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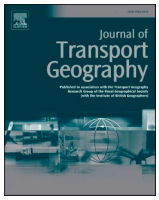

# Rural travel burdens in the United States: Unmet need and travel costs

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ABSTRACT

Transportation accessibility, or the ease of reaching valued destinations, is a critical determinant of a person's ability to satisfy their essential needs. A lack of accessibility can result in travel burdens such as high transportation costs or unmet needs and adversely affect well-being. Prior research establishes the inverse relationship between travel burdens and access to transportation options such as public transit and proximity to destinations as well as a person's resources, including their income and access to a personal vehicle. Although travel behavior is understood to differ across rural versus urban contexts, little is known about the nature of travel burdens in rural communities. Using the 2017 National Household Travel Survey, this study quantifies and compares travel burdens in rural versus nonrural communities in the United States. In each context, we quantify and compare i) the magnitude of travel burdens, ii) who experiences travel burdens, and iii) the individual and environmental factors that are associated with travel burdens. We find higher rates of burdensome travel outcomes among rural residents. People who live in rural areas are more likely to report burdensome travel costs and unmet travel needs due to a lack of transportation options compared to people living in nonrural areas, and these differences are exacerbated for people without car access. Dispersed rural contexts are unique in that they exhibit a combination of higher rates of financial burden and unmet need relative to urban contexts. Within rural areas, financial burdens and unmet need are less prevalent for those who live in a small town when compared with those living in more dispersed areas, which suggests that even a small concentration of services and opportunities may facilitate greater access. Collectively, our results highlight the need for research that attends to context-specific needs and strategies to address travel burdens in rural communities.

## 1. Introduction

The ability to travel to and from essential destinations is necessary to satisfy fundamental needs. Accessibility, the ease with which people can reach desired destinations, varies depending on a person's identity, resources, abilities, and needs as well as the transportation and land use environment in which they live (S. Handy, 2020; S. L. Handy and Niemeier, 1997; Lucas, 2012; van Wee and Geurs, 2004). Difficulty traveling between essential destinations due to personal or environmental factors can result in burdensome travel outcomes such as financially burdensome travel or unmet need resulting from an inability travel at all. These burdensome travel outcomes can adversely impact quality of life (Currie and Delbosc, 2011).

Prior research evaluates the effects of individual and built environment characteristics on travel outcomes that reflect burdens. This research highlights the relationship between burdensome travel outcomes (such as financial stressors and unmet needs) and access to transportation options (such as public transit or a personal vehicle, financial resources, and proximity to destinations) (Allen and Farber, 2020; Blumenberg and Pierce, 2012; Coren et al., 2022). A related body of research highlights differences in travel burdens across rural and urban contexts, noting the greater prevalence of travel burdens (such as high financial costs and longer travel times) in rural and small communities, where the distance to destinations is farther and there are fewer transportation options (Gray, 2004; Kamruzzaman and Hine, 2012; Kolodinsky et al., 2013; Mattioli, 2014, 2021; Smith et al., 2012). Despite distinct differences in the built environment, sociodemographic characteristics, and the magnitude of travel burdens in rural contexts, little is known about the differences in who experiences travel burdens in rural versus nonrural areas and differences in the factors that are associated with travel burdens in rural communities relative to their nonrural counterparts.

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This study quantifies and compares differences in travel burdens and the factors that relate to them in rural and nonrural communities in the United States. Our analysis focuses on two travel burden outcomes: unmet needs (not traveling because a person lacks a transportation option) and financial burden (self-report that travel is a financial burden). We quantify and compare unmet travel needs and financially burdensome travel using the 2017 National Household Travel Survey (NHTS) (FHWA, 2018). We quantify and compare the prevalence of each travel burden and who experiences it in both rural and nonrural contexts. We then use multivariable analysis to assess the individual and built environment factors that relate to the likelihood of experiencing each travel outcome in both rural and nonrural contexts. We also quantify and compare variation in these relationships in two types of rural contexts: small towns and more dispersed rural communities.

## 2. Literature review

### 2.1. Transport disadvantage and accessibility

Prior research that focuses on burdensome travel outcomes evaluates long travel times, high financial costs, inability to travel, reduction of mobility or access, and unmet need. The effects of these outcomes on peoples' lives can be complex and pervasive. Transport disadvantage can be defined as the inability to reach desired destinations due to lack of accessibility to destinations using transit or a personal vehicle (with reference to transportation networks and land use systems) as well as the individual capability of people to reach necessary good and services. In this context, accessibility refers to how well a transportation system facilitates travel between a range of necessary destinations, while capability refers to the specific ability of an individual to travel (Bantis and Haworth, 2020; Lucas, 2012; Lucas and Jones, 2012; Preston and Rajé, 2007).

Prior work also finds that people with sociodemographic characteristics that reflect lower levels of relative privilege (women, people of color, those earning a low income, etc.) are more likely to experience transport disadvantage (Lucas and Jones, 2012). Another vein of research explores the relationship between “forced” car access in car-dependent communities and transport disadvantage. In these communities, car access may be necessary to reach minimum mobility thresholds but conversely impose financial transport disadvantage through the financial stressors of car ownership (purchase, fuel, maintenance), especially among lower-income groups (Brown, 2017; Mattioli, 2014). The implications of forced car access, especially in car-dependent rural communities are complex; to mitigate the high costs of car ownership, some people use alternative modes to driving, ask for rides or make fewer trips (Currie and Delbosc, 2011).

### 2.2. Small and rural community contexts

The majority of prior research on transport disadvantage, vehicle access, and related scholarship focuses on urban and suburban regions. Rural contexts have distinct built environment and sociodemographic characteristics, which may lead to differences in the nature of transport disadvantage. In a nationwide characterization of neighborhood type, Voulgaris et al. establishes the differences between rural and urban areas (Voulgaris et al., 2016). Consistent with prior work, they establish that rural communities are structurally dissimilar from other neighborhood types, including urban and suburban (Voulgaris et al., 2016). Relative to urban and suburban contexts, rural communities have less connected transportation infrastructure, longer distance between destinations, and fewer destinations (Cutsinger and Galster, 2006; Hoggart, 1990; Millward and Spinney, 2011; Voulgaris et al., 2016). Where public transit does exist, services are often infrequent and few destinations are serviced (McAndrews et al., 2018). Rural walk and bike infrastructure is similarly lacking, and greater travel distances between destinations make walking or biking unappealing (McAndrews et al., 2018). In contrast, urban communities benefit from more robust transportation infrastructure and greater density of destinations, yielding greater access to jobs, services, and opportunities (Millward and Spinney, 2011; Voulgaris et al., 2016). Suburban communities can experience more modest but similar benefits in terms of transportation infrastructure and density due to their proximity to urban cores (Cutsinger and Galster, 2006). Finally, rural communities actually exhibit higher rates of poverty than urban communities, even though only approximately 20 % of those living in poverty reside in rural areas (Weber et al., 2005). Prior literature further suggests that there may be a rural effect beyond location and sociodemographic characteristics that make poverty more likely in rural areas (Weber et al., 2005).

Though much prior work addresses rural contexts as a whole, there is wide heterogeneity within these contexts (Brown, 2017; Mattioli, 2014). The proximity of rural destinations and number of feasible travel routes are more limited in rural communities than in urban contexts, but rural communities reflect a broad spectrum of both features (Gray, 2004; Mattioli, 2014; Smith et al., 2012). “Rural” has come to encompass the spectrum of small towns to highly dispersed communities. Along this spectrum, people have vastly different levels of access to jobs, services, and opportunities, and transportation infrastructure (Millward and Spinney, 2011). Small towns benefit from concentrated employment, shopping and recreation cores that contribute to meeting the needs of the surrounding community, and some have bicycle, pedestrian, and transit infrastructure. These cores may help to meet the minimum needs of the community and residents, even if they don't provide the same levels of opportunity as a more urban community (Cutsinger and Galster, 2006).

### 2.3. Travel burdens in small and rural communities

A subset of transportation literature seeks to understand the ways in which the differences between rural and nonrural communities affect travel behavior and, in some cases, travel burdens. This literature indicates that the lower density of rural communities coupled with fewer transportation options leads to increased car dependency and higher transportation costs among rural populations (Gray, 2004; Kamruzzaman and Hine, 2012; Smith et al., 2012). In car-dependent rural communities owning a car generally confers relative advantage and greater mobility, whereas lack of a car is tied to reduced mobility (Kamruzzaman and Hine, 2012). People who have access to a car are able to make faster and more frequent trips at times that are convenient to them, travel longer distances, and reach a wider range of destinations (Mattioli, 2014; Wang et al., 2023). As a community transitions from a dense cityscape to a sparsely populated area, the number of households without cars decreases, and the travel activity and accessibility gaps between households with and without cars widens (Mattioli, 2014, 2021; Wang et al., 2023).

Overall, it is well established that rural households take less frequent but longer trips than urban households, resulting in greater overall miles traveled per person (Esekhaigbe and Bills, 2021; Kolodinsky et al., 2013; Pucher and Renne, 2005; Voulgaris et al., 2016). For rural communities with high rates of travel, greater mobility and travel cost likely reflect the necessity of traveling farther to reach destinations rather than greater realized access. In fact, some vulnerable rural populations travel less than their urban counterparts and are more likely to report difficulties meeting their essential travel needs (Delbosc and Currie, 2011; Smith et al., 2012) and unmet travel need is more prevalent for those lacking vehicle access in rural areas when compared with nonrural areas (Wang et al., 2023). Unmet travel needs, though uncommon, have substantial impacts on the ability to fulfill basic needs (Kolodinsky et al., 2013).

### 2.4. Gap and study objective

Existing research on travel burdens, mobility, and accessibility in rural contexts provides an indication of the potential for significant disparities across and within rural and nonrural contexts (Kamruzzaman and Hine, 2012; Millward and Spinney, 2011; Palm et al., 2023; Smith et al., 2012; Wang et al., 2023). Many of these studies rely on commonly assessed travel behaviors (such as trip distances and rates) either because their focus is on travel behavior more generally, or because difference in activity can imply unmet need, although in some cases they may also reflect unmeasured differences in need (Palm et al., 2023). Furthermore, those that focus on the implications of travel outcomes in terms of rural travel burdens are relatively small in geographic scope, qualitative, or rely on aggregate comparisons rather than examining the factors that relate to outcomes (e.g., through multivariable modeling designed to control for differences in travel needs). In short, little is known about the extent to which people who live in rural areas are more transportation burdened than people who live in urban areas, who experiences financially burdensome travel and unmet need and if sociodemographic disparities are deeper in rural areas, and whether the factors that relate to burden in rural areas are different than in urban areas. Additionally, little is known about the variation in these relationships across different types of rural contexts (Gray, 2004; Palm et al., 2023; Pucher and Renne, 2005; Wang et al., 2023).

This research quantifies and compares the extent and nature of rural travel burdens across the US using a large sample of people living in the US, captured in the 2017 National Household Transportation Survey (NHTS). Our analysis focuses on two measures of travel burdens: unmet needs and financial burden. We divide our analysis of rural travel burdens into three parts. We quantify and compare i) the extent to which people who live in rural areas are more transportation burdened than people who live in nonrural areas, ii) differences in sociodemographic disparities in travel burdens experienced by people who live in rural versus nonrural areas, and iii) whether the individual and environmental factors that relate to financially burdensome travel and unmet need differ across rural and nonrural contexts. We evaluate these questions across two types of rural contexts, including small town and dispersed. We focus on differences between these contexts and urban contexts, although we also attend to differences between rural contexts and suburban and second city contexts.

## 3. Data and methods

We quantify and compare who experiences burdensome travel outcomes and the personal and built environment factors that relate to burdensome travel outcomes across five types of communities, including three that we define as nonrural (urban, second city, suburban) and two that we define as rural (small town, and rural dispersed). Personal and trip characteristics assessed include individual and household sociodemographic characteristics, vehicle access, and transit use. We represent the built environment using measures of accessibility by car, presence of transit, and population density. Burdensome travel outcomes are measured as self-reported financial burden of travel and unmet travel need.

### 3.1. Data

We obtain travel behavior data and personal characteristics from the Federal Highway Administration's 2017 National Household Travel Survey (NHTS) (FHWA, 2018), which has a larger sample size than 2022 NHTS data, predates covid-19 pandemic-era travel behavior which may have still been in flux, and for which we were able to obtain spatially refined data. The NHTS collects information about travel behavior in US households. The survey includes a travel diary of all trips taken during a 24-h period for a sample of 129,696 households. To avoid covarying respondents, we randomly sample one adult aged 22 or older per household and use this sample in all parts of our analysis. This snapshot of daily travel can be linked to respondents' individual and household sociodemographic characteristics as well as vehicle data. The NHTS also includes community classifications developed by Claritas (a private marketing company), which defines five classes of urbanicity and rurality based on population density, commuting patterns, and other built environment attributes. Person level demographic inverse probability weights available in the NHTS allow analysts to use survey responses to estimate US-wide estimates that are intended to be representative of the population as a whole.

Sociodemographic factors are obtained from the NHTS dataset and include age, presence of children in a household, number of adults in a household, education, race and ethnicity, gender, country of origin, household income, employment status, and household car access. Vehicle access is based on the number of cars per driver in a household, where households with no cars are designated as zero-car or car-less, households with less than one car per driver are defined as car-deficit, and households with one or more cars per driver are car-fully equipped, consistent with Blumenberg et al. (2020). All sociodemographic factors are person level measures except for income, car access, number of household adults, and presence of children. These household characteristics are applied to each person in the household.

We use confidential NHTS spatial location data at the US Census block group level obtained from the Federal Highway Administration (FHWA) to join the 2017 NHTS data with data from the Environmental Protection Agency's (EPA) Smart Location Database (SLD), which includes built environment measures at the block group level (EPA, 2018). The joined cross sectional dataset includes the NHTS data matched with three corresponding built environment factors from the EPA SLD based on each respondents' home location: access to transit within 1600 m, jobs reachable within a 45-min drive, and population density.

The analysis focuses on two travel outcomes that directly represent burdens, as indicated by survey responses about the nature of the observed travel behavior that indicate reasons or effects. These measures of burden are self-reported financially burdensome travel and unmet travel needs. The financial burden outcome is measured based on responses to a question asking respondents to indicate their level of agreement with the statement "getting from place to place costs too much" using a five-level Likert scale. This measure is operationalized by designating people who "strongly agree" with the statement as financially burdened, and those who were neutral, "disagree," "strongly disagree" or "agree" as not financially burdened. Our measure of unmet need is estimated based on whether someone did not make a trip on the surveyed travel day and the reason they gave. Respondents were asked to indicate one of ten reasons for not traveling on the travel day, including several options that reflect a lack of need as well as one that we ascribe to unmet need: not traveling due to lack of transportation options. Those who did not travel on the travel day due to a lack of transportation options are classified as experiencing unmet travel need. While this is a relatively direct measure of unmet need, the observation window is brief and likely underestimates unmet need in two ways; first by omitting those who traveled but did so less than needed on a given day, and second by omitting those who experience unmet travel need over longer time periods. Both burdensome travel outcomes are evaluated using people as the unit of analysis.

We use the Claritas classifications to identify community types. In addition to identifying population clusters, the Claritas definition characterizes the land use surrounding the sampled household location with more granularity than a binary urban-rural indicator. There are five categories within this classification scheme: urban, second city, suburban, small town, and rural. The small town and rural designations in the Claritas scheme capture the highest proportions of households classified as rural under the US Census definition (15 % and 83 % respectively, estimated based on household location). According to the parameters of the Claritas definitions, the rural category encompasses more dispersed areas with the lowest population density, while the small town

designation captures rural villages that have small population clusters. Suburban areas have residential population clusters that commute into surrounding areas for employment, shopping, and recreation opportunities. Communities classified as second city have smaller population clusters and less robust public transit options than urban areas. Urban areas encompass the most dense population centers, and feature the highest concentration of employment, shopping, and recreation opportunities along with the most robust transport infrastructure. This analysis focuses on rural and small town areas as two types of rural communities, and treats urban, second city and suburban as nonrural. Our analysis focuses primarily on urban versus rural areas, although we also address urban versus non-urban areas and rural versus non-rural areas. Table 1 illustrates the Claritas-Urban rural continuum and the terminology we use to refer to different types of community contexts in our analysis. Table 2 summarizes the NHTS explanatory variables used in the analysis for each Claritas classification. Travel burden variables are summarized in the results section when we address the first research question (Table 3).

### 3.2. Methods

Our first research question evaluates the extent to which people in rural and urban areas experience differences in burdensome travel outcomes. We evaluate this question by conducting weighted group comparisons for each of the two burdensome travel outcomes using the sample weights provided in the NHTS. We determine whether there are differences in the likelihood that people living in rural and urban areas experience unmet need using a $\chi^2$ test of complete independence. The R function used to conduct these $\chi^2$ tests of complete independence standardizes the weights to avoid inflation of our test statistic. The likelihood that a person experiences unmet need is relatively low, in part because the variable is observed during the snapshot of the surveyed travel day. We might expect that a measure of whether a person experienced unmet need over the course of a year would have a higher prevalence. We also compare whether people who travel in rural and urban areas experience financially burdensome travel at different rates with a $\chi^2$ test of complete independence.

To evaluate the second research question, which focuses on the differences in sociodemographic disparities in travel burdens experienced by people who live in rural versus urban areas, we conduct $\chi^2$ tests of conditional independence for each outcome to evaluate whether different sociodemographic groups experience burdensome travel outcomes differently in each context. The R function used to conduct these $\chi^2$ tests of conditional independence also standardizes the weights to avoid inflation of our test statistic. We stratify these groups by country of origin, race and ethnicity, household car access, and household income based on key populations highlighted in prior literature. These findings provide an indication of the populations most affected by travel burdens across rural and urban contexts and inform the final stage of the analysis.

The third research question focuses on whether factors that relate to transportation burdens are different in rural areas when compared to urban areas. To evaluate this question, we separate survey respondents into populations living in each community type, as defined using the five Claritas classifications. Next, we evaluate separate multivariable models for each travel burden variable (two) for each community type (five), for a total of 10 models. This formulation allows us to evaluate the relationships between person and built environment characteristics and the burdensome travel outcomes *in each community context* to address our research question. To assess whether the factors that relate to travel burdens are significantly different across community contexts, we examine whether the 95 % confidence interval of the estimated or odds ratios in models for rural and nonrural contexts overlap.

Note that most evaluations of travel behavior model the entire population in one model, representing differences across community types using a categorical variable. In order to compare our stratified modeling approach to a more traditional modeling approach, we also evaluate a nationwide model that uses the entire sample and includes a categorical variable representing the community type. This model indicates whether the community context variable is a significant predictor of travel burden using a traditional approach that assumes that the relationship between travel outcomes and person and built environment characteristics does not vary across contexts.

We evaluate both burdensome travel outcomes using binary logistic regression models. The demographic weights are omitted from all multivariable models because the models include many of the demographic factors used to create weights as explanatory variables.

For the unmet need analysis, we also evaluate the extent of bias in the logistic model estimates in light of the sparse outcome variable, as suggested by Greenland et al. (2016). This includes assessing the events per variable (EPV) in the logistic model, comparing simple odds to odds ratios from the logistic model, and evaluating Firth's bias-reduced penalized-likelihood logistic regression, which does not rely on prior estimates to reduce bias (Firth, 1993). We implement the Firth method using the "logistf" package in R, which produces confidence intervals and tests based on profile penalized log likelihood (Heinze et al., 2023). Exact logistic regression can offer an additional (albeit highly conservative) check of modeled *p*-values, though it is computationally intensive. We attempted to perform an exact logistic regression using the "elrm" package in R (Zamar et al., 2021), but it was infeasible for the large dataset used in this study.

**Table 1**
Description of the five claritas urban-rural continuum and terms used in this study.

| Context | Definition | Rural / Non-Rural | Urban / Non-Urban | Examples |
|---|---|---|---|---|
| Urban | Encompasses the most dense population centers with the highest concentration of employment, shopping, and recreation opportunities and the most robust transport infrastructure | Non-Rural | Urban | Los Angeles, CA<br>Miami, FL<br>New York City, NY<br>Washington D.C. |
| Second City | Includes areas with smaller population clusters and less robust public transit options than urban areas | Non-Rural | Non-Urban | Burlington, VT<br>Fredericksburg, VA<br>Carmel, IN |
| Suburban | Residential population clusters that commute into surrounding areas for employment, shopping, and recreation opportunities | Non-Rural | Non-Urban | Evanston, IL<br>Sugarland, TX |
| Small Town | Captures rural villages that have small population clusters | Rural | Non-Urban | Breckenridge, CO<br>Gatlinburg, TN<br>Alleghany County, VA (Alleghany Mountains) |
| Dispersed | Encompasses more dispersed areas with the lowest population density | Rural | Non-Urban | Mariposa County, CA (Yosemite National Park) |

**Table 2**
Summary of NHTS explanatory variables used in analysis by claritas classification.

| | Urban | Second City | Suburban | Small Town | Dispersed |
|---|---|---|---|---|---|
| | Unweighted N | Unweighted N | Unweighted N | Unweighted N | Unweighted N |
| | Wt% | Wt% | Wt% | Wt% | Wt% |
| Age (individual) | 15,719 | 25,886 | 28,723 | 29,042 | 29,624 |
| 22 to 35 years | 27 % | 24 % | 20 % | 17 % | 15 % |
| 36 to 50 years | 27 % | 26 % | 28 % | 27 % | 23 % |
| 51 to 60 years | 19 % | 21 % | 21 % | 22 % | 22 % |
| 61 to 70 years | 17 % | 18 % | 17 % | 19 % | 24 % |
| Older than 70 years | 10 % | 12 % | 14 % | 15 % | 16 % |
| Children <18 (household) | 15,719 | 25,886 | 28,723 | 29,042 | 29,624 |
| Yes | 28 % | 34 % | 37 % | 38 % | 35 % |
| Multiple adults (household) | 15,719 | 25,886 | 28,723 | 29,042 | 29,624 |
| 2 + | 60 % | 62 % | 70 % | 72 % | 76 % |
| Education (individual) | 15,715 | 25,884 | 28,719 | 29,033 | 29,606 |
| High School or Less | 54 % | 43 % | 58 % | 46 % | 33 % |
| Some College | 20 % | 24 % | 15 % | 22 % | 32 % |
| Bachelor's, graduate, or professional degree | 26 % | 33 % | 27 % | 32 % | 35 % |
| Race and Ethnicity (individual) | 15,664 | 25,795 | 28,628 | 28,944 | 29,521 |
| Non-Hispanic White | 45 % | 57 % | 63 % | 76 % | 83 % |
| Non-Hispanic Black | 18 % | 18 % | 13 % | 9 % | 7 % |
| Hispanic or Latino (all races) | 25 % | 18 % | 15 % | 10 % | 6 % |
| Non-Hispanic Multiple or Other Race | 12 % | 8 % | 9 % | 5 % | 4 % |
| Gender (individual) | 15,700 | 25,870 | 28,704 | 29,022 | 29,610 |
| Female | 56 % | 57 % | 53 % | 53 % | 53 % |
| Country of Origin (individual) | 15,714 | 25,875 | 28,711 | 29,030 | 29,612 |
| Born outside of USA | 25 % | 15 % | 17 % | 9 % | 3 % |
| Annual Income (household) | 15,223 | 25,126 | 27,730 | 27,967 | 28,598 |
| Greater than $75,000 | 38 % | 29 % | 48 % | 42 % | 31 % |
| $35,000 to $75,000 | 27 % | 30 % | 27 % | 29 % | 33 % |
| Less than $35,000 | 36 % | 41 % | 25 % | 29 % | 36 % |
| Employment (individual) | 15,718 | 25,886 | 28,723 | 29,041 | 29,623 |
| Employed | 66 % | 64 % | 66 % | 63 % | 56 % |
| Car Access (household) | 15,719 | 25,886 | 28,723 | 29,042 | 29,624 |
| Car-fully equipped | 64 % | 78 % | 85 % | 87 % | 87 % |
| Car-deficit | 13 % | 10 % | 10 % | 9 % | 9 % |
| Zero-car | 23 % | 11 % | 5 % | 5 % | 5 % |
| Log(Jobs within 45-min drive from home) (household) | 15,719 | 25,886 | 28,723 | 29,042 | 29,624 |
| | 12.3 | 10.8 | 11.3 | 9.8 | 8.4 |
| Access to Transit within 1600 m (household) | 15,719 | 25,886 | 28,723 | 29,042 | 29,624 |
| Yes | 96 % | 56 % | 49 % | 9 % | 1 % |
| Transit Used on Travel Day (individual) | 15,698 | 25,844 | 28,689 | 29,018 | 29,589 |
| Yes | 47 % | 18 % | 5 % | 8 % | 3.9 % |
| Log(Population Density in ppl/acre) | 15,719 | 25,886 | 28,723 | 29,042 | 29,624 |
| | 40 | 10.0 | 5.6 | 2.1 | 0.33 |

## 4. Results

### 4.1. Magnitude of travel burdens in rural versus urban contexts

We evaluate the first research question by comparing the weighted share of people that experience unmet need and financially burdensome travel in urban contexts versus each non-urban context (Table 3). The Community Comparison Ratio (CCR) shown in Table 3 indicates disparities between urban and each non-urban context by showing the rate with which non-urban populations in each context experience burdens relative to urban populations. We use urban as the denominator, or reference category, because urban contexts typically offer the highest levels of accessibility. We used a chi-squared test of independence to evaluate whether the rate at which people experience burdensome

**Table 3**
Comparison of the prevalence of travel burdens in each context relative to the urban context.

| Burdensome Travel Outcome | Urban | | | Second City | | | Suburban | | | Small Town | | | Dispersed | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N[1] | Wt. %[2] | CCR[3] | N[1] | Wt. %[2] | CCR[3] | N[1] | Wt. %[2] | CCR[3] | N[1] | Wt. %[2] | CCR[3] | N[1] | Wt. %[2] | CCR[3] |
| Travel is a Financial Burden[4] | 15,293 | | | 25,232 | | | 28,138 | | | 28,331 | | | 28,756 | | |
| | 1,564 | 14% | 1 | 2,384 | 13% | 0.9 | 2,029 | 9% | 0.6 | 2,696 | 11% | 0.8 | 3,614 | 15% | 1.1 |
| Unmet Need [4] | 15,719 | | | 25,886 | | | 28,723 | | | 29,042 | | | 29,624 | | |
| | 23 | 0.2% | 1 | 94 | 0.4% | 2.3 | 68 | 0.5% | 2.8 | 74 | 0.3% | 1.7 | 87 | 0.4% | 2.2 |

[1]N is the total number of survey respondents within each context.
[2]Wt% indicates the weighted percentage of people who experienced the burdensome travel outcome in each context.
[3]The Community Comparison Ratio (CCR) is calculated by dividing the weighted percent of burdened people in each context by the weighted percent of burdened people in the urban context. Cells highlighted in red indicate contexts with a higher percentage of people who experienced travel burdens relative to the urban context, while cells highlighted in blue indicate a lower percentage of people who experienced travel burdens relative to the urban context.
[4]For unmet travel need and travel is a financial burden, the statistical test is a $\chi^2$ test of independence with a test statistic of $\chi^2$, and all chi-squared tests of independence (urban versus all non-urban contexts) are significant at $\alpha = 0.001$.

travel outcomes in each nonurban context is significantly different than the rate at which people who live in urban contexts experience burdensome travel outcomes.

This analysis indicates that people who live in small-town and dispersed areas are 1.7 and 2.2 times as likely to report unmet travel need than urban people, respectively. Differences in second city and suburban contexts are greater at 2.3 and 2.8, respectively, relative to urban contexts. Note that the observed instances of unmet travel are relatively rare across all contexts (although it may be concerning when it does occur), ranging from 0.2 % in urban areas to 0.5 % in suburban areas. This may be due to the variability in the experience of unmet need from one day to the next; our measure captures unmet need on just one day.

The prevalence of financially burdensome travel is far higher than unmet need, ranging from 9 % to 15 % across contexts. Financially burdensome travel is most commonly reported in dispersed contexts, followed by urban contexts. Relative to people who live in urban areas, people who live in dispersed areas are 9 % more likely to report financially burdensome travel, consistent with prior research that establishes that rural households allocate 30 % more of their household income to transport costs (Bureau of Transportation Statistics, 2022). In contrast, people living in small towns are 17 % less likely to report financially burdensome travel when compared with urban areas. Results for second city and suburban contexts are similar to those in small town contexts, with people living in suburban contexts being 35 % less likely to report financial burden than those living in urban contexts.

Differences in unmet need and financial burden across contexts reflect the impact of both the context itself as well as differences in who lives in each context. While these comparisons are important for identifying the prevalence of burdensome travel outcomes in each context, differences in outcomes across contexts should not be interpreted as causal. The next parts of our analysis account for the context and the variation in the demographics of each context to begin to tease apart the ties between burdensome outcomes and contextual and sociodemographic factors.

### 4.2. *Differences in who experiences travel burdens in rural vs urban contexts*

To better understand the differences in the travel burdens experi-

**Table 4**
Comparison of unmet need on travel day across person characteristics and contexts.

| | | Race and Ethnicity | | Car Access | | Income | |
|---|---|---|---|---|---|---|---|
| | | Non-Hispanic White | People of color | At Least Some Car Access | No Car Access | Greater than $35,000 | Less than $35,000 |
| Urban | N[a] | 9572 | 6092 | 13,698 | 2021 | 10,771 | 4452 |
| | n[b] | 10 | 12 | 13 | 10 | 5 | 17 |
| | Wt%[c] | 0.2 % | 0.2 % | 0.1 % | 0.6 % | 0.1 % | 0. 5 % |
| Second City | N[a] | 18,973 | 6728 | 23,953 | 1933 | 16,645 | 8481 |
| | n[b] | 55 | 39 | 34 | 60 | 19 | 70 |
| | Wt%[c] | 0.4 % | 0.5 % | 0.2 % | 2.6 % | 0.1 % | 0.9 % |
| Suburban | N[a] | 21,690 | 6909 | 27,785 | 938 | 21,746 | 5984 |
| | n[b] | 39 | 29 | 34 | 34 | 12 | 50 |
| | Wt%[c] | 0.4 % | 0.7 % | 0.3 % | 6.4 % | 0.1 % | 2.1 % |
| Small-Town | N[a] | 24,451 | 4493 | 28,055 | 987 | 20,469 | 7498 |
| | n[b] | 50 | 24 | 33 | 41 | 15 | 50 |
| | Wt%[c] | 0.2 % | 0.9 % | 0.1 % | 5.0 % | 0.1 % | 0.7 % |
| Dispersed | N[a] | 26,302 | 3196 | 28,875 | 749 | 19,043 | 9555 |
| | n[b] | 64 | 23 | 43 | 44 | 11 | 73 |
| | Wt%[c] | 0.2 % | 1.6 % | 0.2 % | 5.6 % | <0.1 % | 1.2 % |

[a] N is the total number of survey respondents within each context.
[b] n is the number of survey respondents who reported experiencing the burdensome travel outcome.
[c] Wt% indicates the weighted percentage of people who experienced the burdensome travel outcome in each context.

**Table 5**
Comparison of rates of financially burdensome travel across person characteristics and contexts.

| | | Race and Ethnicity | | | | Car Access | | | Income | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Non-Hispanic White | Non-Hispanic Black | Hispanic all races | Non-Hispanic Multiple or Other Race | Car-fully Equipped | Car-deficit | Zero-car | Greater than $75,000 | $35,000 to $74,999 | Less than $35,000 |
| Urban | N[a] | 9391 | 1477 | 2231 | 2141 | 11,989 | 1445 | 1859 | 6568 | 4069 | 4195 |
| | n[b] | 589 | 282 | 392 | 290 | 1081 | 154 | 329 | 344 | 402 | 764 |
| | Wt %[c] | 7.0 % | 22.5 % | 18.9 % | 15.3 % | 11.7 % | 11.3 % | 20.8 % | 6.6 % | 12.0 % | 22.3 % |
| Second City | N[a] | 18,666 | 2417 | 2193 | 1867 | 21,583 | 1878 | 1771 | 8737 | 7702 | 8075 |
| | n[b] | 1362 | 407 | 344 | 263 | 1826 | 220 | 338 | 410 | 620 | 1286 |
| | Wt %[c] | 8.8 % | 18.9 % | 17.6 % | 16.0 % | 11.5 % | 13.0 % | 21.3 % | 5.3 % | 8.9 % | 20.8 % |
| Suburban | N[a] | 21,321 | 2179 | 2136 | 2407 | 25,405 | 1904 | 829 | 13,836 | 7654 | 5690 |
| | n[b] | 1173 | 314 | 259 | 279 | 1708 | 177 | 144 | 602 | 543 | 821 |
| | Wt %[c] | 6.4 % | 14.6 % | 11.4 % | 13.3 % | 7.9 % | 12.0 % | 19.2 % | 5.1 % | 9.2 % | 15.7 % |
| Small-Town | N[a] | 23,922 | 1753 | 1281 | 1278 | 25,605 | 1840 | 886 | 11,629 | 8571 | 7126 |
| | n[b] | 1966 | 297 | 204 | 220 | 2255 | 239 | 202 | 596 | 744 | 1250 |
| | Wt %[c] | 8.9 % | 24.2 % | 13.5 % | 20.4 % | 10.3 % | 15.3 % | 22.5 % | 6.2 % | 11.3 % | 19.3 % |
| Dispersed | N[a] | 25,604 | 1249 | 806 | 994 | 26,481 | 1602 | 673 | 9587 | 9157 | 9046 |
| | n[b] | 2965 | 288 | 152 | 194 | 3189 | 263 | 162 | 625 | 1021 | 1839 |
| | Wt %[c] | 13.8 % | 23.1 % | 19.1 % | 17.1 % | 14.0 % | 21.2 % | 19.5 % | 7.3 % | 12.9 % | 23.4 % |

[a] N is the total number of survey respondents within each context.
[b] n is the number of survey respondents who reported experiencing the burdensome travel outcome.
[c] Wt% indicates the weighted percentage of people who experienced the burdensome travel outcome in each context.

enced by people who live in rural and urban communities, we quantify and compare differences in outcomes for people of different groups (including race and ethnicity, income, and car access) within and across community contexts (Table 4 and Table 5). The categories are aggregated to binary in the unmet need table (Table 4) to avoid evaluating categories that have a small number of responses, whereas we are able to represent more detailed categories in the financial burden table because burdensome outcomes are more commonly observed (Table 5). We conducted $\chi^2$ tests of conditional independence to determine the significance of differences in the rates at which different sociodemographic groups experience travel burdens in each non-urban context versus the urban context. All results shown in Table 4 and Table 5 are statistically significant at $\alpha = 0.001$. These tables summarize the share of people in each group that experience each burden.

#### 4.2.1. Evaluation of unmet need

Looking first at disparities in unmet need for each population across contexts (Table 4), we see that in nearly all contexts groups with less advantage (people of color, no car access, and lower income) experience greater rates of unmet need relative to their more advantaged counterparts. However, disparities between all three groups are larger in small town and dispersed rural contexts than they are in urban contexts. This difference is driven by the relatively high rates of unmet need experienced by people with less advantage in rural contexts relative to urban contexts. In contrast, groups with more advantage living in rural contexts exhibit more similar rates of unmet need when compared to their urban counterparts. This points to the intersection of mobility challenges posed by sociodemographic disadvantage and rurality.

Disparities for those with limited or no access to a vehicle in particular stand out. People who live in small towns or dispersed areas that do not have car access are among the most likely to not travel due to a lack of transportation options, with 5 % and 5.6 %, respectively, of zero-car people who reside in a small town and dispersed contexts experiencing unmet need on a given day, respectively, an order of magnitude higher than the rate observed in urban areas (0.6 %) When compared to people with a car, the disparities observed are dramatic rural contexts, with carless people reporting unmet need at 5.6 % versus 0.2 % for those with a car in dispersed rural areas and 5.0 % versus 0.1 % in rural small towns. The deep divide in unmet need between those with and without cars in rural contexts likely reflects the heightened necessity of car ownership due to the infeasibility of using public transit, cyclist, and pedestrian infrastructure to get from place to place. Interestingly, similar challenges for people without access to a vehicle are present in suburban contexts, which may stem from similarities in the limited number of transportation options.

#### 4.2.2. Evaluation of financial burden

Differences in financial burden across contexts for populations with less advantage are present but are more modest for most disadvantaged populations, as shown in Table 5. The largest differences across contexts are observed for white and car-deficit populations in dispersed rural contexts, who each report financially burdensome travel nearly twice as often as their urban counterparts. Considering disparities for rural versus urban car-deficit households alongside high rates of unmet need for rural populations without cars, these findings suggest that rural populations may face a tradeoff between paying for a minimum level of vehicle access or face unmet transportation needs. It is also notable that households earning less than $35,000 a year in dispersed contexts exhibit similar rates of financial burden when compared with urban households with similar financial resources, while their counterparts in second city, suburban, and small towns exhibit a modestly lower prevalence of financial burden. This may stem from the relatively high costs of transportation in dispersed rural areas and the high cost of transportation combined with housing in urban areas.

Looking at sociodemographic disparities in financial burden within contexts, all contexts show consistent disparities for populations with less advantage (people of color, car-limited and carless, and low income populations),although disparities are again moderated in comparison to disparities observed in unmet need within each context. Racial and ethnic disparities in rural dispersed contexts are modestly smaller than

in urban contexts, largely because of higher rates of financial burden among the rural white population.

### 4.3. Differences in factors that relate to transportation burdens in rural vs urban contexts

The analysis above assesses differences in unmet need and financial burden across contexts and populations, establishing the prevalence of burdensome travel outcomes. This is important for quantifying disparate outcomes experienced by disadvantaged populations while including the confounding effects of multiple characteristics of the population. In this final step of analysis, we deepen our understanding of these relationships by accounting for multiple person and place characteristics to isolate the relationships between burdensome outcomes and contextual and sociodemographic factors.

To explore whether the factors that relate to travel burdens differ between rural and urban areas, we employ two binary logistic regression models. We focus on an analysis of unmet travel needs and financially burdensome travel nationwide, as well as for the five community contexts. It is important to note that with the methods employed in this analysis, we are not establishing causal relationships: we quantify the relationship between sociodemographic and built environment explanatory factors and financially burdensome travel and unmet need.

#### 4.3.1. Evaluation of unmet need

First, we quantify and compare the factors relating to unmet travel need (Table 6), with a focus on how these factors vary across contexts. Looking at the nationwide model, the odds ratios that represent Claritas community classifications are significantly greater than 1 for second city, suburban, and dispersed contexts relative to urban. This indicates that the people living in these contexts are more likely to experience unmet need than their urban counterparts when controlling for other person and household-level characteristics. The small-town coefficient is not significantly different from urban, indicating that unmet needs may be modestly mitigated by the access afforded by small towns. Car access is the most important predicter of unmet need in the nationwide model, followed by employment status and income. In general we observe higher rates of unmet need for people with less privilege (unemployed, no car access, low income, people of color, women).

We then break the data into five sub-models, each evaluating the factors that relate to unmet need in each context. Across most nonurban models, car access, employment, and income stand out as the most important predictors of whether a person experienced unmet travel needs. When controlling for other factors, people living in small towns and dispersed contexts without a car are 16 and 15 times more likely to not travel due to lack of options when compared with their car-fully equipped counterparts, respectively. In terms of income, people with limited financial resources (earning less than $35,000 annually) in suburban, small town, and dispersed contexts are more likely (4.7, 3.3, and 5.0 times, respectively) to have unmet need when compared to households with more financial resources in the same contexts. In small towns, higher access to jobs in the region is positively related to unmet need.

We also compare the confidence intervals of the odds ratios estimated across the five models to assess significant differences between predictors. This comparison can indicate factors that have relationships that are significantly different in different contexts where traditional modeling strategies (i.e. a nationwide model with context controls) can obscure deeper differences. We observe that the confidence interval for zero-car status in both rural models does not overlap with the confidence interval in the urban model. This indicates that the relationship between car access and unmet need is significantly greater in small town and dispersed contexts when compared with the urban context, likely due to differences in access in these contexts and the significantly greater need for a vehicle to meet travel needs.

We note that the observed occurrence of unmet need is relatively sparse, which has the potential to lead to inflated odds ratios in the logistic regression. Despite the large number of people surveyed, unmet need was observed just 23 times in the urban context and 68 to 94 times in the non-urban contexts evaluated, reflecting observed rates ranging from 0.2 % to 0.5 % (Table 4). Greenland et al. (2016) review situations in which sparse outcomes can cause biased estimates in logistic regression, including when models have events per variable (EPVs) that are less than 5 to 10, suggesting several statistical checks and remedies to address potential bias that may result.

Following the discussion in Greenland et al. (2016), we first evaluate

**Table 6**
Binary logistic regression models for unmet need on the travel day.

| | Nationwide | | | Urban | | | Second City | | | Suburban | | | Small Town | | | Dispersed | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Predictors* | *OR*[1] | *CI* | *p*[2] | *OR*[1] | *CI* | *p*[2] | *OR*[1] | *CI* | *p*[2] | *OR*[1] | *CI* | *p*[2] | *OR*[1] | *CI* | *p*[2] | *OR*[1] | *CI* | *p*[2] |
| (Intercept) | 0 | 0.00 – 0.00 | * | 0 | 0.00 – 7.84 | | 0 | 0.00 – 0.05 | * | 0 | 0.00 – 0.00 | * | 0 | 0.00 – 0.00 | * | 0 | 0.00 – 0.00 | * |
| Age (ref: 22 to 34 years) | | | | | | | | | | | | | | | | | | |
| 36 to 50 years | 1.08 | 0.66 – 1.77 | | 1.13 | 0.19 – 8.69 | | 1.15 | 0.47 – 2.97 | | 1.01 | 0.32 – 3.47 | | 1.17 | 0.43 – 3.46 | | 0.8 | 0.28 – 2.43 | |
| 51 to 60 years | 0.89 | 0.54 – 1.48 | | 1.96 | 0.41 – 14.03 | | 0.81 | 0.33 – 2.15 | | 1.07 | 0.32 – 3.82 | | 0.52 | 0.16 – 1.73 | | 0.85 | 0.31 – 2.62 | |
| 61 to 70 years | 0.9 | 0.55 – 1.49 | | 0.49 | 0.05 – 4.50 | | 0.82 | 0.34 – 2.14 | | 1.27 | 0.40 – 4.60 | | 1.04 | 0.37 – 3.27 | | 0.76 | 0.28 – 2.32 | |
| Older than 70 years | 1.3 | 0.81 – 2.14 | | 1.84 | 0.37 – 14.17 | | 1.27 | 0.55 – 3.28 | | 3.12 | 1.06 – 10.98 | | 1.32 | 0.48 – 4.18 | | 0.63 | 0.23 – 1.96 | |
| Children | 1.16 | 0.78 – 1.71 | | 1.81 | 0.43 – 6.52 | | 0.71 | 0.30 – 1.56 | | 2.7 | 1.06 – 6.64 | * | 1.07 | 0.45 – 2.45 | | 0.99 | 0.42 – 2.16 | |
| Multiple Adults | 1.33 | 1.02 – 1.73 | * | 0.67 | 0.22 – 1.82 | | 1.44 | 0.86 – 2.38 | | 0.83 | 0.43 – 1.55 | | 1.97 | 1.09 – 3.53 | * | 1.53 | 0.93 – 2.51 | |
| High School or Less | 1.18 | 0.93 – 1.51 | | 1.37 | 0.51 – 3.59 | | 1.05 | 0.66 – 1.68 | | 1.48 | 0.85 – 2.56 | | 1.18 | 0.68 – 2.06 | | 1.05 | 0.66 – 1.70 | |
| People of Color | 1.37 | 1.07 – 1.77 | * | 1.1 | 0.43 – 2.84 | | 1.28 | 0.80 – 2.02 | | 1.72 | 0.98 – 2.99 | | 1.63 | 0.91 – 2.85 | | 1.14 | 0.66 – 1.91 | |
| Female | 1.49 | 1.17 – 1.93 | * | 1.18 | 0.47 – 3.18 | | 1.49 | 0.93 – 2.43 | | 0.92 | 0.53 – 1.63 | | 1.76 | 1.00 – 3.23 | | 1.92 | 1.18 – 3.27 | * |
| Low Income (Less than $35,000) | 3.2 | 2.30 – 4.49 | * | 2.81 | 0.89 – 10.00 | | 1.66 | 0.89 – 3.19 | | 4.71 | 2.26 – 10.34 | * | 3.31 | 1.61 – 7.00 | * | 4.95 | 2.50 – 10.54 | * |
| Employed | 0.24 | 0.16 – 0.35 | * | 0.27 | 0.07 – 0.92 | * | 0.17 | 0.07 – 0.35 | * | 0.36 | 0.15 – 0.80 | * | 0.39 | 0.17 – 0.83 | * | 0.14 | 0.05 – 0.34 | * |
| No Car Access | 10.75 | 8.17 – 14.18 | * | 2.5 | 0.88 – 6.99 | | 11 | 6.43 – 19.33 | * | 8.22 | 4.55 – 15.02 | * | 16.31 | 8.75 – 31.07 | * | 15.28 | 9.05 – 25.98 | * |
| Log(Jobs within 45-min drive) | 1.08 | 0.97 – 1.21 | | 0.88 | 0.47 – 1.67 | | 0.95 | 0.76 – 1.18 | | 1.12 | 0.85 – 1.47 | | 1.43 | 1.11 – 1.84 | * | 1.04 | 0.86 – 1.26 | |
| Access to Transit | 0.74 | 0.54 – 1.00 | * | 1.06 | 0.21 – 19.34 | | 0.75 | 0.47 – 1.20 | | 0.74 | 0.43 – 1.28 | | 0.89 | 0.38 – 1.81 | | 0.66 | 0.11 – 2.25 | |
| Log(Population Density) | 0.98 | 0.96 – 1.00 | * | 0.99 | 0.97 – 1.01 | | 0.96 | 0.92 – 1.00 | | 1.01 | 0.94 – 1.05 | | 1 | 0.88 – 1.04 | | 0.9 | 0.56 – 1.06 | |
| Location (ref: Urban) | | | | | | | | | | | | | | | | | | |
| Second City | 2.1 | 1.23 – 3.70 | * | | | | | | | | | | | | | | | |
| Suburban | 2 | 1.14 – 3.64 | * | | | | | | | | | | | | | | | |
| Small-Town | 1.78 | 0.94 – 3.47 | | | | | | | | | | | | | | | | |
| Dispersed | 2.39 | 1.18 – 4.93 | * | | | | | | | | | | | | | | | |
| Observations | 124,233 | | | 15,165 | | | 25,040 | | | 27,644 | | | 27,878 | | | 28,506 | | |
| $R^2$ Tjur | 0.023 | | | 0.005 | | | 0.026 | | | 0.024 | | | 0.029 | | | 0.036 | | |

[a]The OR column contains the odds ratio calculated for each variable in the binary logistic regression model. Cells highlighted in red indicate populations that experience a higher rate of travel burden, while cells highlighted in blue indicate a lower rate of travel burdens.
[b]The CI column contains the confidence intervals calculated for each odds ratio at the $\alpha = 0.05$ threshold.
[c]The odds ratios denoted with an asterisk (*) in the p column are statistically significant at a threshold of $\alpha = 0.05$.

the EPV of the unmet need outcome. With 16 predictor variables in the binary logistic regression (Table 6), the EPV ranges from 1.4 in the urban context to 4 to 6 in the non-urban contexts evaluated, pointing to potential bias in the logistic regression, particularly in the urban model. As an initial check of whether logistic regression estimates are grossly inflated, we compare the population-specific odds ratios from the logistic regression to the corresponding simple odds estimated based on cross tabulations (Table 4). If an odds ratio from the logistic model is larger than the corresponding simple odds it would be inconsistent with our expectation that the relationship is likely to diminish when we control for other confounding factors, signaling inflated estimates (Greenland et al., 2016). For example, the odds ratio of people without vehicle access in small towns is relatively large at 16 (Table 6). However, this value is lower than the simple odds of 50 or 35 (estimated from Table 4 as the ratio of the incidence in carless versus car access households using the weighted and unweighted values, respectively). Similar comparisons for other populations and contexts from Table 4 indicate that the modeled odds ratios are similar or lower than the corresponding incidence ratios in each case (not shown), mitigating concerns about grossly inflated odds ratios in the logistic model.

As an additional check, we also repeat the analysis using Firth's bias-reduced logistic regression (Firth, 1993). If we observe important changes in these penalized estimates, it points to serious bias in the original unpenalized estimates (Greenland et al., 2016). The Firth-adjusted odds ratios and confidence intervals (not shown) do not differ substantively from the original logistic model in Table 6. The Firth model reflects the same significant variables, with similar odds ratios and confidence intervals for all significant estimates. Among the significant odds ratios, the largest percent difference observed was for employment in dispersed rural contexts (original odds ratio of 0.14 with confidence interval from 0.05 to 0.34, versus the Firth estimate of 0.16 with confidence interval from 0.06 to 0.36). The largest absolute difference observed was for no car access in dispersed rural contexts (original odds ratio of 15.28 with a confidence interval from 9.05 to 25.98, versus the Firth estimate of 14.77 with a confidence interval from 8.8 to 24.95). The consistency of the original and Firth logistic estimates indicates that any bias in the original unmet need logistic model is modest enough that it does not affect the interpretation of results, despite the relatively sparse outcome variable.

### 4.3.2. *Evaluation of financial burden*

Next, we assess whether the factors that relate to financially burdensome travel differ across contexts (Table 7). In the full nationwide model dispersed contexts are associated with higher levels of financial burden when compared with urban contexts, while second city and suburban contexts are associated with lower levels of financial burden and small town contexts do not differ significantly from urban. Similar to the findings for unmet need, this points to potential similarities in travel burdens across urban and small town contexts. Education level, race and ethnicity, and low income are all also substantively related to financially burdensome travel in the nationwide model.

As in the nationwide model, for financial burden models in all community contexts we observe that education, low income, and race and ethnicity are substantially related to financially burdensome travel, with more modest relationships observed for other factors. In most cases we observe the least privileged identities being the most likely to report experiencing financial burden from travel across models.

The car access predictor is not statistically significant in the dispersed model, although it is significant and positive in the small town model. This observation may reflect people who undertake the financial stressors of accessing one vehicle or costly alternatives to vehicle access in small towns, while those in dispersed contexts do not face higher costs

**Table 7**
Binary logistic regression models for whether travel is a financial burden.

| | Nationwide | | | Urban | | | Second City | | | Suburban | | | Small Town | | | Dispersed | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Predictors* | *OR*[1] | *CI* | *p*[2] | *OR*[1] | *CI* | *p*[2] | *OR*[1] | *CI* | *p*[2] | *OR*[1] | *CI* | *p*[2] | *OR*[1] | *CI* | *p*[2] | *OR*[1] | *CI* | *p*[2] |
| Intercept | 0.07 | 0.06 – 0.09 | * | 0.02 | 0.01 – 0.06 | * | 0.06 | 0.03 – 0.09 | * | 0.03 | 0.02 – 0.06 | * | 0.09 | 0.06 – 0.14 | * | 0.12 | 0.08 – 0.16 | * |
| Age (ref: 22 to 34 years) | | | | | | | | | | | | | | | | | | |
| 36 to 50 years | 1.3 | 1.17 – 1.35 | * | 1.2 | 0.98 – 1.38 | | 1.3 | 1.11 – 1.48 | * | 1.3 | 1.05 – 1.48 | * | 1.3 | 1.07 – 1.47 | * | 1.3 | 1.13 – 1.54 | * |
| 51 to 60 years | 1.2 | 1.09 – 1.26 | * | 1.1 | 0.90 – 1.29 | | 1.2 | 1.01 – 1.37 | * | 1.2 | 1.03 – 1.46 | * | 1.2 | 0.98 – 1.36 | | 1.2 | 1.02 – 1.41 | * |
| 61 to 70 years | 1.1 | 0.97 – 1.14 | | 1.1 | 0.87 – 1.30 | | 1.1 | 0.93 – 1.29 | | 1.0 | 0.85 – 1.23 | | 1.1 | 0.90 – 1.29 | | 1.0 | 0.85 – 1.20 | |
| Older than 70 years | 0.8 | 0.73 – 0.86 | * | 0.8 | 0.64 – 1.01 | | 0.8 | 0.63 – 0.91 | * | 0.7 | 0.59 – 0.90 | * | 0.8 | 0.70 – 1.01 | | 0.8 | 0.65 – 0.93 | * |
| Children | 1.2 | 1.09 – 1.22 | * | 1.3 | 1.10 – 1.49 | * | 1.3 | 1.14 – 1.46 | * | 1.1 | 0.95 – 1.25 | | 1.1 | 1.01 – 1.29 | * | 1.1 | 0.98 – 1.23 | |
| Multiple Adults | 1.0 | 0.98 – 1.08 | | 1.1 | 0.95 – 1.24 | | 1.0 | 0.87 – 1.07 | | 1.0 | 0.90 – 1.14 | | 1.1 | 0.95 – 1.16 | | 1.0 | 0.94 – 1.12 | |
| Education (ref: Bachelor's, graduate, or professional degree) | | | | | | | | | | | | | | | | | | |
| High School or Less | 1.9 | 1.78 – 1.99 | * | 1.8 | 1.52 – 2.12 | * | 1.8 | 1.61 – 2.08 | * | 1.8 | 1.54 – 2.08 | * | 1.8 | 1.62 – 2.06 | * | 2.0 | 1.81 – 2.23 | * |
| Some College | 1.6 | 1.55 – 1.71 | * | 1.5 | 1.29 – 1.71 | * | 1.7 | 1.52 – 1.90 | * | 1.5 | 1.33 – 1.70 | * | 1.6 | 1.45 – 1.79 | * | 1.8 | 1.58 – 1.93 | * |
| Race (ref: Non-Hispanic White) | | | | | | | | | | | | | | | | | | |
| Non-Hispanic Black | 1.7 | 1.62 – 1.85 | * | 2.1 | 1.78 – 2.50 | * | 1.7 | 1.47 – 1.91 | * | 1.8 | 1.57 – 2.15 | * | 1.6 | 1.37 – 1.84 | * | 1.6 | 1.34 – 1.81 | * |
| Hispanic | 1.7 | 1.58 – 1.82 | * | 1.9 | 1.62 – 2.22 | * | 1.6 | 1.41 – 1.88 | * | 1.7 | 1.43 – 2.02 | * | 1.7 | 1.43 – 2.02 | * | 1.6 | 1.30 – 1.92 | * |
| Multiple or Other Race | 1.9 | 1.79 – 2.07 | * | 1.9 | 1.55 – 2.19 | * | 1.8 | 1.53 – 2.11 | * | 2.1 | 1.78 – 2.52 | * | 2.2 | 1.85 – 2.60 | * | 1.6 | 1.36 – 1.92 | * |
| Female | 1.0 | 0.99 – 1.07 | | 1.1 | 0.97 – 1.22 | | 1.0 | 0.89 – 1.07 | | 1.1 | 0.95 – 1.17 | | 1.0 | 0.90 – 1.07 | | 1.1 | 1.01 – 1.17 | * |
| Born outside of USA | 1.2 | 1.12 – 1.29 | * | 1.4 | 1.18 – 1.57 | * | 1.3 | 1.13 – 1.52 | * | 1.1 | 0.96 – 1.32 | | 1.1 | 0.89 – 1.27 | | 0.7 | 0.57 – 0.93 | * |
| Household Income (ref: >$75,000) | | | | | | | | | | | | | | | | | | |
| $35,000 to $74,999 | 1.6 | 1.48 – 1.66 | * | 1.7 | 1.45 – 2.00 | * | 1.6 | 1.36 – 1.79 | * | 1.5 | 1.34 – 1.76 | * | 1.5 | 1.37 – 1.74 | * | 1.5 | 1.37 – 1.70 | * |
| Less than $35,000 | 2.7 | 2.56 – 2.90 | * | 2.6 | 2.23 – 3.13 | * | 2.6 | 2.27 – 3.02 | * | 2.8 | 2.38 – 3.22 | * | 2.9 | 2.51 – 3.27 | * | 2.7 | 2.36 – 2.98 | * |
| Employed | 0.9 | 0.83 – 0.91 | * | 0.9 | 0.81 – 1.06 | | 0.8 | 0.75 – 0.93 | * | 0.9 | 0.77 – 0.98 | * | 0.9 | 0.81 – 1.00 | * | 0.8 | 0.77 – 0.92 | * |
| Car Access (ref: Car-Fully Equipped) | | | | | | | | | | | | | | | | | | |
| Car-deficit | 1.2 | 1.08 – 1.25 | * | 1.1 | 0.87 – 1.29 | | 1.2 | 0.97 – 1.35 | | 1.1 | 0.94 – 1.37 | | 1.2 | 1.05 – 1.44 | * | 1.1 | 0.96 – 1.30 | |
| Zero-car | 1.2 | 1.08 – 1.27 | * | 1.1 | 0.93 – 1.33 | | 1.2 | 1.00 – 1.38 | * | 1.2 | 0.92 – 1.48 | | 1.4 | 1.12 – 1.64 | * | 1.1 | 0.89 – 1.33 | |
| Log(Jobs within 45-min drive) | 0.9 | 0.92 – 0.95 | * | 1.0 | 0.94 – 1.10 | | 1.0 | 0.91 – 0.99 | * | 1.0 | 0.94 – 1.04 | | 0.9 | 0.88 – 0.96 | * | 0.9 | 0.88 – 0.93 | * |
| Transit Used | 1.1 | 1.05 – 1.20 | * | 1.1 | 1.00 – 1.31 | | 1.1 | 1.00 – 1.31 | | 1.5 | 1.21 – 1.90 | * | 1.0 | 0.80 – 1.14 | | 1.0 | 0.81 – 1.20 | |
| Log(Population Density) | 1.0 | 1.00 – 1.00 | * | 1.0 | 1.00 – 1.00 | * | 1.0 | 1.00 – 1.01 | | 1.0 | 1.00 – 1.02 | | 1.0 | 0.98 – 1.01 | | 1.0 | 0.98 – 1.04 | |
| Location (ref: Urban) | | | | | | | | | | | | | | | | | | |
| Second City | 0.9 | 0.84 – 0.98 | * | | | | | | | | | | | | | | | |
| Suburban | 0.9 | 0.82 – 0.96 | * | | | | | | | | | | | | | | | |
| Rural: Small-Town | 1.0 | 0.95 – 1.13 | | | | | | | | | | | | | | | | |
| Rural: Dispersed | 1.2 | 1.09 – 1.34 | * | | | | | | | | | | | | | | | |
| Observations | 121,106 | | | 14,762 | | | 24,392 | | | 24,991 | | | 27,216 | | | 27,668 | | |
| $R^2$ Tjur | 0.052 | | | 0.063 | | | 0.050 | | | 0.041 | | | 0.048 | | | 0.048 | | |

[a]The OR column contains the odds ratio calculated for each variable in the binary logistic regression model. Cells highlighted in red indicate populations that experience a higher rate of travel burden, while cells highlighted in blue indicate a lower rate of travel burdens.
[b]The CI column contains the confidence intervals calculated for each odds ratio at the $\alpha = 0.05$ threshold.
[c]The odds ratios denoted with an asterisk (*) in the p column are statistically significant at a threshold of $\alpha = 0.05$.

than their peers with vehicle access. Coupled with the highly elevated levels of unmet need for those with limited vehicle access in both small town and dispersed rural contexts, this points to a potential tradeoff in rural areas. Rural households may either undertake the financial burden of getting a car to meet mobility needs, or forego vehicle access while paying for alternatives or failing to meet their mobility needs.

We can also examine differences in the relationship between financially burdensome travel and travel behavior and built environment measures across contexts. Access to jobs in the region is inversely related to financial burden in second city, small town, and dispersed contexts, while use of transit is related to financial burden in suburban areas and population density is related to financial burden in urban areas.

Finally we examine confidence intervals that do not overlap to assess differences in the relationships observed across models. Notably, jobs reachable in 45 min by car is more negatively related to financial burden in dispersed contexts than in urban contexts, which may reflect the role that living in a more developed region may play in mitigating rural travel costs. Country of origin (born outside the US) is significantly different across urban and dispersed rural contexts, with a positive relationship with financial burden in urban areas and a negative relationship in dispersed rural contexts. This may relate to the number and variety of jobs available in these contexts and how and where people of different education and resource levels choose to locate.

## 5. Discussion and conclusions

Our findings deepen our understanding of travel burdens in rural contexts. Overall, we find that there are important differences between rural and nonrural areas in terms of unmet travel needs, the relationship between vehicle access and mobility, and the financial and mobility tradeoffs that people face.

People living in dispersed rural areas report higher rates of travel burdens, including both unmet travel need and financially burdensome travel, when compared with residents of urban contexts. This is the case when comparing across groups as well as when we control for potentially confounding personal and built environment factors. Notably, dispersed rural contexts are unique in that they exhibit this combination of higher rates of financial burden and unmet need relative to urban contexts – no other context exhibits this combination of factors. People living in rural small towns exhibit some of the burdens that those living in dispersed rural areas face, although they are also more similar to urban areas in terms of exhibiting mitigated burdens in some cases. This may indicate that the access afforded by rural small towns is tied to better mobility outcomes in those communities than in more dispersed rural communities. Prior work also shows that the clustered density of small towns facilitates social connections and the ability to get a ride (Lovejoy and Handy, 2011).

More granular group comparisons across all community types demonstrate that specific populations more commonly experience unmet travel needs (people of color, those with low income, and those without vehicle access), and that most of the disparities observed are more pronounced in rural areas when compared with urban areas. Those with limited or no vehicle access see the greatest disparities in unmet need. Disparities in financially burdensome travel are more modest, with dispersed contexts exhibiting similar or slightly smaller disparities relative to nonrural contexts.

When we evaluate the factors that lead to unmet travel needs using multivariable modeling, we observe that car access is one of the strongest predictors of unmet travel need. This is consistent with a 2023 nationwide study that uses NHTS and ACS data to deduce that 91 % of all trips in rural areas, and 83 % of all trips in non-rural areas were made by car (Wang et al., 2023). The remaining trips were made using transit, biking, or walking. Compared to their car-fully equipped peers, rural carless residents are 15 to 16 times more likely to make no trips on a given day due to a lack of transportation options when controlling for other factors. These relationships are similar in dispersed and small town contexts. In contrast, when controlling for other factors, car access is not a significant predictor of unmet need in urban areas.

In terms of financially burdensome travel, our multivariable modeling indicates that education, race and ethnicity, and income are important predictors, consistent with prior research evaluating primarily urban contexts (Currie et al., 2009; Currie and Delbosc, 2011). When we control for other factors, we observe that populations that typically exhibit privilege are associated with lower rates of financially burdensome travel in most cases. Vehicle access was not found to be related to financially burdensome travel in dispersed rural contexts, although a lack of vehicle access is related to greater financial burdens in small towns. This finding is interesting considering that prior research has shown that carless households earn substantially less annually than both car-deficit and car-fully equipped households on average (Wang et al., 2023). In conjunction with the higher rate at which carless people experience unmet need in both dispersed and small town contexts, this may point to both the necessity and the financial challenge of vehicle access and its alternatives in small town contexts. Rural households may either undertake the financial burden of getting a car to meet mobility needs, or forego vehicle access while paying for alternatives or failing to meet their mobility needs. Interestingly, small towns exhibit similarities to urban contexts in nationwide models of both unmet need and financial burden, again pointing to the potential mitigation of travel burdens that small town access may provide.

Collectively, our findings indicate that living in dispersed rural communities is related to higher rates of unmet need and financially burdensome travel when compared with urban areas, even when controlling for other characteristics. One of our central findings is that car access is highly related to the likelihood that people experience unmet need across contexts, and in particular in dispersed and small town contexts. This expands upon prior work focused on the determinants and impacts of car access (Blumenberg et al., 2020; Blumenberg and Pierce, 2012; Mattioli, 2014, 2021). Blumenberg's work on the spectrum of car access (zero-car, car-deficit, car-fully equipped) addresses the activity gaps between levels of motorization (activity increases with car access) and the determinants of car access (Blumenberg et al., 2020). Our findings also emphasize the activity gaps between levels of car access by looking not at trip rates but at whether people are able to travel when they need to. In other words, while prior research primarily focuses on reduced activity for people with limited resources (Blumenberg et al., 2020; Kamruzzaman and Hine, 2012; Mattioli, 2014, 2021), our work provides an important addition to this body of research by operationalizing unmet need by selecting people who did not travel at all on the survey date because they do not have adequate transport options to travel where they want or need to go.

Our findings also build upon the concept of “forced car ownership” that Blumenberg, Klein, Mattioli, and other scholars have brought forth (Blumenberg et al., 2020; Blumenberg and Agrawal, 2014; Blumenberg and Pierce, 2012; Klein and Smart, 2017; Mattioli, 2014). Specifically, our findings suggest that vehicles are a key to mobility in rural areas, and that a lack of vehicle access can pose a travel cost burden in some contexts. In small towns, while people without vehicle access experience much higher rates of unmet need than their peers with vehicle access, they are also more likely to report financially burdensome travel. In dispersed contexts unmet needs are strongly tied to vehicle access, but financially burdensome travel is not. These findings point to rural populations faced with tradeoffs between paying high costs to access a vehicle, paying high costs for alternative travel options, and not meeting mobility needs. This supports prior literature that posits that people who live in rural areas are forced to own a car to meet basic mobility needs (Blumenberg et al., 2020; Blumenberg and Agrawal, 2014; Blumenberg and Pierce, 2012; Klein and Smart, 2017; Mattioli, 2014). This relates to a lack of non-auto transportation options and greater vehicle reliance, as rural populations make fewer trips by transit, biking, or walking (Wang et al., 2023).

Finally, we find that there is important variation in outcomes across

rural contexts. Small towns differ from dispersed contexts in that they exhibit similarities to urban areas in terms both unmet need and financially burdensome travel, suggesting that even the micro-scale density of small towns may play a role in alleviating financial burdens and unmet need for many people living in these areas.

While these findings provide critical insight into the extent to which different populations experience financially burdensome travel and unmet need, there are several limitations to this work. This analysis establishes the prevalence of these burdensome outcomes experienced in different types of places and among specific populations (RQ1 and RQ2), and it also isolates the factors that relate to these outcomes (RQ3). However, it does not establish the causal mechanisms that lead to burdensome outcomes, so it does not provide an indication of how changes to a place or a person will change their outcomes.

Additionally, the population sampled in the NHTS underrepresents some racial and ethnic minorities, immigrants, people with limited phone or internet access, and those without a permanent home address. While the NHTS provides sample weights based on US Census data to correct for some of these issues, it is possible that unmeasured (and unweighted) characteristics affect our analysis. We also acknowledge that the definition of rural and nonrural that we use in this analysis greatly simplifies the rich heterogeneity of rural landscapes. Rural community landscapes do not fit neatly into binary categories, or even a spectrum from urban to rural.

There are also notable limitations to our measure of unmet need. While our metric provides a more direct measure of unmet need than activity gaps, it only classifies respondents as having unmet need if they did not travel at all on the surveyed travel day due to lack of transportation options. This observation window is relatively brief and likely underestimates unmet need in two ways; first by omitting those who traveled but did so less than needed on a given day, and second by omitting those who experience unmet travel need over longer time periods. Because we observe unmet need relatively infrequently using this measure, we take care with our interpretation of differences. Overall, unmet need on a given day in the United States exhibits clear differences between urban and rural contexts and populations, particularly for those with and without vehicle access in rural contexts. Although the form of unmet need measured in the NHTS dataset is relatively uncommon for many populations, it is impactful when it does occur.

In terms of our multivariable models of unmet need, all models yielded relatively low $R^2$ values. This may be because the survey instrument's measure of unmet need on a single travel day is an infrequent occurrence that is difficult to predict with the explanatory factors present in this dataset. However, most of the models shown show relationships that we might expect based on prior literature. The urban model, which has the lowest prevalence of observations of unmet need, is particularly limited in explanatory power with both a low $R^2$ value and wide confidence intervals for most odds ratio estimates, resulting in only one significant predictor. However the urban model serves as an important reference point for this rural-focused inquiry and even with the wide range of its confidence intervals we observed differences in the relationship between unmet need and zero-car status when comparing it to rural contexts. Future analysis of survey instruments that evaluate unmet need over longer periods may yield models with more precision and greater explanatory power.

Overall our findings also point to the importance of additional research on rural mobility solutions to address unmet need in rural communities, particularly for those without a vehicle in rural contexts. Ultimately, a deeper understanding of rural transportation experiences and outcomes and their drivers are needed to design policies and programs to address rural travel burdens.

Our findings suggest that vehicle access and the type of rural context are likely to important factors to consider when assessing and addressing unmet needs. While urban solutions often focus on expanding non-auto options, our results suggest that in rural contexts vehicle access may be fundamental to meeting ones mobility needs. Programs that enhance affordable rural vehicle access, for example by supporting vehicle maintenance, providing car-share and/or ride-share opportunities, or expanding demand responsive transit services may increase mobility while mitigating the costs of car ownership. Additionally, living in a small town with a small concentration of services and opportunities may facilitate greater accessibility than living in a more dispersed rural context. This may point to a role for supporting affordable housing and economic development in small town centers as a potential means to reduce rural travel burdens. This micro-density may also increase the viability of alternatives to personal vehicle travel, including walking and bicycling to destinations, rural transit services, formal and informal ride and car-share opportunities.

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Not applicable.

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## CRediT authorship contribution statement

**Sierra Espeland:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Dana Rowangould:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

## Declaration of competing interest

The authors declare no competing interests.

## Data availability

The publicly available data and materials used in the study are available for download at the following link: https://nhts.ornl.gov/. Detailed spatial information for the NHTS survey can be requested from FHWA.

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## References

Allen, J., Farber, S., 2020. Planning transport for social inclusion: an accessibility-activity participation approach. Transp. Res. Part D: Transp. Environ. 78, 102212. https://doi.org/10.1016/j.trd.2019.102212.

Bantis, T., Haworth, J., 2020. Assessing transport related social exclusion using a capabilities approach to accessibility framework: a dynamic Bayesian network approach. J. Transp. Geogr. 84, 102673. https://doi.org/10.1016/j.jtrangeo.2020.102673.

Blumenberg, E., Agrawal, A.W., 2014. Getting around when you're just getting by: transportation survival strategies of the poor. J. Poverty 18 (4), 355–378. https://doi.org/10.1080/10875549.2014.951905.

Blumenberg, E., Pierce, G., 2012. Automobile ownership and travel by the poor: evidence from the 2009 National Household Travel Survey. Transport. Res. Rec.: J. Transport. Res. Board 2320 (1), 28–36. https://doi.org/10.3141/2320-04.

Blumenberg, E., Brown, A., Schouten, A., 2020. Car-deficit households: determinants and implications for household travel in the U.S. Transportation 47 (3), 1103–1125. https://doi.org/10.1007/s11116-018-9956-6.
Brown, A.E., 2017. Car-less or car-free? Socioeconomic and mobility differences among zero-car households. Transp. Policy 60, 152–159. https://doi.org/10.1016/j.tranpol.2017.09.016.
Bureau of Transportation Statistics, 2022. Transportation Economic Trends | Bureau of Transportation Statistics. https://www.bts.gov/product/transportation-economic-trends.
Coren, C., Lowe, K., Barajas, J.M., 2022. Commuting carless: a qualitative study of transportation challenges for disadvantaged job seekers in Chicago, IL. Transp. Res. Rec. 2676 (6), 673–684. https://doi.org/10.1177/03611981221076126.
Currie, G., Delbosc, A., 2011. Transport disadvantage: A review. In: Currie, G. (Ed.), New Perspectives and Methods in Transport and Social Exclusion Research. Emerald Group Publishing Limited, pp. 15–25. https://doi.org/10.1108/9781780522012-002.
Cutsinger, J., Galster, G., 2006. There is no sprawl syndrome: a new typology of metropolitan land use patterns. Urban Geogr. 27 (3), 228–252. https://doi.org/10.2747/0272-3638.27.3.228.
Delbosc, A., Currie, G., 2011. The spatial context of transport disadvantage, social exclusion and well-being. J. Transp. Geogr. 19 (6), 1130–1137. https://doi.org/10.1016/j.jtrangeo.2011.04.005.
EPA, 2018. Smart Location Database Technical Documentation and User Guide Version 3.0. 55.
Esekhaigbe, E.O., Bills, T., 2021. Examining the Travel Behavior of Transport Disadvantaged Communities Using the 2017 National Household Travel Survey (TRBAM-21-04202). Article TRBAM-21-04202. Transportation Research Board 100th Annual Meeting. https://trid.trb.org/view/1759374.
FHWA, 2018. National Household Travel Survey (NHTS)—Policy | Federal Highway Administration. https://www.fhwa.dot.gov/policyinformation/nhts.cfm.
Firth, D., 1993. Bias reduction of maximum likelihood estimates. Biometrika 80 (1), 27–38. https://doi.org/10.2307/2336755.
Gray, D., 2004. Rural transport and social exclusion: developing a rural transport typology. Built Environ. 30 (2), 172–181. https://doi.org/10.2148/benv.30.2.172.54310.
Greenland, S., Mansournia, M.A., Altman, D.G., 2016. Sparse data bias: a problem hiding in plain sight. *BMJ*. Br. Med. J. 352. https://www.jstor.org/stable/26942221.
Handy, S., 2020. Is accessibility an idea whose time has finally come? Transp. Res. Part D: Transp. Environ. 83. https://trid.trb.org/view/1696897.
Handy, S.L., Niemeier, D., 1997. Measuring accessibility: an exploration of issues and alternatives. Nviron. Plan. A 29 (7), 1175–1194. https://doi.org/10.1068/a291175.
Heinze, G., Ploner, M., Dunkler, D., Southworth, H., Jiricka, L., Steiner, G., 2023. logistf: Firth's Bias-Reduced Logistic Regression (Version 1.26.0) [Computer software]. https://cran.r-project.org/web/packages/logistf/index.html.
Hoggart, K., 1990. Let's do away with rural. J. Rural. Stud. 6 (3), 245–257. https://doi.org/10.1016/0743-0167(90)90079-N.
Kamruzzaman, Md., Hine, J., 2012. Analysis of rural activity spaces and transport disadvantage using a multi-method approach. Transp. Policy 19 (1), 105–120. https://doi.org/10.1016/j.tranpol.2011.09.007.
Klein, N.J., Smart, M.J., 2017. Car today, gone tomorrow: the ephemeral car in low-income, immigrant and minority families. Transportation 44 (3), 495–510. https://doi.org/10.1007/s11116-015-9664-4.
Kolodinsky, J.M., DeSisto, T.P., Propen, D., Putnam, M.E., Roche, E., Sawyer, W.R., 2013. It is not how far you go, it is whether you can get there: modeling the effects of mobility on quality of life in rural New England. J. Transp. Geogr. 31, 113–122. https://doi.org/10.1016/j.jtrangeo.2013.05.011.
Lovejoy, K., Handy, S., 2011. Social networks as a source of private-vehicle transportation: the practice of getting rides and borrowing vehicles among Mexican immigrants in California. Transp. Res. A Policy Pract. 45 (4), 248–257. https://doi.org/10.1016/j.tra.2011.01.007.
Lucas, K., 2012. Transport and social exclusion: where are we now? Transp. Policy 20, 105–113. https://doi.org/10.1016/j.tranpol.2012.01.013.
Lucas, K., Jones, P., 2012. Social impacts and equity issues in transport: an introduction. J. Transp. Geogr. 21, 1–3. https://doi.org/10.1016/j.jtrangeo.2012.01.032.
Mattioli, G., 2014. Where sustainable transport and social exclusion meet: households without cars and car dependence in Great Britain. J. Environ. Policy Plan. 16 (3), 379–400. https://doi.org/10.1080/1523908X.2013.858592.
Mattioli, G., 2021. Transport-related Inequalities in the Sustainable Transition Debate, p. 17.
McAndrews, C., Tabatabaie, S., Litt, J.S., 2018. Motivations and strategies for bicycle planning in rural, suburban, and low-density communities: the need for new best practices. J. Am. Plan. Assoc. 84 (2), 99–111. https://doi.org/10.1080/01944363.2018.1438849.
Millward, H., Spinney, J., 2011. Time use, travel behavior, and the rural–urban continuum: results from the Halifax STAR project. J. Transp. Geogr. 19 (1), 51–58. https://doi.org/10.1016/j.jtrangeo.2009.12.005.
Palm, M., Nakshi, P., Yousefzadeh Barri, E., Farber, S., Widener, M., 2023. Uncovering Suppressed Travel: A Scoping Review of Surveys Measuring Unmet Transportation Need. https://doi.org/10.1016/j.tbs.2024.100784.
Preston, J., Rajé, F., 2007. Accessibility, mobility and transport-related social exclusion. J. Transp. Geogr. 15 (3), 151–160. https://doi.org/10.1016/j.jtrangeo.2006.05.002.
Pucher, J., Renne, J.L., 2005. Rural mobility and mode choice: evidence from the 2001 National Household Travel Survey. Transportation 32 (2), 165–186. https://doi.org/10.1007/s11116-004-5508-3.
Smith, N., Hirsch, D., Davis, A., 2012. Accessibility and capability: the minimum transport needs and costs of rural households. J. Transp. Geogr. 21, 93–101. https://doi.org/10.1016/j.jtrangeo.2012.01.004.
Voulgaris, C.T., Taylor, B.D., Blumenberg, E., Brown, A., Ralph, K., 2016. Synergistic neighborhood relationships with travel behavior: an analysis of travel in 30,000 US neighborhoods. J. Transp. Land Use 10 (1). https://doi.org/10.5198/jtlu.2016.840.
Wang, W., Espeland, S., Barajas, J.M., Rowangould, D., 2023. Rural–nonrural divide in car access and unmet travel need in the United States. Transportation. https://doi.org/10.1007/s11116-023-10429-6.
Weber, B., Jensen, L., Miller, K., Mosley, J., Fisher, M., 2005. A critical review of rural poverty literature: is there truly a rural effect? Int. Reg. Sci. Rev. 28 (4), 381–414. https://doi.org/10.1177/0160017605278996.
van Wee, B., Geurs, K.T., 2004. Accessibility evaluation of land-use and transport strategies: review and research directions. J. Transp. Geogr. 12 (2), 127–140. https://doi.org/10.1016/j.jtrangeo.2003.10.005.
Zamar, D., Graham, J., McNeney, B., 2021. elrm: Exact Logistic Regression via MCMC (Version 1.2.5) [Computer software]. https://cran.r-project.org/web/packages/elrm/index.html.