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Multimodal Travel and the Poor:
Evidence from the 2009 National Household Travel Survey

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ABSTRACT

Most travel behavior studies focus on discrete mode-choice outcomes. They predict the likelihood of traveling by a single mode (e.g. solo driving, carpooling, taking public transit, walking, biking). Yet qualitative studies focusing on low-income households suggest that their mode choice does not fit neatly into a single category; they regularly "transportation package," use multiple modes of travel in a single day. We use data from the 2009 National Household Travel Summary to examine the extent to which individuals' engage in multimodal travel and to determine whether low-income individuals transportation package more than higher income individuals, controlling for other factors.

We find that multimodal travel is less—not more--prevalent among low-income adults than higher-income adults. However, there are important differences in the number and mix of modes that appear to be influenced by income. Moreover, low-income multimodal travelers took far more trips than even higher-income unimodal travelers. This finding suggests that providing viable avenues for multimodal travel may enhance low-income individuals' mobility, particularly if they face barriers to automobile access.

KEYWORDS: multimodal travel, travel behavior, low-income travel, national travel survey, modal mix

1. INTRODUCTION

Automobile ownership in the U.S. is almost universal. Ninety-four percent of all households own at least one automobile (U.S. Census Bureau, 2006-08). Most people rely on cars for all trip purposes because they prefer paying the monetary cost of driving to the time costs and inconvenience of alternative transportation modes. Yet some individuals regularly "transportation package:" they use multiple modes of travel. On any particular travel day, they might use cars for some trips and alternative modes for other trips. However, little is known about the determinants of travel behavior for those individuals in the U.S. who rely on multiple modes of travel (Clifton and Muhs, 2012). Beyond the differential monetary and temporal cost of travel, mode choice depends on a wide variety of factors, including personal preferences, lifestyle needs, and the relative availability of alternative modes.

Individuals may engage in multimodal travel either by necessity (i.e. they have limited access to cars) or by choice (i.e. they have access to cars but choose to minimize their use of them for environmental or social reasons). We hypothesize that multimodal travel is more prevalent among low-income individuals compared to higher-income individuals, since they are less likely to live in households with automobiles. Further, even if they live in households with cars, there tends to be less than a one-to-one ratio between household cars and drivers, forcing some individuals to, at times, use other modes of travel (Blumenberg and Pierce, 2012).

We use data from the 2009 National Household Travel Survey to examine the extent to which individuals engage in multimodal travel and to determine whether low-income individuals are more likely to multimodal travel than higher-income individuals, controlling for other factors.

We find that multimodal travel is less—not more—prevalent among low-income persons than higher-income persons. However, there are important differences in the number and mix of modes that are associated with income. Moreover, low-income multimodal travelers took far more trips than even higher-income unimodal travelers. This finding suggests that strategies for improving multimodal travel may also enhance low-income individuals' mobility, particularly if they face barriers to automobile access.

2. LITERATURE REVIEW

There is a growing body of scholarship on the transportation resources and travel behavior of the poor (Agrawal et al., 2011; Berube et al., 2008; Blumenberg and Pierce, 2012; Clifton, 2004; Deka, 2002; Guiliano, 2005; Lu and Pas, 1999; Murakami and Young, 1997; Pucher and Renne, 2003; Passero, 1996; Rice, 2004). In general, these studies show that individuals in low-income households have access to fewer cars than individuals in higher income households and, therefore, tend to rely more on modes other than the automobile. Compared to higher-income individuals, the poor are more likely to live in zero-vehicle households, 21 percent compared to only four percent (American Community Survey, 2005-09). They also are more likely to live in households where there is less than a one-to-one ratio between cars and drivers (Blumenberg and Pierce, 2012). Data from the 2009 National Household Travel Survey show that among households with incomes less than $20,000, the average vehicle to driver ratio is 0.75, a figure that is substantially lower than the one-to-one ratio among higher-income households.

The use of public transportation typically necessitates a multi-modal trip; for example, a single trip involves walking to the bus stop (access or ingress mode), using the bus, and then walking to the final destination (egress mode). Studies show that most bus users access bus stops and their final destinations by walking (Hsiao et al., 1997; Zhao et al., 2003). Users of rail, however, likely access rail stations by car, yet often reach their final destinations on foot (Cervero, 2001; Kim et al., 2007; Loutzenheiser, 1997). In other countries such as the Netherlands, bicycling to transit stops is prevalent (Keijer and Rietveld, 2000; Loutzenheiser, 1997). In households with less than a one-to-one ratio between cars and drivers, individuals may have to compete for the use of a household car and, therefore, will not have unlimited access to a vehicle. In these households, individuals may use cars for some trips but rely on other modes of travel when the household vehicle is unavailable.

Given their limited access to automobiles, low-income individuals may consequently be more likely to use multiple modes. While diverse, the literature on multimodal travel has not adequately examined income as an explanatory variable. Studies of multimodal travel tend to focus on pedestrian access to transit, the percentage of the population that lives within a reasonable walking distance from transit stops and stations and, more specifically, the relationship between walking distance and transit use (Alshalalfah and Shalaby, 2007; Hsiao et al., 1997; Levinson and Brown-West, 1984; Murray et al., 1998; Zhao et al., 2003; Loutzenheiser, 1997).[1] A subset of these studies includes specific data on the modes used by travelers to access and, in a more limited scope, egress public transit (Hsiao et al., 1997; Zhao et al., 2003; Loutzenheiser, 1997). However, these studies tend to indirectly assess multimodal

[1] There is some debate in the literature on the exact distance that is “reasonable.” The distance may depend on the access mode, either bus or rail. As Zhao et al. (2003) find, however, it is commonly accepted that people are willing to walk up to ¼ mile to a transit stop or station beyond which the likelihood of their using transit declines.

travel by focusing on trip chains—trips taken en route to a major destination—that include public transportation.

A second body of literature centers on transportation network design and, oftentimes, the role of real-time information in enhancing multimodal travel (Cambridge Systematics, 1998; Grotenhuis et al., 2007; Hoogendoorn-Lanser et al., 2006; van Nes and Bovy, 2004). These studies emphasize the network modeling intended to improve the physical design of infrastructure, but demonstrate more interest in the efficiency of trip transfers than overall travel behavior.

With respect to individuals' use of multimodal travel based on socioeconomic status and travel needs, however, the literature is sparse, and is almost entirely based on data from outside the U.S. The most relevant of these studies was performed in the Netherlands. Using data from the Dutch National Travel Survey, van Nes (2002) finds that personal characteristics have only a minor influence on multimodal travel, here defined as the use of two or more different modes for a single trip between origin and destination. In this study, two characteristics best predict multimodal travel trip distance: destination type (city centers) and trip purpose (work and education). Krygsman and Dijst (2001) also use data from the 1998 Dutch National Travel Survey to assess multimodal travel—defined as using multiple modes, one of which must be public transit, on a single trip chain—across a number of socioeconomic factors and travel modes. While they do not emphasize income as an explanatory variable, the authors find that the lowest and highest income groups tend to employ multiple modes in trip-making more often than middle-income travelers.

Several other studies use the 2002 German national mobility survey and data from the 1999-2004 German Mobility Panel, which include a one-week travel diary. To assess multimodal travel, Nobis (2007) defines multimodal individuals as those who use two or three modes of transportation in one week. This study focuses on life stage in order to analyze different multimodal combinations and finds that higher income status contributes positively to multimodal travel. Kuhnimhof et al. (2006) use a similarly liberal definition of multimodality—anyone who uses public transit and another mode during the week of study. They categorize multimodal individuals by age, density, and car use/ownership, but not income. Similarly, Kuhnimhof and Gringmuth (2009) mention monetary budget constraints as a factor in determining the likelihood of multimodal travel, but do not reveal how they define budget constraints or clearly discuss the outcome of their modeling.

Most scholars of multimodal travel argue for its importance, particularly in facilitating the use of public transit. (See for example, van Nes and Nobis, 2004). Yet we know very little about multimodal travel in the U.S. For low-income individuals who require access to multiple destinations to maintain their livelihoods and lifestyles, limited transportation resources may necessitate the use of diverse modes of travel.

3. SAMPLE AND METHODOLOGY

We use data from the 2009 National Household Travel Survey (NHTS) to examine multimodal travel in the U.S. and focus on whether lower-income travelers are more likely to use multiple modes of travel on a single travel day. The NHTS records extensive information about one-way trips taken by each individual within a household during a designated 24-hour period (the household's travel day) including the time the trip began and ended, the length and duration of the trip, the mode of transportation and the purpose of the trip.[2] However, we restrict our analysis exclusively to the travel behavior of adults in the sample. Transportation planners often extrapolate single day data to produce annual estimates of travel measures and, in turn, use these estimates to craft policies based on trip-making patterns.

In previous studies of multimodal travel, multimodal travelers are defined as those individuals who use at least two modes as part of a single tour or within a time period longer than a sample travel day.[3] In contrast, we classify individuals as unimodal if they used only one mode on the travel day and multimodal if they used more than one mode, regardless of the number of trips or the number of tours they took on the travel day. We use this classification scheme because we are interested in whether low-income individuals, given their limited household resources, have to cobble together their travel modes—a concept that we refer to as "transportation packaging". Therefore, whether travel occurs as part of a single trip chain is less relevant to our analysis than for studies in which the implicit goal is to increase transit ridership by easing transfers across modes.

However, we exclude short walking trips (less than five minutes) from our classification of multimodality.[4] In other words, if an individual took one trip by car and only one other trip on foot which lasted less than five minutes, we classify this individual as unimodal. All travel typically begins with a walk trip—for example, walking from home to the garage where the car or bicycle is parked or walking from home to the transit stop. However, the reliability of

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[2] "Introduction to the 2009 NHTS" (nd) http://nhts.ornl.gov/introduction.shtml (accessed August 11, 2011).
[3] van Nes (2002) and van Nes and Bovy (2004) analyze trip data; Nobis (2007) and Kuhnimhof et al. (2006) use travel data for a one-week period. Krygman and Dijst (2001) define multimodal travel as a trip (from origin to destination) in which the primary mode is public transit.
[4] We also experimented with a fifteen-minute threshold for walk trips,but this change did not alter our results substantively.

walking data is debatable since walk trips are not uniformly reported in many surveys (Doyle, 2003). Accordingly, we use a time threshold to exclude trips which we deem do not reflect transportation packaging behavior. The exclusion of these short trips, however, does not change the outcome of our modeling notably.

For the purposes of this analysis, low-income households are those with incomes that fall in the bottom income quintile determined by the Current Population Survey's Annual Social and Economic Supplement for 2009, the time of the NHTS survey. The Current Population Survey is a joint data collection effort of the Census Bureau and the Bureau of Labor Statistics. (See http://www.census.gov/hhes/ www/income/data/historical/household/index.html.) In 2009 the upper bound of the bottom income quintile was $20,453. Using categorical income data provided in the NHTS, we classify as low-income households and individuals living in households with incomes below $20,000.

We first use descriptive analysis to assess the socioeconomic differences between travelers and non-travelers as well as differences among travelers by income. We then use two approaches—binary logistic and multinomial logistic regression to analyze the relationship between our response variable and a set of explanatory variables. In our first set of models, we predict the likelihood of multimodal travel among only those individuals who traveled on the survey day, a sample of 206,705. The outcome of the dichotomous dependent variable indicates that the individual either engaged in multimodal travel on the trip day (P=1) or did not (P=0). The logistic regression equation used is the following:

$$\mathit{Logit}\,(P^*) = \beta X + \alpha$$

where P* represents the probability of multimodal travel, X a vector of explanatory variables, β a vector of estimated parameters, and α the log odds of multimodal travel. We then use a multinomial logistic regression to predict the likelihood of no travel and multimodal travel relative to the base which in this case is unimodal travel.

The explanatory variables in the model include relevant socio-demographic and economic characteristics of the individual such as *income*—our primary variable of interest—and *race/ethnicity, age, sex*, and the presence of *children in the household*. Our hypothesis about the contributing factors to multimodal travel draws on the broader travel behavior literature. Recent studies include and sometimes discuss our control variables, but tend to center on the relationship between land use and travel (Ewing and Cervero, 2010), while an earlier body of scholarship focused specifically on socio-demographics and travel (Lu and Pas, 1999).

Again, we hypothesize that multimodal travel is more prevalent among low-income individuals than higher-income individuals, since they are more likely to live in car-less households (Blumenberg and Pierce, 2012). Similarly, we include education—individuals with less than a high school education—with the assumption that there is a positive relationship between those with less human capital and multimodal travel.

Prior research leads us to hypothesize that differences in travel activity by *race/ethnicity*, while mostly explained by income, will still influence multimodal behavior. Most studies show that African Americans are significantly less likely to own automobiles and more likely to travel by public transit, even controlling for income (Berube et al., 2008). We expect that they would also be more likely to engage in multimodal travel. We include *age* as an additional measure of human capital and assets, suggesting that as age and, with it, wealth increases, the propensity to rely on multiple modes decreases (Lu and Pas, 1999; Nobis, 2007). We also include age squared under the assumption that the relationship between age and multimodal travel may increase as seniors are no longer able to drive (Nobis, 2007), although Krygsman and Dijst (2001) present some evidence to the contrary.

The *presence of children in the household* is associated with a reduced number of multimodal trips (Hanson and Hanson, 1981; Krygsman and Dijst, 2001; Nobis, 2007). It also is negatively related to total miles traveled (Giuliano, 2003). Although children in the household are associated with an increased likelihood of trip chaining (McGuckin and Murakami, 1999), they reduce the likelihood of making trips for other trip purposes and, therefore, tend to have only a small effect on trip-making (Lu and Pas, 1999). Household size may also be associated with less multimodal travel (Krygsman and Dijst, 2001; Nobis, 2007). In Germany, workers who lived in households with other adults (over 17) were more likely to be unimodal car users than other population groups (Nobis, 2007).

There also are differences in travel patterns by sex. *Females* tend to travel less than men in terms of aggregate person miles traveled (PMT), although they tend to take more trips and trip-chain more often (Hanson and Hanson, 1981; Lu and Pas, 1999; McGuckin and Murakami, 1999; Rosenbloom, 2006; Wen and Koppelman, 2000). The division of labor within the household explains part of women's diminished length of travel. Women—even working women—remain disproportionately responsible for child care and household-serving tasks and, therefore, are locationally constrained (Kwan, 2000). However, we note that more diverse travel patterns may increase with the age of children and with the range of household activities, in turn increasing multimodal travel.

We also include three activity-identifying variables—*worker, retired,* and *homemaker*—in our model because we expect a strong relationship between activity patterns and travel behavior. As with income, work status has a clear relationship to travel. On average, workers travel more than non-workers, but tend to rely on a single mode—the automobile—compared to other individuals who demonstrate more complex trip structures (Golob, 2000). However, multimodal studies arrive at conflicting conclusions on the relationship between work and multimodal travel. Krygsman and Dijst (2001) find that full-time employment has a marked positive effect on the likelihood of multimodal travel. In contrast, Nobis (2007) concludes the opposite, that employment is negatively related to multi-modal travel.

Over time, the labor force participation rate among seniors has increased (Johnson and Kaminsky, 2010). Therefore, we expect retired persons to travel less and by fewer modes than an assessment of age alone would capture. In the same vein, while homemakers are predominantly female, we hypothesize that individuals with this self-identified occupation may demonstrate even less propensity to travel by multiple modes than the general female population.

Three transportation-related factors also likely influence multimodality among individuals: *the count of daily trips* taken by the individual, *the natural log of person miles (PMT) traveled* by the person and *the number of vehicles* available in the individual's household. The number of daily trips and PMT are correlated, although not as highly as one might expect ($R= 0.33$, $R^2=0.11$). These two variables are, however, likely to have disparate effects on multimodal travel. We expect trip making to be positively related to multimodal travel. The more trips individuals take, the greater the likelihood that they will take at least one trip using a mode other than their primary mode of travel. In contrast, after controlling for the number of trips taken in a day, individuals who travel more miles will be more likely to do so using a single mode because long-distance travel is best accomplished through exclusive automobile use. Finally, we anticipate that weekend travel would be associated with less multimodal travel since on the weekends households have greater flexibility in their tripmaking and can more easily accommodate the use of household vehicles.

Perhaps the most important determinant of the likelihood of multimodal travel is the presence of one or more household vehicles. We hypothesize that having unlimited access to a household vehicle will greatly increase the likelihood that all trips will be made using a vehicle (Krygsman and Dijst, 2001). In general, access to automobiles increases the likelihood of driving. Thirty-four percent of individuals in zero-vehicle households travel by automobile compared to more than 80 percent of individuals who live in households with at least one automobile (Pucher and Renne, 2003).

Finally, our model includes variables that characterize the residential location of households such *as population density* and whether the individual lives in *New York City*. New York City is an outlier in terms of urban form and transit use, having some of the highest residential densities in the country and, consequently, the highest rates of transit use (Dickens and Neff, 2001). The NHTS data do not explicitly identify households' access to public transit. Therefore, many of the geographic characteristics included in our models serve as proxies—albeit imperfect ones—for transit supply and use, that tend to be higher in dense urban areas where origins and destinations are proximate. There is a vast and varied literature on the relationship between urban form and travel most of which shows a statistically significant relationship between characteristics of the built environment and travel behavior, independent of self-selection bias (Ewing and Cervero, 2010). We, therefore, hypothesize that higher residential densities may contribute to the elevated use of non-auto modes and, consequently, to heightened transportation packaging.

4. THE TRAVEL DAY: TRAVELERS AND NON-TRAVELERS, MULTIMODAL AND UNIMODAL TRAVELERS

Table 2 presents sample characteristics for non-travelers, unimodal travelers, and multimodal travelers. As expected, there are significant differences in the characteristics of these three groups with respect to income. Non-travelers (13 percent of the sample) are more likely to be poor than travelers and are almost twice as likely as travelers to fall in the lowest income bracket. Thirty percent of non-travelers live in households with incomes less than $20,000 compared to only 16 percent of travelers. Also, non-travelers are much less likely to work formally and to live in households with automobile access.

Among individuals who traveled on the survey day, approximately 15 percent engaged in multimodal travel. Compared to unimodal travelers, multimodal travelers are more likely to live in households without vehicles, take more trips, and live in higher-density neighborhoods. Unimodal travelers are more likely to be Non-Hispanic white, older, more educated, and live in low-density neighborhoods.

[Insert Table 1 here]

With respect to multimodal travel, the differences between the two income groups are minor. Contrary to our hypothesis, a slightly larger percentage of individuals in higher income households are multimodal travelers than among unimodal travelers. Although the difference between the income groups is very small (16% to 15%), it is statistically significant. The vast majority of multimodal travelers, about 90 percent, used only two modes on the travel day and the remaining used 3+ modes. These percentages are similar across income groups.

However, the modes and mode packages used by low-income and higher-income travelers differ greatly. Among unimodal persons, those in low-income households are more likely than higher-income individuals to rely solely on the bus or walking (see Figure 1). As

Figure 2 shows, a disparity in reliance on non-automobile modes also appears among multimodal individuals. Low-income multimodal individuals create more diverse transportation packages than higher-income persons. Whereas higher-income individuals rely on a car for part of their travel in multimodal packages nearly ninety percent of the time, low-income individuals only package with an automobile two thirds of the time. More specifically, low-income individuals package transit and walking more than twenty-one percent of the time, whereas higher income individuals only do this for seven percent of their multimodal trips.

[Insert Figure1 here]

(Caption: Figure 1. Distribution of unimodal travelers by income and mode)

[Insert Figure 2 here]

(Caption: Figure 2. Distribution of multimodal travelers by income and mode mix)

Finally, low-income multimodal travelers took more trips on the travel day than higher income unimodal travelers. In other words, multimodal status serves as a more robust predictor of the number of trips taken than income. Multimodal status among low-income individuals reflects a heightened need or desire to travel that outweighs the manifold costs associated with linking across modes. If individuals need to get somewhere, even if they are very poor, they will find a way to do so, and multiple modes of transportation can serve as a viable means to satisfy this travel demand.

In short, these findings confirm our expectation that low-income individuals travel differently than higher income persons due to a range of socioeconomic and lifestyle constraints. First, lower income individuals are twice as likely to have stayed home on the travel day as higher income individuals. Further, although the personal automobile remains dominant, when low-income individuals travel, they use different modes than higher-income individuals. While this finding is not novel, we find that the disparity in travel mode by income holds for both unimodal and multimodal persons. However, while these differences remain, the descriptive data indicate that multimodal travel itself is not more prevalent among low-income travelers than higher-income travelers.

5. PREDICTING MULTIMODAL TRAVEL

Table 2 presents the results of two models predicting multimodal travel. Model 1 includes only the income dummy variables and controls for the number of trips taken on the trip day. Model 2 includes the full complement of control variables—race/ethnicity, personal characteristics, principal activity, transportation resources/behavior, and residential location. The excluded variables are the following: *the lowest income category, non-Hispanic white households, households without children*, and *households in neighborhoods with residential densities below 500 persons per square mile*.

[Insert Table 2 here]

Household income was originally our primary variable of interest. Contrary to our hypothesis, we find that *household income* is negatively related to multimodal travel, after controlling for other determinants of multimodal travel such as *vehicle ownership* and *the number of daily trips taken*. Even after reducing the model to include only income and the number of trips taken on the travel day (see Table 2, Model 1), only two of our four income comparison groups are statistically different from the reference group. Travelers in the middle income groups are less likely to engage in multimodal travel than individuals with annual household incomes above $100,000. Individuals with less than a high school education, even controlling for income, are less likely to multimodal travel.

With one exception, the *race/ethnicity variables* are not statistically significant. Compared to *non-Hispanic whites*, multimodal travel is lower among only one minority group: *African Americans*. This population group that is also the least likely to have automobiles and, as these data suggest, are most likely to take all of their trips using a single mode. As predicted, women are less likely to multimodal travel than are men. Also as expected, multimodal travel is negatively related to household size (although the relationship for "child in the household" is not statistically significant). Among the lifestyle groups—*worker, retirement and homemaker*—only "homemaker" is statistically significant. Controlling for sex and number of trips, individuals who are homemakers are less likely to engage in multimodal travel than other adults.

The most powerful variables in the model relate directly to transportation resources and travel behavior. *The number of household vehicles* is strongly and negatively related to multimodal travel.[5] As expected, the more cars that a person has, the less likely they are to resort to multimodal travel. An individual's trip making rate has a robust and positive correlation with the likelihood of employing several modes on the travel day. The direction of this relationship is predictable (as the number of trips goes up, so does the likelihood that one of these trips is taken using another mode), but the strength of this relationship is surprising. Controlling for the *number of trips taken*, however, an increase in personal miles traveled correlates to a decrease in

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[5]Automobile ownership is strongly associated with income. Therefore, we tested our model by excluding the automobile ownership variables. The relationship between income and multimodal travel remains unchanged.

the likelihood of multimodal travel. This finding confirms our original hypothesis that those traveling more miles per trip tend to rely on a single mode, usually an automobile.

Finally, the model shows a positive relationship between *residential density* and multimodal travel, reflecting the propensity of households without automobiles to move to dense urban neighborhoods with extensive mode options. The relationship also may indicate the ability of households in these neighborhoods to forgo automobile use. Further, among multimodal travelers, we find a strong relationship between residential density and the mix of modes employed. Multimodal travelers in the densest neighborhood classification rely on the automobile (and one other mode) less than 50 percent of the time, whereas other multimodal travelers rely on this mix nearly 80 percent of the time. In the very densest neighborhoods, multimodal travelers exclusively use transit and walking 27 percent of the time, whereas those in the next densest classification do so only five percent of the time.

[Insert Table 3 here]

In Table 3 we test our findings using a multinomial logistic model; in so doing, we also are able to examine the determinants of not traveling on the travel survey day. The model shows that individuals who are poor, less educated, and live in large households are less likely to travel compared to unimodal travelers. Additionally, those individuals who were surveyed on weekends are less likely to travel. In contrast, individuals who live in households with children and automobiles are more likely to travel. So too are individuals who are retired or live in medium-density residential neighborhoods.

With respect to multimodal travel, the results are similar to those in the binary logistic model. Relevant for this analysis, income remains negatively associated with the likelihood of multimodal travel. Other negative correlates of multimodal travel include being African

American, having less than a high school degree, living in a household with automobiles, and a weekend survey day. As in Model 2, residential density is associated with greater multimodal travel. While dense urban areas with high levels of transit service may facilitate transit use and walking, we cannot rule out the possibility that households with the need for multimodal travel, move to neighborhoods where it is easy to rely on diverse modes.

6. CONCLUSIONS

Contrary to our original hypothesis, we find that individuals in lower-income households are less likely to multimodal travel than individuals in high-income households (households with income at or above $100,000). In other words—in almost all of our model specifications—income is positively related to the likelihood of multimodal travel. There are, however, important differences in the number and mix of modes that low-income and higher-income individuals choose. Low-income persons are much less likely to travel at all, suggesting that they have constrained mobility compared to higher-income individuals. Further, among those who took a single mode on the travel day, low-income persons are much more likely to travel by non-auto modes, take fewer trips and travel fewer miles than higher income individuals, largely due to budget constraints that limit their use of more expensive and faster travel modes such as the automobile. Among multimodal travelers, there are also important differences between the low-income and high-income group. Low-income persons who took multiple modes on the travel day are more likely to package non-automobile modes than higher-income persons. Surprisingly, low-income multimodal travelers took far more trips than even higher-income unimodal persons.

These findings have implications for both policy and future research. Policymakers should take note that even among low-income individuals, access to multiple modes allows trip making rates on par with higher-income persons. This finding suggests that providing viable avenues for multimodal travel may enhance low-income individuals' mobility, particularly if they face obstacles to gaining access to automobiles. To facilitate multimodal travel, efforts are underway to improve the physical and information infrastructure linking modes. Our models suggest that increasing multimodal capacity in high-density areas will provide the greatest relative return to investment and yield benefits particularly for low-income individuals, who disproportionately reside in dense central-city neighborhoods.

In terms of future scholarship on this topic, several issues need to be addressed to enhance the explanatory power of multimodal travel models. First, changing the unit of analysis for multimodal travel to the household rather than the individual may better capture how households' manage their transportation resources. In low-income households, individuals may have to balance the use of the car by the main income earner, for example, with more diverse transportation packaging by other household members. Even more importantly, utilizing a multi-day rather than a single day travel period may greatly enhance the prediction of multimodal travel among individuals. The NHTS survey provides travel diary data for a single day. By using single-day data for the travel period to predict multimodal travel, however, we may significantly undercount multimodal travelers. Individuals may use a single mode exclusively within a day but package modes over the course of several days. For instance, Kuhnimhof and Gringmuth (2009) use one week travel data from the 2002 German national mobility survey and strongly argue that, because mode choice varies from day to day, single day data do not provide a sufficient basis to assess individual modal preferences.

The NHTS provides one piece of evidence to suggest whether a multi-day diary would alter our analysis of multimodal travel by income status. Individual respondents to the NHTS were asked how many times they had used transit within the previous month. Among those who did travel but did not use multiple modes on the travel day, low-income individuals indicated that they took 4.7 transit trips during the last month while higher-income persons only took 3.1 transit trips. The vast majority of individuals in each group (85% of higher income and 78% of low income) did not use transit at all, but the proportion of individuals taking three or more transit trips, which we interpret as a measure of some reliance on transit in a month's time, was higher among low- income individuals (16% vs. 9%). If we broaden the definition of multimodal travel to include individuals who did not travel on the survey day (a greater proportion of which were low-income) but traveled in the last week or month, we may see a more dramatic income effect on multimodal travel behavior. Our understanding of transportation packaging in the U.S., therefore, would be enhanced if we used travel data over a multi-day period to predict multimodal travel. No such national dataset, however, is currently available in the U.S.

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Table 1. Sample characteristics

Characteristics	Non-Travelers	Unimodal	Multimodal
Income			
< $20,000	30%	15%	16%
$20,000-$39,999	24%	21%	18%
$40,000-$59,999	15%	18%	15%
$60,000-$99,999	18%	25%	26%
$100,000+	13%	21%	25%
Race/Ethnicity			
Non-Hispanic White	68%	72%	70%
African American	15%	12%	12%
Hispanic	11%	11%	12%
Asian	3%	3%	3%
Other	3%	2%	3%
Activity			
Worker	35%	70%	72%
Retired	32%	14%	11%
Homemaker	15%	9%	8%
Other individual/household			
Female	55%	50%	50%
Age (mean years)	52	46	35
Senior (65+)	30%	13%	10%
High school education or less	52%	37%	29%
Household size	2.89	3.08	3.00
Child in household	36%	49%	48%
Transportation Resources/Behavior			
0-vehicle household	12%	4%	12%
1-vehicle household	27%	21%	24%
2+-vehicle household	61%	75%	64%
Personal Miles Traveled (annual mean)	---	16,392	16,717
# of trips (annual mean)	---	1,559	2,234
Weekend survey	37%	28%	24%
Residential Location			
< 500 persons per sq. mile	33%	30%	20%
500-1,999 persons per sq. mile	19%	22%	19%
2,000-9,999 persons per sq. mile	37%	40%	41%
10,000+ persons per sq. mile	11%	8%	20%

New York City	7%	6%	12%
N	36,243	177,393	29,312

Table 2. Bivariate Logistic Regression – Likelihood of Multimodal Travel

Independent Variables	Model 1	Model 2
	Odds Ratio	Odds Ratio
Household Income (excluded $100,000+)		
< $20,000	1.077	**0.719**
$20,000-$39,999	**0.803**	**0.719**
$40,000-$59,999	**0.694**	**0.694**
$60,000-$99,999	0.925	*0.887*
Race/Ethnicity (excluded Non-Hispanic White)		
African American		*0.816*
Hispanic		0.975
Asian		0.988
Other		1.138
Personal Characteristics		
Age		1.000
Age squared		1.000
Female		**0.873**
Less than high school		**0.833**
Household size		*0.954*
Child in household		0.929
Activity		
Worker		0.980
Retired		0.875
Homemaker		*0.841*
Transportation Resources/Behavior		
1-vehicle household (excluded 0-vehicle hh)		**0.378**
2+-vehicle household		**0.279**
Personal Miles Traveled (log)		**0.881**
# of trips on travel day	**1.280**	**1.328**
Weekend survey		**0.829**
Residential Location (excluded < 500 persons per square mile)		
500-1,999 persons per sq. mile		*1.147*
2,000-9,999 persons per sq. mile		**1.287**
10,000+ persons per sq. mile		**2.501**
New York City		*1.200*

N	208,411	206,705
Pseudo R^2	0.074	0.122
Pseudo Log-Likelihood	-76549045	-71731476
Chi-Square Goodness of Fit	0.000	0.000
Bold -- significant < .01; *italics* -- significant < .05		

Table 3. Multinomial Logistic Regression (Base=Unimodal Travel)

Independent Variables	**No Travel**	**Multimodal Travel**
	Odds Ratio	Odds Ratio
Household Income (excluded $100,000+)		
< $20,000	**1.348**	**0.629**
$20,000-$39,999	*1.138*	**0.682**
$40,000-$59,999	0.999	**0.678**
$60,000-$99,999	1.071	**0.855**
Race/Ethnicity (excluded Non-Hispanic White)		
African American	1.029	**0.789**
Hispanic	0.951	0.907
Asian	1.217	0.854
Other	1.150	1.123
Personal Characteristics		
Age	**0.971**	**1.021**
Age squared	**1.000**	**1.000**
Female	0.995	0.962
Less than high school	**1.253**	**0.734**
Household size	**1.102**	0.971
Child in household	**0.660**	1.003
Activity		
Worker	**0.298**	0.955
Retired	*0.843*	0.944
Homemaker	0.965	1.069
Transportation Resources/Behavior		
1-vehicle household (excluded 0-vehicle hh)	**0.607**	**0.449**
2+-vehicle household	**0.575**	**0.308**
Weekend survey	**1.580**	**0.798**
Residential Location (excluded < 500 persons per square mile)		
500-1,999 persons per sq. mile	**0.831**	**1.204**
2,000-9,999 persons per sq. mile	**0.840**	**1.388**
10,000+ persons per sq. mile	0.863	**2.500**
New York City	1.084	1.123
N	244,654	
Pseudo R^2	0.073	
Pseudo Log-Likelihood	-159100000	

Chi-Square Goodness of Fit	0.000	
Bold -- significant < .01; *italics* -- significant < .05		

Figures

Figure 1. Distribution of unimodal travelers by income and mode

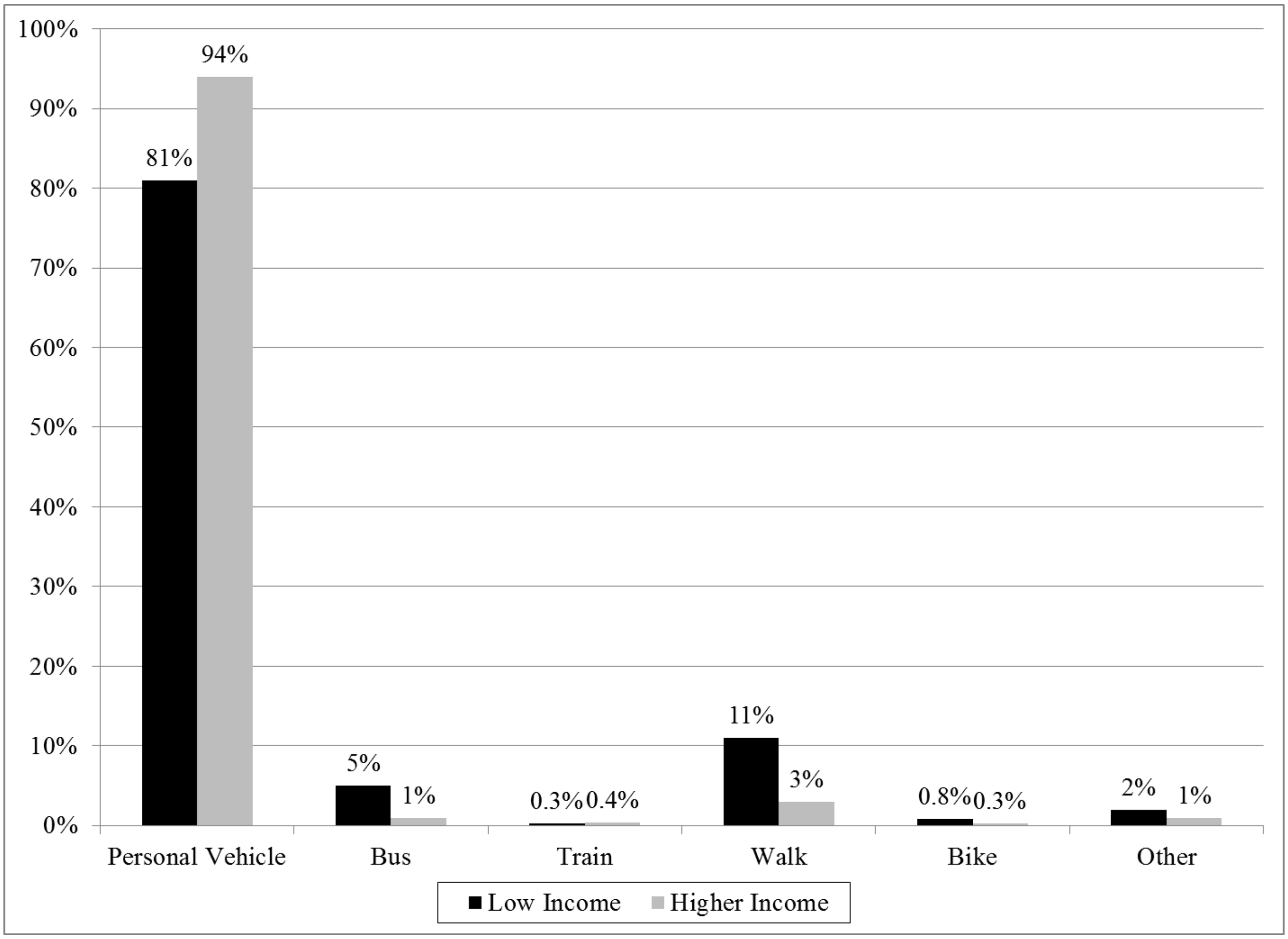

Figure 2. Distribution of multimodal travelers by income and mode mix