Where the Sidewalk Ends:
Disability, Mobility & Environmental Factors

By

William Vassilakis

B.A. University of Illinois – Chicago, 2009

Thesis

Submitted as partial fulfillment of the requirements
For the degree of Master of Urban Planning and Policy
In the Graduate College of the University of Illinois at Chicago, 2011

Chicago, Illinois

Defense Committee:

Piyushimita Thakuriah, Advisor

Kazuya Kawamura

Siim Soot

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"People on their feet are more or less equal. People solely dependent on their feet move on the spur of the moment, at three to four miles per hour, in any direction and to any place from which they are not legally or physically barred. An improvement on this native degree of mobility by new transport technology should be expected to safeguard these values and to add some new ones, such as greater range, time economies, comfort, or more opportunities for the disabled. So far this is not what has happened. Instead, the growth of the transportation industry has everywhere had the reverse effect. From the moment its machines could put more than a certain horsepower behind any one passenger, this industry has reduced equality among men, restricted their mobility to a system of industrially defined routes, and created time scarcity of unprecedented severity."

-Ivan Illich, *Energy and Equity, 1997*

"At the turn of the century, researchers looked to the physical environment- in particular, housing conditions and the state of neighborhoods- to address such significant public health problems as tuberculosis and infectious diseases in general. Today, researchers would benefit by looking again to the physical environment, this time to address issues related to enhancing the independence and mobility of an aging population"

-William Satariano, *American Journal of Public Health, 1997*

1. INTRODUCTION

Millions of Americans are unable to provide their own transportation or have difficulty accessing public transportation (GAO 2003) and therefore do not enjoy the full benefits of employment, education, medical appointments, social visits, and public participation (Thakuriah 2010). A voluminous literature has noted that independent living can be curtailed by transportation limitations (Rogers et al 1998; Barnes et al 1999; Bromley et al 2007; Schmöcker 2009).

Another growing body of literature has explored the relationship between travel behavior and environmental factors (Thakuriah et al 2010). In the context of an aging, auto-dependent society research concerning the effects of the physical environment on functional capacity, ability to complete daily tasks and general independence is increasingly valuable (Satariano 1997). However, to date, few studies have explored the relationship between environment and independent functioning and the field "is in its infancy" (Kawachi 2003). This thesis uses survey data of a transportation-disadvantaged population to analyze the relationships between environmental variables and personal characteristics.

The GAO uses the term "transportation-disadvantaged" to refer to "populations that lack the ability to provide their own transportation or have difficulty accessing whatever conventional public transportation may be available" including people who are elderly, have disabilities, or low incomes (GAO 2007). Though the populations of seniors, people with disabilities, and low incomes overlap considerably, they are commonly studied as distinct groups (Committee on Disability in America). The populations of these groups are substantial and growing. 38.7 million (12.9%) Americans are 65 years or older (US Census); 65 million (22%) have a disability (US Census 2010); 9.48 million (6.1%) have difficulty walking, climbing stairs or standing (Iezzoni et al 2005); 42.9 million (14.3%) live in "absolute poverty" (US Census 2010). In addition, research on transportation-disadvantage is fragmented across a

several disciplines, including transportation planning, urban design, gerontology, rehabilitation, ergonomics, public health, epidemiology and sociology. Following a discussion of relevant federal policy, literature is reviewed, data collection methods are described and an analytical framework is proposed.

2. LITERATURE REVIEW

2.1 Policy Background

Extensive research has shown that existing transportation systems do not meet the needs of people with disabilities (Katzmann 1986; Katzmann 1991; Percy 1992; Burkhardt 2004; Rosenkvist et al 2009) limiting their ability to live independently and to fully integrate with society. Katzmann's 1986 Institutional Disability is a thorough account of how legislative, administrative and judicial processes shaped transportation policy for people with disabilities from the 1950s through 1980s. In 1990 the Americans with Disabilities Act (ADA) was enacted, prohibiting public bodies from discriminating against people with disabilities (ADA 1990). In particular, public transit providers were forced to take measures to make their existing services universally accessible or to provide paratransit alternatives (ADA 1990).

The next major development in disability policy was the result of a landmark 1999 US Supreme Court case, Olmstead v. L.C., which concerning two mentally retarded women who were voluntarily admitted to Georgia Regional Hospital (GRH). The women were confined for treatment in a psychiatric unit though their treatment professionals eventually concluded they could be cared for appropriately in a community-based program. The court found that "the unnecessary segregation of individuals with disabilities in institutions may constitute discrimination based on disability" (US Supreme Court 1999). The decision set a precedent: unjustified isolation or segregation through institutionalization (for example, in hospital or institutionalized care) is a form of disability-based discrimination prohibited by Title II of the ADA (Title II provision specifies, *inter alia*, that no qualified individual with a disability shall, "by reason of such disability," be excluded from participation in, or be denied the benefits of, a public entity's services, programs, or activities. §12132.). The U.S. Congress subsequently instructed the Attorney General to issue implementing regulations (the "integration regulation") that require a "public entity (to) administer … programs … in the most integrated setting appropriate to the needs of qualified individuals with disabilities."

The New Freedom Initiative was established on February 1, 2001 by President George W. Bush, as part of a nationwide effort to remove barriers to community living for people with disabilities and followed up by Executive Order 13217, "Community-Based Alternatives for Individuals with Disabilities", on June 18, 2001 (EO 13217 2001). The order calls on the federal government to assist states and local organizations to swiftly implement the decision of the United States Supreme Court. Specifically, EO 13217 directed six federal agencies (not including the Department of Transportation) to determine whether any policies, programs, statutes and regulations should be revised or modified to

improve the availability of community-based services for qualified individuals with disabilities. The NF Initiative emphasizes access to assistive technologies, work, education, and other opportunities for people with disabilities.

In 2004 wheelchair user and representative from Rhode Island John Langevin was asked at a hearing of the Subcommittee on Human Rights and Wellness of the Committee on Government Reform what types of programs would address the barrier to employment for people with disabilities (U.S. House 2004):

> *Mr. LANGEVIN. "Clearly, the health care and the transportation barriers are the biggest ones to overcome, and I think the greatest benefit would be to bring people with disabilities into the workforce… It is no good to be able to get an application in if you are not able to get back and forth to work. So more assistance for public transportation programs would be of great benefit. I think those are the two biggest and most important tangible examples that I can give you."*

Subsequently, Assistant Secretary of the Department of Education (DOE) Tory Justesen described the components of DOE's implementation of the New Freedom Initiative: increasing access to assistive technology, expanding educational opportunities for people with disabilities, integrating people with disabilities into the work force and generally providing access to community participation. He stressed the importance of transportation as "one of the most key components of accessibility…including employment and basic enjoyment for people with disabilities" (U.S. House).

The US Department of Transportation (DOT) joined the New Freedom Initiative in 2005. The New Freedom (NF) transportation program was instituted by the surface transportation legislation, Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), as a formula program to provide funding for projects designed to reduce transportation barriers and to expand the mobility options available to persons with disabilities beyond the requirements of the ADA. One component of the NF transportation program is an emphasis on connecting persons with disabilities to employment. Only 60 percent of people between the ages of 16 and 64 with disabilities are employed (U.S. Census 2000).

To date, the Federal Transit Administration (FTA), the agency responsible for administering the NF program, has funded programs such as expanded paratransit services, door-to-door or door-through-door (escort programs), volunteer driver programs and aide/escort assistance; travel training, mobility management and driver training for individuals where vehicle operators may receive training to use specially equipped vehicles for persons with disabilities (Thakuriah 2010). In addition, capital programs such as elevator purchases, large capacity wheelchair lifts that are added to vehicles, wheelchair securement areas are added to vehicles and other capital programs to improve mobility conditions for persons with disabilities have also been funded. Between 2006 and 2009, the department expended $338.2 million (capital programs require a 20 percent match, whereas operating programs require a 50 percent match; 10 percent of the

apportionment may be used to support program administrative costs including administration, planning, and technical assistance).

According to authorizing legislation, the stated goal of the NF program is to "assist individuals with disabilities with transportation, including transportation to and from jobs and employment support services" (SAFETEA-LU 2005). At no point does the bill refer to seniors or low-income individuals. In contrast, FTA program guidance text includes both "older adults and people with low incomes" in the prerequisite coordinated planning process (FTA 2007). A myriad of federal programs with origins unrelated to ADA mandates had been established to address the transportation needs of these two additional populations. Seniors had been served by 15 separate federal programs housed in 5 departments (GAO 2004). These programs had proliferated in the context of an aging, auto-dependent society. Transportation needs of low-income individuals, on the other hand, had been provided, not as a right, but "as an element of welfare reform" (GAO 1998). Programs available to low-income transportation-disadvantaged populations, such as the FTA's Job Access and Reverse Commute (JARC) program, almost exclusively provided trips to work or job training. Integration of all three groups into a generalized "transportation-disadvantaged" population promised increased efficiency (GAO 2004).

2.2 "Mobility" and "Disability"

Research relating environmental factors to mobility comes from a wide variety of fields with differing operational definitions of mobility and disability. The difference between what is meant by "mobility" in the transportation versus medical research is partly a matter of scale. In the medical context "mobility" refers to ambulation whereas transportation planners use the term as shorthand for movement on a larger scale between origins and destinations. Accordingly, the different fields measure mobility differently.

Many medical studies research mobility as a component of the Activities of Daily Living (ADL) scale, which measures the ability to perform self-care tasks such as personal hygiene, dressing, feeding oneself, and ambulation. The related Independent Activities of Daily Living (IADL) scale measures ability to do housework, meal-preparation, self-medication, shopping, using the telephone, etc (Lawton 1969; Katz 1983). Research has been done on the relationship between mobility (in the medical context) a variety of factors, including race (Patel 2007), education (Melzer 2001) and sex (Leveille 2000). In contrast, within the transportation literature "mobility has been defined as the potential for movement, the ability to get from one place to another" (Hansen 1959; Handy 1994).

The definition of "disability" has been dynamic across fields less than it has changed over time. An older definition, termed the "medical model" of disability conceives of illness or disability as intrinsic to the individual

(Brisendon 1998). According to this definition, the role of the expert physician is to prescribe medical solutions to "normalize" a disabled person's participation in society as much as possible. In contrast the "social model" distinguishes between impairment, which is a personal attribute, and disability, which is a restriction caused by society that fails to accommodate individuals with impairments (Hughes 1997).

Sociomedical (hybrid) definitions of disability, incorporating both individual characteristics and social/environmental factors, have become common (Verbrugge et al 1994). For example, elements of both models are apparent in the International Classification of Functioning, Disability and Health (ICF), a framework for standardizing the description and measurement of health and disability established by the World Health Organization (WHO) in 2001 (WHA 2001). The framework includes both "body functions and structure," "domains of activity and participation," and "environmental factors" (WHA 2001). Recent research has employed a more nuanced definition of disability not as a dichotomous state but as a dynamic process of "disablement" (Verbrugge, et al 1994). This dynamic model interprets functional limitations as an intermediary between risk factors (e.g. sex and frequency of walking), pathology (e.g. musculoskeletal problems) and the onset and course of IADL disability (Lawrence 1996).

The relationship between environmental factors and travel behavior is of interest to both transportation and medical researchers for different reasons. Transportation research takes travel behavior as a focal subject and safe, efficient, reliable transportation systems as a primary product, an end of in and of itself. To medical researchers, on the other hand, travel behavior is a worthy subject because of its relationship with health. Environmental factors relating to pedestrian accessibility and auto-dependence are of particular interest to both medical and transportation researchers.

2.3 Transportation Research

While there is little argument that travel patterns vary with environmental factors, there is not a consensus regarding the extent to which density, walkability, crime, transit availability, auto-ownership, street connectivity, social organization, and other environmental variables influence travel behaviors, as measured by especially mode choice, trip frequency, and trip length (Handy 1996). The topic is significant and timely as proponents of the increasingly popular New Urbanism design movement claim the ability to influence travel behavior through design, specifically to decrease auto trips and increase transit, walking and bicycling trips (Rodriguez et al 2006). Handy (2002) notes that studies of the built environment/ travel behavior relationship have appeared in the literature with increasing frequency since the early 1990s.

By 2002 more than 70 published studies on the topic were documented (Handy 2002). Inconsistency in methodology (simulations, aggregate and disaggregate), travel characteristics (miles traveled, trip frequency, trip length,

mode choice) and independent variables (density, connectivity, accessibility, pedestrian infrastructure) complicate comparisons between studies. A 2001 review of studies concerning the influence of urban form on travel found empirical support for transportation benefits of livability to be "inconclusive and their behavioral foundations obscure" (Boarnet et al 2001). One thorough review found that environmental characteristics were more significant than socioeconomic factors for predicting trip length, but socioeconomic factors were more significant for predicting trip frequencies and mode choice (Ewing and Cervero 2001). Other studies have identified individual attitudes and preferences "a more significant predictor of travel behavior than either socio-economic characteristics or the built environment" (Kitamura et al 1997).

Finally, two FTA-commissioned studies of NF transportation service users conducted at UIC are particularly relevant to this research. The first clustered NF service users into four groups using self-reported health ratings and IADL measures: 1) healthy with disability, 2) healthy without disability, 3) not healthy without disability and 4) not healthy with disability, suggesting that the services target "younger individuals with disabilities who consider themselves to be in good health but have difficulty functioning independently, as well as seniors, who are more likely to report being in poor health but experience greater levels of independence in performing everyday activities" (Thakuriah 2010). The second paper conducts a Principal Component Analysis on the characteristics of NF services users and finds that 48% of total variance in the sample is accounted for by two principal components (Thakuriah 2011). The first, a "Transportation Deprivation Component" consists of 1) having no drivers license, 2) difficulty using public transportation, 3) receipt of public assistance and 4) having no vehicles in the household; the second component, an "Independence and Health Deprivation Component" consists of 1) living alone status, difficulty traveling independently, 3) perceived health issues and 4) frequency of medical trips (Thakuriah 2011).

2.4 Medical Literature

As of 2003, "only a small number of studies [had] examined the influence of residential neighborhood on functioning and risk of disability among older persons" (Kawachi 2003) and a 1997 American Journal of Public Health editorial exhorted researchers to explore "the effects of the physical environment on functional capacity and on the satisfactory completion of daily tasks" (Satariano 1997). As research followed, observers commented on what seemed to be a "reconnection" of urban planning and public health, spurred by the aging of the population, increasing rates of disability and other public health problems (like obesity, diabetes, heart disease, respiratory conditions, etc) related to auto-dependence (Frank 2008).

Subsequently, a growing body of research focused on the role of the built environment 1) in the disablement

process generally (Beard et al 2009; Clarke et al 2008), 2) in relation to specific elements of functioning (Bowling et al 2007; Clarke et al 2009; Freedman et al 2008), 3) as a predictor of physical activity (Frank et al 2007) and 4) in relation to the safety of pedestrians and bicyclists (Dumbaugh 2008). In addition, research has tested the potential for livable communities to improve air quality and respiratory health (by reducing driving), encourage walking and cycling, and reduce environmental barriers to the mobility of elderly and people with a disability (Jackson 2001). Integrating physical activity into everyday life is recognized as an outstanding solution to the national obesity epidemic (Koplan 2001).

In terms of the disablement process and functional characteristics, significant neighborhood effects have been documented. One longitudinal study found that safe walking environments and access to physical activity facilities correlate with lower rates of decline in walking activity among seniors (Li et al 2005). One study documents that over an 8-year period residents of Connecticut neighborhoods with safety hazards were 1.5 times as likely to report difficulty walking as those in safer neighborhoods (Clarke 2009). A study of the Americans' Changing Lives survey found that over a period of fifteen years, residents in neighborhoods with higher levels of auto-dependence were 1.5 times as likely to report mobility disabilities (Grant 2011). A cross-sectional study found that a self-reported measure of "daily activity limitation" correlated positively with mobility barriers and negatively with transportation access, though residents of more restrictive communities (meaning with more mobility barriers and fewer transportation) did not perform daily activities any less frequently (Keysor et al 2010).

The presence of nearby parks, public transportation and handicapped parking spaces also seem to be related to reduced disability (White et al 2010). A multi-level analysis of community-dwelling older adults found that frequency of walking trips correlated with neighborhood-level disorder (Mendes et al 2009). A factor analysis of data from the US Health and Retirement Study found that economic conditions and the built environment, but not social conditions, are significantly related to disablement; in particular, neighborhood-level economic advantage is associated with reduced risk of lower body limitations, and high connectivity of the built environment is associated with reduced risk of limitations in instrumental activities (Freedman et al 2008). Multinomial logistic regressions of data from the Chicago Community Adult Health Study found that the effect of lower extremity impairment on mobility disability varied significantly with street conditions, suggesting "if street quality could be improved…the disablement process could be slowed or even reversed" (Clarke et al 2008). Other authors were less quick to identify the direction of causation, and so controlled their sample for neighborhood preference, finding that people who prefer a walkable environment are more physically active in walkable neighborhoods, those that do not prefer a walkable environment "walked little and show no change in obesity prevalence regardless of where they live" (Frank 2007).

2.5 Walk Score

Walk Score is one measure of auto-dependence (freely available from walkscore.com) that uses an algorithm "based on walking distances from an address to a diverse set of nearby amenities" (Walk Score 2011). Generally, the measure has been validated and is considered a reliable index of what is variously referred to as walkability, livability "access to walkable amenities" and "the physical activity environment" (Carr 2010). It is also notable that Walk Score significantly correlates positively with crime (Carr 2010).

However, the effect of Walk Score on travel behavior varies with trip purpose and socioeconomic characteristics (Manaugh 2011). A Montreal study found that Walk Score correlates most significantly with home-based shopping trips. The same research identified significant positive correlation between Walk Score and number of walking trips for households with children, women in large households and women in young families whereas Walk Score correlated significantly negatively with wealthy families and did not significantly correlate to middle-class or low-income households at all (Manaugh 2011). In general, wealthy, car-owning households were found to be very particularly sensitive to Walk Score compared to retired or low-income households.

3. METHODOLOGY

3.1 Research Questions

In terms of the social model, mobility disability is neither an independent or categorical variable, but a spectrum of outcomes ranging from mobility to disablement resulting from a combination of personal and environmental predictors. This study hopes to shed light on the following questions:

1) To what extent do subgroups exist within the transportation-disadvantaged population?

2) What environmental factors and service characteristics have an effect on mobility outcomes for these subgroups?

3.2 Sampling

This study uses data obtained by a 2010 University of Illinois-Chicago (UIC) study of NF transportation services conducted for the FTA. The process of identifying services to study was significantly complicated by the absence of a complete sampling frame of services at the time of site selection. NF services were identified based on proposals made to FTA, available via the TEAM-Web online grants application database. The initial goal was to use TEAM Web to construct a database consisting of a (long) list of all services in these project categories (the "population" or master list of projects for each project category), from which probabilistic samples based on stratification variables such as federal region, dollar amount, location type (large urban, small urban and rural) and type of service (project type) would be drawn. This process would have identified all services, for example, within the State of Alaska, within each project category and with clear urban, small urban and rural designation, which had started operations or was being operated using NF funds during the survey period; the latter consideration is important because NF funds were being used in several cases to continue to operate services that had existed for a long time with funding from other sources. Had such a list been possible to construct, we could have surveyed a service within Alaska that had been probabilistically sampled from the universe of services that were currently funded by NF.

Unfortunately, identifying the universe of services was not possible for multiple reasons. First, it was impossible to determine from TEAM Web whether a service had begun to operate and it became clear that many had not begun or had been cancelled due to lack of matching funds. Secondly, applying agencies were unable to provide the all information about services, especially when sub-recipients were involved. It was also difficult to determine when NF funds were being used to pay for the many services that had been operational prior to the NF program and it was not always clear which source of funding was being used at the time of surveying. Thirdly, the description of services as

given in TEAM Web did not always match the scope of services as offered. For example, in Region 1 after locating a fixed-route service that matched our sampling requirements in TEAM Web, further discussions with the manager of the service indicated there was a mismatch between the TEAM Web description and the service as implemented.

The issues mentioned above were also pertinent to a concurrent study of Coordinated Human Services Transportation Planning (CHSTP) processes associated with the Job Access and Reverse Commute (JARC) program and outcomes experienced by JARC users. The search for NF transportation services was "snowballed" onto this related study where states within FTA regions were randomly selected, followed by a more intensive search within states to identify operating programs funded through the NF program. This sampling strategy aims to cover the mix of FTA regions, area sizes, and services funded under JARC and take into consideration the amount of money that is allocated to different areas. With ten regions, three area types (large-urban, small-urban, and rural), and two service types (fixed-route and demand responsive), there are 60 possible region-size-service pairings, 22 of which were sampled using a modified Latin Hypercube Sampling (LHS) method to "cover" the surface of the different combinations of region, size and service. Services were eliminated from the sample if clientele would not have understood the questionnaire (for reasons such as developmental disabilities or cognitive issues, such as paranoid schizophrenia), yielding 10 operational services in 8 states (Table I), funded partially by NF programs, and covering a mix of urban and rural services in approximately the same proportion as FY 2009 NF appropriation.

Table I: Respondents by State

State	Arizona	California	Florida	Illinois	Minnesota	Missouri	Texas	Washington
Respondents	47	56	12	65	14	28	23	25

3.3 Survey Development

Surveys were developed to be understood by respondents with wide variations in reading ability and to allow a respondent's personal assistant or caregiver to aid the respondent. The survey's sixty one items are divided between six sections: 1) service use 2) frequency and travel times of work, school, shopping, medical and social trips before and after beginning to use the service, 3) experience and satisfaction with the service, 4) general transportation experience and difficulties, 5) general sociodemographics and 6) physical, cognitive and emotional conditions. Survey content and language were informed by literature review and input from NF program managers, technically reviewed by an independent, professional survey review committee (UIC Survey Research Laboratory's Questionnaire Review

Committee) and approved by the UIC Institutional Review Board. Finally, the survey instrument was pretested on clients of a Chicago-area NF program. Distribution of the final versions took place between spring 2009 and summer 2010.

3.4 Imputation

Possibly due to the personal nature of many of the questions, the dataset contained a prohibitively high degree of item nonresponse. In order to allow for in-depth analysis, missing values were imputed using a simple random imputation function. This type of imputation was deemed appropriate because extensive searches did not detect structural nonresponse.

3.5 Measures Used

3.5.1 Measures of Mobility Independence

Two measures were used to determine the level of mobility independence. The first, Perceived_Ability, is a self-reported measure on a Likert-type ordinal scale ranging from 1 ("never being able to travel to places such as work, shopping, health care, etc., on your own") to 5 ("always" being able to do so). The Functional_Ability scale reflects the "Mode of Transportation" and "Shopping" aspects of the Lawton-Brody IADL and is constructed from several survey items, ranging from 0 (extreme lack of ability to travel independently) to 6 (strong ability to travel independently) (Table II).

Table II: Measures of Travel Independence, Neighborhood Characteristics and Services Used

Measure	Description	Scale	Mean
Mobility			
Perceived_Ability (Source: User Survey)	Perceived ability to travel independently	5-point Likert scale: 1-Never to 5=Always	2.62
Functional_Ability (Source: User Survey)	Composite of the following questions measuring functional ability to travel: Able to access public transport; Able to shop independently; Able to drive	composite scale: 0 – No ability in any of the 4 functional measures to 1 – Ability in all 4 functional measures	.55
Neighborhood Characteristics			
Walk Score (Source: Walk Score.com)	Measure of area walkability	Interval (Between 0 and 100)	51.75
Density (Source: Census 2000)	Population per square mile	Interval	7896
Prop_ownerocc (Source: Census 2000)	Proportion of units owner-occupied in census tract	Proportion	0.49
Prop_mixrace (Source: Census 2000)	Racial/ethnic diversity - Proportion mixed race in census tract	Proportion	0.25
Prop_senior (Source: Census 2000)	Proportion of persons greater than 65 years	Proportion	0.26
Prop_young (Source: Census 2000)	Proportion less than 18 years in census tract	Proportion	0.16
Service Characteristics			

Prog_volunteer (Source: Program Manager Survey)	Indicator of volunteer driver service	Indicator (1 if volunteer service; 0 if demand-response van or taxi service)	0.30
Operatedby_SeniorCommCenter (Source: Program Manager Survey)	Indicator of service operation by community organization/seni or care center	Indicator (1 if operated by community organization or senior care center; 0 otherwise)	0.49
srvcValue	Measure of difficulties of using the service and perceived value relative to other modes	Composite Index 0 = very difficult to use service and "no improvement at all" over other modes 1 = no difficulties using service; "large improvement" over other modes	.698
SRVC_QUALITY	"Overall, how would you rate the quality of this service?"	1= Very Poor, 2= Poor, 3= Fair, 4= Good, 5= Excellent	3.455

Perceived_Ability and Functional_Ability measure different aspects of the respondents' travel situation (the two scales are not significantly related). Pearson's coefficients indicate evidence of significant positive correlation between Perceived_Ability and number of shopping trips, and significant negative correlation with number of medical trips, needing a personal assistant inside the house, ability to travel independently outside the house and wheelchair use. Interestingly, we did not find a statistically significant association between Perceived_Ability and Rate_Health or self-reported health status, indicating that the health status question ("Overall, how would you rate your health") possibly elicited responses relating to transient ailments, so even those in relatively poor health at the time of reporting may have viewed themselves as being able to generally travel independently. These results indicate that the perceptual measure reflects actual travel and trip-making abilities and patterns to a certain degree, although the modest size of the correlations indicate that other factors are taken into consideration in the perception of independence in travel.

Functional_Ability significantly, negatively correlates with self-rated health and number of shopping trips, and

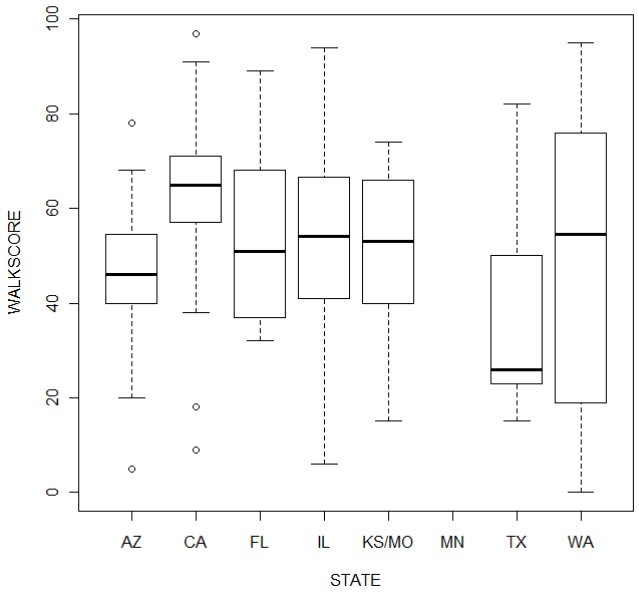
significantly negatively correlates with medical trips, work trips, needing personal assistance inside and outside the house, needing crutches and canes, manual and electric wheelchair and difficulty communicating while traveling. While this measure reflects underlying travel and mobility conditions it is also significantly related to a greater number of specific aspects of the activity of travel, as impacted by the person's disability situation. Health status may interfere with some of the elements of functional ability to travel independently, such a driving or being able to shop, thereby leading to a positive association between the two variables.

3.5.2 Environmental Factors

Environmental factors considered here consist of built environment variables and census tract level population and housing data. The built environment variables include Walk Score, density and area type (urban, suburban or rural). Census tract level data includes the proportions of seniors, young people, mixed-race, and proportion of housing that is owner-occupied.

About 50% of respondents' reside in locations with Walk Scores greater than 52, indicating somewhat to extremely walkable neighborhoods, while close to 25% of respondents neighborhoods almost always require a car. Density, proportion of population under 18, proportion of population over 65 and racial/ethnic diversity of respondents' tracts are also distributed between sites. About 10% of the respondents reside in areas with population density greater than 15,000 persons per square mile. The average owner-occupancy of housing units in areas where respondents reside is close to 50%, although about 10% reside in areas where 100% of housing units are owner-occupied. On average 26% of the population where respondents reside are above 65 years of age; about 10% reside in areas where there are a very high share of seniors (greater than 75%).

Figure I: Walk Scores by State



Four of the 10 service areas we surveyed had a higher percentage of seniors than the US average of 12.6% [30]; however, within these areas there exist geographic clusters of higher density (greater than 50%) senior populations ("Naturally Occurring Retirement Communities"). About 25% also live in racially and ethnically diverse areas where more than 35% of area residents classify themselves as multiple non-White races. Overall the sample contains a wide variety of neighborhoods.

3.5.3 Service Characteristics

Environmental variables describing transportation services include service type and organizational structure of service provider. Six of the 10 service providers studied are non-profit social services centers, three are transit agencies and one is a city-operated senior center. Four of the six social service centers focus exclusively on seniors, whereas the others also serve younger persons with disabilities. The stated purpose of most of these organizations is independent living. We surveyed door-through-door volunteer driver services, van services operated by transit agencies, taxi subsidy programs and integrated van and taxi services. As shown in Table II, approximately 30% of the respondents receive transportation services from volunteer driver programs, whereas the remaining respondents use special van-based transportation services and taxi services. Close to 50% of the respondents receive services operated by senior care centers and community-based centers that assist seniors and younger persons with disabilities.

Since the transportation services vary in terms of cost, convenience, level of service and other variables, a

composite index is used to measure the value of the service to each respondent. This constructed measure of individualized service value (srvcValue) combines 2 groups of ordinal measures: 1) four variables measuring difficulties with using the service and 2) three measures of perceived value of the service relative to other modes. Compared with the perceptual measure ("Overall how do you rate the quality of this service"), service value is a more detailed way of measuring service quality on an individual level.

3.6 Analysis

3.6.1 Clustering

Clustering is regarded as "one of the most useful tasks in the data mining process for discovering groups and identifying interesting distributions and patterns in the underlying data" (Fayyad et al 1996). However, results of clustering algorithms vary depending on features of the data and initial assumptions (Haldiki et al 2002). In order to cluster NF service users, a clustering algorithm and number of clusters must be specified. The number of clusters specified in each case will be determined by the Bayesian Information Criterion (Everitt and Hothorn 2006), which is calculated as follows:

$$-2 \cdot \ln p(x|k) \approx \mathrm{BIC} = -2 \cdot \ln L + k \ln(n).$$

Where P(x|k) is the probability of the observed data (x) given the number of parameters (k) and L is the maximized value of the likelihood function for the estimated model (Ghosh et al 2006). The variables upon which each respondent was assigned a cluster is given in Table III.

Table III: Variables Used to Cluster Respondents

VARIABLE	DESCRIPTION
SRVC_USE_DURATION	Duration of the respondents use of the service
SRVC_LRN_FRND	Learned about this service from a friend
SRVC_LRN_EMPAG	Learned about this service from an employment agency
SRVC_LRN_ADV	Learned about this service from an advertisement
SRVC_LRN_EMPLYR	Learned about this service from an employer
SRVC_LRN_SOCWRKR	Learned about this service from a social worker
SRVC_LRN_OTHER	Learned about this service from another source
DEST_WORK	Use this service to get to work
DEST_SCHL	Use this service to get to school
DEST_CHLD_CARE	Use this service to get to childcare
DEST_HOME	Use this service to get to home
DEST_JB_SRCH	Use this service to get to job search
DEST_SHOP	Use this service to get to shopping
DEST_MED	Use this service to get to medical appointments
DEST_SOCIAL	Use this service to get to social visits
DEST_OTHER	Use this service to get to other destinations
SERV_CHNG_GRAD_SCL	Since you began using this service have you graduated school
SERV_CHNG_BK_SCL	Since you began using this service have you returned to school
SERV_CHNG_JB_TRAIN	Since you began using this service have you completed a job training program
SERV_CHNG_JB_PROM	Since you began using this service have you been promoted
SERV_CHNG_HM_MOV	Since you began using this service have you relocated homes
SERV_CHNG_HV_CHLD	Since you began using this service have you had a child
SERV_CHNG_JB_LOSE	Since you began using this service have you lost a job
SERV_CHNG_HLTH	Since you began using this service have you experienced a major change in your health
SERV_CHNG_INDP	Since you began using this service have you experience a major change in your ability to live independently
SERV_CHNG_NONE	Since you began using this service have you experienced none of the above
RSN_NOT_WRK_SCHL	Not working because of school
RSN_NOT_WRK_HM_MKR	Not working because respondent is a homemaker
RSN_NOT_WRK_RETIRED	Not working because is retired
RSN_NOT_WRK_SICK	Not working because of illness
RSN_NOT_WRK_NOT_FND	Not working because could not find work
RSN_NOT_WRK_TRANSPORT	Not working because of lack of transportation
RSN_NOT_WRK_OTHER	Not working because of other reason
SEX	Sex
AGE	Age
HHSIZ	How many people are in your household
HHWRKRS	How many people in your household are employed
HH_UND16	How many people in your household are under 16
EDUC	What is your highest year or grade of school you have completed
PERS_INC_2008	Total annual personal income from all sources (write in)
PERS_INC_2008_CAT	Total annual personal income from all sources (5 categories)
NHHVEH	Number of household vehicles
VALID_DL	Has valid drivers license
VEH_REPO	Has had a household vehicle reposed in the past two years
HOME_FORECLOSED	Has had a home foreclosed in the last two years

PUBLIC_ASSIST	Has received public assistance in the last two years

3.6.2 Chi Square Tests

A series of Chi Square tests examined the potential for associations. The first compares types of destinations reached using the NF service to a variety of personal characteristics and presents significant associations. The second compares destinations reached using the NF to clusters, in order to inform subsequent discussion of clusters and to establish the clusters validity (in relation to the first chi square tests).

3.6.4 Ordinary Least Squares (OLS) and Ordered Probit models

Functional ability and service value are modeling with OLS regressions because they are continuous variables. Perceived Independence and Perceived Service Quality, however, are modeled using ordered probit models because they are ordinal dependent variables. These models take the form:

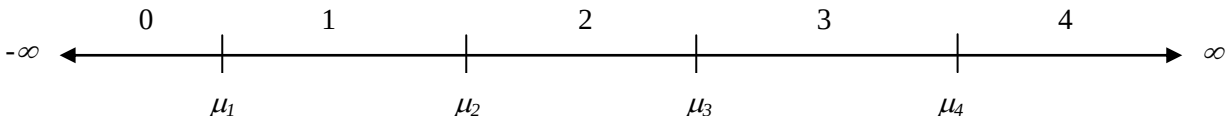
$$y_i^* = \boldsymbol{\beta}' x_i + \boldsymbol{\varepsilon}_i$$

Where Yi* is the (continuous) dependent variable, $\boldsymbol{\beta}$ is a vector of parameters to be estimated, $\boldsymbol{x_i}$ is a vector of independent variables in three groupings: individual, environmental and transportation service variables, and $\boldsymbol{\varepsilon_i}$ is the error term, assumed to be normally distributed with mean zero and unit variance, with cumulative distribution denoted by $F(\cdot)$ and density denoted by $f(\cdot)$. Given a perceived level of independence, an individual falls in category n if

$$\mu_{n-1} < y_i^* < \mu_n,$$

where the m's are thresholds to be estimated, along with $\boldsymbol{\beta}$.

Figure II: Relationship between latent, continuous underlying variable and observed category



$$y_i = \begin{cases} 0 \text{ if } -\infty \le y_i^* \le \mu_1 \text{(never able to travel independently)} \\ 1 \text{ if } \mu_1 < y_i^* \le \mu_2 \text{(sometimes able to travel independently)} \\ 2 \text{ if } \mu_2 < y_i^* \le \mu_3 \text{(able to travel independently about half the time)} \\ 3 \text{ if } \mu_3 < y_i^* \le \infty \text{ (able to travel independently most of the time)} \\ 4 \text{ if } \mu_3 < y_i^* \le \infty \text{ (always able to travel independently)} \end{cases}$$

The probability that respondent *i* falls into category *n* is given by:

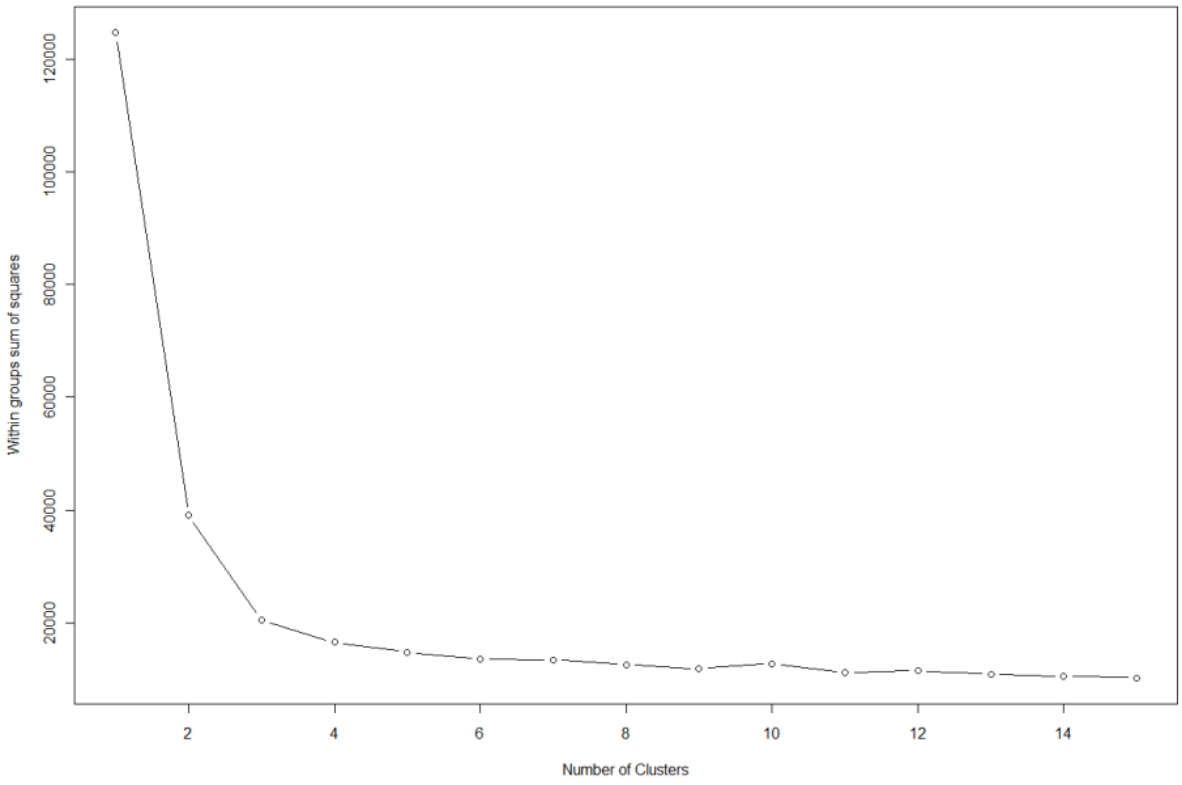
$$\text{Prob}(y_i = n) = \Phi(\mu_n - \beta' x_i) - \Phi(\mu_{n-1} - \beta' x_i),\ n = 0,1,2,3,4$$

4. RESULTS & CONCLUSIONS

4.1 Clustering Results

The within-group sum of squares for different numbers of clusters supports a 3-cluster solution because the bend in the scree type plot at the three cluster point.

Figure III: Within-Group Sum of Squares by Number of Clusters



As the number of clusters increases beyond 3, variance of the within group sum of squares is due to noise rather than clustering.

The Corrected Rand and Dunn indices were used to compare the results of two clustering methods: 1) 3-group Ward's Hierarchical and 2) K-means. The Corrected Rand Index is useful for comparing datasets such as disparate clustering results and ranges from 0 (no similarity) to 1 (identical sets). The two methods yield similar results, indicated by a Corrected Rand Index of 0.9702333. The Dunn index measures the ratio between minimum intracluster distance

and maximum intercluster distance, so that the more well-defined clusters have higher Dunn scores.

$$D = \frac{d_{min}}{d_{max}},$$

The 3 group Ward's Hierarchical clusters have a Dunn Index of 0.09963108 while the 3 group K-means clusters have a Dunn's Index of 0.1120633, so while they are very similar the K-means clusters more accurately reflect variation in the sample.

Table III gives mean values for each cluster on several functional and physical disability factors and factors relating to living and working conditions. The first cluster (n=85) consists of older persons with disabilities likely to be unemployed, use assistive devices, rate their health as poor, have low levels of functional independence and live alone; the second (n= 137), the "oldest old," are in better health, have higher levels of functional independence and less assistive device usage compared to the second group; the third cluster (n=36) consists of younger more likely employed but with a greater share of cognitive and communication impairments and need for audio and visual assistance.

Table IV: Mean Individual, Environmental and Service Characteristics of Clusters

		Cluster		
Variable	**Description**	**1**	**2**	**3**
INDIVIDUAL CHARACTERISTICS				
Perceived_Ability	(See Table II)	2.900	2.500	2.500
Functional_Ability	(See Table II)	0.5531	0.4963	0.6069
Composite_IADL	(See Table II)	12.030	10.600	18.170
Age (years)	Mean age	63.930	85.360	32.120
Rate_Heatlth	Mean; "Overall, how would you rate your health?" (1=Poor, 5=Excellent)	2.720	2.770	3.410
EMPLOYED	Mean; "Are you currently working for pay?" (1=Yes, 0=No)	0.167	0.008	0.619
living_alone	Percent indicating that, including themselves, the number of people living in their household = 1	0.523	0.642	0.222

If survey was completed by anyone other than the respondent, the respondent was asked: Does this person have any of the following long-lasting conditions?				
PRSN_DISABILITY_VISION_AUD	Blindness, deafness, or a severe vision or hearing impairment?	0.333	0.475	0.076
PRSN_DISABILITY_LIMIT_ACTIVITY	A condition that substantially limits one or more basic physical activities such as walking, climbing stairs, reaching, lifting or carrying?	0.619	0.641	0.444
Because of a physical, mental or emotional condition lasting 6 months or more, does this person have any difficulty in doing any of the following activities?"				
PRSND_DIFF_LEARN	Learning, remembering or concentrating	0.521	0.222	0.857
PRSND_DIFF_DRESS	Dressing, bathing or getting around inside the home	0.227	0.111	0.296
PRSND_DIFF_GOING_OUT_HOME	Going outside the home alone to shop or doctor's office	0.476	0.406	0.730
PRSND_DIFF_WRKING	D) Working at a job or business	0.550	0.280	0.481
ENVIRONMENTAL CHARACTERISTICS				
Density	(See Table II)	5384.53	10297.10	3535.22
Walk Score	(See Table II)	49.77	50.02	45.43
Prop_seniors	(See Table II)	0.27	0.29	0.11
Prop_young	(See Table II)	0.16	0.15	0.23
Prop_mixrace	(See Table II)	0.25	0.24	0.31
Area_suburban	(See Table II)	0.48	0.55	0.65
Area_rural	(See Table II)	0.18	0.07	0.26
Prop_ownerocc	(See Table II)	0.50	0.44	0.72
SERVICE CHARACTERISTICS				
Prog_volunteer	(See Table II)	0.15	0.46	0.07
Prog_van	(See Table II)	0.47	0.26	0.76
Operatedby_SeniorCommCenter	(See Table II)	0.38	0.56	0.46

Operatedby_TransitAgency	(See Table II)	0.48	0.25	0.50

Environmental and service factors also vary across the clusters (Table III). On average, cluster 2 respondents live in denser, more walkable environments with the higher proportions of owner occupied housing units and senior populations and the lowest proportion of young people. In contrast, cluster 3 respondents reside in less dense, more auto dependent suburban and rural environments with larger households, fewer seniors, more young people and high proportions of owner occupied housing. Aside from being the least suburban of the three groups, environments of cluster 1 respondents are, on average, between these two extremes.

The three groups are also associated with different service characteristics. Compared to the other groups, cluster 2 respondents are more likely to be using volunteer driver services, whereas cluster 3 respondents are more likely to be using van-based services. In addition, cluster 2 respondents are most likely to be using services operated by senior centers, while clusters 1 and 3 are twice as likely to use services operated by transit agencies.

4.2 Destination Comparison

A number of significant relationships were detected between types of destinations, personal characteristics and perceived service quality. Commuting to work using the transportation service is significantly associated with audiovisual, activity-limiting and learning disability, using a cane, using an electric scooter or wheelchair, being male, not having a valid drivers license, receiving public assistance and with having to recently reduce driving (Table IV). Work is the most common destination for cluster 3 (Table V). Using the service to commute to school is significantly associated with receiving public assistance. Using the service to go shopping is significantly associated with difficulties learning, dressing and work, with being unemployed and with being female. A higher proportion of both clusters 1 and 2 use the service to go shopping than cluster 3. Using the service to reach medical appointments is significantly associated with audiovisual and learning disability, using a cane and wheelchair to travel, being unemployed, having no valid drivers license, receiving public assistance and recently reducing driving. Using the service to make social visits is significantly associated with being unemployed.

There are also significant relationships between destinations and individualized service value. Using the service to commute to work is significantly associated with a negative perception of the service (Table VI). Using the service to

make trips to medical or other destinations, however, is associated with perception of higher service quality.

Table V: Chi Square Associations Between Destinations and Personal Characteristics

	Destinations					
User Characteristics	Work	School	Shopping	Medical	Social	Other
Audio or visual disability	-.29*			.42**		
Activity-limiting disability	-.27**					
Difficulty learning	.40**		-.23*	-.37**		
Difficulty dressing			-.41**			
Difficulty working			-.28*			
Travels with a cane	-.18**			.42**		
Travels with a personal assistant						.17**
Travels with an electric scooter or wheelchair	-.22*					
Travels with a manual wheelchair				.25*		
Employed	.85**		-.44**	-.6**	-.15*	-.14*
Male	.21**		-.16*			
Has valid drivers license	-.22**			.18**		
Receiving public assistance	.17**	.07*		-.18**		
Has needed to reduce driving recently	-.25**			.24**		

* = significant at .01; ** = significant at .001

Table VI: Destinations by Cluster

"Where does this service take you?"	Cluster		
Destination	1	2	3
Work	29.1%	10.2%	62.2%
School	4.7%	3.6%	13.3%
Home	37.2%	21.9%	24.4%
Shop	43.0%	49.6%	22.2%
Medical	58.1%	75.9%	28.9%
Social	19.8%	16.8%	4.4%
Other	19.8%	14.6%	13.3%

Table VII: Chi Square Associations between Destinations and Perceived and Individualized Service Quality Measures

Destination	Perceived Service Quality	Individualized Service Value
Work	.813***	-0.09116**
School	-.215	0.01059
Home	.040	0.02967
Medical	-.457	.06119*
Shopping	-.416	0.03992
Social	-.020	0.01338
Other	-.646**	.06938*

* = significant at .01; ** = significant at .001, ***= significant at .0001

4.3 Perceived Independence

Model 1 measures the combined effect of cluster and environmental factors on perceived ability to travel independently (Table VII). Perceived independence is negatively related to cluster 1 compared to (reference) cluster 2 and significantly, positively related to proportion of owner occupied housing. The significance of cluster membership substantially reduces with the introduction of service characteristics (Table VIII), exposing a significant positive association between volunteer drivers and perceived independence. However, when a measure of the real value of the service is introduced, improving model fit substantially, proportion of owner occupied housing is not a significantly predictor of perceived independence (Table IX). This implies that proportion of owner occupied housing is related to perceived service value but not in terms of convenience, cost and as it compares to other modes.

Table VIII: Ordered Probit Model of Perceived Independence as a Function of Cluster, Environmental Factors

Coefficient	Value
cluster1	-0.432*
cluster3	-0.103
WALKSCORE	0.005
density1000	0.013
prop_ownerocc	1.019**
prop_mixrace	0.155
prop_senior	0.059
prop_young	-1.752
AIC	305.202

*= significant at .05, **= significant at .01

Table IX: Ordered Probit Model of Perceived Independence as a Function of Cluster, Environmental Factors and Service Characteristics

Coefficient	Value
cluster1	-0.205
cluster3	0.199
WALKSCORE	0.008
density1000	0.010
Prop_ownerocc	1.177**
Prop_mixrace	-0.011
Prop_senior	0.386
Prop_young	-0.672
Area_suburban	-0.485
Prog_volunteer	0.786*
operatedby_SeniorCommCenter	-0.194
AIC	304.060

*= significant at .05, **= significant at .01

Table X: Ordered Probit Model of Perceived Independence as a Function of Cluster, Environmental & Service Factors, & Service Value

Coefficient	Value
cluster1	0.554
cluster3	0.494
WALKSCORE	0.016
density1000	0.012
prop_ownerocc	0.292**
prop_mixrace	-0.047
prop_senior	-0.085
prop_young	0.114
Area_suburban	-0.595
prog_volunteer	1.301*
Operatedby_SeniorCommCenter	-0.271
SrvcValue	-0.217
AIC	169.0597

*= significant at .05, **= significant at .01

4.4 Functional Ability

Unlike perceived independence, direct measures of functional ability are negatively significantly related to Walk Score and positively significantly related to proportion of seniors and suburban environments (Table X). When service factors are added (Table XI), proportion of owner occupied housing assumes a significant, negative association with functional independence, but the service factors are not significant. This suggests that respondents most capable of independently functioning in terms of shopping, using public transit and driving are located in more auto dependent

suburban environments with high proportions of seniors.

Table XI: OLS Regression of Functional Ability as a function of Cluster and Environmental Factors

Coefficient	Estimate
(Intercept)	0.401***
cluster1	-0.013
cluster3	0.134
WALKSCORE	-0.002*
density1000	-0.001
prop_ownerocc	-0.140
prop_mixrace	0.126
prop_senior	0.256*
prop_young	0.231
area_suburban	0.134*

***= significant at <.0001, *= significant at .05

Table XII: OLS Regression of Functional Ability as a function of Cluster, Environmental and Service Factors

Coefficient	Estimate
(Intercept)	0.416***
cluster1	-0.032
cluster3	0.101
WALKSCORE	-0.002*
density1000	-0.001
prop_ownerocc	-0.151*
prop_mixrace	0.146
prop_senior	0.245*
prop_young	0.237
area_suburban	0.177*
prog_volunteer	-0.029
operatedby_SeniorCommCenter	-0.048
AIC	-17.753

***= significant at <.001, *= significant at .05

4.5 Value of Service

The value of the transportation service to each respondent is modeled as a function of environmental, service and individual factors. Value of service is significantly positively associated with Walk Score, transit agency-operated (compared to senior center-operated) programs and volunteer driver (compared with taxi voucher or van-based) programs, while is it negatively significantly associated with respondents' receipt of public assistance (Table XII). The model results suggest that specialized transportation services run by transit agencies and volunteer drivers programs in walkable neighborhoods result in the fewest difficulties for users and offer the best improvement over other available modes. The negative relationship between service value and receipt of public assistance suggests that

not only are transportation services available to low-income earners more expensive, difficult to schedule, late to arrive and frequently lacking in proper equipment, but also that these services are inadequate improvements over alternative modes.

Table XIII: OLS Regression of Value of Service as a function of Environmental, Service and Personal Characteristics

Parameter	Estimate
(Intercept)	0.564***
WALKSCORE	0.001'
operatedby_TransitAgency	0.142***
prog_volunteer	0.162***
PUBLIC_ASSIST	-0.061*
AIC	-94.56

***= significant at <.001, *= significant at .05, '= significant at .1

4.6 Omitted-Variable Bias

While the sample contains a wide variety of neighborhoods in terms of the environmental factors measured (Walk Score, density, population and housing characteristics), many variables not included in the study are known to correlate with health outcomes. Since "the vast majority of mobility difficulties are caused by progressive chronic conditions," the omission of these variables may be a source of error (Iezzoni et al 2001). For example, suburban design and density of convenience stores and fast food restaurants are associated with obesity (Li et al 2008); Proximity to grocery stores, smaller block sizes, land use mix, perceived safety, intersection density are associated with walking (Berke et al 2007; Clarke et al 2005; Li et al 2005); The physical condition of streets and sidewalks has a significant effect on the functional impact of lower-extremity impairment (Clarke et al 2008).

In addition, the literature indicates an important distinction between capacity to function and enacted function (Rosso 2011; Glass 1998). While this study assesses capacity to perform certain functional tasks (specifically shopping, driving, and use of public transit), the survey instruments assessment of enacted capacity was limited to use of special transportation services. Information about additional enacted functioning, such as time spent walking, would be useful for future research.

Finally, a major complication of this study that should be addressed in future research is interdependence among family members, friends and neighbors. The survey instrument used here presumes that either respondents may be a capable of traveling independently or they require assistance. We leave the inquiry into family- and neighborhood-level interdependence at that and therefore it is impossible to understand the nature of the assistance. For example, an elderly relative who provides childcare in exchange for transportation service may perceive a higher

degree of independence compared to an ill family member who requires a family member's assistance to make medical trips.

4.7 Detection of Endogeneity Bias

Endogeneity can occur due to simultaneity, omitted variables or measurement error (Woolridge 2001). The ability of a respondent to travel independently may truly be determined by neighborhood and service characteristics, but it may be equally true that neighborhood selection may be determined by ability to travel independently. For example, while the walkability and mixed development aspects of a residential location may lead a senior to experience independence in travel, her ability to travel independently may lead her to reside in an area where such built environment amenities are present. In this case ability to travel independently and environmental factors are simultaneously determined.

The relationship is further complicated by the interplay of environmental and health factors because "mobility restrictions are not typically the results of a single cause, but arise from an interaction of risk factors in various domains, both individual and environmental" (Rosso 2011). While the direct impact of environmental factors on mobility can be clear, there are also less apparent indirect pathways. Many of the same progressive chronic health conditions, such as arthritis, back problems, cardiovascular and pulmonary diseases, and diabetes, which cause "the vast majority of mobility difficulties" are themselves directly related to environmental factors (Iezzoni et al 2001). Low Walk Scores, for example, are associated with respiratory illnesses, cardiovascular disease and hospital admissions (via reduced air quality) and stress, physical inactivity and obesity (via transit access) (SFDPH 2011).

Endogeneity bias can affect estimates of the relationship between the environmental and individual scales, so a series of Hausman tests was estimated to determine endogeneity between Perceived_Ability and Walk Score, density and prog_volunteer, and between Functional_Ability and the same variables, as given in Wooldridge (2001). Two Instrumental Variables (IVs) were used which fit reasonably well in all the cases considered: Area_Size (a dummy variable which takes a value of 1 if the person is located in a large urban area and 0 otherwise) and Prop_HseUnits (total number of housing units in the person's census tract divided by tract area in square miles). We did not find evidence of endogeneity between any of the environmental variables and Perceived_Ability. However, we found evidence of endogeneity between Walk Score and Functional_Ability. Because endogeneity bias can affect the estimates of the relationship between the environmental factors and Functional_Ability, the strength of the relationship between Walk Score and Functional_Ability should be interpreted with caution and remedial steps should be taken in

future research. A 2008 study, for example, found a significant association between walkability and miles walked even controlling for neighborhood preference (Frank 2008).

4.8 Discussion

Analysis of this nationwide sample of specialized transportation service users provides evidence of the diversity of the transportation-disadvantaged population. On the whole, respondents are older, with more disabilities and lower incomes compared to national averages, but within the sample there is wide variation. Clustering allowed the analysis to abstract variation of individual characteristics into one categorical variable to better focus on the environmental and service characteristics, but time constraints prohibited the clustering along other lines.

One alarming finding was that recipients of public assistance are more likely than other respondents to experience significant difficulties with their transportation services. In addition, or perhaps as a result, recipients of public assistance are the least likely to consider their service an improvement over other available modes. This group is defined by high rates of motor, audio/visual and cognitive impairment and includes the majority of employed respondents. A policy remedy may involve a joint effort between transit agencies and volunteer driver programs, which proved least difficult to use and were rated largest improvements over other available modes. Many NF service users making medical trips report recent driving cessation, living alone and traveling with canes and wheelchairs. Strategies that improve the pedestrian environment may be particularly effective at preserving mobility for this group.

The sample size and level of environmental detail gathered for this study are unfortunately inadequate for the task of testing the effect of walkability on functional independence, especially considering the endogeneity of that relationship. Where significant relationships were identified involving Walk Score, as in the positive association with service value, causation is not convincingly established. However, knowledge of significant associations presented above will be useful for policy analysts, even absent verified causation. For example, there seem to be strong relationships between perceived independence and service characteristics, and between functional independence and environmental characteristics. The value of transportation services, though, is associated with environmental, service and individual factors.

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Appendix A: Survey Instrument

National Transportation Survey

We need your help! We are conducting a survey about the XXXXXX service that you use. Completing this questionnaire is not required, but your answers will help improve transportation services. If you have any questions about your rights as a research subject, you may call the Office for the Protection of Research Subjects (ORPS) at the University of Illinois at Chicago toll-free at **1-866-789-6215**. Your answers are completely confidential and cannot be traced back to you in any way because we do not ask for your name. Your responses will be grouped together with a national sample. It will take you about 20 minutes to answer these questions. You may ask someone else to record your answers for you.

This part of the survey asks you about your use of the Rides4Neighbors.

1. **In what month and year did you start using the XXXXXXXXX van service?**
   _____Month _____ Year

2. **How did you learn about the van service?** (*Check all that apply*)
   - ☐ Friend/Caretaker
   - ☐ Employment agency
   - ☐ Advertising
   - ☐ Employer
   - ☐ Social worker/case-worker
   - ☐ Other (Specify) _____

3. **Where does this van service take you?** (*Check all that apply*)
   - ☐ Work
   - ☐ School/College/Job Training
   - ☐ Child-care
   - ☐ Home
   - ☐ Job-seeking activities / Job interviews
   - ☐ Shopping
   - ☐ Medical/Counseling Appointment
   - ☐ Social Visit
   - ☐ Other *(Please specify)* _____

4. **Did you experience any of the following *since* you first started traveling on this van service?** (*Check all that apply*):
   - ☐ I graduated from school
   - ☐ I went back to school
   - ☐ I completed a job-training program
   - ☐ I got a promotion at my job
   - ☐ I moved to a different home
   - ☐ I had a child
   - ☐ I lost a job
   - ☐ I experienced a major change in my health
   - ☐ I experienced a major change in my ability to do day-to-day activities on my own
   - ☐ None of the above

5. **Are you currently working for pay?**
   - ☐ Yes I am currently working → **SKIP TO QUESTION #7**
   - ☐ No, I am not currently working

6. **What are the reasons for which you are not working currently? (***Check all that apply and* **SKIP TO QUESTION #15)**
   - ☐ I am in school
   - ☐ I am a homemaker
   - ☐ I am retired
   - ☐ I am sick or unable to work
   - ☐ I cannot find work/I was laid off

☐ I do not have transportation
☐ Other → *Please specify reason:* _____

Questions about your job and work trips

7. **What street intersection is your primary job located near?** (*for example, Fifth and Main Streets*)

   _____ and _____ ***OR*** **near what place is your job located?** (*for example, St. John's Church, Redmond*)? _____

8. **Do you use the XXXXXXX to commute to work?**
   ☐ No → **SKIP TO QUESTION #15**
   ☐ Yes

9. **How many one-way trips to work do you make per week using this van service?**
   _____ Number of trips per week to work

10. **How much time (in minutes) does it typically take you to reach your job, using this van service**?
    _____ Minutes per one-way trip to work

11. **Were you able to take a job at a new work location because of the van service?**
    ☐ No, I work at the same location as before
    ☐ Yes, I was able to take a job at a new location

12. **Did you work *before* you started to use this van service?**
    ☐ No → **SKIP TO QUESTION #15**
    ☐ Yes

13. **How many one-way trips did you typically make per week to work *before* the van service became available to you?** _____ Number of trips per week to work

14. **How much time (in minutes) did it typically take you to reach your job *before* the van service became available to you?** _____ Minutes per one-way trip to work

Questions about your trips to school, job-training or college

15. **Are you currently in school, a job-training program or college?**
    ☐ No → **SKIP TO QUESTION #21**
    ☐ Yes

16. **Do you sometimes or always use this van to school, a job-training program or college?**
    ☐ No → **SKIP TO QUESTION #21**
    ☐ Yes

17. **How many one-way trips did you make per week to school, job-training or college, *before* the van service became available to you?** _____ Number of trips per week (*Enter 0 if you did not go to school, job-training or college before using the van service*)

18. **How many one-way trips do you make per week to school, job-training or college *now*, using the van service?** _____ Number of trips per week

19. **How much time (in minutes) did it typically take you to reach your school, job-training or college *before* the van service became available to you?**

    _____ Minutes per one-way trip (*Enter 0 if you did not go to school, job-training or college before using the van service*)

20. **How much time (in minutes) does it typically take you to reach your school, job-training or college *now*, when you use this van service?**

_____ Minutes per one-way trip

Questions about your shopping trips

21. **Do you use the XXXXXX to go shopping?**
☐ No → **SKIP TO QUESTION #26**
☐ Yes

22. **How many one-way trips did you make per week to go shopping, *before* the van service became available to you?**

_____ Number of trips per week

23. **How many one-way trips do you make per week to go shopping now, *after* starting to use this van service?**

_____ Number of trips per week

24. **How much time (in minutes) did you typically spend every week to travel to shopping, *before* the van service became available to you?**

_____ Minutes per week

25. **How much time (in minutes) do you typically spend every week now to travel to shopping, *after* starting to use the van service?**

_____ Minutes per week

Questions about your medical trips

26. **Do you use this van to go to a hospital or health care center?**
☐ No → **SKIP TO QUESTION #31**
☐ Yes

27. **How many one-way trips did you make per month to a hospital or for health care service, *before* the van service became available to you?**

_____ Number of trips per month

28. **How many one-way trips do you make per month to a hospital or for health care service now, *after* starting to use this van service?**

_____ Number of trips per month

29. **How much time (in minutes) did you typically spend every week to travel to a hospital or for health care service, *before* the van service became available to you?**

_____ Minutes per week

30. **How much time (in minutes) do you typically spend every week now to travel to a hospital or for health care service, *after* starting to use the van service?**

_____ Minutes per week

Questions about your experience with the XXXXXX

31. **How would you rate the overall quality of this van service?**

☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ Very Poor

32. **How would you rate the reliability of this van service?**

☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ Very Poor

33. How important, if at all, is this van service to you?

☐ Very important
☐ Moderately important
☐ Slightly important
☐ Not important

34. How often do you experience the following issues when you use the XXXXXXXX?

	Always	Most of the time	About half of the time	Sometimes	Never
(a) Difficulty scheduling a trip	☐	☐	☐	☐	☐
(b) On-time arrival	☐	☐	☐	☐	☐
(c) Vehicle lacks proper equipment	☐	☐	☐	☐	☐
(d) Costs too much	☐	☐	☐	☐	☐

35. To what extent is this van service an improvement over the following methods of travel?

	A large improvement	A moderate improvement	A little improvement	No improvement at all
(a) Private car	☐	☐	☐	☐
(b) Public buses or trains	☐	☐	☐	☐
(c) Other paratransit	☐	☐	☐	☐

This part of the survey asks you about your general experiences with transportation

36. How often are you able to travel to places such as work, shopping, health care, etc. on your own?

☐ Always
☐ Most of the time
☐ About half of the time
☐ Sometimes
☐ Never

37. Did you have to stop driving a car, or drive less frequently than you used to?

☐ No → **SKIP TO QUESTION #40**
☐ Yes, I had to stop driving or restrict my driving within the past _____ year(s)

38. Which of the following resulted because you had to restrict driving? (*Check all that apply***)**

☐ Drive less than I used to
☐ Avoid night driving or rush hours
☐ Avoid high-speed roads and highways
☐ Not drive at all

39. Why did you have to drive less or stop driving? (*Check all that apply***)**

☐ Eyesight or night vision is not good
☐ Attention span has decreased
☐ Hearing is not good
☐ Reduced coordination or reaction time
☐ Depth perception has decreased
☐ Chronic illness
☐ Needed assistance to access vehicle
☐ Advised by doctor to give up or limit driving
☐ Had to make expensive vehicle adaptation
☐ Could not pass or renew drivers license

40. How difficult is it for you to use public transportation such as buses or trains to get to places?

- ☐ Extremely difficult
- ☐ Very difficult
- ☐ Moderately difficult
- ☐ Slightly difficult
- ☐ Not at all difficult

41. How often do you have a problem with each of the following when you use public transportation?

	Always	Most of the time	About half of the time	Sometimes	Never
Accessing subway stations or bus stops	☐	☐	☐	☐	☐
Boarding and getting off buses	☐	☐	☐	☐	☐
Paying fares or purchasing tickets	☐	☐	☐	☐	☐
Accessing or understanding schedules & route information	☐	☐	☐	☐	☐
Finding place to sit or for wheelchair	☐	☐	☐	☐	☐
Finding bus or train when needed	☐	☐	☐	☐	☐
Cost of bus or train	☐	☐	☐	☐	☐
Crime in bus stop or station	☐	☐	☐	☐	☐
Quality of audible, visual or tactile information	☐	☐	☐	☐	☐
Inability to take service animals	☐	☐	☐	☐	☐

42. When you travel, do you ever need to use or need help with the following?

	Yes	No
Cane, crutches, or walker	☐	☐
Assistance from another person outside the home	☐	☐
Assistance from another person inside the home	☐	☐
Electric scooter or wheelchair	☐	☐
Manual wheelchair	☐	☐
Audible or visual signage and information	☐	☐
Communicating with others	☐	☐
Oxygen	☐	☐

This final section of the survey asks some background questions about you

43. What street intersection is your home located near? *(for example, Fifth and Main Streets)*

_____ and ____ _____ **OR near what place is your home located?** (*for example, near Johnson Park, Yorkville*)?_____

44. What is your gender?

- ☐ Male
- ☐ Female

45. In what year were you born?

19 _____

46. Including yourself, how many people live in your household?

_____ people

47. Including yourself, how many people in your household work for pay?

_____ people

48. How many members of your household are under 16 years of age?

_____ people

49. What is the highest year or grade of school that you have completed?

- ☐ 5th grade or less
- ☐ 6th, 7th, or 8th grade
- ☐ Some High School
- ☐ High School graduate or GED
- ☐ Some college
- ☐ Completed college

50. Your total annual PERSONAL INCOME (pre-tax) from all sources is (*Enter a number*):

$_____

OR *(Check one of the following boxes*):

- ☐ Less than $10,000
- ☐ $10,000-$19,999
- ☐ $20,000-$29,999
- ☐ $30,000-$49,999
- ☐ $50,000-$69,999
- ☐ More than $70,000

51. How many total vehicles (cars, trucks and motorbikes) does your household own?

_____ Vehicles

52. Do you have a valid drivers' license?

- ☐ Yes
- ☐ No

53. Has a vehicle owned by your household repossessed since January 2006?

- ☐ Yes
- ☐ No

54. Since January of 2006, was a home that you were living in foreclosed on?

- ☐ Yes
- ☐ No

55. Have you received any kind of public assistance (for example, TANF assistance, food stamps, Medicaid) since January 2006?

- ☐ Yes
- ☐ No

56. Overall, how would you rate your health?

- ☐ Excellent
- ☐ Very Good
- ☐ Good
- ☐ Fair
- ☐ Poor

57. How often can you do each of the following without help?

	Always	Most of the time	About half of the time	Sometimes	Never
(a) Use the telephone?	☐	☐	☐	☐	☐

(b) Prepare a meal?	☐	☐	☐	☐	☐
(c) Housekeeping tasks?	☐	☐	☐	☐	☐
(d) Laundry?	☐	☐	☐	☐	☐
(e) Manage medications?	☐	☐	☐	☐	☐
(f) Manage finances?	☐	☐	☐	☐	☐
(g) Shop?	☐	☐	☐	☐	☐

58. Who is completing this survey?

☐ I am completing this survey about myself → **SKIP TO QUESTION #61**

☐ I am completing this survey about another person

59. Does this person have any of the following long-lasting conditions:

	Yes	No
Blindness, deafness, or a severe vision or hearing impairment?	☐	☐
A condition that substantially limits one or more basic physical activities such as walking, climbing stairs, reaching, lifting or carrying?	☐	☐

60. Because of a physical, mental or emotional condition lasting 6 months or more, does this person have any difficulty in doing any of the following activities:

	Yes	No
Learning, remembering or concentrating?	☐	☐
Dressing, bathing or getting around inside the home?	☐	☐
(*Answer if this person is 16 years or older*) Going outside the home alone to shop or visit a doctor's office?	☐	☐
(*Answer if this person is 16 years or older*) Working at a job or business?	☐	☐

61. Please use the space below for additional comments

Appendix B: Variable Sources

Variable	Source
Local_Area	Survey
STATE	Survey
Service_Name	Survey
RESPONDENT_ID	Survey
STATE_ID	Survey
RESPONDENT	Survey
SITE	Survey
MO_SRVC_STRT	Survey
YR_SRVC_STRT	Survey
COMMENTS	Survey
SRVC_USE_DURATION	Survey
SRVC_LRN_FRND	Survey
SRVC_LRN_EMPAG	Survey
SRVC_LRN_ADV	Survey
SRVC_LRN_EMPLYR	Survey
SRVC_LRN_SOCWRKR	Survey
SRVC_LRN_OTHER	Survey
SRVC_LRN_OTHER_DESC	Survey
DEST_WORK	Survey
DEST_SCHL	Survey
DEST_CHLD_CARE	Survey
DEST_HOME	Survey
DEST_JB_SRCH	Survey
DEST_SHOP	Survey
DEST_MED	Survey
DEST_SOCIAL	Survey
DEST_OTHER	Survey
DEST_OTHER_DESC	Survey
SERV_CHNG_GRAD_SCL	Survey
SERV_CHNG_BK_SCL	Survey
SERV_CHNG_JB_TRAIN	Survey
SERV_CHNG_JB_PROM	Survey
SERV_CHNG_HM_MOV	Survey
SERV_CHNG_HV_CHLD	Survey
SERV_CHNG_JB_LOSE	Survey
SERV_CHNG_HLTH	Survey
SERV_CHNG_INDP	Survey
SERV_CHNG_NONE	Survey
EMPLOYED	Survey
RSN_NOT_WRK_SCHL	Survey
RSN_NOT_WRK_HM_MKR	Survey
RSN_NOT_WRK_RETIRED	Survey
RSN_NOT_WRK_SICK	Survey

RSN_NOT_WRK_NOT_FND	Survey
RSN_NOT_WRK_TRANSPORT	Survey
RSN_NOT_WRK_OTHER	Survey
RSN_NOT_WRK_OTHER_DESC	Survey
JOB_STREET1	Survey
JOB_STREET2	Survey
JOB_LANDMARK	Survey
VAN_TO_WORK	Survey
N_ONEWAY_TRPS	Survey
TT_WORK	Survey
JOB_NW_LOC_SRVC	Survey
WRK_BFR_SRVC	Survey
NTRPS_BFR_SRVC	Survey
TT_WORK_BFR_SRVC	Survey
IN_SCHL	Survey
VAN_TO_SCHL	Survey
TRIPS_TO_SCHL_BFR_SRVC	Survey
TRIPS_TO_SCHL	Survey
TT_TO_SCHL_BFR_SRVC	Survey
TT_TO_SCHL	Survey
SRVC_SHOPPING	Survey
TRIPS_SHOP_BFR_SRVC	Survey
TRIPS_SHOP	Survey
TT_SHOP_BFR_SRVC	Survey
TT_SHOP	Survey
SRVC_MED	Survey
TRIPS_MED_BFR_SRVC	Survey
TRIPS_MED	Survey
TT_MED_BFR_SRVC	Survey
TT_MED	Survey
SRVC_QUALITY	Survey
SRVC_RELIABILITY	Survey
SRVC_IMPORTANCE	Survey
PROB_DIFF_SCHEDULING	Survey
PROB_ON_TIME_ARRIVAL	Survey
PROB_LACKS_EQUIP	Survey
PROB_EXPENSIVE	Survey
SRVC_BETR_CAR	Survey
SRVC_BETR_TRNSIT	Survey
SRVC_BETR_PARATRNSIT	Survey
INDEP_TRVL_FREQ	Survey
REDUCE_DRIVING	Survey
REDUCE_DRIVING_YEARS	Survey
DRIVE_LESS	Survey
NO_NIGHT_DRIVE	Survey
NO_HIWAY_DRIVE	Survey

NO_DRIVING	Survey
RSN_NOT_DRV_EYE	Survey
RSN_NOT_DRV_ATTENTION	Survey
RSN_NOT_DRV_HEARING	Survey
RSN_NOT_DRV_COORDITION	Survey
RSN_NOT_DRV_PERCEPTION	Survey
RSN_NOT_DRV_ILLNESS	Survey
RSN_NOT_DRV_ACCESS	Survey
RSN_NOT_DRV_DCTR_ORDER	Survey
RSN_NOT_DRV_VEH_ADAPT	Survey
RSN_NOT_DRV_NO_DL	Survey
DIFF_USE_TRNSIT	Survey
DIFF_SBWY_ACCESS	Survey
DIFF_BOARD_BUS	Survey
DIFF_PAY_FARE	Survey
DIFF_UNDERSTAND_SCHED	Survey
DIFF_SIT_SPACE	Survey
DIFF_FIND_BUS	Survey
DIFF_COST	Survey
DIFF_STATION_CRIME	Survey
DIFF_AUD_VIS_INFO	Survey
DIFF_SRVC_ANMAL	Survey
TRVL_CANE	Survey
TRVL_OUT_HOME_PRSN_ASSIST	Survey
TRVL_IN_HOME_PRSN_ASSIST	Survey
TRVL_ELEC_SCOOTOR_WHLCHAIR	Survey
TRVL_MANUAL_WHLCHAIR	Survey
TRVL_AUD_VIS_INFO	Survey
TRVL_COMM_OTHER	Survey
TRVL_OXYGEN	Survey
HOME_STREET1	Survey
HOME_STREET2	Survey
HOME_LANDMARK	Survey
ADDRESS	Survey
SEX	Survey
DOB	Survey
AGE	Survey
Dupage_agecont	Survey
Dupage_agecat	Survey
HHSIZ	Survey
HHWRKRS	Survey
HH_UND16	Survey
EDUC	Survey
PERS_INC_2008	Survey
PERS_INC_2008_CAT	Survey
NHHVEH	Survey

VALID_DL	Survey
VEH_REPO	Survey
HOME_FORECLOSED	Survey
PUBLIC_ASSIST	Survey
RATE_HEALTH	Survey
FREQ_PHONE_USE	Survey
FREQ_PREP_MEAL	Survey
FREQ_HOUSEKEEPING	Survey
FREQ_LAUNDRY	Survey
FREQ_MAGE_MEDS	Survey
FREQ_MAGE_FINCE	Survey
FREQ_SHOP	Survey
COMPLETED_BY	Survey
PRSN_DISABILITY_VISION_AUD	Survey
PRSN_DISABILITY_LIMIT_ACTIVITY	Survey
PRSND_DIFF_LEARN	Survey
PRSND_DIFF_DRESS	Survey
PRSND_DIFF_GOING_OUT_HOME	Survey
PRSND_DIFF_WRKING	Survey
COMMENTS_OTHER	Survey
CLUSTER	Constructed
Density	US Census
WALKSCORE	Walkscore.com
area	US Census
STFID	US Census
STATE1	US Census
COUNTY	US Census
TRACT	US Census
BLOCK	US Census
STFID_1	US Census
POP2000	US Census
Density1	US Census
WHITE	US Census
BLACK	US Census
AMERI_ES	US Census
ASIAN	US Census
HAWN_PI	US Census
OTHER	US Census
MULT_RACE	US Census
HISPANIC	US Census
MALES	US Census
FEMALES	US Census
AGE_UNDER5	US Census
AGE_5_17	US Census
AGE_18_21	US Census
AGE_22_29	US Census

AGE_30_39	US Census
AGE_40_49	US Census
AGE_50_64	US Census
AGE_65_UP	US Census
MED_AGE	US Census
MED_AGE_M	US Census
MED_AGE_F	US Census
HOUSEHOLDS	US Census
AVE_HH_SZ	US Census
HSEHLD_1_M	US Census
HSEHLD_1_F	US Census
MARHH_CHD	US Census
MARHH_NO_C	US Census
MHH_CHILD	US Census
FHH_CHILD	US Census
FAMILIES	US Census
AVE_FAM_SZ	US Census
HSE_UNITS	US Census
URBAN	US Census
RURAL	US Census
VACANT	US Census
OWNER_OCC	US Census
RENTER_OCC	US Census
F1	US Census
state_no	US Census
RESP_ID	US Census
Kgroups_2	Constructed
Kgroups_3	Constructed
Kgroups_4	Constructed
loc_type	US Census
Area_urban	US Census
area_suburban	US Census
area_rural	US Census
prog_type	Survey
prog_volunteer	Survey
prog_van	Survey
prog_taxi	Survey
op_type	Survey
operatedby_SeniorCommCenter	Survey
operatedby_TransitAgency	Survey
mix_race	US Census
prop_mixrace	US Census
prop_ownerocc	US Census
prop_senior	US Census
prop_young	US Census
prop_hseunits	US Census

density1000	US Census
cluster2	Constructed
cluster3	Constructed
cluster1	Constructed