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Driving decisions of older adults receiving meal delivery: The influence of individual characteristics, the built environment, and neighborhood familiarity

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ABSTRACT

Access and mobility are key ingredients to independence and life satisfaction for older adults. This research addresses a series of gaps in scholarly literature on driving behavior among community-dwelling older adults, particularly those who rely on in-home supportive services to age in place. We explore the influence of a series of factors, including individual attributes, family and household structure, general mobility, and weather preparedness on driving behavior. Using survey data for Meals on Wheels clients in the Town of Tonawanda, New York, a stable first-ring suburb with much aging in place, we construct binary logit models to explore the factors explaining the decision to drive or not. Our findings suggest that age is positively associated, but at a diminishing rate, with driving when health and functional limitations are controlled for; women have lower propensities than men for driving; those who drive have higher overall mobility; driving is negatively associated with mixed land uses near home; housing tenure (duration in years) is positively associated with driving. Weather-related variables are not statistically significant, but this does not diminish the potentially significant impacts of extreme weather events on mobility among older adults.

1. Introduction

New types of travel demand are expected when, by 2050, one in five Americans will be age 65 years or older (Vincent et al., 2010). Moreover, the "oldest old"—people age 80 and older—are projected to increase by 200 percent between 2010 and 2050 (Vincent et al., 2010). Growth in the older adult population, especially those who rely on the highest level of supportive services, raises concerns about mobility, independence, and access to services for that age group (Lynott and Figueiredo, 2011). A large share of such older adults will choose to continue to live in their own homes in suburban communities of metropolitan regions, where travel and access to daily services can be challenging without an automobile (Frey, 2011). Research on travel for older adults consistently emphasizes the importance of driving in determining overall mobility (Marottoli et al., 2000), and even mortality (Edwards et al., 2009), among community-dwelling older adults, i.e. non-institutionalized older adults who live in homes and apartments in neighborhoods. As older adults age, however, the onset of physical and cognitive limitations can spell the end of driving. To ensure that mobility and access to services are

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maintained, planners, healthcare advocates, and policymakers in communities throughout the United States must address challenges associated with aging older adults, their residential patterns, and travel demand.

Access and mobility are key ingredients to independence and life satisfaction for older adults. All community-dwelling older adults—even those with limited mobility—must travel to receive healthcare services, to go shopping, and to access other necessities, not to mention travel for recreation and socialization. Various studies have concluded that although many older adults are ready, willing, and able to leave home on a given day, they cannot because they lack access to appropriate transportation (Bailey, 2004; Hess, 2009; Hess and Russell, 2012; Straight, 2003), a finding corroborated using data from the 2009 National Household Travel Survey (Lynott and Figueiredo, 2011). Social isolation can contribute to a lower quality of life, and more non-drivers than drivers stay home on any given day (Bailey, 2004).

Older adults who prefer to age in place in their current homes will typically face a range of potential personal mobility challenges (related to, for example, physical health, eyesight, ability to walk unassisted, self-confidence) that are exacerbated by external factors such as the built environment and weather conditions. The suburbs, where driving is often the only realistic means of daily travel, are often locations of concentrated aging populations (Bailey, 2004; Frey, 2011; Straight, 2003). Understanding how automobile dependence affects older adults' mobility is crucial to planning for aging in the suburbs.

This study examines driving behavior among a unique population of suburban, community-dwelling older adults in Western New York State who rely on at-home meal delivery. We explore the influence of a series of factors, including individual attributes, family and household structure, general mobility, weather preparedness, and perceptions of weather risk on driving behavior. Using survey data, we also employ quantitative analysis to trace the effects of specific built environment variables associated with active transportation. We first synthesize published literature on relationships for older adults between driving, social support, the built environment, and weather effects in order to develop guiding hypotheses about key relationships of interest. We next introduce original survey data from older adults in New York State that we use to model various influences on older adults' decisions to drive (or not to drive). While the original intent of the survey was to study the impact of extreme winter weather on Meals on Wheels recipients, the survey data are still useful to study the behaviors of a relatively unexamined population. We find that models exploring individual characteristics alongside social and environmental characteristics provide the strongest basis to understand and predict the likelihood of driving among suburban older adults.

2. Complexities of travel decisions for older adults

Numerous studies of older adult travel frame mobility as a function of driving access, highlighting various factors—concentrating mostly on individual characteristics and competence—that impacts the choice and the ability of older adults to give up driving. Fewer studies examine other features important in explaining older adult travel, such as family and household structure, weather, and urban form. Moreover, little attention has been paid to driving and mobility among older adults who are dependent on supportive services to complete daily tasks such as meal preparation. However, with the general aging of the population, mobility challenges faced by this subset of older adults are likely to become more widespread. In the following synthesis of scholarly literature about the topic, we explore key themes about travel for older adults, including driving cessation and the influence of social connections, weather, and the built environment, and we consider characteristics of community dwelling older adults and the impact of supportive services to enable aging in place.

2.1. Driving behavior among older adults

One of the most challenging decisions older adults make is the decision to give up driving, given the reality that life expectancy now exceeds driving expectancy by 7–10 years (Foley et al., 2002). Most literature on older adult travel has focused on factors leading to driving cessation and self-regulation, developing measures of the relationships between driving skill, confidence, and actual behavior (Bailey, 2004; Blanchard and Myers, 2010; Brayne et al., 2000; Edwards et al., 2010; Kilpeläinen and Summala, 2007; Myers et al., 2011; Sullivan et al., 2011). Driving self-regulation, or the decision to voluntarily restrict driving at a certain time, has been tied to perceptions of driving comfort and self-confidence, which vary according to sex, time of day, weather conditions, and age (Blanchard and Myers, 2010). In general, women tend to rate their driving ability lower than men, consistent with a greater willingness or desire to limit or give up driving.

Driving cessation—the choice to give up driving altogether—is linked to significant declines in cognitive and physical capabilities associated with aging (Edwards et al., 2010). Among old and frail drivers, common reasons for giving up driving are health and mental limitations—such as memory loss and visual or hearing impairments—and functional limitations (Brayne et al., 2000; Carr et al., 2006). Among even the oldest segments of the older adult population, however, driving is still the most common and preferred way to get around, especially in suburban settings, even when personal functional limitations exist.

2.2. Weather and driving among older adults

Although travel patterns of older adults has been studied in a number of different literatures, few studies have examined the effect on driving of perceptions of weather risk and preparedness for extreme weather events among older adults. One of the perceived barriers to driving found in previous studies is rainy weather (Baldock et al., 2006; Blanchard and Myers, 2010; Sullivan et al., 2011). Rain often triggers self-regulatory behavior among older adults, and particularly women, due to poor road conditions and decreased visibility. Seasonal variations in driving and travel among older adults have received little attention from researchers. A study of winter driving practices among older adults in Ontario, Canada, finds that, on an average winter day, older adults are more likely to drive than not, although driving frequency decreases during winter compared to summer (Myers et al., 2011). Comfort and self-perception are found to play a mediating role in the decision to drive in winter (Myers et al., 2011). Women, in general, tend to rate their driving ability lower than men and to drive less than men in winter as at other times. Though one study found that driving frequency decreases in wintertime, it is unclear whether winter driving is significantly different from driving during other times of year (Myers et al., 2011). Winter conditions are not associated with the decision to give up driving altogether.

2.3. Social support networks

Framing the decision to drive as an expression of self-regulation (a voluntary limitation on one's driving based on perceived risks) or cessation (a decision, often enforced by physical limitations, to give up driving altogether) risks overlooking other factors that contribute to driving decisions. Also, a focus on individual traits that explain the decisions to drive runs the risk of overlooking potentially significant influences on driving associated with interpersonal and environmental factors (Blanchard and Myers, 2010; Rudman et al., 2010; Schwanen and Páez, 2010; Yeom et al., 2008). Researchers have attempted to capture these complexities in various ways: for example, a qualitative study of older adults in Canada suggests that self-regulation and driving cessation is based on a combination of intrapersonal, interpersonal, and environmental factors (Rudman et al., 2010). Advice from doctors and family members, in combination with physical and cognitive declines, is important in addressing choices to continue or cease driving (Brayne et al., 2000). Several studies have considered the importance of lifestyle and social support networks on driving decisions (Baldock et al., 2006; Stalvey and Owsley, 2000). Among the largest barriers to driving self-regulation are the desires to maintain a lifestyle enabled by driving and the unavailability of family and friends to provide transportation (Baldock et al., 2006; Stalvey and Owsley, 2000).

2.4. Influence of urban form

Although no consistent measure of the influence of the built environment on travel behavior has been established (Crane and Boarnet, 2001), several studies attempt to address the influence of neighborhood factors, such as walkability, access to destinations, and public transit service on physical activity (Cunningham and Michael, 2004). For example, while age, sex, and possessing a driver's license are found to have significant impacts on mobility (number and distance of trips) (Kim, 2003; Moniruzzaman et al., 2013; Morency et al., 2011; Paez et al., 2007), other factors—such as household structure and income and residential location—also influence mobility. Age is negatively associated with mobility but positively associated with neighborhood population and employment density, suggesting that neighborhood factors might play an unexplored role in the number and duration of trips (Kim, 2003, 2011). Studies of associations between spatial variability and travel behavior among older adults in three Canadian cities—Hamilton, Toronto, and Montreal—find support for the influence of spatial heterogeneity on travel practices, including mode choice and trip distance (Moniruzzaman et al., 2013; Morency et al., 2011; Paez et al., 2007). However, the most predominant feature underlying older adult mobility remains automobile access, which exhibits spatial variability.

Studies of the effect of neighborhood typology on mobility for older adults find mixed results. Some researchers find significant support for the role of neighborhood effects in travel decisions (Cao et al., 2010; Moniruzzaman et al., 2013). The presence of neighborhood shopping areas and other nearby businesses and the presence of continuous neighborhood sidewalks reduces vehicle miles driven among older adults, while more frequent public transit service increases transit trips, and having a commercial business nearby increases walking (Cao et al., 2010). A study of older adults in Montreal demonstrates mixed associations between mode choice and neighborhood variables (Moniruzzaman et al., 2013). While neighborhood street density and building density are significant predictors of choosing walking or riding public transit instead of driving, a higher mix of land uses is only associated with an increased likelihood of walking, and intersection density is not associated with mode choice behaviors. Transportation options decrease for older adults in suburban communities. One study of suburbanites finds no significant relationship between actual built environment characteristics, such as having nearby businesses and access to public transit, and mobility (Kim, 2011). Across neighborhood typologies, it seems that automobile access and the ability to drive are the most prominent determinants of mobility for older adults (Kim, 2011; Paez et al., 2007).

2.5. Older adults and supportive services

Although a majority of older adults, despite frailties, continue to drive, non-drivers tend to have higher functional limitations (Carr et al., 2006) which may increase their reliance on supportive services. A study of home-bound older adults finds that 95 percent of participants possessed limited mobility and 11 percent experienced severe mobility limitations (Charlson et al., 2008). In general, the presence of supportive services in a community may dampen the effect of physical and cognitive limitations associated with aging (Muramatsu et al., 2010). Such supportive services help to improve mental health, BMI, and nutrition in older adults, and have been linked with slowing or even reversing declines in functional limitations (Charlson et al., 2008; D'Antoni et al., 1996; Kretser et al., 2003). No study to date, however, examines the mobility, and particularly driving behavior, for older adults who rely on in-home supportive services. The centrality of driving in determining overall mobility has not been demonstrated for this population, nor has the overall tendency to drive despite functional declines. Our research focuses on older adults who rely on at least one in-home supportive service—home-delivered meals—for everyday living.

3. Research plan

This research addresses a series of gaps in scholarly literature on driving behavior among community-dwelling older adults, particularly those who rely on in-home supportive services to age in place. The intent is to understand factors that influence driving among older suburbanites who depend on daily meal delivery. A large body of research has demonstrated the importance of driving aptitude and self-efficacy, weather, sex, reliance on others, household structure, and the built environment in determining the travel patterns of older adults (Cao et al., 2010), but little is known about the specific behaviors—especially daily travel—of those dependent on some type of daily functional support. Driving is seen as one of the most significant factors in high levels of mobility among all older adults—particularly salient given significant challenges in increasing public transit ridership among older adults (Crane and Boarnet, 2001; Hess, 2009; Hess and Russell, 2012)—although it is not clear whether driving is such an essential component of mobility for older adults who are more reliant on others. Developing this work can point planners and policymakers in new directions when seeking to reduce automobile dependence among older adults.

Our research is motivated by several hypotheses. First, we suspect that age and reliance on others will have a negative effect on driving among older adults who rely on supportive services. We predict that women will be less likely to drive than men and expect that approaches that combine intrapersonal, interpersonal, and environmental factors in predicting driving will have the greatest explanatory power. Perceptions of weather are expected to have a greater impact on driving than the built environment because weather is likely to be more salient in wintertime, when the data were gathered. At the same time, we expect that variations in the built environment significantly affect driving.

3.1. Study site

For our study site we chose Erie County within Western New York State. Erie County is of particular interest for exploring issues associated with an aging population. Although it has a higher percentage of older adults than the United States as a whole, where older adults make up 13 percent of the U.S. population, there is a sense that the challenges it faces around aging will be faced by communities around the nation in the future (Frey, 2011). We study an inner-ring suburb with a manageable population size, in part because of the growing awareness of concentrated aging in suburban communities (Frey, 2011).

The Town of Tonawanda is situated in Erie County, New York, immediately to the north of the City of Buffalo (see Fig. 1). A first-ring suburb, Tonawanda's history has mirrored that of Buffalo, in that it has experienced population loss and economic decline in recent decades. The Town has a range of dense urban development near Buffalo and low-density separation of uses typical of early suburban development. Compared to the rest of Erie County, Tonawanda's population is older, with 20 percent of its population at least 65 years of age. Fewer older adults in Tonawanda live in poverty or have no vehicles available than the rest of the county; 37 percent of older adults in Tonawanda have at least one disability.

Many older adults in Tonawanda have aged in place (Hess and Russell, 2012)—a term used to describe older adults who choose to remain in their own home as they age instead of moving elsewhere to receive care, such as with relatives or in an assisted living facility (Marek and Rantz, 2000). Such older adults often rely on support networks for assistance with instrumental daily activities such as getting meals, visiting the doctor, and completing household chores.

We partnered with a local non-profit *Meals on Wheels* service to distribute surveys during regular meal delivery (Hess and Street, 2012). *Meals on Wheels* services provide daily home meal delivery to older adults and people with disabilities at low cost. Typically, individuals who use *Meals on Wheels* services are community-dwelling older adults whose nutritional status (and health) could be compromised in the absence of meal support. *Meals on Wheels* services ensure the availability of nutritional meals and social contact, both of which can be limited for older adults, and enable older adults to delay or avoid institutionalization and remain in their own homes (D'Antoni et al., 1996; Keller, 2006; Wilson and Dennison, 2011).

3.2. The survey

A four-page pen-and-paper self-completion large print survey was developed to gather data on behavior among *Meals on Wheels* clients. The survey was designed to facilitate easy completion, with minimal writing required. Questions began simply and could be answered quickly. It consisted of 38 questions divided into three sections. The first included a set of simple questions about the respondent's current health and a series of 'Yes/No' questions about the ability to perform day-to-day activities, such as housekeeping, shopping, and driving.

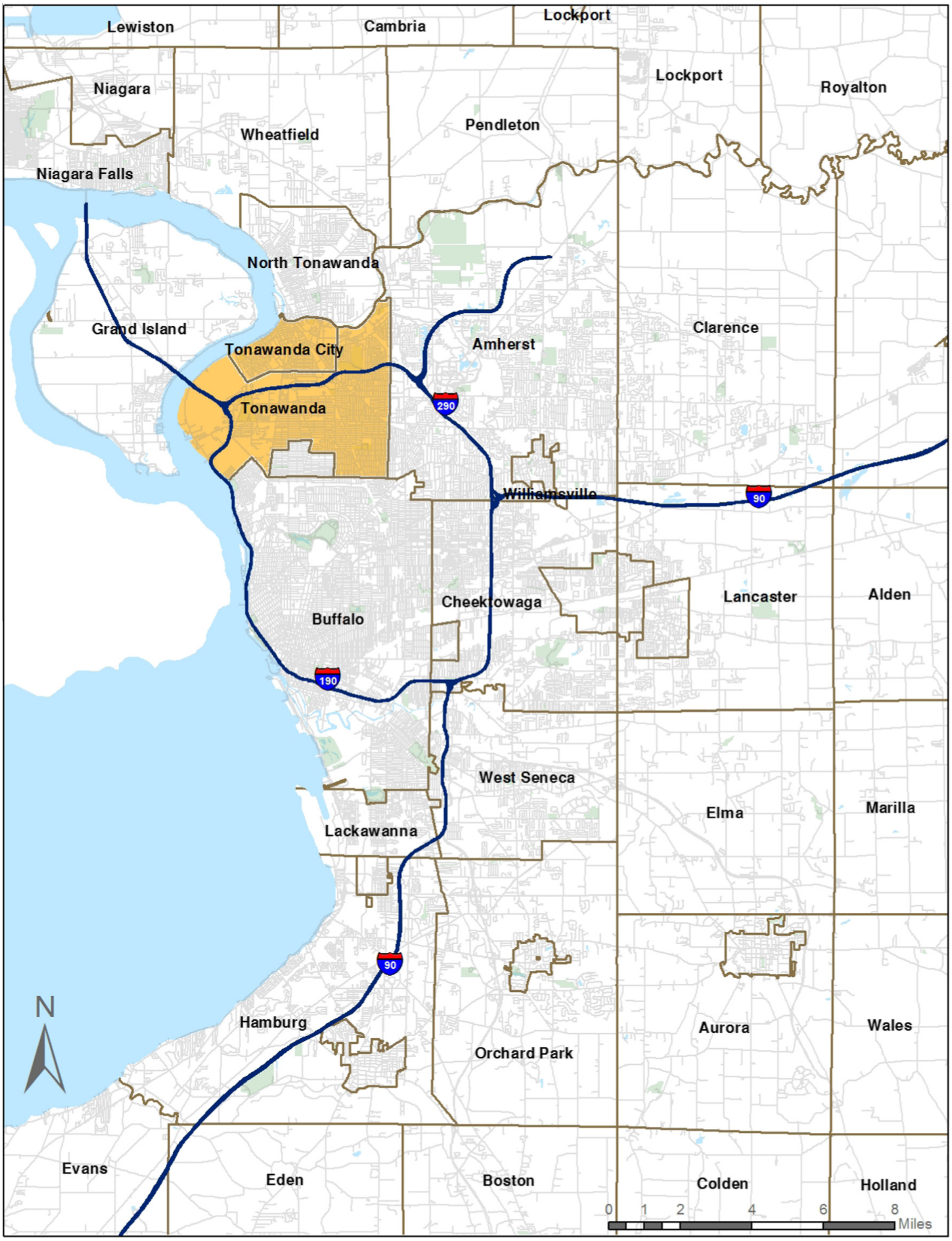

Fig. 1. Western New York State and Town of Tonawanda.

Questions were fashioned after the Instrumental Activities of Daily Living (IADL) scale, developed by Lawton and Brody (1969) to accurately assess older adults' ability to complete a range of day-to-day tasks, including traveling, shopping, and taking medications. A series of questions concerns previous winter weather experience and winter weather preparedness. These questions measure both utilitarian provisioning practices and perceptions of winter weather, including anxiety about the threat of inclement weather. The third set of questions addresses basic demographic and housing characteristics, gathering information about sex, education, race, marital status, the length of time lived in the current location, and household size.

The survey population included all clients of *Meals on Wheels* in the Town of Tonawanda. It was delivered to (and completed surveys were collected from) *Meals on Wheels* clients by volunteer drivers during regular meal distribution times in January, 2012 (surveys were delivered to all clients in the same week and collected the following week). As an incentive, participants were given a $4.40 book of U.S. postage stamps. Each individual who received a survey was given a book of stamps with the initial survey package; individuals could keep the stamps whether they completed the survey or not. The survey instrument and protocol were approved by the University at Buffalo Institutional Review Board.

A total of 280 surveys were distributed, reaching every *Meals on Wheels* client, and 150 completed surveys were received for a response rate of 54 percent. This response rate is relatively high (Hess and Street, 2012), especially since the modest budget for the project did not permit us to issue prompts or reminders to complete the survey.

3.3. Respondent characteristics and survey response summary

Table 1 presents population characteristics and responses taken from the survey results and Tonawanda *Meals on Wheels* databases. The majority of respondents are white females. Age varies from 60 to 99 years, with an average age of 84 years. Most respondents have a high school diploma or some college experience, though a small share have a bachelor's degree or higher. Most respondents are widows or widowers. The respondents average 2.7 children, with an average of 1.5 of those children living within 40 km (25 miles)—close enough to provide aid regularly or in case of need. Nearly two-thirds of respondents report living alone, and those who live with others most often live with a spouse or partner (68 percent).

Most respondents report that they are in good (35 percent) or fair (48 percent) health at the time the survey was completed, while smaller shares report either excellent or poor health. However, when asked more generally whether their health gets in the way of things they like to do, most (69 percent) respond that it does. Responses to IADL questions are summarized in Table 2. Although most respondents had left their homes in the past week, they needed help doing so. Most had not driven themselves; nor had they used public transportation to travel during the previous week. A majority of respondents needed help with shopping and housekeeping, which can be strenuous and time consuming. Few left their neighborhood in the previous week, and many reported needing assistance preparing food, taking medication, and managing finances. However, most respondents required no assistance with one of the most basic tasks—using the telephone. The average length of time a respondent has lived in his or her home is 34 years, which suggests a trend of aging in place among older adults in Tonawanda.

Table 1
Characteristics of respondents ($n = 150$).

Demographics	Housing characteristics
Age	Household size
Mean: 84 years	Live alone: 64%
Range: 60–99 years	Live with others: 36%
Standard deviation: 9.3	Children: 18%
Sex	Spouse/partner: 68%
Female: 69%	Other: 14%
Male: 31%	Housing tenure
Race	Rent: 31%
White/Caucasian: 95%	Own: 69%
Black/African American: 4%	Length of time at current address
Asian: <1%	Mean: 34 years
Marital status	Range: 1–78 years
Married: 28%	Standard deviation: 23
Widow/widower: 59%	
Never married: 7%	
Divorced or separated: 6%	
Education	
Some High School: 14%	
High School Diploma: 48%	
Some College: 29%	
Bachelor's Degree: 9%	
Graduate Degree: 5%	
Number of children	
Range: 0–10 children	
Average: 2.7 children	
Within 40 km (25 miles): 1.5 children	

Table 2
Instrumental activities of daily living response.

Do you require assistance with	Additional questions
Going places	Have you driven a car within the past week?
Yes: 71%	Yes: 28%
No: 29%	No: 72%
Housekeeping	Do you use public transit once per week or more?
Yes: 70%	Yes: 5%
No: 30%	No: 95%
Shopping	During the past week have you been outside of your
Yes: 63%	Neighborhood?
No: 37%	Yes: 54%
	No: 35%
Preparing food	Home?
Yes: 47%	Yes: 73%
No: 53%	No: 27%
Finances	
Yes: 42%	
No: 58%	
Taking medications	
Yes: 41%	
No: 59%	
Using the telephone	
Yes: 9%	
No: 91%	

3.4. The built environment

Tonawanda *Meals on Wheels* client locations were geocoded as *x,y* coordinates using ArcGIS 10 (Esri, 2012). Additional spatial information was gathered using 2011 parcel data from the New York State Tax Assessor files and bus stop location data provided by the Niagara Frontier Transportation Authority. A land use mix variable was created to describe the combination of residential and commercial land uses for a buffer area with a radius of 0.8 km (0.5 mile) around a respondent's home. Higher values indicate a greater heterogeneity of land uses, while lower values indicate single use. This is a simplified version of a measure developed in Frank et al. (2004) and used by Hess and Russell (2012) to quantify public transit access and BMI among older adults. Another measure of the built environment is intersection density, which is calculated as the sum of the number of three- and four-leg intersections within a buffer area with a radius of 0.4 km (0.25 mile) around a respondent's home. Though evidence suggests that fixed-bandwidth measures of built environment exposure are inappropriate for older adults, we opted for such measures due to a lack of available data on differences in trip length among homebound older adults who rely on social services (Moniruzzaman et al., 2013; Morency et al., 2011; Paez et al., 2007). Finally, the distance along the street network between each client's location and the nearest bus stop is calculated using the Network Analyst extension in ArcGIS 10.

3.5. Data preparation and model development

Explanatory variables are arranged in four vectors, and each model includes one additional vector of variables than the model preceding it (see Table 3). Two index variables (HELP_INDEX and WEATHER_INDEX) are developed by summing dichotomous component values. HELP_INDEX describes the composite of IADL questions, while WEATHER_INDEX is a composite of the following yes/no questions: whether winter weather limits activity and whether a respondent had called for help, run out of supplies, run out of food, or missed meals during inclement winter weather. The first set of variables includes individual factors that can predict driving, including age, sex, race, education, and current health. The second set of variables describes dependence on others, taken as a composite of the IADL questions, proximity to children, length of time in current home, and travel behavior. The third set of variables specifically addresses winter weather preparedness and perceptions of weather effects on a respondent's ability to perform daily tasks. The final set of variables addresses the influence of the built environment around a respondent's home. Two variables, the distance to the nearest commercial parcel and the distance to the nearest bus stop, are used to address the influence of the built environment. Specifying four models allows for tests of the added explanatory effect of additional sets of variables on the probability of driving.

Basic descriptive statistics for the variables included in the models are presented in Table 4. Of 150 survey respondents, 143 remain in the analytic sample (due to missing responses for 7 observations for age and sex variables). Respondents were more likely to have not driven—only about 28 percent reported driving. This focus on independence and driving is one of the major differences between this study and previous work on older adult travel (Brayne et al., 2000; Carr et al., 2006).

Table 3
Variable definitions.

Variable	Operational definition (units, if applicable)	Variable type
Dependent variable		
DRIVE	Indicates whether respondent drove in the last week: 0 = Did not drive in last week, 1 = Drove in last week	Dichotomous
Independent variables		
AGE	Age of respondent (years)	Continuous
AGE_SQ	Square of respondent's age (years)	Continuous
FEMALE	Respondent's sex, 0 = Male, 1 = Female	Dichotomous
NONWHITE	Respondent's race, 0 = White, 1 = Nonwhite	Dichotomous
HEALTH	Health of respondent, 0 = Fair, poor, 1 = Good, excellent	Dichotomous
BACHELORS	Indicates whether respondent has a bachelor's degree, 0 = No, 1 = Yes	Dichotomous
HEALTHRESTRICT	Indicates whether health restricts activity, 0 = Health does not restrict activity, 1 = Health restricts activity	Dichotomous
HOUSEDURATION	Length of time in current home (years)	Continuous
COHABITATE	Indicates whether respondent lives with others, 0 = Lives alone, 1 = Lives with others	Dichotomous
CHILDNEAR	Indicates whether respondent has a child living within 40 km (25 miles), 0 = No, 1 = Yes	Dichotomous
LEAVENHOOD	Indicates whether respondent left both home and neighborhood in the last week, 0 = No, 1 = Yes	Dichotomous
LEAVEHOUSE	Indicates whether respondent left home but not neighborhood in the last week, 0 = No, 1 = Yes	Dichotomous
HELP_INDEX	A composite of eight Instrumental Activities of Daily Living measuring dependence on others. Activities include: Answering the telephone, going shopping, housekeeping, food preparation, doing laundry, traveling, taking medicine, and doing finances. Each value is dichotomous and higher scores indicate greater dependence	Continuous
ANXIOUS	Indicates whether respondent gets anxious when they hear about an impending winter storm, 0 = No, 1 = Yes	Dichotomous
WEATHER_INDEX	A composite of six dichotomous responses to weather preparedness, including: Whether winter weather limits activity and whether a respondent had called for help, run out of supplies, run out of food, or missed meals during inclement winter weather	Continuous
WEATHER_PLAN	Indicates whether respondent has a plan in case of a severe winter storm, 0 = Do not have a plan, 1 = Have a plan	Dichotomous
LUM	Index of the mix of residential and commercial parcels in a 0.8 km (0.5 mile) area round respondent's home; ranges between 0 (homogenous use) and 1 (total mix of uses)	Continuous
INT	Number of intersections in 0.4 km (0.25 mile) area around respondent's home, weighted by number of legs	
BUSSTOPDIST	Distance to the nearest bus stop (miles)	Continuous

Table 4
Descriptive statistics of respondents.

Variable	*N*	Mean	Std dev	Minimum	Maximum
DRIVE	143	0.28	0.45	0	1
AGE	143	85.03	8.35	54	97
AGE_SQ	143	7300.22	1340.50	2916	9409
FEMALE	143	0.69	0.47	0	1
NONWHITE	143	0.06	0.23	0	1
HEALTH	143	0.36	0.48	0	1
BACHELORS	143	0.08	0.27	0	1
HEALTHRESTRICT	143	0.69	0.46	0	1
HOUSEDURATION	143	34.11	23.07	0	78
COHABITATE	143	0.64	0.48	0	1
CHILDNEAR	143	0.74	0.44	0	1
LEAVENHOOD	143	0.44	0.50	0	1
LEAVEHOUSE	143	0.17	0.38	0	1
HELP_INDEX	143	3.57	2.38	0	8
ANXIOUS	143	0.43	0.50	0	1
WEATHER_INDEX	143	1.66	1.22	0	6
WEATHER_PLAN	143	0.73	0.45	0	1
LUM	143	0.17	0.17	0	0.99
INTQTMILE	143	12.63	5.37	1	26
BUSSTOPDIST	143	0.26	0.19	0.00	0.99

3.6. Analysis

We construct binary logit models to measure the likelihood of a respondent having driven in the past week. Given a two-category (yes/no) dependent variable, the binary logit model is appropriate for this dependent variable because it efficiently fits qualitative response variables using a generalized linear modeling approach (Greene, 2000).

We define the latent variable y_i^* as follows:

$$y_i^* = X_i'\beta + \varepsilon_i \quad (1)$$

where

$y_i = 1$ if $y_i^* > 0$; and $y_i = 0$, otherwise.

X_i' = a transposed vector of independent variables.
β = parameter vector of X_i'.
ε_i = an error term presenting individual disturbance.

The probability that a respondent drove in the last week is defined as p_i, while it is assumed that ε_i follows a logistic distribution function as described in Eq. (2).

$$p_i = Pr(y_i^* > 0) = \frac{\exp(X_i'\beta)}{1 + \exp(X_i'\beta)} \tag{2}$$

Therefore, maximum likelihood estimation is applied for the logit model of p_i which is a function of linear predictors as suggested in Eq. (3).

$$\text{logit}(p_i) = \ln\left(\frac{p_i}{1 - p_i}\right) = X_i'\beta \tag{3}$$

To test for influences of a number of factors on driving, we specify four tiered binary logit models depending on independent variable sets. These tiered models are used to test which group of factors most contributes to variance explained in driving. Coefficients are generated for independent variables predicting the log-odds of driving.

Model 1: Individual factors
X1 = [AGE, AGE_SQ, FEMALE, NONWHITE, HEALTH, BACHELORS].
Model 2: Social network, dependence on others, and travel restrictions
X2 = *X1* + [RESTRICT, HOUSELENGTH, ALONE, CHILDNEAR, LEAVEH, LEAVENH, HELP_INDEX].
Model 3: Winter weather factors
X3 = *X2* + [ANX, WEATHER_INDEX, WEATHER_PLAN].
Model 4: Build environment factors
X4 = *X3* + [LUM, INTQTMILE, BUSSTOPDIST].

4. Results

4.1. Models 1 and 2 – Individual factors, household structure, and social support

Results and parameter estimates for Models 1 and 2 are presented in Table 5. A number of factors emerge as significant predictors of driving. The first model considers only individual factors that predict the likelihood of driving. Age and age squared are both associated at the 0.01 level with driving. Age is positively associated, but at a decreasing rate, with driving in the first and the second models because the squared term of age is negative in each model. This suggests that respondents are more likely to drive as they age, but the linear effect of age decreases as age increases. The dummy variable indicating female sex is significant at the 0.01 level in the first model and at the 0.05 level in the second model, demonstrating an association between sex and the likelihood of driving. Women (coded as 1) have a lower probability of driving than men—a relationship that confirms previous research (Myers et al., 2011). Though 94 percent of respondents are white, race has a significant association with driving: non-white respondents have higher log-odds of driving than do white respondents.

The second model enhances the first model by including variables related to family structure and dependence on others. This group of factors increases the explained variance in driving. Four variables are significant at the 0.1 level or lower. The length of time a respondent has lived in his or her home positively affects the likelihood of driving. Respondents who report leaving both their home and their neighborhood in the past week are also likely to have driven, and individuals who only left their home were even more likely to have driven. The parameter estimates for Help_Index, which is a composite of IADL, have a demonstrated negative association with driving (Brayne et al., 2000). We also find that older adults with greater dependence on others for completing IADL are significantly less likely to drive ($p < 0.01$). The presence of a nearby child and the effect of health on overall activity are not significant in this model.

4.2. Models 3 and 4 – Weather perceptions, preparedness, and the built environment

The third and fourth models explore the potential effects of additional variables on driving; they also demonstrate the effects on the first vectors of controlling for additional covariates (see Table 6). Included in the third model are variables related to winter weather, including anxiety about inclement winter weather events, past experience of inclement winter weather, and a respondent's plan for what to do in case of extreme winter weather. None of these weather-specific variables is statistically significant.

In the fourth model, we introduce three neighborhood-level variables: the mix of commercial and residential land uses within a 0.8 km (0.5 mile) radius around a respondent's home, the number of three- and four-leg intersections within a 0.4 km (0.25 mile) radius along the street network around a respondent's home, and the distance between a respondent's home and the nearest bus stop. Land-use mix and intersection density are both significant predictors of driving. Land use

Table 5
Models 1 and 2 results.

Variables	Model 1		Model 2	
	Estimate	S.E.	Estimate	S.E.
Intercept	−42.9643***	15.8070	−61.9435***	22.6863
AGE	1.1247***	0.3936	1.6047***	0.5650
AGE_SQ	−0.0072***	0.0024	−0.0102***	0.0035
FEMALE	−1.7936***	0.4226	−1.7142***	0.5577
NONWHITE	2.0159**	0.8870	2.5345**	1.1977
HEALTH	−0.0450	0.4367	−0.7509	0.6673
BACHELORS	−0.4530	0.8056	0.0511	0.9599
HEALTHRESTRICT			−0.3241	0.6843
HOUSEDURATION			0.0254*	0.0130
COHABITATE			−0.6345	0.5876
CHILDNEAR			−0.3710	0.6282
LEAVENHOOD			1.5961**	0.7296
LEAVEHOUSE			2.9126***	0.8344
HELP_INDEX			−0.5024***	0.1513
Model fit statistics				
AIC	155.8397		124.4274	
−2 Log L	141.8397		96.4274	
Pseudo *R*-sq	0.1621		0.3382	

Pseudo *R*-squared calculated using the Aldrich–Nelson approach, $R/(R+N)$, where R is the likelihood ratio, $-2 * (\text{LogL} - \text{LogL0})$.
* Significant at the 0.1 level.
** Significant at the 0.05 level.
*** Significant at 0.01 level.

Table 6
Models 3 and 4 results.

Variables	Model 3		Model 4	
	Estimate	S.E.	Estimate	S.E.
Intercept	−59.4574***	21.6619	−72.7944***	21.9034
AGE	1.5655***	0.5409	1.9860***	0.5540
AGE_SQ	−0.0100***	0.0033	−0.0126***	0.0034
FEMALE	−1.6897***	0.5879	−2.1793***	0.6561
NONWHITE	2.5506**	1.2138	4.7955***	1.7163
HEALTH	−0.7034	0.6902	−0.6116	0.7818
BACHELORS	0.1213	0.9650	0.5170	1.0255
HEALTHRESTRICT	−0.0735	0.7323	−0.2396	0.7875
HOUSEDURATION	0.0279**	0.0134	0.0409***	0.0151
COHABITATE	−0.6537	0.5957	−0.5259**	0.6666
CHILDNEAR	−0.5478	0.6798	−0.6237	0.7537
LEAVENHOOD	1.9866**	0.8628	2.2871**	0.9686
LEAVEHOUSE	3.3121***	0.9925	3.9566***	1.1229
HELP_INDEX	−0.4752***	0.1529	−0.5898***	0.1666
ANXIOUS	0.2781	0.5834	−0.0472	0.6269
WEATHER_INDEX	−0.3491	0.2860	−0.2314*	0.2952
WEATHERPLAN	−0.6728	0.7381	−0.7480	0.7953
LUM			−5.2499**	2.2113
INTQTMILE			−0.1664**	0.0700
BUSTOPDIST			−3.4872**	1.7335
Model fit statistics				
AIC	127.5369		124.0872	
−2 Log L	93.5369		84.0872	
Pseudo *R*-sq	0.3469		0.374	

Pseudo *R*-squared calculated using the Aldrich–Nelson approach, $R/(R+N)$, where R is the likelihood ratio, $-2 * (\text{LogL} - \text{LogL0})$.
* Significant at the 0.1 level.
** Significant at the 0.05 level.
*** Significant at 0.01 level.

mix is negatively associated with driving, suggesting that a greater mix of residential and commercial land uses near a respondent's home is related to a lower likelihood of driving. Intersection density is similarly associated with driving: more three- and four-leg intersections near a respondent's home correspond with a lower likelihood of driving. For certain older adults, congestion—more people, more buildings, more movement—associated with land use mix and intersection density could be perceived as risky for driving. Bus stop distance is negatively associated with driving in this model. Respondents who live closer to public transit stops are less likely to drive than those who are less well-served by public transit.

The fourth model, which includes 19 covariates, produces few changes in covariates compared to the first three models. Even with a small degree of freedom, outcomes from the final model suggest both consistency and improvement in the coefficient estimation. Age, sex, and race remain significant predictors of driving, while the length of time in one's current home remains marginally significant in the fully elaborated model, suggesting that familiarity with one's neighborhood is an important component in driving continuation. While our unit of observation is a single person, cohabitating remains negatively associated with driving. This final model is the most robust of the four models because the −2 Log Likelihood (−2LL) values are smallest (and the pseudo *R*-squared is highest). Furthermore, chi-square tests based on decreases in the −2LL and the degrees of freedom from the third model to the fourth model demonstrate a statistically significant difference between the two. The chi-square values confirm that Model 3 and Model 4 are different at the 5 percent level because the current gap of −2LL (9.45) at three degrees of freedom is greater than the 5 percent critical point, 7.815 (Park et al., 2008).

4.3. Limitations

We recognize that our methodology has several limitations. Registered users of Meal of Wheels were eligible to participate in the survey, and if more than one *Meals on Wheels* users resided at a certain address, it is possible that we received more than one response per household. We rely largely on self-reported survey data—including reports of past driving—rather than objective data. We do not perform robust tests of driving cessation, perceptions of driving for older adults, or driving competency for the study population. We also do not gather data on driver's licensure, vehicle ownership, or household income, though these factors are known to be significantly associated with older adult mobility (Moniruzzaman et al., 2013; Morency et al., 2011; Paez et al., 2007). Our findings have limited generalizability because we do not measure travel for longer than the course of a week. To improve on this research approach—in which we include measures of built environment, social networks, and weather on older adults driving behavior—we recommend a future study incorporating older suburbanites who do and do not receive home meal delivery and which also includes additional factors such as vehicle availabily, drivers licensure, and driving self-regulation. Similarly, though we study older adult behaviors in wintertime, we cannot offer conclusive evidence on the specific effects of winter weather on older adult driving. Therefore, the considerations of weather and climate in this study are helpful in describing the effect of perceptions of risks to inclement winter weather, when previous studies have indicated that driving decreases, rather than unique characteristics of wintertime driving behavior. Seasonal and climatic variations in travel behavior and mobility among this population of older adults should be a topic of future study.

5. Conclusion

This study offers new evidence about driving behavior of older adults and introduces results for a relatively unexplored sub-population of older adults—driving behavior of community-dwelling suburban older adults who depend on home meal delivery. Although we expected otherwise, among members of this suburban study population, age has a positive association with driving, however the association diminishes with increasing age. This positive association between age and driving not only seems counterintuitive, it appears to contradict findings from previous studies (Brayne et al., 2000; Carr et al., 2006; Myers et al., 2011; Paez et al., 2007) where age is negatively associated with driving. "Oldest old" adults, however, are less likely to drive in general, as shown in our models by the quadratic variable of AGE_SQ. In Model 4, the effect of age on the probability of driving decreases when respondents are older than age 78.[1] Thus, in our study, a plausible explanation for this difference in the relationship between age and driving is that driving may be less dependent on age *per se* (at least when considered in isolation) than on a complex set of factors including need for assistance with IADL and health status (for which age sometimes serves as a proxy) and availability of social networks, as suggested by Schwanen and Páez (2010) and Donorfio et al. (2008). After all, our models suggest that a lower ability to perform IADL is associated with a sharp reduction in the likelihood of driving.

Our model results confirm strong links between sex and driving for older adults, supporting our original hypothesis: women have lower propensities than men for driving. This suggests that interventions to increase mobility among older adults should have a strong sensitivity to these sex-based differences. Although this study does not investigate interactions between sex, driving, and other independent variables, previous studies have shown that perceptions of driving capability are lower among females (Myers et al., 2011). The link between cohabitation and a decrease in driving, which appears in our final model, may be linked to sex differences in driving behavior. Findings from D'Ambrosio et al. (2008) suggest that women who live alone tend to drive more than women who cohabitate. The emergence of cohabitation as a significant factor may reflect this phenomenon.

[1] In the logit model, the marginal effect of a quadratic variable (x) on the probability of an event (p_i) is calculated as $\frac{\partial p_i}{\partial x} = p_i(1 - p_i)\,(\hat{\beta}_1 + 2\hat{\beta}_2 x)$, where $\hat{\beta}_1$ and $\hat{\beta}_2$ are estimated coefficients for x and x^2, respectively. Based on results of Model 4, the marginal effect of age is rewritten as $\frac{\partial p_i}{\partial age} = p_i(1 - p_i)(1.9860 - 0.0252 \times age)$. When age reaches 78, the marginal probability is still positive; however, when age reaches 79, the marginal probability becomes negative. Therefore, the direction of the marginal probability of driving changes when the age of a resident exceeds 78 years.

While driving is the dependent variables in our models, its association with overall mobility confirms findings in other studies (Marottoli et al., 2000). For example, travel outside the neighborhood has strong associations with the likelihood of driving. However, trip distance may play an important role for individual decisions to drive. Older adults may drive independently for a short distance trip, but they may depend on their spouse, family members, or transportation services for longer driving; respondents who report only leaving home (and not their neighborhood) exhibit a stronger association with driving than do respondents who leave both the home and the neighborhood. Our hypothesis that variations in the built environment are associated with driving behavior was confirmed, however perhaps not for obvious reasons. Though older adults may want to walk more in places with a high land use mix and intersection density (Cao et al., 2010; Moniruzzaman et al., 2013), in winter, when the study took place, these places may deter walking. Public transit service—measured by the distance to the nearest bus stop—was associated with a lower likelihood of driving, however public transit ridership was low among the survey respondents. Due to these findings and to limitations in the survey design, we cannot conclude that built environment features are associated with an increase in non-auto travel mode choice.

Housing tenure is strongly associated across our models with driving and is likely to correspond with familiarity with one's area. Familiarity with one's surroundings appears to be important in predicting driving and thus overall mobility (although someone with a shorter time in a residence could indeed have high familiarity with a neighborhood or region). In winter, familiarity may be especially salient, since knowledge of local traffic patterns and road conditions may increase one's sense of confidence in making a trip safely. In past research, older adults who had lived in their home more than ten years were likely to have more transportation options than those who had lived in their home between three and ten years (Kim, 2011). The direct effect of housing tenure on neighborhood familiarity, driving comfort, and overall mobility among older adults should be explored in future research on aging in place for a full range—urban, suburban, and rural—of community settings.

Despite the constraints that winter weather can impose on drivers of any age, weather preparedness and perception variables are not statistically significant across our more complex models. An artifact of the timing of the survey administration is that the research was conducted during one of the warmest and least snowy winters on record (Hess and Street, 2012). Further, among the survey population, the average length of time a respondent has been in his or her own home is more than 34 years, suggesting familiarity not only with the neighborhood but also with the region's (in)famous winter weather. Consequently, older suburbanites may have routinely accounted for winter weather adjustments in their expectations of driving for their entire adult lives. That lifetime experience, coupled with the extraordinarily mild winter during our fieldwork, may have limited our capacity to detect increased sensitivity to driving in snowy weather that we expected to find in the study population. This does not diminish the potentially significant impacts of extreme weather events on mobility among older adults, nor the importance for older adults who drive to plan for times when they temporarily cannot drive (during extreme weather, for example) or permanently cease driving (due to decreased functional performance or poor health status).

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