatch between home and daily activity locations, i.e. shopping centres, employment centres, and schools. With the spreading out of neighbourhoods, zoning constraints, and the dominance of the automobile, some research foundations are funding new initiatives that attempt to bring together public health and urban planning researchers to identify ways of changing transportation and land-use policies that negatively impact walking and bicycling – now increasingly labelled ”active-transportation”.

Another important health link with transportation is the study of the spatial distribution of healthcare facilities in developing and developed countries. Low-income women are often disproportionately affected by home-healthcare facility separations because they do not have access to private vehicles, and must walk or rely on public transport, which may not meet their needs. In two studies on prenatal care accessibility, McCray (2000, 2003) found travel-related constraints exist when analyzing the travel patterns of low-income women in Detroit, Michigan, and rural South Africa. Using focus groups and geovisualization of public transit routes, McCray (2000) found that low-income women’s transportation needs for prenatal care could not be fully met by Detroit Department of Transportation (DDOT) bus routes, and therefore supported the use of specialized healthcare paratransit services. The monetary cost of the fixed-route system, unreliable scheduling of DDOT buses, attitudes of other DDOT riders, personal safety concerns, and the shortage of direct bus routes to healthcare facilities prevented or discouraged women from obtaining healthcare. The majority of the participants had children under the age of six, and would have needed to take at least two buses to reach their chosen healthcare facility. Within this environment, the specialized paratransit service, the Healthy Baby Service, was created to lessen the travel burden and encouraged low-income

women to keep their prenatal care appointments by utilizing drivers who have been trained to address some of the social and health needs of their clients while en route.

In a study conducted in northern KwaZulu Natal, South Africa, McCray (2003) addresses the environmental factors and socio-economical factors that motivate or discourage women from utilizing prenatal care in the Ubombo Magisterial District. A multinomial logit model is used to explore the many factors that inhibit or support a woman's use of prenatal care services. Geovisualization is also used to explore the effects of travel mode, and to relate the levels of prenatal care utilization to the spatial distribution of healthcare facilities. In order to address these factors, one must understand how the environment and culture play a role in shaping women's lives and their travel patterns. Travel is understandably difficult in this rural low-income area where transport options are limited. However, many of the documented factors in the public health literature, as affecting prenatal care utilization, do not apply in this region. Fetching water as a daily activity, which is usually not associated with prenatal care utilization, has a significant negative impact on utilization. An important piece of this exploration is addressing time constraints and the cultural context. After time has been spent attending to essential tasks that the entire family is dependent upon, do rural women have "*remaining time*" left to visit a healthcare facility?

3.4 Land-use Issues and Accessibility

Over the past few decades, researchers have sought to understand the linkage between land-use patterns and travel behaviour, mostly related to the journey to work. A variety of factors or combination of factors have been used to characterize urban form, including distance from the urban centre, average distance from commercial facilities, distance from the nearest transit stop, population density, housing stock, the degree of land-use mix, and a measure of neighbourhood walk-ability, to name a few. Characterization of travel can be average trip length, trip frequency, modal split, or total vehicle miles travelled. Researchers who support the land-use and travel behaviour linkage argue that individuals who reside in transit/pedestrian-oriented developments tend to walk or use transit more and make shorter trips. The studies are many, ranging from aggregate models (Friedman, Gordon, & Peers, 1994; Holtzclaw, 1990) to disaggregate models (Cervero & Kockelman, 1997; Handy, 1996). Still, other researchers apply caution in interpreting these results, and suggest that people living in different communities cannot be adequately compared due to sample biases (Crane & Crepeau, 1998), and socio-economics factors may have a stronger effect on travel patterns than simply land-use factors (Hanson, 1982a; Stead, 2001). A number of analytical techniques, including multiple regression analysis, were used in these studies to consider how the variations

in socio-economic factors explain travel distance. Added to the differences caused by socio-economic levels, individual attitudes, perceptions, and values (Gärling, Gillholm, & Gärling, 1998) have also been shown to significantly affect travel behaviour and account for a larger proportion of the travel variance than land-use (Kitamura, Mokhtarian, & Laidet, 1997).

These studies support the inclusion of socio-economic factors in land-use/accessibility studies, especially those that seek to better understand, model, and address the accessibility needs of the transportation disadvantaged.

4. Data Collection Methods: do they capture information that matters?

Data collection can be divided into two main categories: the observation of actual or "revealed" behaviour, versus the elicitation of possible future behaviour or "stated responses". We discuss mostly the expansion of the former under the activity-based paradigm. Indeed, a better understanding of actual spatio-temporal behaviour is a prerequisite for data collection about responses to future conditions.

4.1 Revealed behaviour methods

The collection of data on revealed household travel behaviour has been affected in stages by the activity-based paradigm. Initially, the focus was on survey instruments that asked respondents to record daily sequences of activities, and the travel needed to undertake them was observed by asking "how did you get there?" only after responding to "what did you do next". This approach was implemented in a number of metropolitan travel surveys in the USA. Among the best known is described in Stopher (1992). This approach was shown to produce a fuller picture of the travel day, notably with regard to short trips that were often missed by trip diaries. In subsequent stages, the data requirements of activity-based models led to a variety of instruments that targeted activity *patterns* (for example, Arentze et al, 2000). In the mid 1990s, it was recommended that the focus of these instruments be broadened to activity generation/participation, activity scheduling, cognitive processes, dynamics over horizons from within-day to long term, and the policy sensitivity of a wide range of measures that affect activities (Lee-Gosselin and Polak, 1997).

In the most recent stage, attention has shifted to the observation of *decision processes* in association with the observation of behavioural outcomes, the activity/travel patterns themselves, a preoccupation that has a longer history with some Stated Response data collection methods, as discussed below. Much of the attention has been given to observing scheduling processes, incorporating the notions of: a "repertoire" of possible activities on which a respondent draws to fill their schedule; the progressive refinement of schedules involving combinations of routinised, individually planned and impulsive activities; different levels of advanced planning, coordination and negotiation within households and social networks; and the simultaneous planning of multiple activities. This implies a level of detail in data collection that is feasible only for small and medium-sized samples. Doherty and Miller (2000) developed a computer-aided self-interview (CASI) package, CHASE[1], that keeps an automatic log of all entries, modifications and deletions made by a respondent in the course of a seven days' use of an electronic time planner. Respondents are encouraged to plan and re-plan the days ahead and are queried automatically about the reasons and timing each time something is changed. They are also queried about associated travel, and other data are collected through interviews at the beginning and the end of the observed week. An alternative approach with related objectives is described by Ramadier et al (2002). Like CHASE, this manual survey package traces the evolution of decisions about activities and travel throughout a seven day period, but with less detail on each change in the schedule, and with a much more substantial follow-up interview seeking to understand both spatial and temporal activity planning that was revealed during the observed week. This package is a major part of the methodology for the Quebec Panel Survey that is described in some detail below.

A concern with these recent developments is the substantial response burden that is associated with obtaining detailed data on activity location and timing over multi-day periods, alongside detailed data on temporal and spatial scheduling. Technology is playing an increasing role. Current experiments by the authors and others involve augmenting scheduling surveys with monitoring technologies, notably vehicle- and person-based Global Positioning System (GPS) loggers. Sometimes these are linked to portable CASI devices, sometimes as passive devices in combination with prompted recall techniques through which respondents provide information such as mode, accompanying persons or activities at stops that cannot easily be observed or inferred electronically[2] (Stopher et al, 2003). In addition, for some purposes there is a

[1] CHASE: Computerised Household Activity Scheduling Elicitor

[2] In principle, other passive techniques such as monitoring electronic financial transactions could be employed, but these are usually infeasible for travel behaviour researchers.

compelling case for observing revealed behaviour over multi-week periods, and this is increasingly feasible with monitoring devices that run automatically, transmitting data using telemetry, such as was recently introduced in the Atlanta region on a sample of 1200 private vehicles to monitor vehicle use and conditions immediately preceding crashes. However, even diaries are sometimes tolerated for long observation periods, such as six weeks in a European study (Axhausen et al, 2002). At the same time, retrospective techniques covering decades, inspired by biographical and ethnographic approaches, are starting to find their place in transport studies. Examples include car-use (Lee-Gosselin and Turrentine, 1997), car ownership (Mohammadian and Miller, 2003) and residential mobility (Séguin and Thériault, 2000); in the first example, information from a retrospective instrument was used to build customised scenarios for a Stated Response survey.

There has been considerable effort in recent years to collect new types of data on the relationships between travel and information and communications technologies (ICTs). At first this focussed on telecommuting (see Golob and Regan, 2001; Kwan 2002). Useful conceptual frameworks have also been proposed for dealing with the complex relationships between people's activity-travel behaviour and their use of (ICTs) (e.g. Mokhtarian 1990). For example, Kwan (2001) has formulated a cognitive model that conceives the individual as an extensible agent and conceptualizes individual access in the information age through notions such as cyberspatial cognition and computer-built long term memory. Dijst (2003) has developed the action space model for studying the impact of ICTs on individual access to opportunities based on different types of constraints on ICTs. However, collecting data on the interactions between individual activities or travel in the physical world and in cyberspace poses a serious challenge to the researcher, especially with respect to people's Internet activities. Some researchers have used an adapted version of conventional activity-travel diary as instrument for collecting people's activities in cyberspace (e.g. Mokhtarian and Meenakshisundaram 1999), while others have attempted to develop and use new data collection methods.

4.2 Stated Response Methods

Arguably, Stated Response (SR) data collection methods – those that elicit behavioural responses, relevant constraints, or both, under hypothetical situations – have made a seminal contribution to the methods now used to research spatial and temporal activity, whether revealed or stated. Much of the SR data collected are rather narrow in scope. For example, the most widely used class of SR surveys, Stated Preference (SP), are confined by design to tradeoffs between limited numbers of attributes and pre-defined options, although some "adaptive" SP techniques do take respondents through a filtering stage to identify relevant

choice sets among a wide range of possibilities. However, other classes of SR involve more complex problem-solving in time and space. In particular, gaming-simulation methods such as HATS (Jones, 1979) or CUPIG (Lee-Gosselin, 1989) illustrated long ago the value of exploring the decisions underlying activity patterns, and engage respondents in observing and interpreting their own decisions "reflexively". Broad reviews of SR are given in Lee-Gosselin (1996; 2003).

4.3 How well are the tools used?

It can thus be said that the data collection toolkit has evolved considerably in recent years. With the consent and the collaboration of respondents, it is possible to collect microdata on sequences of action in time and space, and on the personal and inter-personal decision processes that led to those actions, in considerable detail and over multi-day periods (and sometimes longer). These are the data that are sought by several emerging modelling and analysis approaches, such as multi-agent microsimulation. However, to what extent have packages using this toolkit addressed the full range of accessibility issues on which surveys are expected to inform public policy?

It is clear that much remains to be done to ensure that such data collection and analysis techniques are adaptable to a full range of subpopulations. It is also evident that demographic, cultural, economic, political and technological developments are leading to more complexity in behavioural dynamics. It is our view that the current advances in modelling require, at least at the specification stage, multi-method data designs that yield relatively holistic descriptions of how people perceive the temporal, spatial and cyberspatial attributes of potential activities, and of how they interact with others to organise them. In the following section, we present three case studies of data collection packages that have attempted to respond to parts of this challenge.

5. Bringing balance and filling gaps

The three case studies that are briefly described are examples of a large number of possible multi-method approaches to data collection that can broaden the scope of data on activities in time and space, and their underlying decision processes. Each data collection package was undertaken primarily to aid the design and specification of behavioural models, but each also yields empirical results that are of interest for exploring trends and evaluating the potential impacts of policies and technologies.

5.1 The Québec Panel Survey

As part of a large programme on the behavioural foundations of long-term simulations of land-use and transport interactions[3], two longitudinal surveys were initiated in 2002. One is in Toronto and the other is in Québec City. Each of these was designed as a three-wave survey focussing on the decision processes of panels of about 300 households. Unlike traditional transport panels using identical survey instruments in each wave, these two surveys anticipate varying the instruments so that each wave builds on the experience of respondents in the previous wave. Different but complementary designs were adopted in the two regions. The Toronto Panel Survey is centred on activity scheduling using the CHASE package (see above, Section 4.1) and is described in Roorda and Doherty (2002). The Québec Panel Survey shares with Toronto the parallel collection of data on both behavioural outcomes and underlying decisions, but places greater emphasis than Toronto on the perceptions of respondents about the ways they organise their activities in time and space. As mentioned above, the Québec survey seeks less detail than Toronto in the systematic collection of activity scheduling attributes, and more detail on a holistic interpretation of the activity and travel patterns that, in the case of both surveys, are recorded by respondents over a seven-day observation period.

The Quebec Panel Survey instrument package, known as STOAT[4] consists of:

1. *A startup in-home interview of the household, during which:*
   - Basic information is gathered on the structure of the household, household vehicles, residential mobility history, activity repertoire with travel modes, etc.,
   - All adults over 16 are instructed in the use of the paper instruments
   - A fax machine is lent to the household and installed

2. *Paper instruments:*
   - On a single Weekly Planning Sheet, organised into 7 columns with a time scale similar to desk diary, each adult is asked to record all known activities for the coming week during the startup interview; on the evening of each day, they are asked to add, delete and modify entries (by crossing out, erasing, etc.) for any of the days remaining;

[3] SSHRC Major Collaborative Research Initiative, 2000-2005: Access to activities and services in urban Canada: behavioural processes that condition equity and sustainability

[4] Spatio-Temporal Organisation of Access and Travel

- Respondents use seven daily Activity and Travel Log to record actual behaviour, one day at a time
- Once per day, the current state of the Weekly Planning Sheet, and that day's Activity and Travel Log, are faxed to the university; the date and hour of transmission is automatically recorded on each sheet.
- Support is provided by telephone based on material received

3. *In-depth home interview soon after the 7 day observation period, including:*
   - Validation of paper instruments
   - A sorting game that addresses the perceived spatial/temporal fixity of activities
   - Retrospective recording of details on planning horizons and interdependence
   - Holistic interpretation by each adult of the way they approached the spatial and temporal organisation of their activities
   - Semi-structured group interview about "projects" (sets of jointly-planned activities), activity negotiation, unsatisfied demand, and expectations about the future

4. *Data entry programme, VESTA:*
   - Entry screens and relational database in Microsoft Access™
   - Designed to align with CHASE data format, where possible
   - Usable for direct entry by interviewer in startup interview

Extensions of the STOAT package under test and development include the use of Global Positioning System (GPS) personal loggers to reduce respondent burden in the tracking of daily activity patterns, and the integration of GIS support to the geocoding of activity locations. The STOAT package uses a reflexive approach that facilitates the changes in the second and third waves to recognise and exploit the cumulative effects of participation in the earlier wave(s). Thus, our view is that panel "conditioning" is normal and substantial given the extent of participation required, and that the researcher and respondents are engaged in a joint learning process.

Through quota sampling, a representative range of households with different life-stage, residential location and vehicle ownership characteristics are drawn from published directories. Recruitment is effected by letter with telephone follow-up, and by approaching disadvantaged subpopulations through intermediaries (see below). It is a requirement of the Québec panel that all adults under the same roof who are involved in each other's activities participate for a household to be eligible: as a result, about two thirds of the sampled households yield information on the interactions between two or more adults. A choice of financial incentives is offered worth between Cdn$20 and Cdn$30.

This is a complex package that draws on a number of the theoretical frameworks and on developments in both revealed behaviour and stated response survey methods discussed above. In particular, it is designed to strengthen the understanding of spatio-temporal activity organisation, building on respondents' own perceptions about personal and household activity. The resulting data are used both for exploratory analysis and to generate a base of rules and meta-rules needed in multi-agent simulation. Initial results from the early stages of the first wave, based on 64 households, 115 adults, 2556 activities and 800 trips were presented by Joud et al (2003). These indicate, for example, that spatio-temporal routinisation is highest in among the over 75s and among 25-54 year olds. They also already provide considerable detail on the variations between different classes of respondents in the extent to which access to services, shopping and social activities requires advanced planning, negotiation and coordination with others.

5.2 Quebec Low-Income Women's Project

Much research has focused on the differences in travel behaviour between women and men, and many studies agree that gender, household responsibilities, and life-cycle are significant factors that influence travel behaviour (Hanson, 1982; Lee-Gosselin, 1989b; Niemeier & Morita, 1996; Rosenbloom, 1995; Wilson, 2001). However, little attention has been given to how transportation and land-use patterns affect the activity choices of low-income women. Women, due to household and employment responsibilities, face high levels of space-time constraints (Kwan, 1999b). These constraints inhibit their abilities to choose beneficial activities that affect the quality of life.

The Quebec low-income women's travel behaviour study (McCray, Brais, & James) is a multi-method stand alone study and complements the Quebec Panel Study. The intent was also to encourage socio-economic diversity within the panel study by increasing the representation of the transportation disadvantaged. This population is often invisible or underrepresented in travel behaviour studies that involve the use of a daily activity diary over multiple days. Part of the challenge in recruiting this population is that historically, low-income individuals have had a mistrust of government and university research. Key to developing a trust relationship is working directly with community leaders and showing early on, conceivable benefits to the community, in return for their input.

Thirty-three participants, with an average age of 40 years, were recruited from 5 women centres, 3 in the city and 2 in the suburbs. The centres are designed to address the needs of low-income women, the majority of which are unemployed. Twenty-one of our study participants

were unemployed and 8 were students. Approximately 50% (N=17) of the women had children living with them in the household. Only 7 of the women had access to a car in the household. Of the 33 women participating in the focus group discussions, 8 volunteered to enter the Quebec Panel Study.

The value added in conducting this study goes beyond a simple recruitment tool. Using an innovative activity-based methodology, the travel patterns of study participants are analyzed using focus-group discussions, map exercises, and questionnaires. This triangular approach allows one to examine activities undertaken on a regular and occasional basis, to explore issues of personal safety dependent on the time of day, and to understand the challenges of using public transportation. Information is also gathered on places women would like to access, including leisure activities and discount shopping, but cannot for various reasons, such as using the bus. The focus group results are then confronted in the analysis with quantitative data on the travel patterns of women in vehicle-less households, derived in GIS using data from a regional Travel Survey.

The FG discussions serve as a means of assessing accessibility needs related to health care, school, employment, shopping (grocery and malls), social activities (visiting family or friends), and entertainment. Women share their experiences of using public transit and the challenges that exist if one has small children, or is disabled or elderly. Also during this time researchers gain an understanding of the extent to which women are knowledgeable of the public transit system and available fare saver programs, such as the one-day pass that allows unlimited rides. These discussions often reveal ways in which women strategically chain trips on one day to get the most out of a transit day pass. The large group session ends with a general discussion of safety issues, dependent on the time of day, and is dealt with more on an individual basis during the map exercise.

The map exercise is designed to obtain information in three basic areas:

- places women visit on a *regular basis* and on an *occasional basis*;
- places women *would like to visit*, but cannot due to mobility constraints; and
- areas women feel *unsafe,* during the day, evening, or both

Women are given maps of their community and surrounding areas to indicate their home location along with places they visit, which are colour coded according to whether the place is accessed on a regular or occasional basis. To assist researchers in the analysis of data, a separate sheet of paper is used to list the names and addresses or cross streets of places of interest.

Along with the labelling of place, respondents also indicate the mode used. When the mode of travel is the bus, the route number is indicated. Respondents and researchers immediately see the relationship between distance and type of visit. Places visited on a regular basis are more often closer to the home location than those places visited on an occasional basis. In addition to capturing information on places women visit, the study also addresses accessibility desires; places women would like to visit, but cannot due to mobility constraints. These places are indicated on maps with a separate colour: they turned out to be places of entertainment (movie theatres), recreation (ports, campsites, and beaches), discount shopping (warehouse stores and shopping centres), and intra-urban transit stations (train or bus). Mobility constraints include the bus not providing service to the place of interest, and bus scheduling conflicts including untimely bus transfers and limited service at certain times of day. In some cases women, through their social networks, are able to utilize a private vehicle as a passenger. Incorporating GIS mapping to verify bus routes and schedules, and to show travel times from home locations to places of interest, aids in validating accessibility challenges identified during the FG discussions. The GIS environment also supports the use of Quebec's 2001 O-D survey of 27,000 households to identify disadvantaged women, with limited transport options and from low job categories, to benchmark the results from the small detailed sample of FG participants. The O-D data provides the larger picture of identifying accessibility challenges among all women who are heads of households, alone or in a couple.

This kind of multi-method approach seems indispensable to establish the limits of activity and action space, and the ways in which the boundaries of both can be changed, for those who experience social exclusion

5.3 Adding cyberspace to diaries of activities and travel

Arguably, "travel" in cyberspace is an increasingly serious omission from most data collection on spatio-temporal behaviour, but there are some recent developments to correct this. Kwan (2003), for instance, used a logging program installed on respondents' computers to directly record individuals' activities on the Internet as part of an activity-travel diary survey. This was a pilot study conducted in Columbus, Ohio (USA), in which data were collected from a sample of Internet users. In the study, an activity-Internet diary was developed and used to collect detailed data about the space-time characteristics of an individual's physical and cyberspatial activities. The data collected include the location, timing, duration and space-time fixity of an individual's Internet activities and physical activities over a 24 hour period. The active recording of these data was complemented by the automatic logging of respondents' Internet activities for the survey period.

Preliminary results suggest that both men and women expand their action space and access to opportunities with the use of the Internet, mainly owing to the increased opportunities that the Internet provides for transactions (Kwan, 2003). However, women in the sample still face considerable space-time constraints associated with certain activities they need to perform in the physical world when compared to men. They seem to have a tendency to fit their Internet activities into their existing schedule instead of adopting fundamentally new ones. The data also indicate that women do not use the Internet primarily to help reduce their space-time constraints (e.g. through e-shopping). They instead use the Internet mainly for social and recreational activities that are not temporally fixed.

The method used in this pilot study seems to have some potential for studying the interaction between people's activity-travel behaviour and their use of ICTs. It is based on the behavioural model of human cyberspatial cognition formulated by Kwan (2000, 2001). As argued in Kwan (2001), human behaviour in cyberspace bears certain similarities with spatial behaviour in the physical world. Behavioural theories about spatial learning, spatial cognition, as well as choice and decision-making behaviour may be helpful for understanding the patterns of individual activities in cyberspace. For instance, many features of spatial learning and wayfinding have their equivalents in cyberspace (e.g. using bookmarks as landmarks, and building long-term memory using computer-assisted history mechanisms; Allen, 1999; Golledge, 1999). This in turn suggests that conventional models in transportation research may be extended along this line to provide the behavioural foundation for including human cyberspatial activities in the study of individual accessibility. Models that conceive the individual as an extensible agent and focus on the access interface between the individual and cyberspace will be particularly helpful. Using these models, fundamental notions in conventional accessibility measures - such as distance, impedance and attractiveness of opportunities - can be reformulated and applied to the study of individual accessibility to opportunities in both the physical world and cyberspace.

The results of the pilot study, however, reveal several difficulties specific to the use of Internet logging procedures. First, similar to the use of "active" GPS in recording people's activity locations, Internet logging methods assume that research subjects have sufficient computer skills to handle the installation of the logging program as well as to identify and save the correct log file. Different levels of computer knowledge of the subjects may render the method less reliable in certain situations. Second, there is serious concern about violation of personal privacy because the logging program keeps a complete record of one's Internet activities during the survey period. However, human subject protection procedures legally sanctioned by the government and implemented by the Institutional Review Board of research institutions

(in the USA) may mitigate this concern to a certain extent. Third, in this pilot study men were considerably under-represented (only 36% of the sample). This hints at the possibility that surveys involving Internet logging may tend to bias the sample towards female respondents. Lastly, although data are collected about people's Internet activities, how a person's activities in the physical world and in cyberspace interact can still be quite unclear. Qualitative information about the decision-making process and motivations behind people's Internet use should also be collected in future research.

The three case studies described in this section illustrate various multi-method approaches developed by the authors to address the complexity of accessibility. These approaches are more sensitive to individual differences than many traditional approaches. They are also more inclusive of groups and issues that are often ignored but are important to society (e.g. the transportation disadvantaged). It is apparent that we cannot understand everything with a single approach, be it traditional trip generation, activity scheduling or gaming-simulation, as useful as each approach may be. A holistic understanding of human activity-travel behaviour calls for the innovative combination of a variety of methods, each component of which may shed light on a particular aspect of the whole picture.

6. Conclusion

This paper is something of a cautionary tale. It says that to bring the broader issues of equity/accessibility into the latest travel behavioural modelling efforts, we need ways to incorporate multiple classes of microdata, some of which have hitherto been associated only with qualitative methods. The way we design microdata collection must recognise the needs of new computational opportunities (process models, spatio-temporal statistics in GIS, multi-agent microsimulation, etc.), but we need to work from the problems to the models rather than vice-versa. In a similar vein, supporting information technologies such as GPS and laptops with CASI software are transforming some survey methods, but the variable set should not default to whatever they can provide: these supports should be used in combination with other techniques, notably skilled in-depth interviewing, to keep our focus on the inclusiveness of the issues and people studied.

The modelling challenge is about complexity. As Koskenoja and Pas (2002), put it (p 561), "…complexity deals with non-linear, nested structures, which lead to unexpected higher level behaviours". The recent focus on decision processes to understand such structures is indispensable, but we need to make sure that the data collection includes respondent *perception*

and *cognition*. Thus, it is very useful to efficiently track the sequencing, timing and grouping of activities, as does the instrument designed for the Albatross model (Arentze et al, 2000). We must also ask people when and why they planned and changed activities, as does CHASE (Doherty and Miller, 2000). But we must also find ways to characterise how people perceive the limits of their own action space/time (including action cyberspace), and the limits of a feasible – albeit conditionally feasible – activity space/time.

Finally, it remains central, as Heggie and Jones (1978) asserted long ago, to understand decisions about activities and travel in terms of the degree to which they are linked in *either or both* of the spatio-temporal and interpersonal dimensions. The three data collection case examples presented represent, of course, only a partial response to the data needs of contemporary models, but they are sensitive to both these dimensions. The 2003 Lucerne IATBR Conference, with its focus on nets, offers a timely opportunity to build a consensus on how to keep data collection in pace with evolving behaviour patterns.

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