Social Exclusion in Space and Time

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1. Introduction

The concept of *social exclusion* is central to social policy in Europe and increasingly in other regions of the world (Gore, Figueiredo and Rodgers 1995). Social exclusion emerged in France during the 1960s and 1970s as an umbrella term describing individuals with problems unprotected by then current social insurance principles. This included the disabled, elderly, substance abusers and single parents. Social exclusion was viewed as a failure of key state institutions at maintaining positive relationships between society and some individuals (Bhalla and Lapeyre 1997). In the 1980's, the term evolved to include more general types of social disadvantages created or exacerbated by rapid and dramatic economic change, rising social inequity, retraction of the welfare state and increasing segregation that threaten to breakdown relationships between society and some individuals (Mohan 2002; Silver 1995). These disadvantages manifest themselves as unemployment, lack of marketable skills, low income, poor housing, high crime, poor health and family breakdown (Social Exclusion Unit 2001).

Social exclusion is a multifaceted concept that requires careful measurement, particularly when analyzing policy and decisions regarding the allocation of infrastructure, monies or services. In practice it is often defined as the ability to participate in major social institutions such as employment, health care and education as well as the ability to obtain the resources and services that comprise the accepted standard of living for the society (Bhalla and Lapeyre 1997; Williams 2002). Measurements typically include attributes such as unemployment, public assistance, education, health and available services at some level of geographic aggregation such as census or political units (e.g., DETR 2000).

Place-based measures are useful but incomplete since they cannot capture the full spectrum of social exclusion. Exclusion is an evolving pattern that encompasses all facets of an individual's life (Rodgers 1995); only some of which occur at a particular place such as a person's home or neighborhood. Place-based manifestations of social exclusion are epiphenomena: social exclusion emerges from the interactions of individuals and households whose life histories are constrained for varying periods of time from the possibilities offered by a society. Place-based factors such as segregation are important as evidence of social exclusion, but relative to how these affect these individual life courses rather than as a direct incarnation of exclusion (Byrne 1999). Place-based measures are incomplete since they cannot capture these individualistic life experiences: they suffer from the ecological fallacy of applying aggregate measures to individual cases. However, individual, *people-based measures* are also incomplete: they suffer from the individualistic fallacy of ignoring synergistic, ecological effects at the place level. Considering both place and people is necessary for a full depiction of quality of life and its exclusion (National Research Council 2002).

A focus on places in social exclusion analysis may partially account for the neglect of transportation and *information/communication technologies* (ICTs) such as the Internet and mobile telephony. It is increasingly heroic to assume that simple geographic propinquity is sufficient in societies and regions with high automobile ownership, sparse and sometimes retracting public transit networks, sprawled cities, multiple income households and short-term employment contracts. Transportation must be considered as an essential technology for livability in these settings (Solomon 2000). It is also increasingly difficult to maintain a conceptual division between transportation and ICTs in social exclusion analysis, or transportation science, urban planning, civil engineering and other endeavors that shape our cities and lives. Many people use these technologies in a seamless manner. There are also an increasing number of services and opportunities available online. A "digital gap" with respect to high bandwidth and mobile communication technologies can combine with the lack of transportation resources to sharpen social exclusion (Grieco 1995).

This paper suggests that the *space-time activity theory* (STAT) can provide new, people-oriented insights into social exclusion. STAT highlights accessibility and extensibility in space and time as a strictly necessary condition for participating in activities, obtaining resources and acquiring information. *Accessibility* refers to a person's physical reach in space and time through movement while *extensibility* refers to the ability to project presence beyond physical location in space and time. STAT views social exclusion as differential constraints on peoples' abilities to access or extend themselves to activities, resources and information that are available at few locations in space and for limited durations in time. STAT approaches can complement place-based analysis by highlighting exclusion created by social differences in *space-time autonomy* or the ability to control one's physical or virtual location in space and time. Many individualistic factors combine to restrict space-time autonomy. These include spatial separation between key life activities, work, household and social network obligations that require presence or telepresence at fixed locations in space and time, and a lack of transportation and ICTs to facilitate presence and telepresence at these locations. Space-time constraints and activity patterns vary substantially with respect to key social factors such as socio-economic status, life style, life cycle, household size and organization, vehicle availability and gender role (Hanson and Hanson 1981a, 1981b; Kwan 1999, Lu and Pas 1999; McNally 1998; Pas 1984). These social dimensions are relevant to questions of access and social exclusion.

The fundamental object in STAT is an individual's physical and virtual path in space and time. These paths are sensitive indicators of opportunities and experiences ranging from a day to their lifetime (Kwan 2002). STAT also scales to encompass aggregate phenomena such as neighborhoods, cities and regions at many geographic and temporal scales (Hägerstrand 1970; Pred 1981). STAT also supports integrated analysis of transportation and ICTs and their effects on individuals' lives. It is well-suited for answering questions of access, exclusion and evolution in a world where transportation costs are dropping but becoming more unequal across geographic space, and cyberspace is Outer Space for some people. STAT views time as the common, scarce resource that links and sometimes excludes people, activities, transportation and ICTs (Miller 2005).

Another benefit of a STAT approach to social exclusion relates to advances in geographic information systems (GIS) and location-aware technologies (LATs). These technological advances are encouraging researchers to development new space-time theories, models and computational techniques, including new tools for urban and transportation science. This has two positive implications for social exclusion analysis. First, social exclusion analysts can exploit the progress in the STAT models, tools and technologies (Kwan 2002; Preston and McLafferty 1999). Second, since the STAT perspective is emerging as a dominant theme in transportation science and engineering (Timmermans, Arentze and Joh 2002) there are unprecedented opportunities to inject social exclusion considerations into the planning and engineering processes that shape our cities and lives. Required to exploit these opportunities is greater interaction and cross-fertilization between social exclusion and STAT researchers.

The next section of this chapter provides background by discussing social exclusion measures, transportation, ICTs and social exclusion, exclusion as a spatio-temporal process and space-time activity theory. Section 3 discusses social exclusion in space and time. This includes a discussion of major components of STAT and how they relate to questions of exclusion. Section 4 highlights advances in GIS and LATs, as well as their implications for analyzing social exclusion. Section 5 concludes with some brief comments.

2. <u>Background</u>

2.1. Measuring social exclusion

Social exclusion is a multifaceted concept, spanning social, economic and political dimensions. It is often associated with manifest pathologies of places and people such as unemployment, poor skills, low incomes, poor housing, high crime environments, poor health and family breakdown that together prevent people from participating fully in society (Social Exclusion Unit 2001). Social exclusion is often measured in terms of a basic standard of living as well as a right to participate in major social institutions such as employment, health care and education (Bhalla and Lapeyre 1997).

An example social exclusion measure is the U.K. Index of Multiple Deprivation (IMD), developed by University of Oxford for the U.K. Department of Environment, Transport and the Regions (DETR). The IMD consists of six dimensions measured at the U.K. census ward level and weighted as indicated in Table 1. IMD dimensions include income, employment, health, education and housing; these reflect the major social institutions of society to which individuals are perceived has having participation rights. Previous versions of this index (known as the Index of Local Deprivation) included crime as a measurable pathology, but the Oxford research concluded that available crime data or their surrogates were too inconsistent or inadequate. Future versions of this index may include environmental factors such as land, air and water quality and land use (DETR 2000).

Dimension	**Weight**	**Measured attributes**
Income	25%	Adults and children receiving means-tested benefits
Employment	25%	People who are unable to work to unemployment, sickness or disability
Health Deprivation and Disability	15%	People who suffer from poor health or disabilities
Education, Skills and Training	15%	Adults with lack of qualifications, children without full-time education, school performance and educational challenges (native language secondary, absenteeism)
Housing	10%	People with unsatisfactory or no housing
Geographical Access to Services	10%	Access to post office, food shops, basic medical care and primary school.

Table 1: U.K. Index of multiple deprivation (based on DETR 2000).

The IMD includes "geographic access to services", measuring the availability of goods and services that comprise a basic standard of living. Individuals are excluded if they lack the market goods, services and amenities that are considered standard in a particular society (Solomon 2000; Williams 2002). While useful as surrogates, aggregate geographic access measures such as counts per spatial unit are incomplete: they do not adequately capture the time or cost required to obtain these good and services through available transportation resources. Just as important, these measures mask individual differences in the availability of these resources (Solomon 2000).

2.2. Transportation, ICTs and social exclusion

Transportation serves several critical functions for individual and communities (Solomon 2000). Transportation provides the means to *access* employment, health care, goods and services. Transportation can serve *social* purposes, allowing individuals to meet and socialize with others, particularly people who are not in close proximity to home or work. There are direct mental and physical *health* benefits: the ability to get out helps a person feel engaged with a community and life. Transportation can provide *symbolic* benefits: for example, new bus service or a light rail station can be viewed as public commitments to a community to reduce isolation. Finally, *economic* benefits can occur if investments such as new road or rail connections increase the economic viability of a community by reducing its isolation (although there is a danger of consequent higher property values displacing some residents).

Transportation can contribute to social exclusion in two ways. First, inadequate transportation can deny individuals and communities the accessibility, social, health, symbolic and economic benefits that are enjoyed by included individuals and communities. Second, the negative externalities of transportation are often concentrated in areas with high levels of social exclusion; this includes congestion, accidents, air pollution and unhealthy levels of noise (Social Exclusion Unit 2002). Although we will mostly be concerned by inadequate transportation services in this chapter, environmental justice issues related to the incidence of negative transportation externalities is an important topic worthy of additional investigation in social exclusion research. Inadequate transportation is not completely coincident with social exclusion: transportation may be only a minor difficulty relative to other problems of the socially disadvantaged. However, it can be part of a vicious cycle: inadequate transportation can be a possible consequence of exclusion, which in turn heightens exclusion by diminishing access to key resources, opportunities and activities. Inadequate transportation can also undermine other public policy initiatives for increasing opportunities for education, health care, employment and community building (Social Exclusion Unit 2002; Solomon 2000).

Transportation can no longer be considered separately from ICTs in many societies and regions. More activities are occurring online, including public, social and financial services that are critical to those who live at the economic margin. The ability to substitute *in-home activities* for *out-of-home activities* (e.g., banking or shopping online rather than traveling to the bank or store) can free time that can be used for other activities, including commuting. However, the relationship between transportation and ICTs is more subtle and complex than just a substitution effect. ICTs can also *complement* transportation by making providing information about places, people and activities that otherwise would have gone unnoticed or would have seemed daunting and uninviting. In fact, growth in travel demand at all geographic scales has paralleled a rise in demand for information and communication technologies (Couclelis 2000). Access to ICTs allows a person to conduct a wider range of activities at any given location (e.g., banking while at work or a café, working while at a bank or a café). For some individuals, activities are becoming less tightly connected with specific, dedicated locations (such as offices, banks and cafés; see Couclelis and Getis 2000). ICTs also facilitate the coordination of travel and activities with others (Krizek and Johnson 2003).

2.3. Social exclusion as a spatio-temporal process

Social exclusion implies a comprehensive and evolving pattern of isolation from sufficient material resources, living conditions, employment, community decision-making, political processes, social rights and employment (Rodgers 1995). Social exclusion is manifest when individuals cannot obtain the resources, experience the living conditions and amenities or participate in the activities that are customary for the societies in which they belong (Solomon 2000; Williams 2002).

Social exclusion is best understood from the perspective of the individuals' dynamic life trajectories operating within a particular socio-spatial context. Exclusion occurs to specific people at particular moments in time and is at least partially a consequence of the history, including both the society and the individual. In addition, exclusion conditions the evolving trajectory of an individual's life over the remaining course of time. The interaction of these different trajectories manifests itself as complex social dynamics, such as increasing inequity and segregation over space and time (Byrne 1999).

In the United States, there are similar debates surrounding the more pleasant sounding but closely related concept of community *livability* or quality of life. Community livability is an ensemble concept that encompasses social, economic and environmental dimensions of an individual's existence within a community. This operates at multiple spatial and temporal scales. Lifestyles unfold over time scales ranging from real-time to roughly a century and spatial scales ranging from local to global. Individual and community actions play out over these spatial scales and at temporal scales to the millennial and beyond. Because of these interconnections and dynamics, comprehensive livability measures must encompass both place and people over space and time. For example, gentrification may appear to be a beneficial process from a place-based perspective since this can create rising property values, average income and education levels. However, it appears less beneficial from the perspectives of the low-income people who are displaced and must rebuild community networks that were painstakingly constructed over years (National Research Council 2002).

2.4. The space-time activity perspective

The space-time activity perspective highlights peoples' allocation of time among activities in geographic space. This perspective has its roots in the pioneering work of urban planners and geographers such as Chapin and Hägerstrand (Burns 1979). It is now emerging as a dominant theme in transportation science and engineering (Timmermans, Arentze and Joh 2002).

The fundamental unit is the individual's trajectory in space and time. Individuals generate space-time trajectories since activities such as home, work, shopping, child and elder care, maintaining family, social and community networks, recreating, obtaining medical care and so on only occur at few locations in space and for limited durations in time. Individuals use transportation and ICTs to trade time for space in movement or virtual interaction, facilitating activity participation. Individual trajectories *bundle* or cluster in space and time for shared activity participation. Aggregate activity systems emerge from the "ballet" of space-time adjustments among individuals and their activity patterns (Pred 1977), generating space-time ecological structures such as trendy nightclub districts and gentrified neighborhoods (Goodchild and Janelle 1984). Awkward and aggressive aspects of the space-time ballet include people with 90 minute one-way commutes to work.

Space-time activity analysis offers an unprecedented opportunity to improve understanding of the role of transportation and communication in social exclusion. Space-time activity analysis can enhance social exclusion research and policy by integrating transportation and communication in a theoretically consistent manner. STAT can incorporate the role of transportation and ICTs in social exclusion from a defensible first principle, namely, an individual's allocation of time among activities in space. Space-time activity analysis is individualistic, dynamic and histographic, but conceptually links to aggregate spatio-temporal dynamics such as neighborhood change and urban sprawl (Pred 1981). Space-time activity analysis highlights social differences in constraints, activities and experiences among individuals (Kwan 2002). Patterns of time allocation among different activity types vary strongly by socio-demographics such as age, gender role, employment status, life-cycle stage and income (Hanson and Hanson 1981a, 1981b; Kwan 1999; Lu and Pas 1999; McNally 1998; Pas 1984). These socio-demographic variables are also closely related with the location and timing of key *space-time anchor points*, in particular, home and work locations as well as scheduling constraints that compel presence at these and other locations for fixed and set durations (Kwan 1999).

Since the space-time activity perspective is becoming a dominant theme in transportation research, there are powerful new simulation methods, exploratory techniques and data collection technologies are emerging for space-time activity analysis, potentially allowing new breakthroughs. There is also an opportunity for social exclusion analysis to influence transportation planning to an unprecedented degree. The aggregate, place-centric and trip-based methods that previously dominated transportation engineering do not easily admit questions of exclusion since they mask individual differences and focus on system throughput rather than the individual's use of transportation and ICTs to conduct their lives (Jones 1989; Miller 2005).

3. Social Exclusion in Space and Time

This section of the chapter examines social exclusion from the space-time activity perspective. This includes overviews of major STAT components, namely, *space-time anchors*, *space-time activity organization*, *space-time accessibility* and *space-time extensibility.* The theoretical discussion draws from Miller (2004, 2005); the reader can consult the original sources for more detail. Coupled with each component is discussion of its implications for *spatio-temporal exclusion*: social exclusion of an individual by constraining their presence and telepresence in space and time, thereby reducing their ability to participate in activities, obtain resources and benefit from opportunities.

3.1. Space-time anchors

All activities and events that make up an individual's existence have both spatial and temporal dimensions that cannot be meaningfully separated. The events or activities that comprise a person's existence at any temporal scale (daily, monthly, lifetime) have spatial extent and temporal duration. Activities such as home, work, shopping and socializing occur only at a few locations in space and for limited durations in time; these locations and times are sometimes referred to as *space-time stations*. The sparse spatial distribution and limited durations of activities means that the individual must be at different locations at different time periods to participate, although communication can be used as a substitute for transportation for some activities. This requires the individual to allocate time to movement or communication. At a fundamental level, this involves the trading of time for space by the individual. Transportation and ICTs determine efficiency of this tradeoff by allowing more space to be overcome per unit time (Pred 1977).

The *space-time path* traces the movement of an individual in space with respect to time. Figure 1 illustrates a space-time path among three space-time stations: home, a childcare center and work. The person represented by this path must be at home until a certain time. She then escorts her child to a childcare center and then continues on to work. After work, she stops to buy groceries and then must return to the childcare center to escort her child back home. Note that the path is vertical when the individual is stationary in space and is horizontal when she is moving through space (i.e., trading time for space).

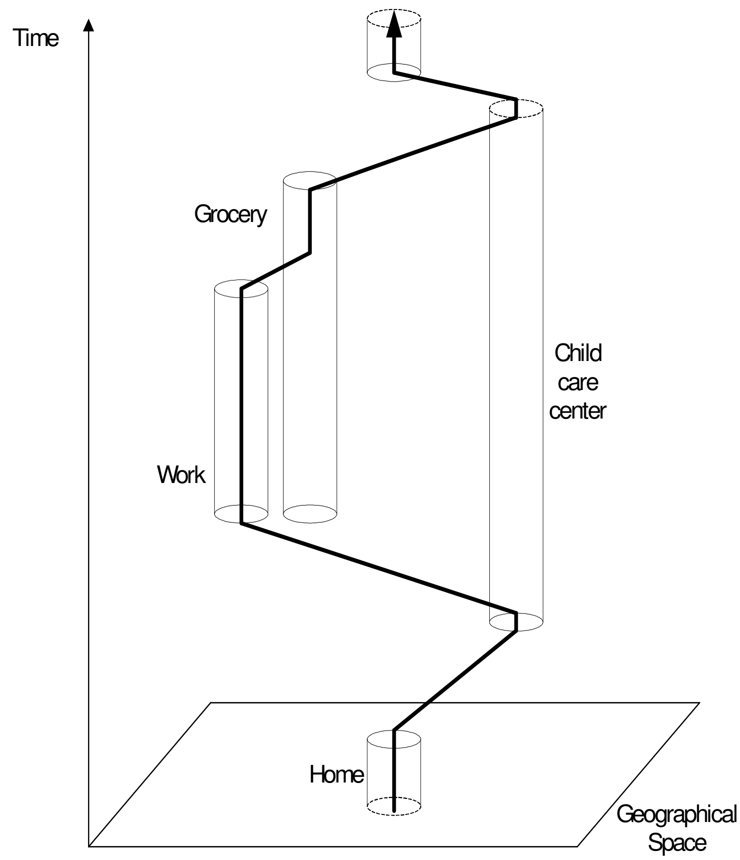


Figure 1: A space-time path and stations

Activities differ with respect to their pliability in space and time. *Fixed activities* are events that are relatively difficult to relocate or reschedule. For example, people are often required to work at a specific location for a designated duration. A person's home is usually fixed in place (at least over the short run) and maintenance or familial obligations require presence for regular intervals. For example, childcare is only available for certain hours of the day. *Flexible activities* are relatively easy to reschedule and relocate. A person can shop at a grocery store at otherwise idle times between work and home hours; she also has some choice over where this occurs. There are limits on flexible activities as well (e.g., retail outlets have limited hours and few locations, one cannot socialize if friends are not available), but the activity is flexible if there are some degree of freedom to the individual(s) involved.

There is only a finite amount of time available to a person to allocate among activities over any time horizon (daily, weekly, monthly, annually); this is sometimes referred to as the individual's *time budget*. The fixed activities dominate a person's time budget; flexible activities must occur in the residual time intervals between fixed activities. The spatio-temporal travel and activity patterns that emerge from the allocation of time among anchors leads to the concept of an *activity space* or the limited portion of the environment used by an individual for their activities and travel. Three major factors determine the spatial extent of an individual's activity space: i) movement near the person's home location; ii) movement to and from regular activities such as work and school, and; iii) movement proximal to the locations where these regular activities occur (Golledge and Stimson 1997). Thus, the locations and timings of key fixed activities act as *space-time anchors.* These anchors can contribute to social exclusion by preventing a person from participating in activities in other locations and times (Schönfelder and Axehausen 2003a, 2003b).

The *job-housing balance* debate in the urban planning community highlights the negative consequences of spatial separation between residential and employment locations. Much of this debate centers on consequences such as "wasteful" commuting between home and work that generates traffic congestion and environmental degradation. From this perspective, job-housing balance is controversial. One problem is scale-dependency, e.g., a small neighborhood is never balanced while a region is always balanced. It also implicitly assumes that people want to live near where they work. There are several confounding factors, including dual-income households, job mobility and non-work related factors that influence residential choice (Giullano 1991; Levine 1998). Evidence suggests that dramatic land-use changes are required to reduce vehicle miles traveled (Peng 1997) and that jobs and housing seem to balance or at least stabilize over time (Giulliano 1991; Wachs et al 1993). It is doubtful that balancing jobs and housing will reduce traffic congestion and air pollution (Levine 1998).

Although it is a weak concept with respect to travel demand management, jobs-housing imbalance is useful for understanding social exclusion in space and time. From an individual-level space-time perspective, jobs and housing are never balanced unless they are the same location, and even in this case there is still a need to devote time to work. Social differences with respect to compulsory presence at these space-time anchors as well as their locations and timings translate into potential for social exclusion by creating corresponding restrictions on the ability to be at other times and places. For example, longer commutes means that some individuals have less time available for other activities. Although certainly not a universal phenomena, low income and minority women tend to have longer commute distances and times due to housing expenses, employment characteristics or household organization (e.g., Gober, McHugh and Lecerc 1993; McLafferty and Preston 1996, 1997; Wachs et al 1993). An exacerbating factor is the association of low-income employment with less time flexibility; examples include shift work that strictly compel presence at work for fixed hours of the day and days of the week. Strict penalties for repeated tardiness can include termination of employment: this can induce individuals to leave early for work, further reducing their time budget for other activities. There is a need for additional research on the spatial, temporal, gender and social dimensions of jobs-housing imbalance (Preston and McLafferty 1999), particularly as they translate into spatio-temporal constraints on other activities.

Recent decades has witnessed urban sprawl or the shift of urban development from traditional, compact forms to dispersed, automobile-oriented forms in many cities in North America, Europe and other regions of the world. There is a great deal of debate surrounding the measurement, causes and consequences of urban sprawl (e.g., Lopez and Hynes 2003). There is also skepticism whether policies designed to discourage or reduce sprawl will alleviate one of its major consequences, namely, travel demand and congestion (see Boarnet and Crane 2001). However, the effects of sprawl on social exclusion are clear: sprawl can increase exclusion through increased segregation due to selective population movement to the suburbs, loss of employment, retailing, services and amenities in the central city, increased demand for services such as health and policing and increased traffic congestion (Power 2001). From a space-time perspective, sprawl can create or exacerbate spatio-temporal exclusion by creating a corresponding dispersion of activity locations, increasing the amount of time required for access, particularly if congestion accompanies sprawl. This can result in some activities becoming infeasible due to time budget and scheduling constraints. Increasing spatial segregation can create a corresponding decrease in social contacts and networks as the daily activity spaces of different social groups become more disjointed, reducing exposure and the possibilities for contact and interaction (Schell and Yoav 2001).

The literature discussed above suggests that there could be substantial differences among different social groups with regard to activity spaces; these should reflect differences in spatio-temporal inclusion and exclusion. However, there is scant direct empirical evidence regarding the relationship between activity spaces, socio-demographic factors and social exclusion. Schönfelder and Axehausen (2003a, 2003b) develop three measures of activity spaces and analyze their relationships to socio-demographic characteristics and social exclusion. Measures of activity spaces include confidence ellipses, kernel density estimates and minimal spanning trees. Confidence ellipses extend the concept of confidence intervals in statistics to the distribution of activity locations in two-dimensional geo-space. The size and orientation of the ellipse is a surrogate for the individual's activity space. Kernel density estimates compute a density surface from the person's activity locations; the spatial extent and volume of the density surface measures the activity space. The minimal spanning tree captures the transportation network by forming the shortest path tree that reaches the activity locations; the length of the tree and the size of the area buffered from the tree measures the activity space. Using 1999 data from two German cities, they found no substantial differences among the activity spaces of different social groups, including those traditionally considered at risk for exclusion (female, lower income, elderly). However, the data in their study was not collected specifically for social exclusion analysis and any differences might be masked by the sampling procedures. Explicit and focused research on activity spaces and social exclusion is required.

Space-time anchors can be facilitating as well as constraining since they embed the individual within community and service networks that are strongly rooted in one's residential neighborhood and work place. These networks form since a person's home and work anchors are usually proximal or coincident with others' home and work anchors, facilitating contacts and interactions. Since homelessness is often (but not always) preceded by unemployment, homeless individuals lose their two major facilitators of support networks. These networks must be rebuilt without the benefit of home and work anchors

In a study of homeless activity patterns in Los Angeles, CA, Wolch, Rhimian and Koegel (1993) note that homeless with more extensive travel patterns are likely to be newly homeless who attempt to maintain links to their former communities and home-based social networks. Long-term homeless people show less mobility, settling in to a familiar routine involving travel among a few proximal space-time stations such as homeless missions. This pattern means that they lose touch with their previous networks; they often give up trying to look for work. In addition to voluntary mobility, homeless are often forced to move by welfare regulations and the geographic distribution of relevant space-time stations. Policy implications include the establishment of service opportunity hubs in geographically dispersed locations to ameliorate the need to move to concentrated and isolated areas.

3.2. Household organization, social networks and space-time constraints.

Household organization and social networks influence the allocation of time among activities in space. Multi-person households can create greater *role specialization*; this can have positive or negative effects on time allocation. The presence of multiple adults allows activities to be consolidated and duplication of effort to be minimized, freeing up time for other activities. The presence of dependent children can increase demands on time for servicing activities; adults sharing tasks can offset these constraints. Household organization can also create *competition for resources*. Although larger households tend to have more resources, some resources such as time, transportation or ICTs can experience greater competition. For example, household members must often negotiate and schedule the use of a car or a computer with an Internet connection. Multi-person households also lead to *joint activity participation*. Sharing activities among adults can reduce the amount of time that an individual must dedicate to these activities. However, joint activities must be negotiated and scheduled with respect to the precise location and time. This implies increased interdependence and spatio-temporal constraints that can offset the benefits of joint activity participation to some degree (Jones 1989).

STAT implies that social differences in activity organization and inequities in negotiating joint activities creates the potential for social exclusion if this creates differences in spatio-temporal constraints. As noted previously, there is strong evidence that activity patterns vary across key social dimensions. There is also evidence that these differences translate into differentials in space-time autonomy.

Differences between traditional gender roles are particularly sharp. Women spend more time on household maintenance activities and less time on leisure than men, with the result that women make more frequent but shorter trips (Hanson and Hanson 1981b; Lu and Pas 1999; Pas 1984). Women's trip scheduling and chaining also tends to be more complex than men, especially if there are dependent children in the home, creating more spatio-temporal constraints on their activity participation (Gordon, Kumar and Richardson 1989). Kwan (1999) reports evidence that women have less space-time accessibility than men since they perform traditional gender role activities related to familial maintenance activities despite full time employment. Kwan (1999) also notes that women face the same commute times and lengths as men; this suggests that traditional, trip-based measures of accessibility mask these important gender-related differences. Hanson and Hanson (1981a) report that women adjust their schedules to accommodate their full-time employment with little or no adjustments from their male partners Women are also less able to adjust their schedules and travel patterns to accommodate alternative schedules or transportation modes (Rosenbloom and Burns 1993). Childcare obligations can require low-income women to seek employment closer to home than men (Chapple 2001).

Social networks outside the home require investments of time for their development and maintenance: these networks often arise as a function of a person's movement and location in space and time (e.g., many people acquire most of their friends through their home neighborhood and work place) (National Research Council 2002; Rowe and Welch 1990). These introduce additional space-time constraints since they introduce new coupling constraints. However, they are often beneficial, not only for a person's psychological welfare but also as a potential source of temporal resources. In a study of travel behavior among low-income residents in Merseyside, UK, Grieco (1995) notes that residents use social relationships and time as a type of mobility resource. To alleviate space-time constraints associated with low income (e.g., lack of professional childcare), people will borrow and repay time favors (e.g., having a neighbor watch a child so you can run an errand). Types of time borrowing include: i) provision of shopping services (e.g., shopping for a neighbor); ii) provision of escort services (e.g., taking a neighbor's child to childcare); iii) provision of childcare services. However, these linkages can create complex inter-household temporal dependencies, exacerbating activity scheduling problems and creating other space-time pressures.

3.3. Space-time accessibility

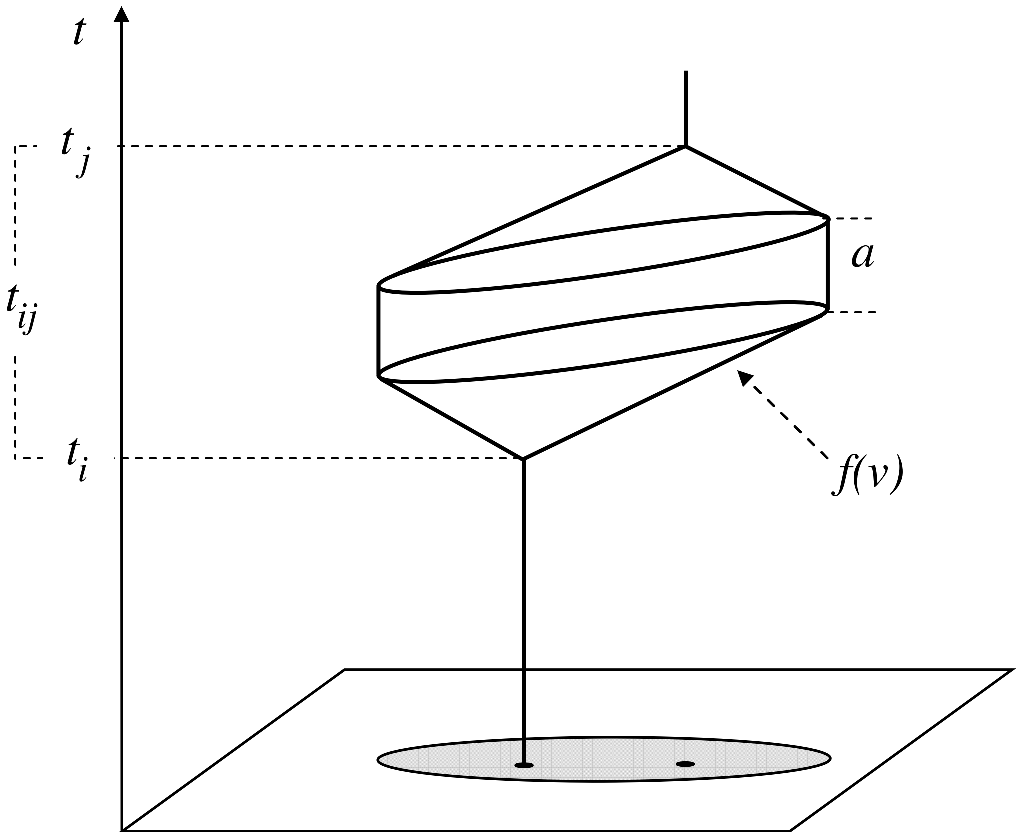
Solomon (2000) defines adequate transportation as consisting of "four A's." Adequate transportation must be *affordable* in terms of expense relative to income. Automobile ownership may be financially impossible for some people. Bus and rail tickets can also be a major expense particularly for those earning minimum wages. Some individuals may also require private taxis, particularly if public transit service does not coincide with their schedules. This can be a necessary but considerable expense. Second, it must be *available*. While a personal automobile is frequently available, this may not be useful if the automobile is shared among several family members or friends. The public transit network may be spare and scheduled service may be infrequent relative to a person's needs. It must also be *accessible*, both with respect to the vehicles themselves and the nodes of the system. An automobile may be financially feasible to an elderly person but inaccessible due to the acuity required for operation. Regular bus services may be inaccessible to individuals in a wheelchair; these individuals may require special service that is less frequently available. Finally, adequate transportation must be *acceptable* to the individual. Public transit may be affordable, available and accessible but still unacceptable to a woman who leaves work late at night and has safety concerns.

Analysis and planning of public transportation routes often relies on simple stop-related access measures such as the number of people with a specified distance of transit stops. Network connectivity is sometimes considered as well (e.g., Murray 2001; O'Neil

1995; O'Neil, Ramsey and Chou 1992). This ignores the spatio-temporal consequences of public transit. While it is theoretically possible to complete long trips using a combination of walking and public transportation, the time required to complete these journeys may make them unattractive or even infeasible. This is especially true if individuals must execute "trip chains" such as escorting a small child to day care before traveling to work. Wait times at system interfaces such as route and mode junctions can be lengthy and the time penalty for missing a connection can be severe. Individuals who work subject to strict time schedules may need to budget extraordinarily long time intervals for commuting to ensure prompt arrivals at work if these trips are conducted using pubic transportation (Solomon 2000).

A fundamental analytical device for measuring accessibility is the *space-time prism*. The prism delimits the possible locations for the space-time path. Figure 2 illustrates a prism. Fixed activities and coupling constraints anchor a space-time prism since by definition these allow only one spatial possibility during their duration. For example, the first anchoring location in Figure 2 could be the person's home that she can leave no earlier than time t_i and the second anchoring location could be work where she must be no later than time t_j. At some time during the time interval $t_{ij} = (t_j - t_i)$, the person must stop at some location to conduct an activity that will require at least a time units, for example, shop at a grocery store or pick-up a child up at day care. The person can move with an average maximum velocity v. Figure 2 shows only one type of space-time prism. We can also construct space-time prisms for cases where the two fixed activities are at the same location, one of the fixed activity locations is unspecified, and/or the minimum required flexible activity time is unspecified (see Burns 1979).

The interior of the prism is the *potential path space*: this shows the points in space and time that the person could occupy during this travel episode. A person cannot participate in an activity unless its space-time path (reflecting its location and available times) intersects the potential path space to a sufficient degree. The projection of the potential path space to geo-space provides the *potential path area*: all spatial locations that the person could occupy. A person cannot participate in an activity unless its location falls within the potential path area (ignoring the temporal duration of activities).



. **Figure 2: A space-time prism**

The classic space-time prism assumes unrealistically that travel velocity is continuous and uniform across time and space. In most settings travel is restricted to transportation networks. Travel velocities within these networks vary by location and time based on the capacity of the infrastructure and the movement of other individuals. Relaxing the uniform travel velocity assumptions has been an active research area for the past decade. New techniques are available for constructing space-time prisms within static and dynamic networks, the latter involving time varying travel times due to flow and congestion within the network (Miller 1991, 1999; Wu and Miller 2001). For example, Figure 3 illustrates a network-based potential path area in Salt Lake City, Utah, based on automobile travel from the specified origin with a fifteen minute time budget. It is also possible to construct the prism for multimodal transportation networks such as walking and public transit (O'Sullivan, Morrison, and Shearer 2000). These can create realistic space-time prisms that are directly applicable to planning and policy.

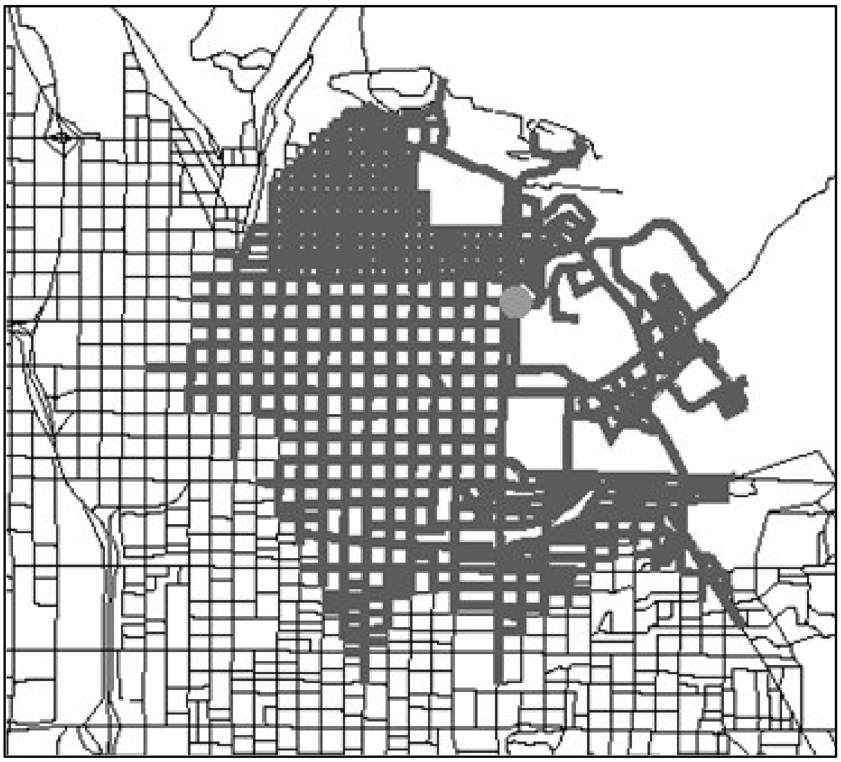


Figure 3: A network-based potential path area (based on Miller 2004)

Although increasing the space-time coverage and efficiency of private and public transportation is useful, there are also other strategies for improving the size of a person’s prism, thereby reducing excluded locations in space and time. Burns (1979) theoretical analysis of space-time prisms suggests that strategies for freeing time are more effective than those aimed at increasing travel velocities (e.g., *flex-time* policies that allow employees some latitude over scheduling time spent at work, with the motivation that some will work later or earlier to avoid congestion and therefore also reduce its intensity). There is some empirical evidence supporting the use time policies in improving accessibility and autonomy (Jones 1989). However, some efforts to increase the prism volume can have a detrimental effect in the long-run if they lead to greater dispersion of anchors (e.g., policies or infrastructures to encourage automobile use). From a STAT perspective, the ideal strategies are those that maximize the potential *intersections* among prisms, paths and stations. This may involve increasing the prism volumes, but they also must control for longer-term effects on the prism anchors and the location and timing of stations with respect to prisms.

STAT recognizes other constraints on space-time accessibility *Authority constraints* impose certain conditions of access in particular space-time domains. For example, a private shopping mall can impose more constraints than a traditional city center on individuals' space-time autonomy since private space can be more effectively restricted from occupancy during certain hours and days and for some purposes. Another example: a gardener could successfully enter a gated suburban community during the time but would find this more difficult during the night. The increasing privatization of spaces for activities such as shopping and enterainment creates a potential for greater authority restrictions on space-time autonomy and exclusion for vulnerable populations such as the homeless.

3.4. Space-time extensibility

STAT often makes a distinction between *in-home activities* versus *out-of-home activities*. The distinction between these activity classes is evident from their labels: in-home activities occur at home while out-of-home activities occur elsewhere. This distinction is meaningful since out-of-home activities generate movement in space and demand for transportation. The boundary between in-home and out-of-home activities is becoming less distinct due to the rise of information and communication technologies. While these technologies have been available since the first postal systems and especially the inventions of the telegraph and telephone, they are becoming more pervasive with the rise of the Internet and mobile phone networks.

Although strongly rooted in physical space, the emphasis on time availability in time geography corresponds well with the view that time is the scarce commodity of the information economy and ICT-accelerated modern lifestyles (Gleick 1999; Goldhaber 1997). Regularities between cyberspace and geo-space mean that locations in cyberspace can be related to geographic locations at different scales using hybrid information and geographic space (Batty and Miller 2000). Adams (2000) and Kwan (2000a) have extended the space-time path to include virtual extensibility.

ICTs can be classified with respect to their spatial and temporal constraints. Table 2 illustrates these modes (Janelle 1995; Harvey and Macknab 2000). Spatial constraints require either physical presence or telepresence, while temporal constraints require either synchronous or asynchronous interaction. *Synchronous presence* (SP) requires coincidence in both time and space. An example is face-to-face (F2F) interaction. *Synchronous telepresence* (ST) requires only coincidence in time; these include telephones, radio, and TV. *Asynchronous presence* (AP) requires coincidence in space but not time: an example is a traditional hospital chart or a note left on someone's office door. *Asynchronous telepresence* (AT) does not require coincidence in space and time; these included books, newspaper, email, and webpages.

	Spatial	
Temporal	Physical presence	Telepresence
Synchronous	**SP** Face to face (F2F)	**ST** Telephone Chat rooms Radio and television Teleconferencing
Asynchronous	**AP** Post-it® notes Traditional hospital charts	**AT** Mail Email Fax machines Printed media Webpages Electronic hospital charts

Table 2: Communication modes based on their spatial and temporal constraints (based on Harvey and Macnab 2000; Janelle 1995)

The relationships between presence, telepresence and activities can be complex. Table 3 provides a typology with example activities relative to transportation-ICT interactions (Krizek and Johnson 2003). The subdivision of fixed activities into subsistence and maintenance is standard in STAT: these refer respectively to activities associated with obtaining fundamental living resources (e.g., employment) and those associated with household maintenance (such as grocery shopping, cooking, cleaning, childcare, sleeping). There is an uneven distribution of research across these types, with most research concentrated on ICTs and subsistence-related travel (e.g., telecommuting) and maintenance activities (e.g., shopping) (Krizek and Johnson 2003). Less well understood but critical from a STAT perspective are the cross-activity relationships, i.e., how the relationship between transportation and ICTs in an activity influences the relationship between transportation and ICTs in another activities, as well as the time spent in these activities.

		Relationship between transportation and ICTs		
	Activity type	**Substitute**	**Complement**	**Modify**
Fixed activities	**Subsistence**	Telecommuting and homeschooling	Arranging and booking work-related travel	Work-related communication while at home, traveling or participating in other activities
	Maintenance	Online banking and shopping	Online shopping guides (to “bricks and mortar” shops)	Completing errands involving travel while telecommuting from home
Flexible activities		On-demand video Purchasing concert or film tickets online	Online restaurant, nightlife and travel guides	Better coordination and increased flexibility in communicating and meeting with friends and family.

Table 3: Relationships between transportation/ICTs and activities (based on Krizek and Johnson 2003)

A lack of information can also exacerbate other spatial and temporal constraints on activity participation. Uncertainty about the travel environment can reduce accessibility. Theoretical analysis of space-time prisms suggests that uncertainty about travel velocities can require a person to leave the first fixed activity earlier in order to ensure meeting the second coupling constraint. This reduces available time, the prism volume and therefore space-time accessibility. Accessibility decreases as uncertainty increases and with higher penalties for missing the coupling constraint at the second fixed activity. Uncertainty about the activity locations and their attributes can require the person to budget time for spatial search to find the locations or comparison shop, also reducing the prism volume (Hall 1984).

Similar to transportation, there are several dimensions that determine the adequacy of ICTs for an individual. These dimensions include *technology* (available bandwidth), *autonomy* (whether the individual is monitored and controlled while using ICTs), *skill* (knowledge of how to search and download information), *social support* (advice from experienced users) and *purpose* (economic productivity, social capital, consumption, entertainment) (DiMaggio and Hargittai 2001; Warschauer 2003). In the

United States, there is an historic "Digital Divide" between ICT users and non-users along ethnic, gender and age dimensions (Hoffman, Novak amd Schlosser 2001). Although the collapse in price of end-user devices and services as well demographic transitions has closed much of this divide, income remains a substantial determinant of ICT adoption, with lower income households being much less likely to use these technologies across major ethnic groups (Compaine 2001; Walsh, Gazala and Ham 2001; Norris 2001). Regional differences in ICT use persist at the international scale, particularly between rich and poor regions and nations (Norris 2001). Still lagging is adoption of ICTs by people with different abilities such as vision impairment, exacerbating the potential social exclusion caused by a physical world not always designed to be accommodating (Warschauer 2003).

Information poverty caused by a lack of ICT resources can be a pervasive influence on social exclusion as the lack of transportation resources. The combined effects of the need to physically search for information, the time constraints imposed by this search as well as the higher levels of uncertainty associated with the physical sources of information contributes substantially to marginalization. Without access to information, access to resources and opportunities is also blunted (Carter and Grieco 2000). ICTs are increasingly a major conduit for facilitating social networks (Warschauer 2003); a lack of ICTs means that social networks may be stunted and require more time for development and maintenance. The lack of social resources creates additional constraints on individuals who can use these relations to alleviate many of the time pressures associated with low-income (Grieco 1995).

A lack of information about the transportation environment can be particularly constraining if a person relies on public transit. Trip planning using public transit is often more complex than planning similar trips using a private automobile. In addition, the time penalty of missing a connection can be severe, creating pressure to "play it safe" by leaving early and/or walking. Information on changes in public transit routes and schedules are often not propagated well to the population that depends on these services, leading to an impression of schedule irrationality. This can greatly exacerbate the time pressures and constraints experienced by low-income people (Grieco 1995)

STAT implies that there are also indirect, higher-order constraints imposed by a lack of ICT resources. As suggested by Table 3, linkages among activities in space and time as well as the complexity of relationships between transportations and ICTs means that inadequate ICTs can propagate space-time constraints beyond the specific activity directly affected. For example, Saxena and Mokhtarian (1997) find that telecommuting from home not only shifts the location of the non-work trips (moving them closer to home rather than work) but its distribution with respect to spatial direction. Non-work trips on commuting days tend to be oriented towards the work location. Although not conclusive, this evidence is consistent with a loosening of the space-time prism with respect to the anchoring locations (i.e., the second fixed activity coincides with the first activity location, changing the space-time prism volume).

4. New Approaches to Old Problems

Section 3 suggests that there are natural and fruitful linkages between STAT and questions of social exclusion. Section 3 also suggests that questions surrounding space-time exclusion are sparse and peripheral in the literature. While there has been much research on social exclusion and space-time activities independently, the degree of overlap between these research domains is minimal.

As noted previously in this paper, the is a great potential for expanding STAT-based analysis of social exclusion as well as injecting social exclusion issues and questions into urban and transportation planning and engineering. These potentials relate to the development of new spatial and location-aware technologies that are increasingly being adapted and used in space-time activity analysis as well as transportation engineering (Timmermans, Arentze and Joh 2002). This section of the paper (based on Miller 2005) briefly discusses these technological and methodological developments. Also discussed are privacy issues raised by the use of these methods in social exclusion research.

4.1. Data collection

One of the traditional problems with collecting space-time activity data is the expense and error of traditional methods (Golledge and Stimson 1997; Golledge and Zhou 2001).

Recall methods require subjects to recall and report activities during some previous time period. This relies on subjects' abilities to remember activities and their locations at a later time period; therefore, the period of recall must be short. *Stylized recall methods* require subjects to report normal activities that occur during some typical time period. This raises definitional problems with respect to what are "typical" activities and what is "normal" time period. *Diary methods* require subjects to record activities in a diary, either in a free-format manner or at pre-determined time periods. Previous research suggests that diary methods produce the best data (Ettema, Timmermans, van Veghel, 1996; Pas and Harvey, 1996); nevertheless, it has significant problems. Individuals are sometimes unwilling to report certain activities and often underreport short trips and the number of stops during a multi-purpose trip (Brog, Meyburg and Wermuth 1982; Golledge and Zhou 2001; Purvis 1990)

New LATs can greatly enhance the collection of activity data (Greaves and Stopher 1998). Global positioning systems (GPS) combined with recording devices such as personal digital assistants (PDA), in-vehicle navigation systems and cellular telephones can allow for more accurate and detailed recording of activities in space and time (Murakami and Wagner 1999). Continuing advances in voice recognition software and natural language processing will allow voice interfaces to be integrated into in-vehicle navigation systems, cell phones and PDAs. This can facilitate diary methods for collecting activity data through more natural data entry, potentially reducing under-reporting and related errors. GPS receivers can also collect network travel time information during the travel event, allowing calibration of aggregate travel time data (see Guo and Poling 1995). The detailed location and time information available from a vehicle-mounted GPS receiver can also facilitate subjects' memory of activity purpose using recall methods after the event (Stopher and Wilmot 2000).

The rise of *location-based services* (LBS) through wireless communication networks offers another vehicle for collecting STA data. LBS provide specific, targeted information to individuals based on their geographic location, typically though wireless communication networks and devices such as PDAs, cell phones and in-vehicle navigation systems (Benson 2001). LBS technology can support analysis of individuals trajectories in space and time combined with users' information access patterns (Smyth

2001). Non-response biases may be lower since these technologies will be more ubiquitous and accepted than unique special-purpose data collection efforts. Changes in space-time activity behavior induced by the data collection effort may also be smaller.

A potential problem with using LBS data in analyzing social exclusion is selection bias: the people of greatest interest in social exclusion analysis are the people least able to afford these services. However, some predict worldwide deployment levels reaching one billion devices by 2010 and penetration rates similar to the use of cellular telephones (Bennahum 2001; Smyth 2001). Nevertheless, LBS data must be used with caution in social exclusion analysis.

4.2. Analysis

A difficulty with analysis of space-time activity data is a combinatorial explosion of the information space. Decisions such as the number of activities within a time period, sequencing, timing, mode and route choice are interlinked, implying an information space that is exponential with respect to choice dimensions (Ben-Akiva and Bowman 1998). Consequently, traditional methods for activity analysis such as econometric and statistical techniques (e.g., O'Kelly and Miller 1984), utility maximizing models (e.g., Kitamura 1984) and rule-based reasoning (e.g., Garling, Kwan and Golledge 1994) require substantial reduction of the information space for tractability. This means that only a small subset of the possible interactions among these decision dimensions, activity types, transportation and ICTs can be analyzed. This can miss many of the complex, higher-order effects such as the propagation of space-time constraints across activity types and episodes.

Emerging are new computational techniques for exploring space-time activity data that do not require *a priori* restriction of information space and activity linkages. van der Knaap (1997), Huisman and Forer (1998) and Kwan (2000b) develop cartographic visualization techniques for exploring space-time paths. Arentze et al. (2000) apply decision tree induction methods to STA data. Joh, Arentze and Timmermans (2001) adapt multidimensional sequencing methods from genome research to measure similarities among activity patterns. Arentze and Timmermans (2000) develop a computational process model (CPM) of activity patterns driven by heuristic behavioral rules for scheduling activity programs. Their ALBATROSS (A Learning Based Activity and Transportation Oriented Simulation System) attempts to simulate the way individuals solve activity scheduling problems based on decision rules induced from empirical activity data. For a more complete review of space-time activity analysis methods see Timmermans, Arentze and Joh (2002).

4.3. Privacy and control

The sensitive reader may have become increasingly uneasy while reading this chapter, particularly the previous section. Clearly, there are important ethical issues surrounding the tracking and recording of individuals' activities in space and time. LATs can provide unprecedented powers for privacy invasion and control by preventing a person from certain locations in space and time as well as certain spatio-temporal trajectories (e.g., loitering on a street corner, crossing paths with someone you are forbidden to contact; CNN 2003). This creates the possibility of *geoslavery* or the pervasive ability to track and control a person's space-time trajectory (Dobson and Fisher 2003). As geographer Jerome Dobson colorfully asks, "How long would Ann Frank's diary be if she was wearing on of these [LAT] devices?"

GIS and LATs are no different from any non-trivial technology in the sense that they could be used for tremendous good as well as tremendous bad. This should not lead us to abandon or ignore these technologies just as we have not abandoned similar "double-edged" technologies such as the clock, electricity or the computer. The private sector will be using LBS to market products and services more effectively: these technologies and services should also be used to make our cities more equitable, livable and sustainable. It should also be noted that this chapter does not call for the exclusive tracking of socially disadvantaged or vulnerable persons: rather, questions of social exclusion should be included in broader analyses of transportation, ICTs and cities using space-time activity data.

Space-time activity data can be used in an ethical and respectful manner using standard or perhaps expanded human subjects review protocols in place at most universities and research institutions; policy research is required on these issues. The application or modification of these protocols to the primary data collection or the use of secondary (LBS-derived) is also an open research question. *Locational privacy* is an emerging issue in geographic information science, and new techniques are being developed such as *locational masking* that protect location privacy by introducing known and controlled error into the data (see Armstrong 2002; Armstrong, Rushton and Zimmerman 1999).

5. Conclusion

Transportation and ICTs have been neglected in social exclusion analysis partly due to the use of static and aggregate place-based measures and analysis. Place-based analysis ignores individual differences in social exclusion created spatio-temporal constraints on activity participation, obtaining resources and exploiting opportunities. Factors such as the location of key life activities, the organization and coordination of activities with respect to households and social networks and differences in the ability to trade time for space in movement and interaction through transportation and ICTs can effectively exclude some individuals from the institutions, goods, services and information that are standard for a particular society. People-based measures are a complement, not a replacement, for people-based measures of spatio-temporal exclusion: together they provide a fuller depiction of social exclusion as a multi-scale phenomenon in space and time. New developments in GIS and location-aware technologies have great potential for enhancing understanding of spatio-temporal exclusion and increasing its relevance in planning and engineering, although the potential negative consequences of these technologies for privacy and control must be addressed as well.

This paper suggests a potential synergy between space-time activity theory (STAT) and issues of social exclusion, particularly with respect to individual differences in the adequacy of transportation and ICTs. Long-standing and sometimes controversial issues such as jobs-housing imbalance and sprawl have new relevance for social exclusion when seen from a STAT perspective. However, this paper also illustrates that issues of social exclusion have not been extensively and explicitly addressed by STAT researchers. STAT researchers have concerned themselves with social, demographic, life cycle and gender differences in space-time activity patterns and constraints, but mostly how they relate to modeling travel demand. Research such as Kwan (1999, 2002) or

Rowe and Wolch (1990) that explicitly address questions of space-time constraints and social exclusion are rare. Clearly, there is a strong need for closer interaction between STAT and social exclusion research to explore the issues and dimensions raised in a preliminary manner here.

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