

A Tale of Two Perspectives: The Mileage-based User Fee Conundrum

Hyunjun Hwang

The University of Texas at Austin
Department of Civil, Architectural and Environmental Engineering
301 E. Dean Keeton St. Stop C1761, Austin TX 78712, USA
Email: hjhwang@utexas.edu

Irfan Batur

Arizona State University
School of Sustainable Engineering and the Built Environment
660 S. College Avenue, Tempe, AZ 85287-3005, USA
Email: ibatur@asu.edu

Dale Robbennolt

The University of Texas at Austin
Department of Civil, Architectural and Environmental Engineering
301 E. Dean Keeton St. Stop C1761, Austin TX 78712, USA
Email: dar4836@utexas.edu

Angela J. Haddad

The University of Texas at Austin
Department of Civil, Architectural and Environmental Engineering
301 E. Dean Keeton St. Stop C1761, Austin TX 78712, USA
Email: angela.haddad@utexas.edu

Miguel G. Rodriguez Ocana

Arizona State University
School of Sustainable Engineering and the Built Environment
660 S. College Avenue, Tempe, AZ 85287-3005, USA
Email: mgrodr15@asu.edu

Ram M. Pendyala

Arizona State University
School of Sustainable Engineering and the Built Environment
660 S. College Avenue, Tempe, AZ 85287-3005, USA
Email: ram.pendyala@asu.edu

Chandra R. Bhat (corresponding author)

The University of Texas at Austin
Department of Civil, Architectural and Environmental Engineering
301 E. Dean Keeton St. Stop C1761, Austin TX 78712, USA
Email: bhat@mail.utexas.edu

ABSTRACT

The limitations of the current transportation funding system based on federal and state gas taxes have resulted in steep shortfalls in the Highway Trust Fund in the U.S., especially given the growing adoption of high fuel-efficient gasoline vehicles and electric vehicles. While the notion of mileage-based user fees (MBUF) has received attention as an alternative to the current gas tax, public support for MBUF is still low. In this study, we unravel the potential reasons for such low public support by examining the perceived fairness of the MBUF system through the conceptualization of fairness from two perspectives: fairness based on the perspective that everyone pays equally for using the infrastructure, and fairness based on the perspective that those who do not adopt more fuel-efficient vehicles should not be unduly disadvantaged. Using a bivariate ordered model with attitudinal variables, and employing data from the first wave of the Transportation Heartbeat of America (THA) Survey conducted from October 2024 through January 2025, the effects of socio-economic, demographic, and attitudinal factors on each of the two perspectives of MBUF fairness are examined. The findings suggest substantial heterogeneity in fairness perceptions based on these factors, as well as based on the specific perspective of fairness considered, underscoring the importance of crafting MBUF-based policies with care and sensitivity to different groups of individuals to garner broad support.

Keywords: mileage-based user fee, pricing policy fairness, mobility management, multivariate econometric model, individual attitudes, transportation funding

1. INTRODUCTION

The construction and maintenance of the transportation system in the U.S. is highly dependent on revenue collected through the gas (fuel) tax. For a long time, the increase in vehicle miles of travel (VMT) and the complete reliance on fossil fuel based vehicular technology meant that the total fuel consumption – and hence gas tax collections – increased consistently, thus providing sufficient funds to construct and maintain a relatively young transportation infrastructure system. More recently, however, there has been a fundamental shift in travel demand and vehicle fleet composition that has motivated a renewed look at alternative funding mechanisms to address the nation's transportation needs. Total gasoline consumption peaked in 2018 and has not increased since then (U.S. Energy Information Administration, 2024). There are two key reasons (among others) for this phenomenon. First, the total travel demand, as measured by vehicle miles of travel (VMT), has largely remained flat over the past several years (with a considerable dip during COVID years). Second, the vehicle fleet has become increasingly fuel efficient and electrified, thus further contributing to a suppression of gasoline consumption in the United States. These dual forces, acting together, have contributed to shortfalls in the Highway Trust Fund and necessitated transfers from the General Fund at the federal level to ensure that spending obligations could be met (Kile, 2021; Delucchi, 2007). In addition, over the last dozen years, 31 states have raised or reformed their gas taxes to help reverse losses in gas tax purchasing power caused by rising construction and maintenance costs and improvements in vehicle fuel efficiency (Institute on Taxation and Economic Policy, 2019). A number of these states have abandoned the use of a flat gas tax rate in favor of an inflation indexed gas tax, thus allowing them to raise sustainable gas tax revenues well into the future.

Concerns about the future solvency of the Highway Trust Fund and the reluctance to raise the gas tax at both the federal level and in many states (not to mention the potential futility of such a strategy in the wake of increased market penetration of hybrid and electric vehicles) have motivated the exploration of alternative funding mechanisms for the nation's transportation system (e.g., Jenn et al. 2015). Electric vehicles (EVs) tend to be heavier and generate higher torque on their wheels, which can damage roads more than their internal combustion engine (ICE) counterparts (Mattinzioli et al., 2023) and pay no conventional fuel taxes. In light of these developments, a strategy that has received considerable attention is that of a mileage-based user fee (MBUF), where drivers pay a per-mile fee rather than a gas tax. This revenue generation mechanism has been recommended as an alternative to motor fuel taxes by two national commissions of the U.S. Congress (National Surface Transportation Infrastructure Financing Commission, 2009; U.S. House Committee on Transportation and Infrastructure, 2008).

Although MBUF schemes are being considered and tested on an experimental basis in a few areas, the widespread implementation and adoption of such a revenue mechanism has been stymied by various factors. In general, it has been difficult to garner widespread public support for MBUF, with recent surveys showing support levels below 50 percent (Agrawal and Nixon, 2024). Nelson and Rowangould (2024a) identify four reasons for public opposition to MBUF. These include a perceived increase in personal cost, distrust for how the funds will be used, concerns about privacy and mileage detection/monitoring technology, and questions about their fairness.

While all four reasons need to be addressed for MBUFs to gain popular support and traction, the one about fairness is particularly intriguing and important as it relates directly to the values that people hold dear (Jakobsson et al., 2000). Unless a policy can appeal to the values that are important to people, it will be met with considerable resistance and become difficult to implement (Chen and Wang, 2025; Holguín-Veras et al., 2020). Public perceptions on the fairness of MBUF

present a conundrum. MBUF may be viewed as fair and appropriate because all users pay the same per-mile fee *for using the infrastructure*, regardless of the type of vehicle that they are driving. On the other hand, the fee may be viewed as unfair because it does not suitably reward drivers who have adopted the use of fuel-efficient, hybrid, or electric vehicles (National Academies of Sciences, Engineering, and Medicine, 2016). If a gas-guzzling sport utility vehicle (SUV) or pickup truck is paying exactly the same fee as a compact hybrid or electric vehicle, then there is no mechanism in place to reward the adoption of more sustainable vehicular technologies that protect the environment and reduce greenhouse gas emissions. Because of these dueling considerations, the same person may feel conflicted when it comes to assessing the appropriateness of a MBUF and deciding whether to support such a revenue generating strategy. In addition to the sustainability dimension, people may also have concerns about the differential implications of a MBUF policy by income level, place of residence (rural), or other transportation disadvantaged groups (these groups can no longer mitigate transportation costs by adopting smaller fuel-efficient or hybrid vehicles, as they pay the same per-mile fee regardless of vehicle type). While it is theoretically possible to vary MBUF schemes by vehicle class, vehicle size, vehicle fuel type, time and location of infrastructure use (charge more in congested times and locations), and so on, the implementation of such differential pricing schemes is quite complicated and may necessitate the use of rather intrusive monitoring technologies. As such, only the case of a constant (non-varying) MBUF structure is the subject of this study.

Because of the conflicting considerations presented in the previous paragraph, it is not appropriate to view the public perception of MBUF fairness in general terms. Context and basis matter. To fully appreciate public perceptions of the fairness of MBUF, a multitude of dimensions need to be considered, and the concept needs to be studied through the prism of multiple lenses reflecting opinions based on different values. This approach would render it possible to identify the specific aspects of the MBUF system that raise concerns for different groups of people; such insights would be valuable in implementing pricing schemes and messaging campaigns that address concerns from multiple perspectives.

A number of earlier studies have explored the implications of MBUFs in lieu of gas taxes. When comparing MBUF to the current fuel tax system in terms of income-based fairness, research findings on regressivity present conflicting claims. Some studies argue that it is more regressive (Knittel et al., 2025; Rahman et al., 2025; Park, 2022), others contend that it is less regressive (Metcalf, 2023; Paz et al., 2014; Weatherford, 2011), and at least one study indicates that there is no significant difference in the regressive nature of the tax (Burris et al., 2013). For the most part, however, research to date suggests that the difference in income distribution effects between the two systems (gas tax vs MBUF) is not particularly substantial. In terms of regional disparities, studies have shown that MBUF tends to be less favorable to urban residents because rural residents tend to drive larger SUVs and pickup trucks, but would pay the same per-mile fee as urban residents driving more efficient vehicles under a MBUF scheme (Eastern Transportation Coalition, 2019; Nelson and Rowangould, 2024b). To address these issues, some have proposed applying MBUFs with differentiated rates based on household income (Yang et al., 2016) or vehicle type (Eastern Transportation Coalition, 2019).

Studies of perceptions and public support for MBUF show that, while people are generally willing to pay more for transportation infrastructure investments, their support for MBUF schemes is quite low, with some improvement to a 40 percent level of support when the MBUF is presented as a replacement for the gas tax (Agrawal and Nixon, 2024). Support, as expected, is particularly higher among younger populations, non-drivers, and public transport users. Nelson and

Rowangould, (2024a) conducted an experiment where they assessed public support for MBUFs over multiple phases of a survey with an educational component introduced between survey waves. The results showed significant opinion shifts after each educational session, with perceptions of policy fairness being the most influential factor in shaping support levels. Thus, it is clear that perceptions of fairness are critical to garnering support for a MBUF scheme.

This study aims to further contribute to the extant literature by shedding light on public perceptions of the fairness of MBUF based on two different perspectives (noted earlier). Specifically, the study seeks to determine the extent to which people feel MBUF schemes are *fair* because they charge all road users the same per-mile fee for using the transportation infrastructure, and the extent to which such schemes are *unfair* because they do not differentiate between vehicles of different types, sizes, and fuels. This assessment is performed using data collected in the Transportation Heartbeat of America (THA) survey, conducted nationwide by the National University Transportation Center on Understanding the Future of Travel Behavior and Demand (TBD) in late 2024 and early 2025. A multivariate econometric model system that jointly accounts for the influence of socio-economic and demographic factors, attitudes and values, and lifestyle preferences in shaping perceptions of fairness of MBUF along multiple dimensions is estimated and presented in this paper. Insights from the model can be used to assess strategies for garnering support for such schemes in the future.

The rest of this paper is organized as follows. The next section offers a detailed description of the survey and data used in the study. The third section presents the model framework and methodology. The fourth section presents model estimation results. The fifth section offers a discussion of average treatment effects derived from the model. The sixth section offers concluding remarks and directions for future research.

2. DATA DESCRIPTION

This section presents an overview of the survey and the data set used in this study. The survey and sample characteristics are presented first, and a more in-depth description of the endogenous variables and latent attitudinal factors is presented second.

2.1. Survey Overview and Sample Characteristics

The data used in this study is derived from the Transportation Heartbeat of America (THA) survey conducted in the United States from October 2024 through January 2025. This nationwide survey is intended to collect detailed information about socio-economic and demographic attributes, mobility trends and choices, traveler behavior and values, attitudes and perceptions, and lifestyle preferences and personality traits for a sample of U.S. residents from across the nation. The survey was administered with the help of a commercial firm to an online panel of survey respondents assembled by the firm. In order to ensure that the respondent sample included respondents from all socio-economic and demographic groups and census divisions of the country, a quota sampling approach was adopted. Quotas (with some degree of tolerance) were specified for demographic variables such as age, gender, race, employment status, educational attainment, and household income (besides census division). The resulting respondent sample included 8,212 observations. The survey instrument incorporated a number of attention checks and quality assurance measures to enhance response quality. The data set was augmented based on the residential zip code with built environment variables (population density, employment density, network density) from the Smart Location Database 3.0 of the Environmental Protection Agency (EPA, 2021). This data

augmentation process, coupled with the elimination of obviously erroneous data records, resulted in a final analysis data set of 8,030 observations.

The socio-economic and demographic characteristics of the sample are depicted in Table 1. The sample shows a slightly higher percentage of females than males. All age groups are well-represented in the respondent sample, with 21.3 percent aged 65 years or over, 12.6 percent aged 18-24 years, and 20 percent aged 35-44 years. Nearly 46 percent are full-time workers, while 43.5 percent are non-workers. The educational attainment distribution shows that one-third of the sample has a high school diploma or less, while nearly 15 percent have a graduate degree. About 65 percent of respondents identify as White, while 15.4 percent identify as Black. Those who identify as Hispanic constitute 20 percent of the sample. In terms of household income, 11.1 percent reside in households with income of \$150,000 or higher, while 17.1 percent reside in households with income less than \$25,000. Nearly one-in-five respondents reside in single person households, while 47.8 percent reside in households with three or more persons. About two-thirds of respondents reside in stand-alone homes, and nearly 60 percent report owning their homes. Vehicle ownership is fairly high, with more than 50 percent of respondents residing in households with two or more vehicles and only 8.5 percent residing in households with no vehicles. Finally, just under 20 percent identified their residential location as rural in nature. Overall, the sample depicts the type of rich variation that would render the data set suitable for the type of model estimation effort undertaken in this study.

2.2. Endogenous Variables and Attitudinal Indicators

There are two specific Likert-scale statements in the THA survey that served as the basis to formulate the key endogenous variables used in this study. The two statements are as follows:

- Statement 1: Charging drivers per-mile for road use would be *MORE* fair than the gas tax, because everyone pays the same for use of the roads regardless of vehicle fuel efficiency.
- Statement 2: Charging drivers per-mile for road use would be *LESS* fair than the gas tax, because the mileage fee doesn't reward people who buy cleaner vehicles.

Respondents were asked to indicate the extent to which they agree or disagree with these statements on a five-point Likert scale. As the two statements collect information about fairness perceptions of MBUFs in opposite directions, thus rendering it difficult to interpret model estimation results and assess respondent consistency, the directionality of the second statement is reversed for analysis and modeling purposes in this study. Specifically, if a respondent indicated "strongly agree" for the second statement, the response was recoded as "strongly disagree" that MBUF is more fair than the gas tax (and vice-versa). Similarly, if a respondent indicated "somewhat agree" for the second statement, then the response was recoded as "somewhat disagree" that MBUF is more fair than the gas tax (and vice-versa). While one may question whether the statement and the responses are truly reversible, this adjustment (however approximate in representing true opinions) was necessitated by the opposing directionality of the original statements. The second statement may essentially be re-interpreted or recast as whether an individual considers MBUF *MORE* fair than the gas tax because it *does not penalize* those who do not drive fuel efficient and alternative fuel vehicles.

The main outcome variables are then named as follows to reflect the nature of the two statements, with the second statement recast as described above.

- MBUF Fair – Equal Pay: This refers to the first statement and captures the inclination to consider MBUF more fair than the gas tax because everybody pays the same per-mile fee for using the road infrastructure.
- MBUF Fair – No Clean Vehicle Reward (Reversed): This is the transformed version of the second statement, where the MBUF is considered more fair than the gas tax because it does not unduly penalize those that do not embrace fuel efficient and alternative fuel vehicles.

The distributions of these two outcome variables are shown in the bottom half of Table 1. It is seen that a large percentage of individuals indicate that they are neutral towards the MBUF relative to the gas tax, suggesting that there may be limited awareness and uncertainty of the cost, policy, and implementation implications of a MBUF relative to the gas tax for many in the sample. Alternatively, it is entirely possible that respondents see both pros and cons of the MBUF relative to the gas tax and hence indicate that they are neutral. In both cases, it is found that more than 30 percent of respondents somewhat disagree or strongly disagree that the MBUF is more fair than the gas tax.

Figure 1 captures the extent to which there is dissonance in responses to these two statements. The figure shows the bivariate relationship between the two outcome variables, revealing a pattern of extremes where one group provided consistent responses to both statements while the other group provided exactly opposing answers (strongly agree - strongly disagree; somewhat agree - somewhat disagree). Not considering the respondents who answered neutral to both statements, it is found that 21.7 percent answered consistently with the same response, while 18.3 percent answered in an exactly opposite way. In the figure, it is found that 48.8 percent of individuals who strongly disagreed with the MBUF Fair – Equal Pay statement also strongly disagreed with the MBUF Fair – No Clean Car Reward statement (reflecting a fairly high degree of consonance). On the other hand, 52.8 percent of those who strongly agreed with the MBUF Fair – Equal Pay statement indicated that they strongly disagreed with the MBUF Fair – No Clean Car Reward statement, indicating a high degree of dissonance among this group. It would appear that a majority of respondents who feel that MBUF is fair because it charges the same per-mile fee to all regardless of vehicle type also feel that a fee that does not reward use of fuel efficient and alternative fuel vehicles is problematic. It is clear that these individuals agree that everybody should pay consistently for use of the roadway infrastructure, but some accommodation needs to be made to reward those who use vehicles that aid the environment.

TABLE 1 Socio-Economic and Demographic Characteristics and Outcome Variables of the Sample

Individual Demographics (N=8,030)		Household Characteristics (N=8,030)	
Variable	%	Variable	%
Gender		Household annual income	
Female	53.3	Less than \$25,000	17.1
Male	46.7	\$25,000 to \$49,999	22.0
Age category		\$50,000 to \$99,999	30.5
18 to 24 years	12.6	\$100,000 to \$149,999	19.3
25 to 34 years	13.8	\$150,000 to \$199,999	7.1
35 to 44 years	20.0	\$200,000 or more	4.0
45 to 54 years	16.5	Household size	
55 to 64 years	15.8	One	19.4
65 years or older	21.3	Two	32.8
Employment status		Three or more	47.8
Full-time worker	45.6	Housing unit type	
Part-time worker	10.9	Stand-alone home	66.6
Non-worker	43.5	Attached home/apartment	27.1
Education attainment		Other	6.3
High school or less	33.0	Home ownership	
Some college or technical school	29.5	Own	59.2
Bachelor's degree(s)	22.7	Rent	35.5
Graduate degree(s)	14.8	Other	5.3
Race		Vehicle ownership	
Asian or Pacific Islander	7.6	Zero	8.5
Black	15.4	One	40.6
White	65.4	Two	34.1
Other	11.6	Three or more	16.8
Ethnicity		Location	
Hispanic	20.1	Urban	80.4
Non-Hispanic	79.9	Rural	19.6
Main Outcome Variables			
MBUF Fair – Equal Pay		MBUF Fair – No Clean Car Reward (Reversed)	
Strongly agree	11.8	Strongly agree	11.4
Somewhat agree	20.4	Somewhat agree	11.9
Neutral	35.5	Neutral	42.0
Somewhat disagree	13.6	Somewhat disagree	21.0
Strongly disagree	18.7	Strongly disagree	13.7

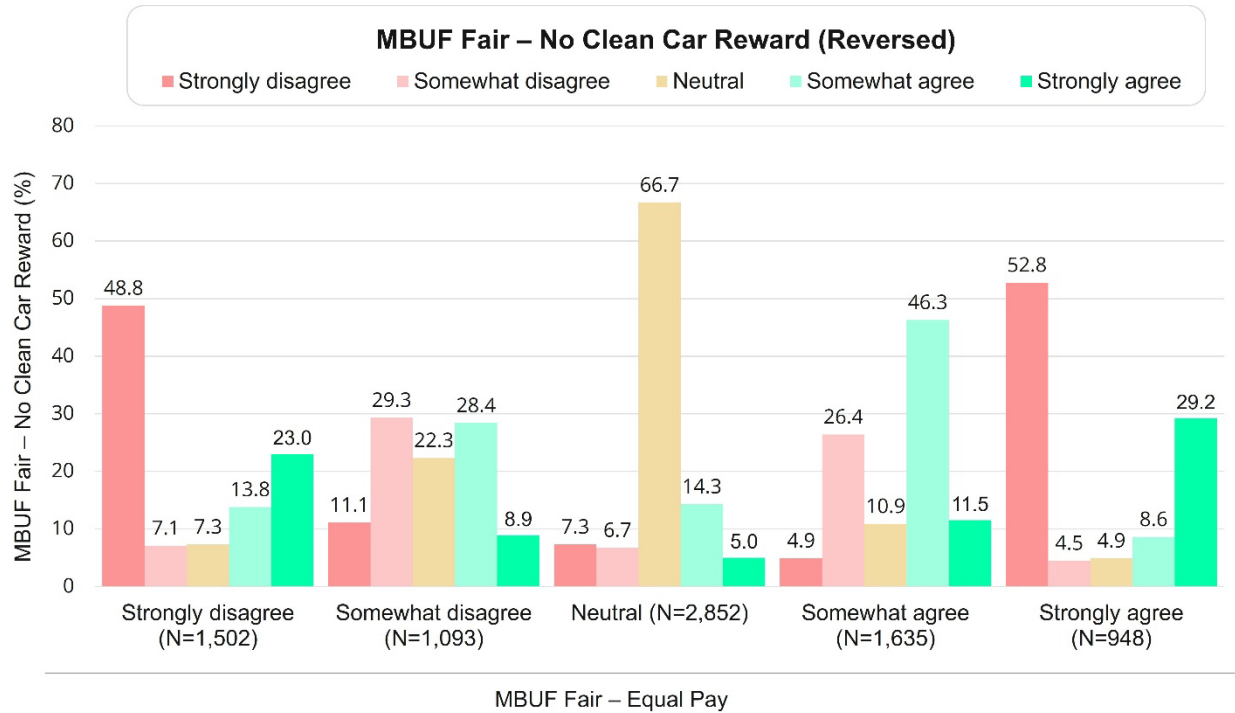


Figure 1. Bivariate Relationship between Main Outcome Variables (N=8,030)

2.3. Latent Attitudinal Constructs

The model system specified and estimated in this study incorporates a number of latent attitudinal constructs to reflect the influence of attitudes, perceptions, values, and preferences on the outcomes of interest. The attitudinal factors are constructed using a number of Likert-scale statements included in the survey and reflect those that would potentially influence people's perceptions of the fairness of MBUFs relative to the existing gas tax. The latent attitudinal constructs were initially specified using exploratory factor analysis (EFA) and then further refined and finalized using confirmatory factor analysis (CFA). The final set of attitudinal factors and the distributions of responses on the indicator statements associated with each factor are depicted in Figure 2.

Four latent attitudinal constructs were developed for use in this study. These latent constructs were chosen for their statistical significance, behavioral intuitiveness, interpretability, relevance to the key outcome variables of interest, and coverage of attitudinal dimensions. The first factor shown in the figure is Congestion Burden Perception (CBP). This factor is comprised of statements that indicate the extent to which respondents consider traffic congestion to be a major problem, are willing to pay more for a faster trip, and adjust their schedules to avoid congestion. The second factor reflects a Pro-Transit Attitude (PTA), indicating whether respondents try to choose a home with access to public transportation, like the idea of using public transit for their mobility needs, and use a less polluting means of transportation. The third factor is called Positive Travel Engagement (PTE), which captures the degree to which respondents try to use travel time effectively, consider travel a useful transition between activities, and generally enjoy the act of traveling itself. Finally, the fourth factor includes two indicator statements reflecting their inclination towards a Suburban Lifestyle (SL). The two statements capture the extent to which respondents feel that apartment living does not provide sufficient privacy and the extent to which they prefer living in a spacious home, even if it is farther from destinations they visit and public

transit. Overall, taken together, the latent attitudinal constructs capture a multitude of dimensions that could affect people's perceptions of MBUF fairness.

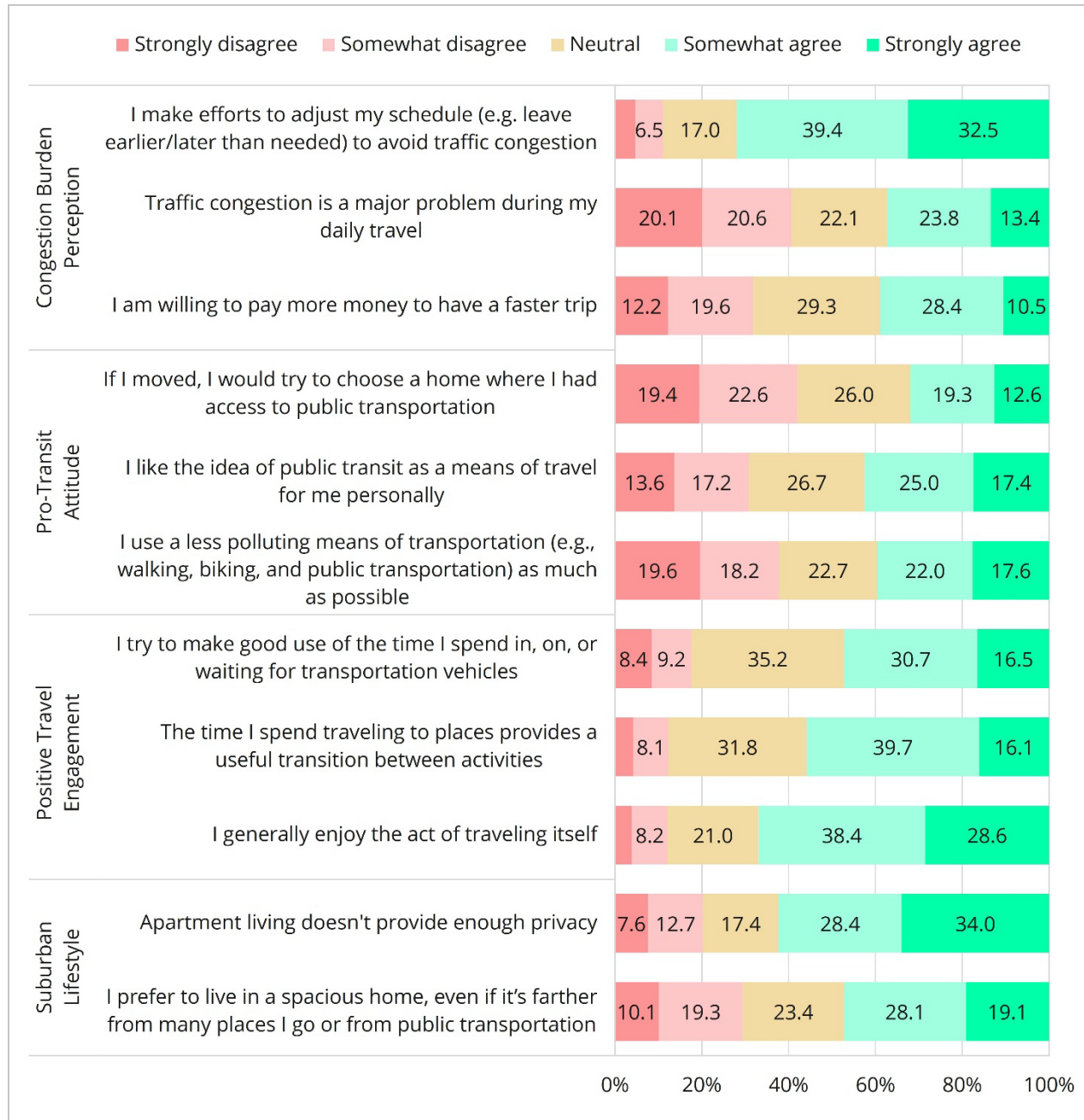


Figure 2. Agreement with Attitudinal Indicators Defining Latent Constructs (N=8,030)

3. METHODOLOGY

This section provides a brief overview of the model structure and framework used in this study. The adopted structure constitutes a special case of the Generalized Heterogeneous Data Model (GHDM), developed by Bhat (2015), that incorporates threshold shifters within a bivariate ordered model system to address the uneven distribution of outcome variables. For brevity, only a qualitative description of the modeling approach is provided here, as the full formulation is lengthy

and notation-heavy. Interested readers are referred to Bhat (2015) for details on the GHDM formulation and estimation and to Anderson et al. (2024) for a detailed discussion on threshold shifters in a model with ordinal outcomes where choice dissonance is present.

Figure 3 offers a simplified representation of the model structure. The main outcome variables (i.e., MBUF is fair because everyone pays equally, and MBUF is fair because there is no fuel efficient vehicle reward) appear on the right-hand side of the figure. In the GHDM framework, exogenous variables, including socio-demographic, household, and other characteristics, can affect the main outcomes directly or indirectly through four latent constructs, which are mapped to various attitudinal indicators as described in the previous section. Between the two outcome variables, the one reflecting fairness because everyone pays equally affects the second outcome, which reflects fairness based on not rewarding clean cars, through special parameters called threshold shifters.

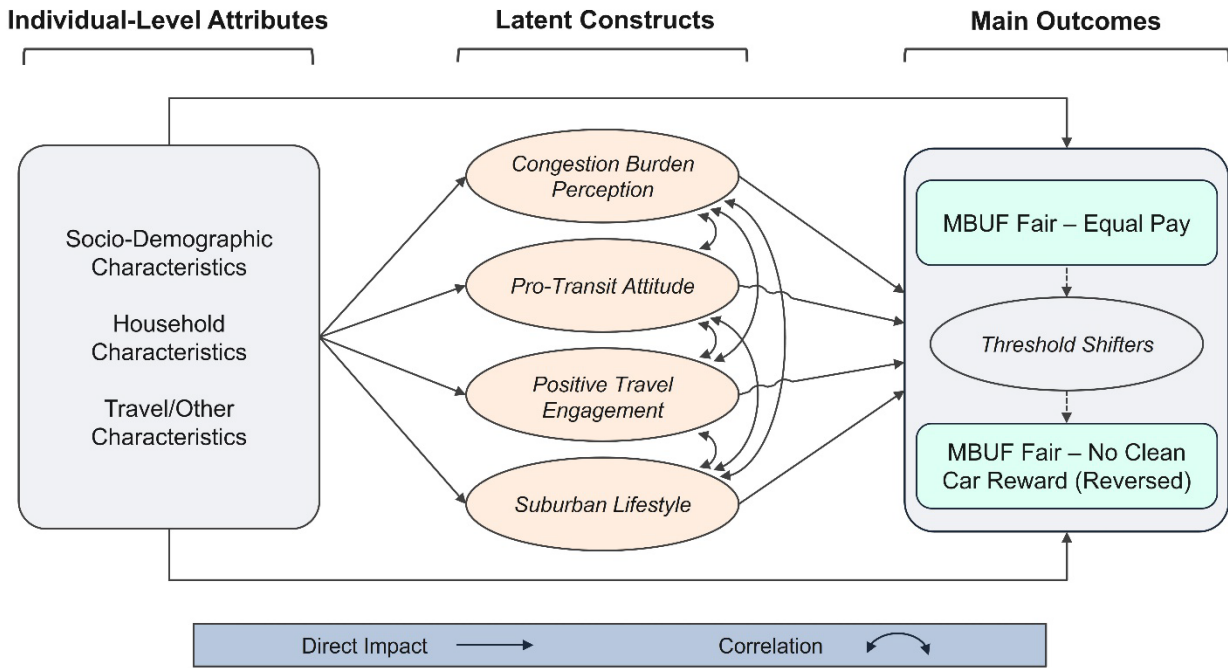


Figure 3. Model Framework

As discussed earlier in the data section, there are noticeable inconsistencies in how respondents answered the two distinct statements regarding the fairness of MBUFs. While it is reasonable to expect consistent responses from individuals regarding their perceptions of MBUF fairness, it is found that responses exhibited dissonance in many cases. Some selected the same category for both statements, while others chose opposing categories. This suggests that there may be unobserved factors or individual-specific rationalizations that influence how fairness is interpreted across different dimensions. For instance, one respondent might agree that MBUF is fair across both dimensions because it treats everyone equally regardless of vehicle type, while another might agree with only one of these reasons for considering MBUF to be fair.

To account for such interdependencies between responses to the two fairness statements, GHDM captures correlations between the two outcome variables indirectly through latent constructs. However, the correlation effects are not adequate to capture the extent of response dissonance seen in Figure 1. Therefore, threshold shifters are introduced in the model structure. In

an ordinal response model, each observed ordered category corresponds to an interval on an underlying continuous latent propensity variable bounded by thresholds. The shifters, based on the formal structure developed in prior work (Anderson et al, 2024), allow the thresholds used to discretize one latent propensity variable associated with an ordinal outcome to be conditionally adjusted based on the observed outcome of another ordinal variable. Specifically, in the current study, thresholds for the latent outcome variable (representing the second fairness dimension, *MBUF Fair – No Clean Car Reward*) are adjusted as a function of the observed response to the first dimension (*MBUF Fair – Equal Pay*).

For example, suppose a respondent selects the n^{th} category for the first statement ($n=1,2,3,4,5$), and the k^{th} category for the second statement ($k=1,2,3,4,5$). In an ordered probit model, it is then assumed that their latent utility y_1^* lies between the $(n-1)^{th}$ and n^{th} thresholds, denoted as $\psi_{1,n-1}, \psi_{1,n}$ and y_2^* lies between the $(k-1)^{th}$ and k^{th} thresholds, denoted as $\psi_{2,k-1}, \psi_{2,k}$. For consistency, threshold boundaries are set such that $-\infty = \psi_{1,0} < \psi_{1,1} \dots < \psi_{1,4} < \psi_{1,5} = \infty$ and $-\infty = \psi_{2,0} < \psi_{2,1} < \dots < \psi_{2,4} < \psi_{2,5} = \infty$. In contrast to the standard ordered probit model, which assumes fixed thresholds across individuals and across outcomes, the model used in this study allows the thresholds for one outcome – y_2^* in this case, (e.g., the upper threshold for category k of the second statement, $\psi_{2,k}$) – to shift leftward or rightward based on the observed category n of the first statement. This structure captures potential consonance or dissonance patterns in the joint response behavior, reflecting interdependence between different levels of the two outcomes.

Shifter effects operate on the upper thresholds of all categories except the highest, for which they apply to the lower threshold. A negative shifter narrows the threshold interval by moving the upper bound leftward, along with all thresholds to its right; this reduces the probability of selecting that category. A positive shifter has the opposite effect: it expands the interval and increases the likelihood of selection. For the highest category, which lacks an upper threshold, shifter effects act on the lower bound. A negative coefficient moves this boundary leftward, widening the interval and increasing selection probability of the highest category, whereas a positive coefficient shifts it rightward, narrowing the interval and reducing selection probability of the highest category. These nuances should be kept in mind when interpreting model results.

As illustrated in Figure 4, these shifter effects take three distinct forms within the model structure. First, generic consonance (cluster) shifters capture systematic tendencies for respondents to select the same response category across both statements. For example, suppose a respondent selects “somewhat disagree” to both statements. In that case, the threshold interval for “somewhat disagree” in the second dimension is widened by shifting all higher thresholds (those to the right of the associated threshold) outward (Figure 4b). This adjustment – shifting all thresholds to the right rather than only the specific threshold (i.e., 2|3) – ensures that while the likelihood of selecting a particular category (“somewhat disagree”) increases, the corresponding decrease in probability is distributed across multiple categories rather than concentrated in a single one (such as “neutral”).

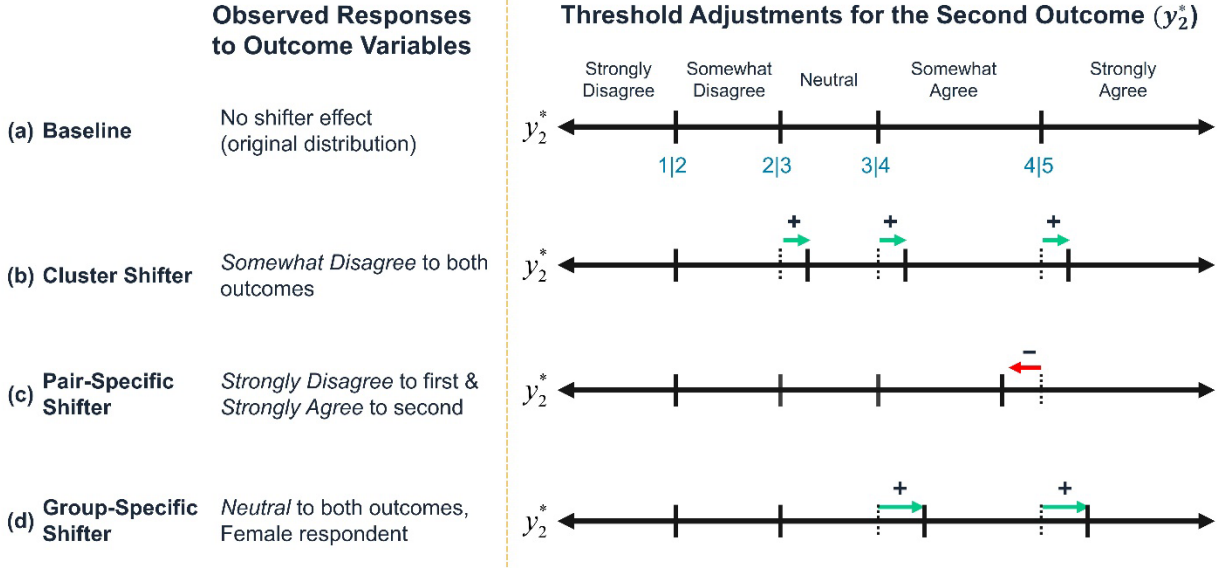


Figure 4. Conceptual Diagram of Threshold Shifters

Second, *outcome-specific (pair-specific) shifters* address response patterns in which individuals interpret the fairness dimensions in opposing ways. For instance, some respondents who “strongly disagree” with the equal-pay justification may “strongly agree” that MBUF is fair because it does not reward cleaner vehicles. In such cases, the thresholds surrounding the “strongly agree” category in the second dimension are shifted leftward - widening the interval for that category for those who selected “strongly disagree” in the first dimension (Figure 4c). This shift captures the inverse relationship in reasoning between the two statements.

Third, *socio-demographic (group)-specific shifters* allow the magnitude of these effects – whether in the form of cluster shifters or pair-specific shifters – to vary across population groups. As shown in Figure 4d, for example, individuals identifying as female may exhibit a higher conditional probability of choosing “neutral” in the second dimension when they also choose “neutral” in the first. To capture this tendency, an additional clustering shift is applied to the threshold interval corresponding to the “neutral” - “neutral” combination for female respondents, indicating a more cautious or moderate response tendency within this group.

Overall, this modeling approach that incorporates threshold shifter effects enables capturing both consonant and dissonant tendencies in respondents' fairness evaluations, while preserving the ordinal nature of the outcomes and accounting for respondent-level heterogeneity.

4. MODEL ESTIMATION RESULTS

This section presents model estimation results in detail. The results of the latent construct model component are presented first, and estimation results for the behavioral outcomes model are presented second.

4.1. Latent Construct Model Component

Estimation results for the latent construct model component are presented in Table 2. The bottom half of Table 2 shows the factor loadings corresponding to various attitudinal indicator statements for all four stochastic latent constructs. It is found that all of the attitudinal indicator statements have statistically significant factor loadings and are quite appropriate for representing the

corresponding latent constructs. Just above the factor loadings, correlations between the latent constructs are shown. It can be seen that all correlations are significant, suggesting that it is appropriate to treat these constructs as correlated endogenous variables in the overall modeling framework. The remainder of this subsection is devoted to describing the influence of exogenous variables on the stochastic latent constructs (top half of the table).

When compared with men, women are found to exhibit lower levels of congestion burden perception, presumably because they travel fewer vehicle miles than men (Hu, 2021). Women also have a less pro-transit attitude, potentially because of safety concerns associated with transit use and the inflexibility of transit service to meet the complex trip chaining patterns of their travel (Hu, 2021). Finally, women exhibit lower positive travel engagement, suggesting that they do not enjoy traveling as much as men; this is likely because of the greater burdens of household obligations and childcare responsibilities that they bear (Ciciolla and Luthar, 2019). Older age groups depict lower congestion burden perception, presumably because they have more flexible schedules and the resources to overcome congestion (Fournier and Christofa, 2021). Older individuals, particularly those 65 years and older, are likely to have mobility limitations that reduce their levels of pro-transit attitude and positive travel engagement (Ravensbergen et al., 2021). As expected, older individuals exhibit a more suburban lifestyle preference, presumably because of household needs and the presence of children (Coogan et al., 2018). The race and ethnicity variables show that Black individuals exhibit a higher level of positive travel engagement; as this group utilizes transit and alternative modes to a greater extent (American Public Transportation Association, 2017), they are able to put their travel time to good use and avoid the ills of driving (in congestion). Non-Hispanic White individuals, on the other hand, exhibit a more suburban lifestyle orientation – thus contributing to lower levels of congestion burden perception and pro-transit attitude. In suburban regions, congestion levels tend to be lower than in urban centers, and transit service tends to be quite limited. Those with a higher level of education (college degree or higher) have a lower suburban lifestyle propensity (they find urban amenities appealing) and have a higher pro-transit attitude, stemming from their awareness of the benefits of a transit-oriented lifestyle (Zhong et al., 2022). They also have a higher congestion burden perception, stemming from their busy schedules. Those with a lower than high school level of educational attainment exhibit lower levels of positive travel engagement, presumably because they are less effective at utilizing spare time during travel (Przepiorka and Blachnio, 2017).

Individuals in higher income households exhibit greater perceptions of congestion burden, presumably because of their hectic work-dominated schedules (Institute for Employment Studies, 2003). They are also less pro-transit, as reported in Magassy et al. (2024), because they enjoy high vehicle ownership and likely feel that transit is not a suitable mode to meet their mobility needs. They have a positive travel engagement, which means that they enjoy traveling and try to put their travel time to good use, consistent with their higher value of travel time (Fournier and Christofa, 2021). They are also more suburban oriented in their lifestyle preference. Those with children, who tend to be more time and schedule constrained due to child obligations, exhibit higher levels of congestion burden and tend to be more suburban oriented, presumably for good schools, safety, and open space for the children (Jung and Yang, 2016). Finally, individuals in households with multiple adults have a lower pro-transit attitude, likely due to more complex household travel patterns (that are ill-served by transit), and a higher suburban lifestyle propensity (consistent with larger household sizes). On the other hand, single adults are less likely to embrace a suburban lifestyle due to the amenities provided by urban centers (Lee, 2021).

TABLE 2 Determinants of Latent Variables and Loadings on Indicators (N = 8,030)

Explanatory Variables (base category)		Structural Equations Model Component							
		Congestion Burden Perception		Pro-Transit Attitude		Positive Travel Engagement		Suburban Lifestyle	
		Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat
Individual Characteristics									
Gender (not female)	Female	-0.347	-13.93	-0.201	-14.69	-0.179	-14.31	na	na
Age (*)	25 to 44 years	na	na	na	na	na	na	0.283	11.08
	45 to 64 years	-0.432	-14.23	-0.233	-14.31	-0.229	-14.36	0.329	13.22
	65 years or older	-0.859	-20.35	-0.439	-20.41	-0.473	-15.82	0.215	10.14
Race and ethnicity (*)	Non-Hispanic Black	na	na	na	na	0.371	10.52	na	na
	Non-Hispanic White	-0.350	-15.27	-0.428	-25.78	na	na	0.067	10.15
Education (*)	High school or lower	na	na	na	na	-0.159	-9.91	na	na
	Bachelor's degree(s) or higher	0.228	8.84	0.192	12.39	na	na	-0.220	-9.19
Household Characteristics									
Household income (less than \$50,000)	\$50,000 to \$99,999	0.360	11.62	-0.209	-13.27	0.159	9.43	0.273	10.85
	\$100,000 or more	0.797	20.63	-0.185	-10.41	0.242	11.38	0.436	12.68
Number of children (none)	One or more	0.163	6.68	na	na	na	na	0.117	5.93
Number of adults (*)	One	na	na	na	na	na	na	-0.246	-11.55
	Two	na	na	-0.078	-8.40	na	na	0.220	10.82
Correlations Between Latent Constructs									
Congestion Burden Perception		1	na	0.371	25.28	0.573	6.33	0.313	45.38
Pro-Transit Attitude				1	na	0.683	49.97	-0.321	-39.68
Positive Travel Engagement						1	na	0.127	9.50
Suburban Lifestyle								1	na
Attitudinal Indicators		Loadings of Latent Variables on Indicators (Measurement Equations Model Component)							
I am willing to pay more money to have a faster trip		0.671	30.50						
Traffic congestion is a major problem during my daily travel		0.439	36.47						
I make efforts to adjust my schedule (e.g., leave earlier/later than needed) to avoid traffic congestion		0.137	17.79						

TABLE 2 (Continued)

Attitudinal Indicators	Loadings of Latent Variables on Indicators (Measurement Equations Model Component)							
	Congestion Burden Perception		Pro-Transit Attitude		Positive Travel Engagement		Suburban Lifestyle	
	Coef	t-stat	Coef	t-stat	Coef	t-stat	Coef	t-stat
I use a less polluting means of transportation (e.g., walking, biking, and public transportation) as much as possible			1.502	85.09				
I like the idea of public transit as a means of travel for me personally			1.224	83.88				
If I moved, I would try to choose a home where I had access to public transportation			0.899	97.50				
I generally enjoy the act of traveling itself					0.286	32.35		
The time I spend traveling to places provides a useful transition between activities					0.540	53.13		
I try to make good use of the time I spend in, on, or waiting for transportation vehicles					1.066	50.23		
I prefer to live in a spacious home, even if it's farther from many places I go or from public transportation							0.590	33.33
Apartment living doesn't provide enough privacy							0.620	35.26

Note: Coef = coefficient; "na" = not applicable; (*) Base category is not identical across the model equations and corresponds to all omitted categories.

4.2. Bivariate Model of Behavioral Outcomes

The behavioral outcomes model takes the form of a bivariate ordered probit model where each outcome is measured on a five-point ordinal scale (strongly disagree to strongly agree). The two outcomes represent the extent to which individuals feel that a MBUF scheme is fair because everybody pays the same per-mile fee and the extent to which individuals feel that a MBUF is fair because it does not reward users of fuel efficient and alternative fuel vehicles (i.e., it does not penalize users of larger fossil fuel vehicles).

The model estimation results are shown in Table 3. The coefficients refer to exogenous variable effects on the underlying latent propensities of the two MBUF-related fairness ordinal responses. As is well known, in ordered-response models, even the sign of coefficients does not immediately translate to an unambiguous direction of effects on the ordinal outcomes themselves, except for the two extreme categories of “strongly disagree” and “strongly agree”. But, for presentation simplicity, in this section, this study (somewhat loosely) interprets a positive effect of an exogenous variable as implying more fairness (with the understanding that this strictly implies a higher probability of selection of the “strongly agree” ordinal category, and a lower probability of selection of the “strongly disagree ordinal category). Similarly, the study interprets a negative effect as implying less fairness (with the understanding that this strictly implies a higher probability of selection of the “strongly disagree” ordinal category, and a lower probability of selection of the “strongly agree ordinal category).

The results in Table 3 are quite consistent with expectations and behaviorally intuitive. Latent constructs influence perceptions of fairness of MBUF quite significantly. Those who perceive a higher congestion burden are more likely to feel that MBUF schemes are less fair than the gas tax. As these individuals already experience or feel the burden of congestion, they may feel reluctant to embrace a pay-per-mile system regardless of the rationale. Towards the bottom of the table, the interaction term of congestion burden perception with long distance commuting of greater than 50 miles (80 kilometers) is associated with a lower perception of fairness due to no reward for driving clean vehicles. Long distance commuters are likely to own and operate more fuel efficient and alternative fuel vehicles as they get more benefit from reduced fuel cost (Brase, 2017) and hence it is no surprise that they feel a scheme that does not reward their environmentally friendly vehicle choices is less fair. Back to the top of the table, a pro-transit attitude is associated with a feeling that MBUF is fair because drivers have to pay for the roadway infrastructure they use and the revenue may be used to enhance transit services (Agrawal and Nixon, 2024). Those who enjoy traveling (positive travel engagement) believe it is more fair that drivers pay on a per-mile basis, but also feel that a scheme that does not reward clean car usage is less fair than a gas tax (as evidenced by the statistically significant -0.178 coefficient). This latter effect is tempered for women, as evidenced in the interaction coefficient of +0.071 on the interaction variable of positive travel engagement \times female (see under interaction terms in the table). Those who embrace a suburban lifestyle feel that a MBUF that does not reward clean car usage is more fair than a gas tax; as suburban residents tend to drive larger gas-guzzling vehicles, this finding is consistent with expectations (Wilson, 2021).

The remaining exogenous variable effects in the table refer to the direct effects of exogenous variables after accommodating for any indirect effects through the four latent constructs. In terms of age, those who are in the peak travel years (45-64 years) tend to feel that MBUF is less fair than a gas tax, presumably because of the distances that they need to drive for work and other activities. Asians, who tend to own fuel efficient and electric vehicles to a greater extent than the rest of the population (Consumer Reports, 2022), feel that a MBUF that does not

reward clean vehicle use is less fair than a gas tax. A high work-from-home frequency is associated with a higher level of fairness perception, presumably because these individuals would not be exposed to the pay-per-mile scheme as much as regular commuters. It is interesting to see that ridehailing drivers consider the scheme more fair than the gas tax, suggesting that they prefer a scheme where everybody pays a flat fee-per-mile for using roadways.

A higher household income is associated with a higher likelihood that the MBUF will be perceived as more fair than the gas tax because everybody pays the same per-mile fee. High-income groups are more willing than others to pay for transportation investments and infrastructure use than other groups in the U.S. (Nixon and Agrawal, 2019). They are likely to support a system where the beneficiary pays for the infrastructure, and they do not necessarily feel an undue burden due to their high income level. The presence of children is also associated with a higher perception of fairness of the MBUF; as households with children tend to accrue more miles of travel and own larger vehicles, such households may feel that a fixed pay-per-mile fee is more fair than a gas tax.

Vehicle composition and profile tend to have a significant impact on perceptions of MBUF fairness. Individuals living in vehicle sufficient households deem a MBUF where everybody pays the same to be less fair than a gas tax; it is likely that multi-vehicle households own a mix of vehicle types (Energy Institute Blog, 2023) and would like to see a differential MBUF that accounts for the potential presence of fuel efficient vehicles in the household fleet. In addition, these households are likely to be quite auto-centric in their travel patterns (Kwon, 2022), and hence may perceive a MBUF as punitive – given how many vehicle miles of travel they accrue. As expected, owners of electric or hybrid vehicles believe that a MBUF is more fair than a gas tax as they too would pay for the use of the roadway infrastructure; however, they believe that a scheme that does not reward their vehicle type choice is less fair than a gas tax scheme. On the other hand, individuals in households that own larger SUVs are likely to perceive a MBUF that does not penalize the use of larger fossil fuel vehicles as more fair than the current gas tax scheme.

Those residing in urban areas consider a MBUF as less fair, presumably because urban residents drive more fuel efficient vehicles (Ou et al., 2022) and hence feel that a fixed per-mile fee is less fair than a gas tax. It is also seen that residents of the Mountain and New England regions consider a fixed per-mile MBUF less fair than the gas tax. This is likely because residents of the Mountain region drive long distances (Federal Highway Administration, 2018) and hence may perceive that they would be paying more under a MBUF than a gas tax. Residents of the New England region tend to exhibit higher levels of fuel efficient vehicle ownership, and are therefore more likely to feel that a fixed MBUF that does not recognize vehicle type is less fair than the current gas tax. Finally, in terms of interactions, it is found that highly educated women feel that a fixed per-mile MBUF is less fair than the current gas tax, presumably because they are more sensitive to the impact on low income populations and the need to account for fuel efficient vehicle types in charging road user fees. It is also seen that lower educated high income individuals perceive the MBUF that does not reward clean car usage as less fair than the current gas tax. This negative coefficient is statistically significant and implies that these individuals, more so than others, feel that clean vehicle usage should be rewarded in a MBUF scheme. This finding merits further investigation in future research.

Because the two statements are strongly related to one another (perceptions of fairness of MBUF, but for two different reasons), the responses to the two statements are connected through a series of threshold shifter effects that account for both consonance and dissonance in responses to these two statements (these shifter effects for “MBUF Fair – No Clean Car Reward” outcome work off the thresholds for the outcome; these overall thresholds are listed under the label of

“Thresholds” above the “Threshold Shifter Effects” panel in Table 3). All cluster shifters operated in the direction of increasing the tendency for individuals to give the same answer to both questions (consonance). It should be noted that the last cluster shifter (choosing “strongly agree” for both) has a negative sign, which may seem opposite in effect to the other (positive) coefficients. However, this negative coefficient reflects the same consonance effect. This is because an increase in an individual’s tendency to respond with level 5 to the second question necessitates a leftward shift in the fourth threshold, leading to the negative coefficient for capturing the same underlying consonance pattern. This indicates that, even though the two statements offered different rationales, there is a significant number of individuals who focus on the main aspect of the question – namely, whether the MBUF is more fair than the current gas tax (regardless of rationale).

Three pair-specific shifters are statistically significant. These shifters operated in the direction of increasing the tendency for individuals to give diametrically opposite answers to the two statements (e.g., strongly agree – strongly disagree, somewhat agree – somewhat disagree). This represents dissonance in response patterns and indicates that there exists a significant group of individuals with opposing positions on the fairness of a MBUF stemming from the specific rationale used in the two statements.

A couple of group-specific shifters were also found to be significant. The first indicates that, when women choose “neutral” for the first statement, they are more likely than men to choose “neutral” for the second statement as well. The second group-specific shifter indicates that those with a graduate degree who choose “strongly disagree” for the first statement are less likely to choose “strongly agree” to the second statement where clean vehicle usage is not rewarded. This means that this group has a lower probability of giving completely opposite answers, focusing more on the main question of whether MBUF is fair, regardless of rationale. Overall, when perceptions of two highly related statements are modeled, it is clear that consonance and dissonance effects are significant, calling for the use of threshold shifters to reflect such effects.

The goodness-of-fit statistics of the model are presented in the final section of Table 3. The GHDM estimated in this study is compared against a GHDM without threshold shifters and a standard bivariate ordered probit model that does not include threshold shifters and the stochastic latent constructs (but includes all exogenous variables from the GHDM models that either feature as effects on the latent constructs or as direct effects on the outcomes). A number of goodness-of-fit metrics are examined and compared, including log-likelihood measures, predictive log-likelihood measures, predictive Bayesian Information Criterion (BIC), predictive adjusted likelihood ratio index, and average probability of correct prediction. The two GHDM models can be compared using a nested likelihood ratio test based on the log-likelihood values at convergence, which yields, based on the values in the first numeric row under “Data Fit Measures” a value of 433.8 (twice the difference of log-likelihood values at convergence), way higher than the chi-squared value 10 degrees of freedom at any reasonable level of statistical significance. The GHDM models cannot be compared with the bivariate ordered model using the likelihood ratio test, because the latter model is not a nested version of the GHDM models. For this reason, the implied probabilities of the two main outcomes are computed based on the GHDM models, and thence the predictive log-likelihood from the GHDM models. These are then comparable to the log-likelihood from the bivariate ordered model. The resulting statistics show that, overall, the GHDM estimated and presented in this study is superior to a GHDM without threshold shifters as well as a standard bivariate ordered probit model without the threshold shifters or stochastic latent constructs.

TABLE 3 Estimation Results of MBUF Fairness Model Components (N = 8,030)

Explanatory Variables (base category)		MBUF Fair – Equal Pay		MBUF Fair – No Clean Car Reward	
		Ordered (5-level): strongly disagree (1) to strongly agree (5)			
		Coef	t-stat	Coef	t-stat
Latent Constructs					
Congestion Burden Perception		-0.038	-13.96	-0.152	-13.93
Pro-Transit Attitude		0.252	33.94	na	na
Positive Travel Engagement		0.055	11.21	-0.178	-16.48
Suburban Lifestyle		na	na	0.062	13.69
Individual Characteristics					
Age (< 45 or ≥ 65 years)	45 to 64 years	-0.152	-11.73	na	na
Race (not Asian)	Asian	na	na	-0.147	-4.39
WFH frequency (<3 days)	Three or more days per week	0.170	8.33	na	na
Ridehailing driver (No)	Yes	0.061	6.80	na	na
Household Characteristics					
Household income (<\$100K)	\$100,000 or more	0.092	6.40	na	na
Number of children (none)	One or more	0.058	5.37	na	na
Vehicle availability (deficient)	Sufficient (# vehicles ≥ # adult drivers)	-0.084	-11.29	na	na
Number of electric or hybrid vehicles (none)	One or more	0.258	8.61	-0.312	-9.49
Number of SUVs (None)	One or more	na	na	0.072	9.40
Location (Rural)	Urban	-0.037	-10.17	na	na
Census division (*)	Mountain	-0.080	-4.09	na	na
	New England	-0.067	-5.51	na	na
Interaction terms (*)	Congestion Burden Perception × Commute longer than 50 miles (80km)	na	na	-0.301	-5.11
	Positive Travel Engagement × Female	na	na	0.071	13.28
	≥ Bachelor’s degree(s) × Female	-0.069	-5.12	na	na
	Highschool or less × ≥ \$100,000	na	na	-0.183	-5.00
Thresholds					
1 2		-1.122	-59.54	-1.269	-61.03
2 3		-0.669	-38.24	-0.656	-40.25
3 4		0.308	18.13	0.065	10.04
4 5		1.079	51.86	0.621	14.59
Threshold Shifter Effects (“First statement” – “Second statement” response pairings)					
Cluster Shifters					
“Strongly disagree” – “Strongly disagree”		na	na	0.676	22.97
“Somewhat disagree” – “Somewhat disagree”		na	na	0.781	25.46
“Neutral” – “Neutral”		na	na	1.641	33.82
“Somewhat agree” – “Somewhat agree”		na	na	0.940	13.35
“Strongly agree” – “Strongly agree”		na	na	-0.175	-3.81

TABLE 3 (Continued)

Explanatory Variables (base category)	MBUF Fair – Equal Pay		MBUF Fair – No Clean Car Reward	
	Ordered (5-level): strongly disagree (1) to strongly agree (5)			
	Coef	t-stat	Coef	t-stat
<i>Pair-Specific Shifters</i>				
“Strongly disagree” – “Strongly agree”	na	na	-0.481	-10.94
“Somewhat disagree” – “Somewhat disagree”	na	na	0.603	8.85
“Somewhat agree” – “Somewhat disagree”	na	na	0.159	8.92
<i>Group-Specific Shifters</i>				
Woman × “Neutral” – “Neutral”	na	na	0.171	5.35
Graduate degree(s) × “Strongly disagree” – “Strongly agree”	na	na	0.091	3.25
Data Fit Measures	GHDM	GHDM without threshold shifters	Bivariate ordered model	
Log-likelihood at convergence	-127,850.45	-128,067.35	-23,811.60	
Log-likelihood at constant	-129,088.17	-129,088.17	-25,210.05	
Number of non-constant parameters	88	78	34	
Predictive log-likelihood	-21,923.98	-23,419.37	-23,811.60	
Constants-only predictive log-likelihood	-25,210.05			
Predictive adjusted likelihood ratio index	0.127	0.070	0.054	
Predictive Bayesian Information Criterion (BIC)	44,191.57	47,540.03	47,928.89	
Average probability of correct prediction	0.103	0.071	0.052	

Note: Coef = coefficient; “na” = not applicable; (*) Base category is not identical across the model equations and corresponds to all omitted categories.

5. Average Treatment Effects

The results presented in the previous section offer estimates of model coefficients that reflect the influence of different variables on the underlying propensities of the endogenous MBUF ordinal perception variables of interest. However, because of the ordinal nature of the endogenous outcomes and the GHDM model framework that incorporates a series of latent constructs that mediate exogenous variable effects (see Figure 3), it is difficult to decipher total effects on the outcome variables from the model coefficients. Hence, the notion of average treatment effects (ATEs) is widely used in econometrics to measure the potential overall impact of treatments on the endogenous variables of interest. The ATE represents the mean causal effect of a treatment on an outcome across a population and is defined as the expected difference between potential outcomes under treatment and control conditions, holding all other exogenous variables constant. These ATEs, as presented in this section, enable an assessment of the total effects of exogenous variables on the endogenous variable outcomes, while considering the influences through various different pathways and quantifying the contribution of each pathway (component) to the total ATE.

Table 4 displays the ATEs and the breakdown of the contributions of component pathways to the total ATE for each of the two endogenous outcome variables. The ATE itself represents the change in proportion of respondents (in percentage point terms) who somewhat or strongly agree that a MBUF is more fair than the gas tax, when comparing a scenario where all individuals possess the base level of an exogenous variable to one where all possess the treatment level (while the

ATEs can be computed for each of the five ordinal categories for each of the two ordinal outcome variables, for presentation compactness, the ATEs for a single combined category of “somewhat agree” and “strongly agree” are presented). Also, when there are multiple discrete categories of an exogenous variable, the ATE effects for only the lowest category and select groupings of the other categories of the exogenous variable are presented. The first three columns of Table 4 show the exogenous variables and the definitions for the base and treatment levels. For example, the third row shows how perceptions of MBUF fairness based on an equal payment argument would change when all respondents are in the 45-64 year age group compared to a scenario when all respondents are in the 18-24 year age group. The treatment contributes to the ATE through various pathways, but the final outcome values are shown in the last three columns of the table. The BL column shows that the combined percentage of “strongly agree” and “somewhat agree” (that MBUF is fair) is 35.2 percent under the base level conditions. The TL column shows that this value changes to 28.2 percent under the treatment level conditions, leading to a total ATE of -7.0 percentage points. In other words, if a sample of 100 18-24 year-old individuals was compared to a sample of 100 45-64 year-old individuals (keeping all other exogenous variables constant), then there would be seven fewer instances of individuals agreeing (somewhat agree or strongly agree) that MBUF is more fair than a gas tax because everybody pays equally.

The five columns in the middle of the table present a decomposition of the total ATE into its constituent components attributable to different pathways. The first four subcolumns represent effects through latent constructs, capturing both the influence of changes in each latent variable (due to a change in an exogenous variable) and the magnitude of the effect of each latent variable (through its estimated coefficient) on the outcome variable. The final subcolumn labeled “direct” captures direct effects and any socio-demographic specific shifter effects. Using the age group example, from Table 2, the 45-64 year-old age group exhibits lower congestion burden perception (CBP), pro-transit attitude (PTA), and positive travel engagement (PTE), and a higher suburban lifestyle (SL) propensity compared to the baseline under-25 year-old segment. For the MBUF Fair – Equal Pay outcome variable, lower CBP increases the tendency to agree that MBUF is more fair than a gas tax, while a lower PTA and PTE decreases the tendency to agree that the MBUF is more fair than a gas tax (SL has no particular effect on this outcome variable). The signs of the entries shown in that row in Table 4 depict the directionality of the effect contributed by that component under the treatment condition, while the absolute values of the entries represent the relative contribution of each pathway to the total effect. In this particular row (corresponding to treatment level 45-64 years), the direct effect contributes the most and in a negative direction, leading to a decrease in the percentage of individuals who would consider MBUF fair (due to equal pay argument) under the treatment level.

The remainder of the table can be interpreted in a similar fashion. It should be noted that some socio-economic effects are reflected through specific shifters (e.g., graduate degree, female). Overall, it can be seen that the ATEs are rather modest, except for a few instances such as the age effect and electric vehicle ownership effect. Clearly, electric vehicle owners feel that a MBUF is more fair than the gas tax because everybody pays for using the roadway infrastructure (ATE of 9.1), but they do not feel such a scheme is fair if it does not reward the use of clean fuel efficient and alternative fuel vehicles (ATE of -7.4). Other differences in ATEs between the top half of the table (corresponding to MBUF Fair – Equal Pay) and the bottom half of the table (corresponding to MBUF Fair – No Clean Vehicle Reward) similarly indicate that the nature of the scheme and the rationale underlying the scheme is critical to engendering perceptions of fairness across the population, which is also discussed briefly in the next section.

TABLE 4 Average Treatment Effects (ATEs) for Agreement to MBUF Fairness (N = 8,030)

Attribute	Base Level (BL)	Treatment Level (TL)	Contribution Through Latent Constructs and Direct Effects to Total ATE (%)					Agree MBUF is Fair (%)		Total ATE (%)
			CBP	PTA	PTE	SL	Direct	BL	TL	
MBUF Fair – Equal Pay										
Gender	Male	Female	13.2	-50.6	-9.9	0.0	-26.2	33.6	31.1	-2.5
Age	24 years or younger	25 to 44 years	na	na	na	na	na	35.2	35.2	0.0
		45 to 64 years	6.9	-24.7	-5.4	0.0	-63.0	35.2	28.2	-7.0
		65 years or older	19.5	-64.9	-15.6	0.0	0.0	35.2	31.6	-3.6
Education	High school or lower	Graduate degree(s)	-8.5	48.2	8.7	0.0	-34.7	32.0	32.4	0.4
Race and ethnicity	Hispanic	Non-Hispanic White	11.2	-88.8	0.0	0.0	0.0	33.9	30.7	-3.2
		Non-Hispanic Black	0.0	0.0	100.0	0.0	0.0	33.9	34.6	0.7
Weekly WFH frequency	Less than three days	Three days or more	0.0	0.0	0.0	0.0	100.0	30.9	36.8	5.9
Ridehailing driver	No	Yes	0.0	0.0	0.0	0.0	100.0	31.8	33.8	2.1
Household income	Lower than \$50,000	Higher than \$100,000	-16.3	-25.2	7.3	0.0	51.3	32.6	33.6	1.0
Number of children in household	None	One or more	-9.5	0.0	0.0	0.0	90.5	31.7	33.4	1.8
Number of adults in household	Three or more	Two	0.0	-100.0	0.0	0.0	0.0	32.6	31.9	-0.7
Household location	Rural	Urban	0.0	0.0	0.0	0.0	-100.0	33.3	32.1	-1.2
Household vehicle availability	Deficient	Sufficient	0.0	0.0	0.0	0.0	-100.0	34.3	31.4	-2.9
Number of electric or hybrid vehicles in household	None	One or more	0.0	0.0	0.0	0.0	100.0	31.1	40.2	9.1
MBUF Fair – No Clean Car Reward (Reversed)										
Gender	Male	Female	65.7	0.0	7.6	0.0	-26.7	24.5	25.5	1.0
Age	24 years or younger	25 to 44 years	0.0	0.0	0.0	100.0	0.0	22.7	23.2	0.4
		45 to 64 years	56.7	0.0	26.5	16.8	0.0	22.7	25.8	3.0
		65 years or older	63.5	0.0	30.5	6.0	0.0	22.7	28.3	5.5
Education	High school or lower	Graduate degree(s)	-29.2	-19.0	-25.4	-22.9	-3.4	26.0	23.9	-2.1
Race and ethnicity	Hispanic	Non-Hispanic White	93.1	0.0	0.0	6.9	0.0	24.6	26.1	1.5
		Non-Hispanic Black	0.0	0.0	-100.0	0.0	0.0	24.6	23.3	-1.3
		Non-Hispanic Asian	0.0	0.0	0.0	0.0	-100.0	24.6	21.1	-3.5
Commute distance	50 miles (80km) or shorter	Over 50 miles (80km)	100.0	0.0	0.0	0.0	0.0	25.0	28.0	3.0
Household income	Lower than \$50,000	Higher than \$100,000	-51.1	0.0	-14.1	11.4	-23.5	26.8	22.0	-4.7
Number of children in household	None	One or more	-77.8	0.0	0.0	22.2	0.0	25.1	24.6	-0.5
Number of adults in household	Three or more	One	0.0	0.0	0.0	-100.0	0.0	24.9	24.5	-0.4
		Two	0.0	0.0	0.0	100.0	0.0	24.9	25.2	0.3
Number of electric or hybrid vehicles in household	None	One or more	0.0	0.0	0.0	0.0	-100.0	25.9	18.5	-7.4
Number of SUVs in household	None	One or more	0.0	0.0	0.0	0.0	100.0	24.1	25.9	1.8

Note: CBP = Congestion Burden Perception; PTA = Pro-Transit Attitude; PTE = Positive Travel Engagement; SL = Suburban Lifestyle; na= not applicable.

6. DISCUSSION AND CONCLUSIONS

This paper is aimed at understanding public perceptions of MBUF schemes in the context of two different rationales. MBUFs are often presented as a potential replacement for the gas tax as the nation's fleet becomes increasingly fuel efficient and characterized by electric and other alternative fuel vehicles that render the gas tax increasingly obsolete and the highway trust fund insolvent. The MBUF schemes generally entail individuals paying a fixed per-mile fee, thus ensuring that all road users – regardless of vehicle fuel type and efficiency – pay for their use of the roadway infrastructure. The MBUF scheme may then be seen as potentially fair because everybody pays the same amount per-mile of roadway infrastructure use. At the same time, it may be seen as unfair because users of fuel efficient and alternative fuel vehicles are not rewarded in any way for their environmentally conscious choices (while the gas tax naturally accommodates such differentiation).

In order to understand factors driving public perceptions of the fairness of MBUF, this study reports on results derived from the Transportation Heartbeat of America (THA) Survey conducted in late 2024 and early 2025 across the United States. More than 8,000 responses were obtained. Respondents were asked to indicate the extent to which they feel MBUF is more fair than the gas tax because everybody pays equal, and the extent to which they feel MBUF is less fair than the gas tax because it does not reward environmentally conscious vehicle choices. The multivariate econometric model system accounts for the effects of socio-economic and demographic characteristics and latent attitudinal factors in unraveling the effects of various exogenous variables on perceptions of MBUF from these two different perspectives. The model formulation also incorporates the notion of threshold shifters, which account for the consonance and dissonance in the way individuals responded to the two MBUF fairness perception questions.

Overall, the results indicate that a large fraction of individuals are uncertain about the fairness of a MBUF with more than 35 percent indicating “neutral” as their response to the two questions (although not necessarily the same 35 percent). While 32 percent somewhat or strongly agree that MBUF is fair because everyone pays equal, only 23 percent agree that it is more fair than the gas tax because it does not differentiate between vehicle fuel types. In other words, support for such user fee schemes remains rather tepid even in an era of growing market penetration of electric vehicles. Model estimation results show that a host of socio-economic, demographic, and attitudinal factors affect perceptions of fairness along the two dimensions of rationale. For example, those who perceive congestion as a burden (which includes higher-income individuals, younger cohorts, and those with children) express a lower perception of MBUF fairness regardless of the rationale. On the other hand, high-efficiency vehicle users and high-income individuals believe that it is more fair than the gas tax on the grounds that everybody pays equal, but disagree that it is more fair because drivers of clean vehicles are not differentially rewarded. Those who prefer suburban lifestyles, and hence more likely to drive larger vehicles and longer distances, believe that the MBUF is more fair than the gas tax because it does not differentiate among vehicle types. Frequent commuters, who may not have work schedule flexibility, largely spurn the notion that MBUF is more fair than the gas tax because everybody pays equal.

These findings suggest that MBUF schemes need to be crafted with care and sensitivity to different groups of individuals to garner broad support (Kallbekken et al. 2013). For those perceiving congestion as a burden already, adding a MBUF is simply not appealing. These groups need to be informed that the MBUF is a replacement for the gas tax, is not meant to raise additional revenue when compared with a gas tax (i.e., it is meant to be largely revenue-neutral), and could potentially provide congestion relief as a pay-per-mile fee may reduce vehicle miles of travel in

some contexts. It would appear that some differentiation with respect to vehicle type choice is warranted. This could contribute to broader public support, especially among those who currently use fuel efficient and electric vehicles, while also encouraging the faster adoption of fuel efficient and alternative fuel vehicles among others. This differentiation (i.e., charging lower MBUF for drivers of efficient vehicles) should be done with care and in a balanced manner to avoid loss of support among (suburban) households that drive larger fossil fuel vehicles; these households should not perceive that they are being penalized (in any substantive way) compared to the current gas tax. One way to do this is to allow the MBUF itself to be a fixed, uniform pay-per-mile scheme, but offer discounted registration fees or other special perks for alternative fuel vehicle owners (e.g., Hoen and Koetse, 2014). Finally, some accommodation for income differentiation may be warranted to ensure that frequent commuters, particularly those in lower income occupations, are not adversely impacted – which would lead to loss of support among this demographic. While special subsidies or differential pricing could be offered as part of an income-based MBUF scheme to help such individuals, it may also be prudent to view MBUF as part of a larger transportation policy package where lower income commuters are providing transit subsidies and transportation vouchers, and alternative modal options (such as public transit) are improved using a portion of the revenue collected through the MBUF scheme. As the gas tax becomes increasingly outdated and technology becomes increasingly advanced, the time is ripe for a concerted effort to begin the transition towards a well-crafted, demographically sensitive MBUF system in the United States.

ACKNOWLEDGMENTS

This research was partially supported by the National Center for Understanding Future Travel Behavior and Demand (TBD), which is a University Transportation Center sponsored by the U.S. Department of Transportation under grant numbers 69A3552344815 and 69A3552348320.

REFERENCES

- Agrawal, A. W., and H. Nixon. Getting Mileage Fees Right: What Does the U.S. Public Think? *Public Finance and Management*, 2024. 23(1–2):22–73.
- American Public Transportation Association. *Who Rides Public Transportation 2017*. American Public Transportation Association, Washington, DC, 2017.
- Anderson, S. M., K. E. Asmussen, S. Saxena, I. Batur, R. M. Pendyala, and C. R. Bhat. An Investigation of Dissonance in Telework Frequency. *Transportation Research Part C: Emerging Technologies*, 2024. 166:104712.
- Bhat, C. R. A New Generalized Heterogeneous Data Model (GHDM) to Jointly Model Mixed Types of Dependent Variables. *Transportation Research Part B: Methodological*, 2015. 79:50–77.
- Brase, G. L. What Would It Take to Get You into an Electric Car? Consumer Perceptions and Decision Making about Electric Vehicles. *The Journal of Psychology*, 2019. 153(2): 214–236.
- Burris, M., S. Lee, T. Geiselbrecht, and T. Baker. *Equity Evaluation of Sustainable Mileage-Based User Fee Scenarios*. Publication SWUTC/14/600451-00007-1. Southwest Region University Transportation Center (US), 2013.
- Chen, Y., and H. Wang. Why Are Fairness Concerns so Important? Lessons from a Last-Mile Transportation System. *Transportation Research Part A: Policy and Practice*, 2025. 192: 104361.
- Ciciolla, L., and S. S. Luthar. Invisible Household Labor and Ramifications for Adjustment: Mothers as Captains of Households. *Sex Roles*, 2013. 81(7):467–486.

- Consumer Reports. *Across Racial Demographics, Interest in Purchasing Electric Vehicles Is Considerable, but Systemic Barriers Persist*. September 2022. https://advocacy.consumerreports.org/press_release/across-racial-demographics-interest-in-purchasing-electric-vehicles-is-considerable-but-systemic-barriers-persist/ Accessed July 15, 2025.
- Coogan, M., G. Spitz, T. Adler, N. McGuckin, R. Kuzmyak, and K. Karash. *Understanding Changes in Demographics, Preferences, and Markets for Public Transportation*. Transportation Research Board, 2018.
- Delucchi, M. A. Do Motor-Vehicle Users in the US Pay Their Way? *Transportation Research Part A: Policy and Practice*, 2007. 41(10):982–1003.
- Eastern Transportation Coalition. *Equity and Fairness Considerations in a Mileage-Based User Fee System*. Technical Memorandum. Eastern Transportation Coalition. 2019.
- Energy Institute Blog. *Three Facts About EVs and Multi-Vehicle Households*. July 2023. <https://energyathaas.wordpress.com/2021/09/20/three-facts-about-evs-and-multi-vehicle-households/> Accessed July 28, 2025.
- EPA. *Smart Location Database Version 3.0*. 2021.
- Federal Highway Administration. *Highway Statistics 2017*. U.S. Department of Transportation, Federal Highway Administration, 2018.
- Fournier, N., and E. Christofa. On the Impact of Income, Age, and Travel Distance on the Value of Time. *Transportation Research Record: Journal of the Transportation Research Board*, 2021. 2675(3):122–135.
- Hoen, A., and M. J. Koetse. A Choice Experiment on Alternative Fuel Vehicle Preferences of Private Car Owners in the Netherlands. *Transportation Research Part A: Policy and Practice*, 2014. 61:199–215.
- Holguín-Veras, J., T. Encarnación, and C. A. González-Calderón. User Perception of Fairness of Time-of-Day Pricing and Other Typical Toll Discounts. *Transportation Research Part A: Policy and Practice*, 2020. 137:560–581.
- Hu, L. Gender Differences in Commuting Travel in the US: Interactive Effects of Race/Ethnicity and Household Structure. *Transportation*, 2021. 48(2):909–929.
- Institute for Employment Studies. *Working Long Hours: A Review of the Evidence, Volume 1 – Main Report*. Institute for Employment Studies, Brighton, UK. 2003.
- Institute on Taxation and Economic Policy. *Most States Have Raised Gas Taxes in Recent Years*. June 2019. <https://itep.org/most-states-have-raised-gas-taxes-in-recent-years-0419/> Accessed July 25, 2025.
- Jakobsson, C., S. Fujii, and T. Gärling. Determinants of Private Car Users’ Acceptance of Road Pricing. *Transport Policy*, 2020. 7(2):153–158.
- Jenn, A., I. L. Azevedo, and P. Fischbeck. How Will We Fund Our Roads? A Case of Decreasing Revenue from Electric Vehicles. *Transportation Research Part A: Policy and Practice*, 2015. 74:136–147.
- Jung, G., and T.-C. Yang. Household Structure and Suburbia Residence in US Metropolitan Areas: Evidence from the American Housing Survey. *Social Sciences*, 2016. 5(4):74.
- Kallbekken, S., J. H. Garcia, and K. Korneliussen. Determinants of Public Support for Transport Taxes. *Transportation Research Part A: Policy and Practice*, 2013. 58:67–78.
- Kile, J. *Testimony on Addressing the Long-Term Solvency of the Highway Trust Fund*. Congressional Budget Office, Washington, DC, 2021.

- Knittel, C. R., G. E. Metcalf, and S. Saraf. *From Tank to Odometer: Winners and Losers from a Gas-to-VMT Tax Shift*. National Bureau of Economic Research (NBER). Working paper No. w33894. 2025.
- Kwon, K. Rethinking VMT: Factors Affecting Household VMT Focusing on Differences between ICEVs and EVs. Preprint. Accessed July 28, 2025. <https://www.researchsquare.com/article/rs-2395159/v1>.
- Lee, H. *Are Millennials Leaving Cities? Yes, But Young Adults Are Not*. Harvard University Joint Center for Housing Studies, May 2021. <https://www.jchs.harvard.edu/blog/are-millennials-leaving-cities-yes-young-adults-are-not> Accessed July 15, 2025.
- Magassy, T. B., I. Batur, A. Mondal, K. E. Asmussen, C. R. Bhat, and R. M. Pendyala. Multidimensional Analysis of Willingness to Share Rides in a Future of Autonomous Vehicles. *Transportation Research Record*, 2024. 2678(6):865–880.
- Mattinzioli, T., A. A. Butt, and J. Harvey. Literature Review on Pavements and Electric Vehicle Interaction: A Research Roadmap. *Transportation Research Part D: Transport and Environment*, 2023. 122:103886.
- Metcalf, G. E. The Distributional Impacts of a VMT-Gas Tax Swap. *Environmental and Energy Policy and the Economy*, 2023. 4(1):4–42.
- National Academies of Sciences, Engineering, and Medicine. *Public Perception of Mileage-Based User Fees*. The National Academies Press, Washington, DC, 2016.
- National Surface Transportation Infrastructure Financing Commission. *Paying Our Way: A New Framework for Transportation Finance*. U.S. Department of Transportation, Washington, D.C., 2009.
- Nelson, C., and G. Rowangould. Lacking Knowledge or Lacking Support? An Informed Choice Study of Support for Mileage Fees as an Alternative to Gas Taxes. *Transportation Research Interdisciplinary Perspectives*, 2024a. 27:101208.
- Nelson, C., and G. Rowangould. Data-Driven Analysis of Rural Equity and Cost Concerns for Mileage-Based User Fees in Vermont. *Transportation Research Record: Journal of the Transportation Research Board*, 2024b. 2678(7):327–339.
- Nixon, H., and A. W. Agrawal. Would Americans Pay More in Taxes for Better Transportation? Answers from Seven Years of National Survey Data. *Transportation*, 2019. 46(3):819–840.
- Ou, S., Z. Lin, C. (Ross) Wang, S. Davis, S. Jiang, M. Hilliard, H.-L. Hwang, X. Hao, and R. Yu. Improving the Effectiveness and Equity of Fuel Economy Regulations with Sales Adjustment Factors. *iScience*, 2022. 25(9):104902.
- Park, S. *Equity and Mileage-Based User Fees: An Analysis of the Equity Implications of Mileage-Based User Fees Compared to the Gas Tax in the SCAG Region*. UCLA: Institute of Transportation Studies. 2022.
- Paz, A., A. Nordland, N. Veeramisti, A. Khan, and J. Sanchez-Medina. Assessment of Economic Impacts of Vehicle Miles Traveled Fee for Passenger Vehicles in Nevada. *Transportation Research Record: Journal of the Transportation Research Board*, 2014. 2450(1):26–35.
- Przepiorka, A. M., and A. P. Blachnio. The Relationships between Personality Traits and Leisure Time Activities: Development of the Leisure Time Activity Questionnaire (LTAQ). *Neuropsychiatry*, 2017. 7(6):1035–1046.
- Rahman, M., H. Ju, and M. Burris. Income and Geographic Distribution of a Vehicle Miles Traveled Fee: Case Study of Four States. *Transportation Research Record: Journal of the Transportation Research Board*, 2025. 2679(4):615–629.

- Ravensbergen, L., K. B. Newbold, R. Ganann, and C. Sinding. ‘Mobility Work’: Older Adults’ Experiences Using Public Transportation. *Journal of Transport Geography*, 2021. 97:103221.
- U.S. Energy Information Administration. *How Much Gasoline Does the United States Consume?* 2024. <https://www.eia.gov/tools/faqs/faq.php?id=23&t=10>, Accessed July 15, 2025.
- U.S. House Committee on Transportation and Infrastructure. *The National Surface Transportation Policy and Revenue Study Commission Report: “Transportation for Tomorrow.”* Publication 110–91. U.S. Government Printing Office, Washington, DC, 2008.
- Weatherford, B. A. Distributional Implications of Replacing the Federal Fuel Tax with per Mile User Charges. *Transportation Research Record: Journal of the Transportation Research Board*, 2011. 2221(1):19–26.
- Wilson, K. *SUV and Pickup Purchases Soar — But Who’s Buying?* Apr, 2021. Accessed July 28, 2025. <https://usa.streetsblog.org/2021/04/21/suv-and-pickup-purchases-soar-but-whos-buying>
- Yang, D., E. Kastrouni, and L. Zhang. Equitable and Progressive Distance-Based User Charges: Design and Evaluation of Income-Based Mileage Fees in Maryland. *Transport Policy*, 2016. 47:169–177.
- Zhong, X., C. Bernasconi, and N. Maalouf. Willingness to Support Transit Index: Understanding the Impact of Political, Ideological, and Socio-Demographic Traits on Support for Public Transit. *Journal of Public Transportation*, 2022. 24:100007.