Gender and Individual Access to Urban Opportunities: A Study Using Space–Time Measures*

Mei-Po Kwan
The Ohio State University

Conventional accessibility measures based on the notion of locational proximity ignore the role of complex travel behavior and space–time constraints in determining individual accessibility. As these factors are especially significant in women's everyday lives, all conventional accessibility measures suffer from an inherent "gender bias." This study conceptualizes individual accessibility as space–time feasibility and provides formulations of accessibility measures based on the space–time prism construct. Using a subsample of European Americans from a travel diary data set collected in Franklin County, Ohio, space–time accessibility measures are implemented with a network-based GIS method. Results of the study indicate that women have lower levels of individual access to urban opportunities when compared to men, although there is no difference in the types of opportunities and areas they can reach given their space–time constraints. Further, individual accessibility has no relationship with the length of the commute trip, suggesting that the journey to work may not be an appropriate measure of job access. **Key Words: accessibility, gender, space–time constraints, urban opportunities.**

Introduction

Recent debate on gender/ethnic differences in access to employment opportunities raises concerns about the difficulties in using the length of the commute trip as a measure of job access (McLafferty and Preston 1996; Wyly 1996). As either long or short work trips can be taken as indicators of spatial inequality in the access to employment (the former for inner-city minorities, the latter for suburban women employed in female-dominated occupations), it is recognized that "correct" interpretations of results depend on a contextualized understanding of the life situations of the individuals being studied. Other studies also suggest that the accessibility experiences of individuals in their everyday lives is much more complex than what can be represented by conventional measures of accessibility (Pickup 1985; Kwan 1998; Talen and Anselin 1998).

In this paper, I examine the problem of using conventional measures to evaluate personal accessibility. I argue that these measures ignore the situational complexities of activity-travel behavior and the role of space–time constraints in shaping the accessibility experience of individuals. As these factors bear significantly upon women's everyday lives, all conventional accessibility measures suffer from an inherent "gender bias" that has hitherto gone unnoticed. In view of these limitations of conventional accessibility measures, this study argues that defining accessibility as space–time feasibility instead of locational proximity would enable a better understanding of individuals' accessibility experiences. It provides formulations of alternative accessibility measures for studying gender differences in access to urban opportunities based on the construct of the space–time prism.

Despite the advantages of space–time accessibility measures, few studies have implemented them due to operational difficulties such as the geoprocessing capabilities required. To examine gender differences in individual accessibility, I use a network-based GIS method to operationalize space–time measures. Data for the study are derived from a travel diary data set collected in Franklin County, Ohio, a digital transportation network, and a land parcel geographic database of the study area. Results of the study, based on a subsample of European Americans, indicate that there are significant gender differences in individual access to urban opportunities for full-time employed women and men, although no difference was observed in the composition and types of opportunities available to these individuals. Further, individual accessibility has no

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significant relationship with the length of the commute trip, suggesting that the journey to work may not be an appropriate indicator of job access.

Conventional Accessibility Measures

Conventional accessibility measures are based on three fundamental elements (Hanson and Schwab 1987). First, a reference location serves as the point from which access to one or more other locations is evaluated. The reference location most often used is the home location of an individual, or the zone where an individual's home is located when zone-based data are used. Second, a set of destinations in the urban environment is specified as the relevant opportunities for the measure to be enumerated. This set may include employment opportunities (for evaluating job access) or particular types of shops, services or facilities. Further, each opportunity may be weighted to reflect its importance or attractiveness. Third, the effect of the physical separation between the reference location and the set of urban opportunities on access is modeled by an impedance function, which represents the effect of distance decay on the attractiveness of the relevant opportunities.

Based on these three elements, various types of accessibility measure can be specified. Morris et al. (1979) provide a helpful typology of accessibility measures comprising two broad groups: relative and integral measures. Relative accessibility measures describe the degree of connection between two locations (Ingram 1971). They are expressed in terms of the presence or absence of a transport link, or the physical distance or travel time between two locations. Examples of this type of measure are commuting distances or times used in recent studies on the spatial mismatch between population subgroups and jobs (e.g., Ihlanfeldt 1993). Integral measures, on the other hand, represent the degree of interconnection between a particular reference location and all, or a set of, other locations in the study area. They have the general form:

$$A_i = \Sigma W_j f(d_{ij})$$

where A_i is the accessibility at location i, W_j is the weight representing the attractiveness of location j, d_{ij} is a measure of physical separation between i and j (in terms of travel time or distance), and $f(d_{ij})$ is the impedance function. When impedance is expressed in the form of a distance decay function similar to those found in gravity models, the access measure is a gravity-based measure (Handy and Niemeier 1997; Helling 1998; Levinson 1998). The most commonly used impedance functions are the inverse power function and the negative exponential function. In the case where an indicator function is used as the impedance function to exclude opportunities beyond a given distance limit, the measure is a cumulative-opportunity measure (Wachs and Kumagai 1973; Talen 1997). This measure indicates how many opportunities are accessible within a given travel time or distance from the reference location.

A further distinction could be made depending on whether an access index is enumerated and used as an indicator of physical or place accessibility (how easily a place can be reached or accessed by other places), or personal or individual accessibility (how easily a person can reach activity locations). As will be shown below, this distinction is important if the objective is to understand the accessibility experienced by individuals in their everyday lives, and to avoid the problem of ascribing the accessibility of a location or area (e.g., census tract) to a person at that location or in that area (Pirie 1979).

Limitations of Conventional Accessibility Measures

One major difficulty in using conventional measures to evaluate individual accessibility stems from the concept of accessibility they operationalize, namely, accessibility as locational proximity of opportunities with respect to a single reference location. There are several problems with this notion. First, as accessibility is measured with respect to a single reference location such as home or the workplace, all travel or activities (whether actual or potential) which contribute to personal accessibility are assumed to be based on this single origin. This amounts to assuming that all potential trips, which contribute to the accessibility of a person residing at a particular location, start from that single reference point. Such an assumption, however, deviates quite significantly from many characteristics of activity-travel behavior observed in recent research.

As past studies have shown, a substantial proportion of intra-urban travel consists of multi-purpose, multi-stop journeys, and potential stops at various locations may become more accessible by virtue of their proximity to sites other than home or the workplace (Hanson 1980; O'Kelly and Miller 1983; Kitamura et al. 1990; Golledge and Stimson 1997). A study by Richardson and Young (1982) demonstrates that, without considering the effect of linked trip or trip chaining behavior, conventional measures may considerably underestimate the accessibility to activities of non-central urban locations. Similarly, Arentze et al. (1994) conclude that methods taking multipurpose travel into account may lead to different evaluations of the differential accessibility in real-world situations. The complex linkages and interdependencies between activities in a person's daily life therefore render the evaluation of accessibility in terms of a single reference location problematic. An example of this is the multipurpose journey to work where the work trip is linked to travel to essential facilities. As observed in several studies, the availability of child-care facilities is often an important factor determining the accessibility of certain job locations for women with young children (Michelson 1985, 1988; Tivers 1985, 1988; Hanson and Pratt 1990; Bianco and Lawson 1996; England 1996a, 1996b; Myers-Jones and Brooker-Gross 1996; Gilbert 1998). In other words, access to jobs depends not only on where the jobs are, but also on the location of child care facilities which renders some job locations more feasible than others. Using the length of the commute trip as a relative measure of job access can therefore obscure the accessibility experience of individuals, especially women, in their everyday lives, since job location may be constrained by the location of essential facilities rather than the reverse.

A second problem of conventional accessibility measures is their ignorance of the role of individual time-budget and space–time constraints in determining personal accessibility. As every individual faces a particular set of space–time constraints imposed by the space–time fixity of obligatory activities in their everyday lives, personal accessibility is contextually constituted in the sequential unfolding of these activities (Pirie 1979). In other words, individual accessibility is determined not by how many opportunities are located close to the reference location, but by how many opportunities are within reach given the particularities of an individual's life situation and adaptive capacity (Dyck 1989, 1990; England 1993). Conventional access measures based on locational proximity of opportunities to a single reference point simply cannot reflect interpersonal differences associated with these contingencies of everyday life: they tend to reflect place accessibility rather than individual accessibility.

Such inability of conventional accessibility measures to reflect individual differences besides those captured by the impedance function leads to an inherent bias when these measures are used to examine gender differences in accessibility. As many studies observe, 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; Miller 1982, 1983; 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; Pratt and Hanson 1991; Johnston-Anumonwo 1992; Kwan 1999a, 1999b). These factors led Pickup (1985, 106) to conclude that

> Conventional "spatial" accessibility measures of access to shops or jobs were meaningless for women whose activity choices were continually facing additional time constraints from their gender role. For the analysis of men's job choices, such measures might have more adequacy.

Similarly, Kwan (1998) observes that the spatial pattern of individual accessibility for men has a stronger relationship with place accessibility than does that for women. To overcome the inherent gender insensitivity of conventional accessibility indices, space–time measures based on the time-geographic framework provide attractive alternatives.

Space–Time Accessibility Measures

All space–time measures of individual accessibility are based on Hägerstrand's (1970) time-geographic framework and the space–time prism construct. Lenntorp (1976) provides the earliest operational formulations of space–time accessibility measures based on the notion of an individual's reach, which is the physically accessible part of the environment given the individual's space-time constraints. In three-dimensional terms, this accessible portion is the space–time prism or potential path space (PPS). The projection of the prism onto planar geographic space delimits the reachable area by the individual and is called the potential path area (PPA). The volume of the space–time prism and the area delimited by the PPA were specified as accessibility measures by Lenntorp (1976). Another early formulation was provided by Burns (1979), who conceptualizes individual accessibility as the freedom to participate in different activities. Based on the concept of space–time autonomy, he formulates two accessibility measures using the space–time prism construct. One is based on the set of locations reachable by an individual, while the other is based on the set of reachable routes of the transportation network.

There are several extensions of the original formulations of space–time accessibility measures after Lenntorp and Burns. Landau et al.'s (1982) study identifies the feasible locations to be included in an individual's destination choice set based on the person's space–time constraints and the minimum amount of time required for an activity. Kwan and Hong (1998) incorporate the effect of spatial knowledge on the size and spatial configuration of the choice set based on an extension of Golledge et al.'s (1994) work on feasible opportunity sets. By extending the problem of destination choice from a particular activity to all non-fixed activities in a day, the size of the feasible opportunity set delimited in these studies can be formulated as space–time measures of individual accessibility. For instance, Villoria (1989) implements such a measure using geometric methods. To overcome the limitations of geometric implementation, Miller (1991) and Kwan (1998) develop network-based GIS methods for operationalizing space–time accessibility measures. Miller (1999) further extends space–time measures through integrating three notions of accessibility into a single analytical framework. He also develops computational procedures for enumerating the proposed measure within transportation networks.

Operationalizing Space–Time Measures: Concept and Implementation

What follows is an explanation of the concept behind the operational method used to enumerate space–time measures in this study. Every individual has a daily activity program consisting of a number of out-of-home activities. Among these activities, some are spatially and/or temporally fixed for the individual (e.g., workplace), while others can be undertaken at various locations or times of the day (e.g., grocery stores). The former type of activities are referred to as "fixed activities" which serve as "pegs" in the daily space–time trajectory of the individual (Cullen et al. 1972). Since the area in the urban environment within reach by an individual is determined by the space–time requirements associated with these fixed activities, the feasible region for an individual on a particular day can be derived based on the space–time coordinates of consecutive pairs of fixed activities. The procedures for deriving this region are described as follows.

For any given pair of consecutive fixed activities, a given amount of time is available for travel and participation in "flexible" activities between them. Based on the locations of the pair of fixed activities in question, a spatial search is performed on the transportation network to find all urban opportunities within reach given this specific time constraint. The area so identified is the PPA, which delimits an area containing all feasible routes and urban opportunities given the space–time constraints defined by the particular pair of fixed activities (Burns 1979; Miller 1991). If the individual has n out-of-home fixed activities to perform in a day, there will be $n+1$ pairs of consecutive fixed activities when the starting and ending home stops are regarded as fixed space–time pivots. This in turn means that $n+1$ distinct PPAs can be delimited. To obtain the set containing all feasible opportunities for the day, these individual PPAs are aggregated to form a daily potential path area (DPPA).

These procedures for deriving the DPPA are illustrated in Figure 1 using the actual travel diary data of a resident of Franklin County, Ohio. This person performed three out-of-home activities on the day: work, attending an event at a church, and having a meal at a restaurant before returning home. With the former two activities being fixed, three PPAs are identified based on three consecutive pairs of fixed locations along the person's space–time path (with the starting and ending home stops included as fixed locations). These three individual PPAs (in the middle of the diagram) are then aggregated to form the daily potential path area (DPPA). Two-dimensional representations of

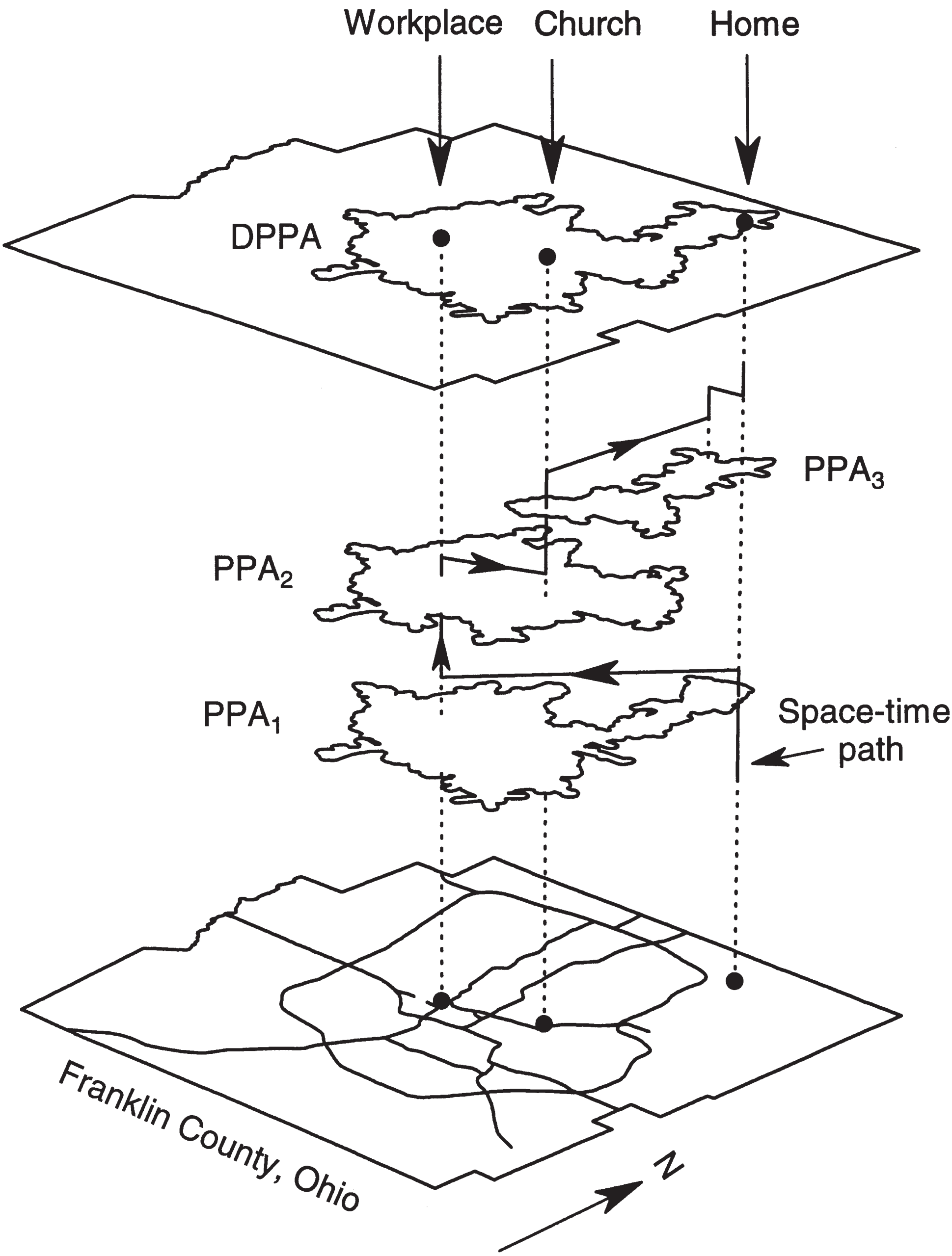

Figure 1: *Derivation of the daily potential path area (DPPA) using actual data of an individual in the subsample. While all locations are real activity sites, the timing and duration of these activities were modified to improve visual clarity.*

the daily potential path area (DPPA) derived and the network arcs it includes are shown in Figure 2. Based on this delimitation of the DPPA, three space–time measures of individual accessibility can be specified: (a) the number of opportunities included in the DPPA, (b) an area-weighted sum

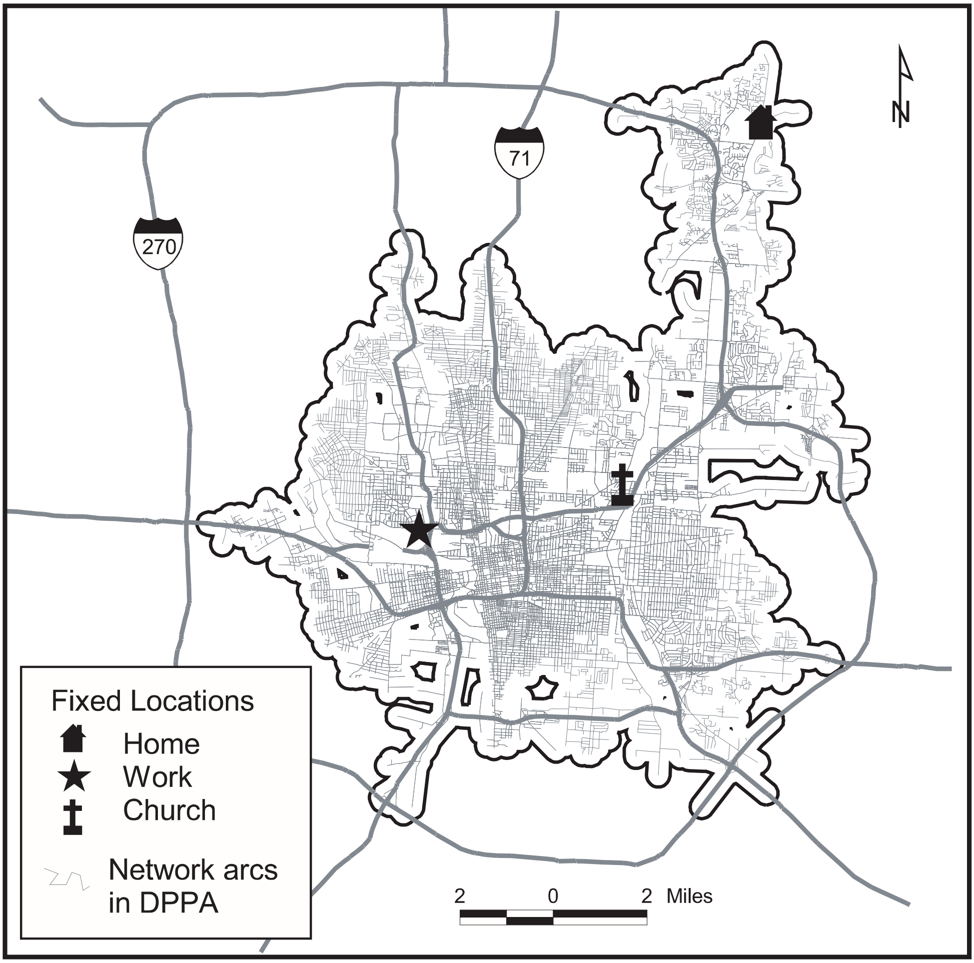

Figure 2: *Daily potential path areas (DPPA) of the individual. This is a two-dimensional representation of the DPPA in Figure 1.*

of all opportunities contained in the DPPA, and (c) length of the network arcs or road segments included in the DPPA.

To implement these space–time measures, not only detailed travel diary and time-budget data are needed. Geoprocessing capabilities are also required to handle a person's daily activity schedule (including the locations of all fixed activities), the complexities of a realistic travel environment (e.g., transport network geometry and variations in travel speed), and the spatial distribution of urban opportunities. Without these, past attempts to operationalize the prism construct had to resort to geometric methods based on the straight-line distance between fixed activities (e.g., Lenntorp 1976). Although the PPAs or DPPA so derived take the familiar shape of spatial ellipses, they are far from being realistic representations of an individual's PPAs or DPPA, which are not likely to be in any convenient geometric shapes (as showed in Figures 1 and 2). Further, it was not possible to evaluate the number and composition of opportunities included in an individual's DPPA without incorporating information about urban opportunities into a geographic database. With the spatial data handling capabilities of recent GIS and the development of network-based GIS methods (Miller 1991; Kwan and Hong 1998), meeting some of these requirements for computing space–time accessibility has become possible. This study uses the procedures formulated in Kwan (1998) for this purpose.

Study Area and Data Collection

The study area for this research is Franklin County, Ohio (Fig. 3). The county is located at the center of the seven-county Columbus Metropolitan Statistical Area (MSA). Its main urban area consists of the city of Columbus and several smaller cities. It is 542 square miles in area and had an estimated population of one million in 1995 (City of Columbus 1993). A two-day travel diary data set I collected in the study area in 1995 provides the individual activity-travel data for this study. Among the detailed activity-travel data collected, two specific items used in this paper are street addresses of all activity locations and the subjective space–time fixity ratings of all out-of-home activities (i.e. the difficulty in changing the location or time of an activity).

Two digital data sets provide additional information needed for this study. One of these is a detailed digital street network of Franklin County called Dynamap/2000. The network database contains 47,194 arcs and 36,343 nodes of Columbus streets and comes with comprehensive address ranges for geocoding locations. Activity locations collected in the travel diary survey are geocoded on this street network using ArcView GIS. The GIS procedures for enumerating the space–time measures are also implemented on this network after creating a realistic representation of the travel environment of the study area (e.g., variations in travel speed with road types). The home-work distances for all individuals in this study are measured in terms of network distance and travel time on the network.

Another source of data is a digital database of all land parcels in the study area maintained by the Franklin County Auditor's Office. Among the 34,442 non-residential parcels in the database, 10,727 parcels belonging to seven land-use categories are selected as the urban opportunities for this study.[1] These land-use types include shopping and retail facilities, restaurants, personal-business establishments such as banks, indoor entertainment (e.g., theaters), outdoor recreational activities, educational institutions (except higher education), and office buildings (vacant, agricultural, and industrial parcels are excluded). Since the average area of these parcels is 0.00379 square miles, they can be treated as point entities given the spatial scale of the study area. Subsequent analysis uses a point coverage of the centroids of these parcels.

The spatial pattern of these urban opportunities is shown in Figure 4 in the form of an opportunity density surface (outdoor recreation

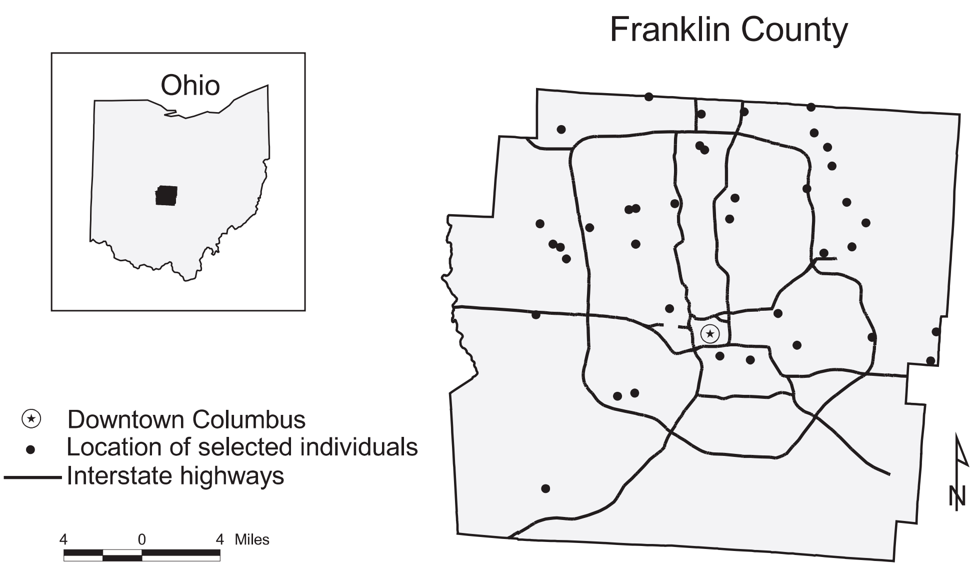

Figure 3: *The study area and home locations of the individuals in the subsample.*

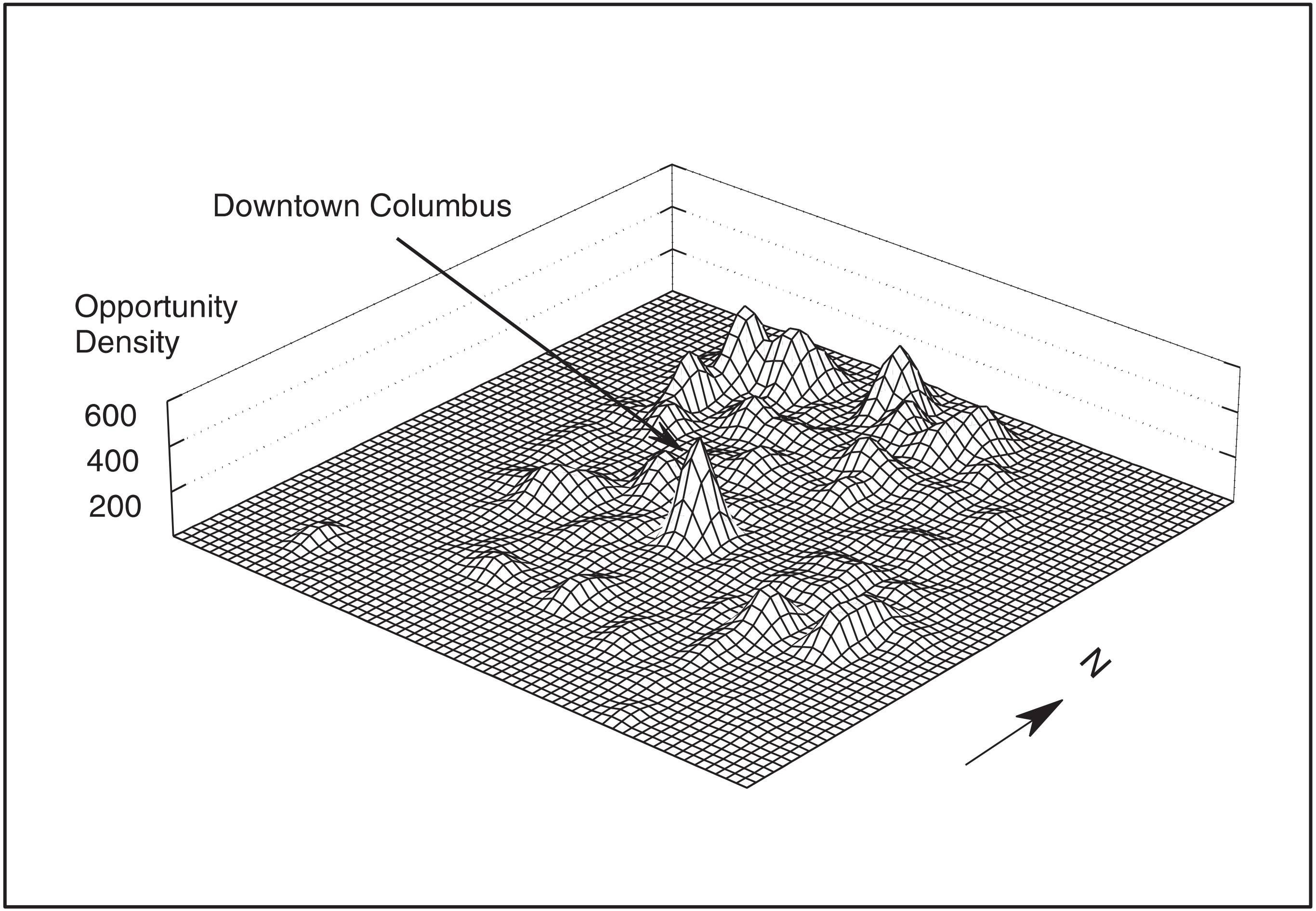

Figure 4: *Density surface of urban opportunities in Franklin County, Ohio.*

is excluded due to large areal extent). The surface was generated by covering the study area with 18,542 grid cells of 0.036 square miles, and using kernel estimation based on each parcel's weighted area and a search radius of one mile (Gatrell 1994). The surface indicates that, besides a peak in downtown Columbus (center of surface), urban opportunities are mainly concentrated along major transport arterials and their intersections. Several peaks are found in the northern part of the County along segments of the I-270 and Morse Road.

Analysis and Results

Despite the original attempt to obtain a representative random sample of the population of the study area, many gender/ethnic subgroups are underrepresented in the final sample. For instance, less than 2% of the respondents are African Americans, while that group accounts for 16% of the County's population in 1990. As many population subgroups in the sample are too small for comparative analysis (e.g., African Americans and part-time employed European American men), gender/ethnic groups with 15 or more employed individuals were first identified.[2] This led to a subsample of 56 full-time employed European Americans (27 women and 29 men) for the study. Understandably, this subsample is small in size and does not represent the population of the study area. When compared to the population of Franklin County, Ohio, individuals in the subsample have a higher level of access to automobiles (all regularly use their own cars) and a higher household income (median household income is about $75,000 a year in contrast to the County's average of $30,375 in 1990). 76% of the individuals in the subsample hold managerial and professional occupations, while only 30.5% of the population in the County hold such positions. Home locations of these individuals are spatially scattered in the study area and are largely outside the older urban core of Columbus (Fig. 3).

Results reported in this paper are thus specific to these highly mobile, upper-middle-class European Americans. Further, the focus of the paper on the simple dichotomy of women and men is largely the result of the limitations imposed by the small size and characteristics of the original sample. If a larger and more representative sample had been available, more refined groupings which take into account the effects of and interactions between gender, race, life-cycle stage, income, occupational status, and age could have been used in the analysis (e.g., Janelle and Goodchild 1983).[3] Although limited to examining individual accessibility in terms of the over-generalized categories of women and men, I do not presume or intend to argue that women's (and men's) diverse, complex and gendered experiences of everyday life can be reflected by using such a simplistic dichotomy (the problem of doing so is noted by Fuss 1989; McDowell 1993; Pratt and Hanson 1993; Staeheli and Lawson 1995; Kobayashi 1997). The terms "gender" and "gender differences" in this paper are used, and should be understood, in terms of the context of this study. Further, the effects of local geography on the results are not examined due to data limitations.

To examine gender differences in access to urban opportunities, three space–time accessibility measures were computed for each individual in the subsample. These measures are the number of opportunities in the daily potential path area (DPPA), the sum of the weighted area of these opportunities, and length of the network arcs included in the DPPA. The weighted area of a parcel equals the parcel's area (in acres) multiplied by a building-height factor based on the number of stories of the structure on the parcel. Further, the length of network arcs included in the DPPA is used as a surrogate for the area or size of the DPPA. Although GIS procedures can be used to find this area, computational intensity of the topological operations involved renders them infeasible. The value of all measures reported here is the average of the two survey days for each individual. The geoprocessing required for enumerating these space–time accessibility measures was performed in ARC/INFO GIS.

Gender Differences in Space–Time Accessibility

In terms of all three space–time accessibility measures, full-time employed women in the subsample have lower levels of access to urban opportunities when compared to full-time employed men (Table 1). Their daily potential path areas (DPPAs) are 64% smaller in area (in terms of the length of network arcs) and contain 44% less urban opportunities (in terms of their number and weighted area) than those of men.

Further, all gender differences in space–time accessibility are significant at $p < 0.10$, while many are significant at the $p < 0.05$ level as the ANOVA results in Table 1 indicate.

As these women and men are full-time workers and on average work 8.2 hours a day, they have about 6.8 hours a day for pursuing non-employment activities (assuming that each has 15 hours left after allowing for sleep and other essential maintenance activities). Since these individuals face similar time-budget constraints, gender differences in space–time access to urban opportunities observed here are largely the result of the constraints associated with the space–time fixity of the non-employment activities they need to perform in their everyday lives. In other words, women in the subsample experience lower level of accessibility because they face more space–time constraints in their non-work hours than men. As many of these constraints are gender-role-related, these results corroborate past observations that women's employment is not accompanied by major role shifts among members of the household (Hanson and Hanson 1981; Michelson 1985, 1988; Gregson and Lowe 1993; Aitken 1998). Instead, these studies found that domestic and childcare responsibilities are still primarily borne by women in dual-career households independent of their employment status or the birth of a child. This suggests that changing the share in gender-role-related responsibilities within a household between women and men may be an important step for increasing individual access to urban opportunities for women.

Despite the lower levels of space–time accessibility of women when compared to that of men, women's access to different types of urban opportunities in relative terms is similar to that of men. In terms of either the number or weighted area of opportunities, both women and men have virtually the same composition of various types of opportunities in their DPPAs (Table 2). Individual access to office buildings and shopping facilities is highest for both groups. Further, there is no major difference in the composition of opportunities in the DPPAs of these individuals when compared to the County's pattern (except a slightly higher percentage of office buildings and a slightly lower percentage of outdoor recreational facilities for both groups of individuals).

In addition to the lack of gender difference in the composition of opportunities in the DPPAs, there is also no significant difference in the average size of the parcels in the DPPAs of these individuals (Table 3). Since downtown Columbus is characterized by a large number of small land parcels, while areas outside the older urban core have more large land parcels in relative terms, the average size of land parcels included in a DPPA indicates the spatial tendency of the DPPA to a certain extent. If the average size of land parcels in a DPPA is smaller than that of the County's average, the DPPA includes more parcels in the older urban core than those in suburban areas. So this result suggests that there is no major difference in the spatial tendency of the DPPAs of the full-time employed women and men in the subsample. Further, since average

Table 1 *Space–Time Accessibility of Individuals in the Subsample*

	Full-time employed women		Full-time employed men		Franklin County	
	Number of opportunities	Weighted area of opportunities	Number of opportunities	Weighted area of opportunities	Number of opportunities	Weighted area of opportunities
Land-use types						
Shopping	546.5*	662.1*	798.6*	962.5*	3052	4020.9
Food	213.5	98.0*	313.9	147.5*	1195	689.8
Personal business	294.8*	217.7*	423.9*	316.3*	1611	1367.9
Entertainment	6.9	18.1	9.8	25.3	45	130.8
Recreation (outdoor)	118.6	1206.9	175.8	1750.6	1015	10338.6
Education	193.8	614.3*	274.7	891.1*	996	3946.0
Office buildings	542.5*	1070.2	777.6*	1449.1	2813	5502.1
All land-use types	1916.5*	3887.3	2774.4*	5542.4	10727	25996.1
Length of network arcs in DPPA (in miles)	1008.0*		1652.7*			

** Difference between women and men significant at p < 0.05 (all other differences are significant at p < 0.10)*
Sources: Travel diary survey conducted in Columbus, Ohio, 1995; Franklin County Auditor's Office.
Note: Values for both groups of individuals are group means for a particular land use type. Weighted areas are in acres.

Table 2 *Percentage of Various Types of Urban Opportunities in DPPA*

	Full-time employed women		Full-time employed men		Franklin County	
	Percent of number of opportunities	Percent of weighted area of opportunities	Percent of number of opportunities	Percent of weighted area of opportunities	Percent of number of opportunities	Percent of weighted area of opportunities
Land-use types						
Shopping	28.5	17.0	28.8	17.4	28.5	15.5
Food	11.1	2.5	11.3	2.7	11.1	2.7
Personal business	15.4	5.6	15.3	5.7	15.0	5.3
Entertainment	0.4	0.5	0.4	0.5	0.4	0.5
Recreation (outdoor)	6.2	31.0	6.3	31.6	9.5	39.8
Education	10.1	15.8	9.9	16.1	9.3	15.2
Office buildings	28.3	27.5	28.0	26.1	26.2	21.2
All land-use types	100%	100%	100%	100%	100%	100%

Sources: Travel diary survey conducted in Columbus, Ohio, 1995; Franklin County Auditor's Office.

Table 3 *Average Size of Land Parcels in DPPA*

	Full-time employed women (area in acres)	Full-time employed men (area in acres)	Franklin County (area in acres)
Land-use types			
Shopping	1.21	1.21	1.32
Food	0.46	0.47	0.58
Personal business	0.74	0.75	0.85
Entertainment	2.62	2.58	2.91
Recreation (outdoor)	10.18	9.96	10.10
Education	3.17	3.24	3.96
Office buildings	1.97	1.86	1.96
All land-use types	2.03	2.00	2.42

Sources: Travel diary survey conducted in Columbus, Ohio, 1995; Franklin County Auditor's Office.
Note: Values are group means for a particular land-use type.

sizes of the land-use parcels in the DPPAs of the two groups are slightly smaller than that of Franklin County, their DPPAs cover more areas in the old urban core than suburban areas.

The lack of difference in the composition and average parcel size of the opportunities included in the DPPAs of the women and men in the subsample indicates that there is no significant difference in the spatial tendency of their DPPAs in terms of their coverage of various parts of the study area. Underlying this similarity in the spatial tendency of the DPPAs, however, is a subtle gender difference in the density of opportunities included in the DPPAs (in terms of the number of opportunities and their weighted area per mile of network arcs in the DPPAs). For instance, opportunity density for the full-time employed women is 3.26 per mile of network arcs, while that for the full-time employed men is 2.59 (difference significant at $p < 0.05$). This difference may be due to the adaptive strategies adopted by the women in the subsample who, when facing more restrictive space–time constraints than men, attempt to negotiate their space–time paths through areas with a higher density of urban opportunities as a means of compensating the disadvantages of their smaller DPPAs. It supports the assertion of past studies that women are creative urban actors with transformative capacities who are actively engaged in redefining the meaning and use of urban space when trying to juggle their multiple roles (Dyck 1989, 1996; England 1993, 1996b). Although gender roles may impose additional space–time constraints on the daily lives of women, and the spatial structure of the urban environment may further disadvantage them relative to men (Saegert 1981; McDowell 1983; Hayden 1984; Weisman 1992), women are not passive victims of their circumstances but are active agents involved in reconstituting the conditions of their lives as they engage in creating their particular geographies in the routine practices of everyday life.

Space–Time Accessibility and the Journey to Work

Past research on the journey to work reveals that gender/ethnic differences in commuting are not only outcomes of the complex interaction between gender roles, occupational segregation, and travel mobility, but are also highly dependent on sociospatial context, including the residential and employment location of the population subgroups in question (e.g., see studies reviewed in Blumen 1994; Gilbert 1997; McLafferty and Preston 1997). While most of these studies observe that European-American women in general work closer to home than do European-American men, there are also cases where certain subgroups of European-American women travel as far as their male counterparts (England 1993; Hanson and Pratt 1994, 1995). Contrary to what these studies have observed, the full-time employed women in the subsample have longer commutes than men (both groups being European Americans) in terms of network distance between home and the workplace (9.8 miles for women and 7.2 miles for men) and travel time (19.9 minutes for women and 16.4 minutes for men) (differences significant at $p < 0.05$, Table 4). Given that these women and men have similar racial and socio-economic characteristics, come from the same set of affluent dual-earner households in suburban Columbus, and work at spatially scattered locations in the study area, the longer journey to work of the women in the subsample can be ascribed to their high occupational status when compared to men in the subsample (82% of women hold managerial and professional occupations as compared to 71% of men).

But what makes this observation particularly significant is the relationship between individual accessibility and journey to work. Since women in the subsample have lower levels of space–time access to urban opportunities (Table 1) and face more space–time constraints than men (Kwan 1999b), their longer journeys to work are contrary to the interpretation of past studies that long commutes for upper-middle class women reflect their less constrained life situations. If these European-American women can actually experience lower levels of access to urban opportunities even though they have longer journeys to work, the length of the commute trip may not be an appropriate indicator of how constrained their everyday lives are. Although this particular relationship between individual accessibility and the length of the work trip is specific to the subsample and may be different for other gender/ethnic subgroups and in other spatial contexts (as shown in Johnston-Anumonwo 1997; Preston and McLafferty 1993), it calls into question an often adopted view about this relationship: that the long commutes of upper-middle-class European-American women indicate that they are relatively free of constraints or oppressive life situations. While this, by extension, does not provide direct support for questioning the assertion that the short journeys to work of minority women indicate the availability of jobs near their homes, it does highlight the need to be more cautious about using the length of the work trip as a measure of job access (Kwan 1999c).

Table 4 *Correlations of the Home-Work Distance with the Number of Opportunities and Weighted Area in DPPA*

	Full-time employed women		Full-time employed men	
	Number of opportunities and home-work distance	Weighted area and home-work distance	Number of opportunities and home-work distance	Weighted area and home-work distance
Land-use types				
Shopping	-0.07	-0.08	-0.01	-0.05
Food	-0.05	-0.04	-0.01	-0.05
Personal business	-0.03	-0.05	-0.00	0.01
Entertainment	-0.06	-0.01	-0.06	-0.10
Recreation (outdoor)	0.22	-0.03	-0.10	-0.08
Education	-0.02	0.02	0.00	-0.06
Office buildings	-0.06	-0.08	0.01	-0.02
All land-use types	-0.04	-0.05	-0.01	-0.05
Home-work distance (in miles)	9.8*		7.2*	
Travel time to work (in minutes)	19.9*		16.4*	

** Difference between women and men significant at p < 0.05*
Source: Travel diary survey conducted in Columbus, Ohio, 1995.

In recent debate on gender/ethnic differences in access to employment opportunities, the length of the commute trip is often used as a measure of job access. In their study of the differences in job accessibility between African-American and European-American youths, Ihlanfeldt and Sjoquist (1990, 268) express this view by stating that, "If jobs are nearby, commuting time will be low. Conversely, if jobs cannot be found nearby, travel time will be high." However, data of the Columbus subsample indicate that the length of the commute trip (in terms of travel distance) has no relationship with individual access to urban opportunities (no correlation coefficient is larger than 0.25 or is significant at $p < 0.05$ in Table 4). This suggests that the use of work trip length as a measure of access to jobs, which is one type of urban opportunity, may be inadequate for understanding the access experience of individuals belonging to different gender/ethnic subgroups.[4] Commuting time can be low or high for a variety of reasons other than job access, and the often-assumed determinate relationship between them needs to be critically reexamined for each sociospatial context (Giuliano 1988; England 1993, 1994; Brun and Fagnani 1994; McLafferty and Preston 1996; Johnston-Anumonwo 1997; Immergluck 1998).

This suggests that situating the journey to work in the wider context of the totality of everyday life instead of treating it as an isolated problem of job access may be a more fruitful direction for future research. As England (1993, 237) argues, "journeys to work should be viewed as part of a much larger time-space budgeting problem." In other words, treating the journey to work as an outcome of a highly complex decision-making process involving elements of constraints, choice, and the transformative capacity of individuals is more desirable than using it as an indicator of job access (Burnett and Hanson 1982; McLafferty and Preston 1996). In view of this, more appropriate means for representing or measuring individual access to urban opportunities and jobs are needed for revealing how, and to what extent, individuals of different gender/ethnic subgroups are disadvantaged in their everyday lives (Johnston-Anumonwo 1997). As the space–time measures of individual accessibility used in this study are based on the notion of space–time feasibility instead of locational proximity, they have several advantages over conventional accessibility measures for incorporating the effect of the interaction between a person's constraints and the availability of urban opportunities in space–time.[5]

Discussion and Future Research Directions

Using space–time accessibility measures, this study suggests that access to urban opportunities for women in the subsample is significantly less than that of men. These gender differences in individual access to urban opportunities are largely due to differences in space–time constraints that results in different sizes of DPPAs. The study also indicates that there is no relationship between individual accessibility and the journey to work, which is often used as a measure of job access. This suggests that the length of the commute trip may not be an appropriate indicator of how much constraint an individual faces. Much future research is needed to decipher the complex relationships between access to urban opportunities (including jobs) and the length of the commute trip.

Although space–time measures have advantages over conventional accessibility measures, several qualifications are warranted at this point for the proper interpretation of these results. First, since the land parcel data set used in this study does not provide information about the opening hours of establishments, their effect on individual accessibility was not taken into account by either the operational measures or results presented in this paper. For instance, since women in the subsample undertook more out-of-home activities in the evening (when many facilities were closed) than men, the space–time measures as implemented in this study might have overestimated the number of opportunities they can access. Given this limitation and the fact that women in the subsample are still observed to have lower levels of accessibility when compared to men, the effect of this problem is an underestimation of the gender gap in accessibility rather than a change in the direction of gender differences. Since different operational methods for dealing with the interaction between individual space–time constraints and opening hours of facilities have been developed in past studies (e.g., Landau et al. 1982; Kwan and Hong 1998), future research needs to collect and incorporate data about opening hours into space–time formulations. This is especially important if the method is to be applied to other groups of individuals who engage in a variety of work-hour arrangements (e.g., rotating or night shifts) that affects both the time-budget and space–time constraints a person faces.

Second, findings of this study are based on a specific population subgroup which consists of affluent, employed European Americans from suburban Columbus, Ohio, who rely on their own cars for transportation. Given the particularity of this sociospatial context and sample, and the contextual nature of gender differences in commuting and individual accessibility, it should be emphasized that the paper's main contribution is methodological rather than empirical. I intend to highlight the point that relationships between space–time constraints, individual accessibility and journey to work are not as determinate as often assumed in the past and are therefore difficult to generalize. The paper also reveals some of the methodological problems involved in using work trip length as a measure of job access. It attempts to open new avenues for future exploration of these complex relationships. In light of Rose's (1997, 307) assertion that feminist research should not aim at producing knowledge that claims to have universal applicability, this paper does not intend to make broad generalizations or knowledge claims with applicability to other sociospatial contexts or gender/ethnic subgroups.

Further, since my purpose in this paper is to propose more gender-sensitive accessibility measures in comparison with conventional accessibility indices, the space–time measures are formulated largely in analytical-quantitative terms. Using this particular discursive form, the study suggests that it is possible to uncover the gender bias of a particular technique in its own terms (that is, in the language of quantitative methods) even without invoking ontological or epistemological arguments. Based on the premise that quantitative methods can still be useful for answering certain questions in feminist research (Lawson 1995; McLafferty 1995), results of this study suggest that future feminist research using quantitative methods needs to subject these methods to critical scrutiny before accepting them as appropriate for addressing a particular set of questions.

A cautionary note on the theoretical underpinnings and limitations of the space–time measures used in this study is also warranted. Hägerstrand's time-geographic framework, on which the space–time measures of this study are based, has been subject to several rounds of critiques (e.g., Giddens 1984; Gregory 1985; Harvey 1989). Dyck (1989) and England (1993) have also emphasized that women are not just victims of gender-role constraints, but are also active agents with transformative capacity. What is particularly relevant to this study, however, is the feminist critique of Rose (1993), who criticizes time-geography for its masculinist conception of space and the body, its repression of feminine subjectivity, and its erasure of the specificity and positionality of the master subject.[6] As Rose (1993) argues, time-geography (and thus the space–time measures used in this study) cannot take into account the effect of women's fear of violence or attack in public spaces on their mobility (as elaborated in Valentine [1989] and Pain [1991]). To reveal the richness and complexities of the lived experiences of women (and men), the space–time measures in this study therefore need to be complemented by a contextualized understanding furnished through ethnographic methods such as in-depth interviews or participant observation. Future research needs to consider how multiple methodologies can be used in this kind of study. ■

Notes

[1]Since this parcel data set does not provide information about the opening hours of establishments, their effect on individual accessibility is not taken into account by either the operational measures or results presented in this paper.

[2]Identification of population subgroups at this stage was based on gender, ethnicity and employment status (full-time versus part-time). Due to the group-size requirement of 15 or more and the small sample size, only the gender dimension remains as the major differentiating criterion between subgroups.

[3]The higher degrees of freedom provided by such a sample would also allow the use of log-linear and structural equation models as originally intended.

[4]Although space–time measures are used in this study to evaluate access to urban opportunities, some of the results in Table 4 allow a connection between urban opportunities and job opportunities. As most individuals in the subsample hold managerial and professional occupations, the weighted area of office buildings in the DPPA can be used as a surrogate for

job opportunities for this particular group of individuals. For other population subgroups, different land parcel categories may be specified to better represent the relevant job opportunities.

[5]Another fruitful direction is the application of spatial-statistical methods to small-area data (e.g., Talen 1997; Immergluck 1998).

[6]Gregory (1994), however, is rather positive about time-geography in his reassessment of Hägerstrand's framework while calling into question Rose's assertion about the inherent phallocentrism of the perspective (pp. 127–128). Laws (1997) indicates the possibility of a post-structuralist appropriation of the time-geographic perspective for understanding feminine spatiality based on theories of embodied female identities and corporeality. Hanson and Pratt's (1995) re-interpretation of their earlier observations in terms of feminist containment narratives based on the reciprocal constitution of feminine subjectivity and bodily comportment suggests a similar direction. Further, some of Rose's (1993) criticisms may also be addressed through extending Adams' (1995) time-geographic re-theorization of personal boundaries. Lastly, a variety of representational strategies may be used to compose rich pictorial narratives of women's (and men's) everyday experiences (Gregory 1994, 249–251). These approaches together suggest that a feminist re/deconstruction of time-geography, perhaps based on the work of Grosz (1990, 1994), Foucault (1977), and Young (1989), may provide new ways for understanding the spatio-temporal experiences of women's (and men's) everyday lives in their particular sociospatial contexts.

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MEI-PO KWAN (Ph.D., University of California, Santa Barbara) is Assistant Professor in the Department of Geography, The Ohio State University, Columbus, OH 43210-1361. E-mail: kwan.8@osu.edu. Her research interests include gender/ethnic issues in transportation geography, GIS, spatial analysis, spatial cognition, and travel behavior.