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Equity Evaluation of Sustainable Mileage-Based User Fee Scenarios

by Mark Burris, Sunghoon Lee, Tina Geiselbrecht, Richard Baker and Brian Weatherford

This paper examined equity changes from the imposition of a mileage-based user fee (MBUF) based on how revenue is collected as well as how it is spent. Using the 2009 National Household Travel Survey along with detailed transportation spending estimates, four scenarios were examined. A scenario where an MBUF is combined with a federal tax and includes a greater focus on maintenance spending was the most geographically equitable. Researchers also found that considering funding disbursement when examining the effect of a shift to an MBUF may change the equity of a funding option as compared to only examining revenue source.

INTRODUCTION

The Texas gas tax has been 20 cents per gallon since 1991, and the federal gas tax has been 18.4 cents per gallon since 1993. While the population, number of registered vehicles, and vehicle miles traveled (VMT) in Texas have all increased, funding for transportation has not kept pace due to inflation and the improved fuel efficiency of the vehicle fleet. As a result, while damage to infrastructure has increased due to increased VMT, the money available for maintaining and improving roadways is actually declining (Cho and Powers 2006; Cauchon 2010). Several solutions for increasing revenue have been proposed, such as increasing the gas tax, indexing the gas tax to inflation, expanding toll roads, and increasing the vehicle registration fee. The National Surface Transportation Infrastructure Financing Commission provided several funding options to satisfy growing funding needs but identified a mileage-based user fee (MBUF) as the best long-term strategy (National Surface Transportation Infrastructure Financing Commission 2009). Based on this background, this research will focus on the effect of an MBUF on equity.

The objective of this research is to examine the equity impacts resulting from not only a change in how transportation funding is assessed and collected but also in how it is spent. Several likely funding scenarios were developed, focusing on asset management and environmental sustainability. For example, one scenario directs a much larger portion of revenues to the repair and maintenance of transportation infrastructure than currently planned. Planning documents examined for this effort indicate that funding shortfalls will result in a lower emphasis on maintenance related activities in the state (Texas Department of Transportation 2012a). In fact, there is current consideration to allow lower-functional-classification roads be maintained at a lower pavement score than those in a higher functional class in order to preserve maintenance funds. This research examines the impact of diverting a larger portion of transportation funding to maintenance, relative to current state plans, with respect to geographic equity. Another scenario charges vehicles an MBUF while focusing additional spending on environmentally friendly projects such as transit system expansion projects. Thus, this scenario would entail a significant shift from how revenues are currently spent and could cause considerable equity implications. These were the two primary scenarios examined. These scenarios were compared to using the gas tax for projects as projected in the Texas Department of Transportation's (TxDOT's) unified planning program document (Texas Department of Transportation 2012a). With National Household Travel Survey (NHTS) data for Texas, the change in user fees for travelers under the new fee systems was estimated. By combining this with how the new funding will be allocated, the research determined how much travelers would spend on MBUFs and what portion of these revenues benefitted them. In this manner, a full picture of the equity impacts, both costs and benefits, was obtained.

The second section of this paper reviews the literature surrounding transportation funding, MBUFs, and equity. The third section examines TxDOT's planned future spending, by category, for the next decade. This research breaks the spending into six categories: 1) urban construction spending, 2) rural construction spending, 3) urban maintenance spending, 4) rural maintenance spending, 5) urban environmental spending, and 6) rural environmental spending. These categories are useful for examining equity when funding amounts shift between these six categories. The fourth section discusses the traveler data obtained from the NHTS. The fifth section discusses the analysis methodology and results from several scenarios examined. Finally, the sixth section contains the conclusions and recommendations based on this research.

LITERATURE REVIEW

This research estimates potential equity changes when the transportation funding method and spending allocations are changed. In this research, the new spending focus area is sustainability, which includes social, economic, and environmental progress of society (Zietsman et al. 2011). Thus, equity (sustainability in terms of social progress and the first of the three areas of social progress) is examined from the perspective of shifts in funding to asset management and protection of the environment (the other two types of societal progress under sustainability). The literature review examines issues surrounding these three concepts of sustainability as well as examining previous MBUF studies.

Sustainability

Sustainability includes a holistic consideration of economic, social, and environmental progress with a long-term perspective (Zietsman et al. 2011). Social progress focuses on social welfare outcomes, such as human health and education attainment, rather than on material wealth, while economic progress is related to the increase of quantity, such as the gross domestic product that measures the quantity but not the quality of market activities (Litman 2009). Environmental progress emphasizes a conservation ethic and policies that reduce any waste of resources such as air, water, and land. The principles of sustainable development have significant implications for allocation of transportation funding because transport activities tend to be resource intensive. Thus, if a sustainable development policy becomes a primary determinant in the allocation of transportation funding, then transportation funds will be used to increase mobility (the economic progress), improve equity (the social progress), and reduce environmental impacts (the environmental progress). For example, the additional funding for more transit projects may reduce the negative environmental impacts from transportation.

An MBUF can change a traveler's behavior by changing travel costs, which in turn can affect energy consumption and emissions for each traveler. Thus, MBUF strategies can be designed to reduce environmental emissions. In addition, the funds can be allocated for environmentally friendly transportation policies such as public transportation and non-motorized modes. The equity impacts of such shifts are the focus of this research.

Asset Management

Transportation asset management is a decision-making procedure for making cost-effective decisions about the design, construction, maintenance, rehabilitation, retrofit, replacement, and abandonment of transportation assets, with the purpose of maintaining or improving the value of these assets over time (Meyer and Miller 2001). In recent years, the national costs of preserving and operating the current transportation infrastructure, valued at $1.75 trillion, have rapidly increased (U.S. Department of Transportation 2007). If current trends continue, state departments of transportation (DOTs) and other public-sector owners of highway infrastructure will be unable to afford to maintain the transportation system, let alone construct additional capacity (U.S. Department of Transportation 2007). Thus, a transportation asset management strategy may be a primary concern for allocating transportation funds through an MBUF policy. This research examines impacts of increasing the amount of funds spent on maintenance among those aspects of asset management.

Equity of Transportation Expenditure

Equity refers to the distribution of impacts and benefits. Transportation planning and funding decisions have significant and various equity impacts. Transportation equity is commonly classified into two types of equity: horizontal and vertical. Horizontal equity means that same socio-economic status individuals and groups should receive equal shares of resources, bear similar costs, and be treated the same in other ways. On the other hand, vertical equity has to do with the distribution of impacts and benefits among individuals and groups considered different in abilities and needs. These differences may be based on income, social class, transportation ability, and need (Litman 2012). This research focuses on examining horizontal equity with respect to geographic location (urban and rural residents), and vertical equity with respect to household income.

MBUF Research

There are only a handful of studies related to the equity impacts of an MBUF. Burris and Larsen (2012) recently examined potential equity impacts of MBUFs. Their research focused on the equity of funding collection. In their research, Texas data from the 2009 NHTS were used to examine the equity impacts of four MBUF scenarios: 1) flat MBUF scenario, 2) flat MBUF for added revenue scenario, 3) three-tier MBUF scenario to encourage "green" vehicles, which have high fuel efficiencies, and an 4) urban versus rural distinction scenario. In the first scenario, a flat MBUF scenario, the rate of the MBUF was set to recover the same net revenue as the gas tax. In the second scenario, the MBUF rate was increased to raise revenues needed according to a 2030 needs study. In the third scenario, vehicles with high fuel efficiency paid a lower MBUF. In the fourth scenario, since urban roadways and rural roadways have different costs, characteristics, and travelers, rural and urban roadway users were charged a different MBUF. The vertical equity of all MBUF scenarios was similar to the vertical equity of the current Texas gas tax. These results were similar to a previous study of Oregon drivers by Zhang et al. (2009). In terms of horizontal equity, the urban versus rural scenario was more geographically equitable, and a three-tier MBUF scenario to encourage "green" vehicles was found to be the least horizontally equitable. In scenarios 1, , and 4, the horizontal equity was more equitable than the horizontal equity of the current gas tax. Oregon conducted an MBUF pilot study in 2006 (Rufolo and Kimpel 2008). The pilot study compared driver behavior under two scenarios: 1) being charged an MBUF equivalent to the amount paid under the state gas tax, and 2) being charged a higher MBUF during the peak hours and a lower MBUF during the off-peak hours. Over 90% of participants stated that they would agree to replace the current gas tax with an MBUF. This result may not be surprising because the participants already favored the MBUF before the pilot study and thus participated. However, it is still impressive that 90% of participants agreed with the replacement of the gas tax after experiencing the MBUF. The pilot study also found that the MBUF strategy in the second scenario is useful to reduce the VMT during peak hours. Weatherford (2011) evaluated the equity impacts of a flat MBUF using the 2001 NHTS data for the entire United States. His research suggested a rate of 0.98 cents per mile to replace the current federal gas tax. This VMT fee structure would lead to less of a transportation tax burden on low-income households, rural households, and retired households. The result that rural households pay less under VMT fee structure was similar to results of a previous study by McMullen et al. (2010). However, his research noted that overall changes related to equity are relatively minimal. His research also recommended that any future MBUF scenario needs to consider a policy to promote the use of fuel-efficient vehicles.

DISBURSEMENT OF FUTURE TRANSPORTATION FUNDING IN TEXAS

This section examines estimates of future transportation expenditures for the period 2012 to 2021 and is based on the data from the 2012 Unified Transportation Program (UTP) (Texas Department of Transportation 2012a).

Classification of Future Transportation Expenditures

The future expenditure estimates are classified according to sustainability, as well as the region where the funding is allocated: 1) urban construction spending, 2) rural construction spending, 3) urban maintenance spending, 4) rural maintenance spending, 5) urban environmental spending, and 6) rural environmental spending. Most transportation projects related to economic sustainability are concerned with: (1) the enhancement of travelers' mobility and reduction in travel costs, which can also be viewed primarily in terms of construction projects; and (2) maintenance or asset management projects that economically prolong the useful life of an existing system. Thus, in the above categorization, construction and particularly maintenance spending is related to economic sustainability. Inflation and improved fuel efficiency standards will continue to erode tax revenue for future transportation improvements, so maintenance projects may demand higher portions of the budget just to keep the system operational. For this reason, this research separates construction and maintenance spending. Environmental spending is classified as the spending for transportation projects that aim to improve or preserve the environment even though they accompany either construction or maintenance works. Funding for construction of bike/pedestrian paths and transit rehabilitation and improvement programs is included in our environmental spending category. The geographical distribution, rural versus urban, of future transportation funding is also considered. A review of how detailed spending estimates are provided in terms of geographical boundaries shows the statewide long range transportation plan (SLRTP) (2012c), the Metropolitan Transportation Plan (MTP), the Texas Rural Transportation Plan (TRTP), and UTP use the county boundary. Thus, this research also uses the county boundary to delineate between a rural and urban area. Furthermore, according to the Census Bureau's definition of an urban area (U.S. Census Bureau 2012), if a county has a population greater than 50,000 people and is contained within the metropolitan planning organization (MPO) boundary, this research considers the area to be an urban area. As a result, 54 of the 254 counties within Texas are considered urban areas, and 200 counties are considered rural areas. In 2010, the 54 counties have population of 7,676,751 households (86%) and the 200 counties have 1,246,182 households (14%).

Classification of Future Transportation Expenditure Estimates

The SLRTP (Texas Department of Transportation 2010), UTP (Texas Department of Transportation 2012a), TRTP (Texas Department of Transportation 2012c) and many MPO documents, such as the MTP for the Abilene Metropolitan Planning Organization (Abilene Metropolitan Planning Organization 2010) were selected to estimate statewide long-range transportation expenditure because they provide relatively comprehensive transportation plans over longer periods of time. However, each source had issues regarding the classification of future spending into our six identified categories.

Based on review of the SLRTP, UTP, MTP, and TRTP, this research concluded that the 2012 UTP is the best source to use for statewide future transportation spending estimates. The future spending estimates in the UTP are reclassified into the six categories defined in the previous section. The UTP includes estimates of the total amount of funds spent from 2012 to 2021 for projects in 12 categories, two additional categories, and four programs (Texas Department of Transportation (2012a) for the categories/programs and their spending estimates). Thus, to reclassify the UTP into our six categories, each category/program of the UTP was first split into three categories: 1) maintenance, 2) construction, and 3) environmental. These spending estimates were then divided into rural and urban expenditure. If possible, the split of urban versus rural spending was obtained through the total amount of project expenditures planned for urban and rural areas from a project list of each category/program of the UTP. If that was unavailable, then reliable data sources, such as the District and County Statistics (Texas Department of Transportation 2012b) that include the amount of the current construction and maintenance spending, were used instead. Since MBUFs will be collected from surface transportation modes, Aviation and State Waterways and Coastal Waters Programs are excluded in the analysis. As mentioned in the previous section, all counties within Texas were classified as either rural or urban using both the criteria of 50,000 population and MPO boundary for this analysis. After reviewing a description and the project list of each TxDOT category/program in the UTP, which define characteristics of each category/program, it was classified into our six categories as in Table 1 (see Burris et al. [2013] for details of the classification).

Table 2 provides the total amount of predicted spending in the six categories for the next 10 years (see Burris et. al [2013] for details of the estimates). Most transportation funds (77.6%) will be used in urban areas. Only a small portion of the funds (10.6%) will be used for the transportation projects related to improvement of the environment, whereas 52.0% and 37.4% of the expenditures will be used for maintenance and construction, respectively.

Table 1: Classification of the UTP's Categories/Programs into the Six Categories

Urban Spending		
Construction	**Maintenance**	**Environmental**
• Category 2: Metropolitan and Urban Corridor Projects • Category 3: Non-traditional Funded Transportation Projects • Category 4: Statewide Connectivity Corridor Projects • Category 7: Metropolitan Mobility/Rehabilitation • Category 12: Strategic Priority • Category 8: Prop. 14 Safety Bond	• Category 1: Preventive Maintenance and Rehabilitation • Category 6: Structures Replacement and Rehabilitation • Category 8: Safety • Category 11: District Discretionary	• Category 5: Congestion Mitigation and Air Quality Improvement • Category 9: Transportation Enhancement • Category 10: Supplemental Transportation Projects • Category 10: Earmarks—Fed. Share • Railroad • Transit
Rural Spending		
Construction	**Maintenance**	**Environmental**
• Category 3: Non-traditional Funded Transportation Projects • Category 12: Strategic Priority • Category 8: Prop. 14 Safety Bond	• Category 1: Preventive Maintenance and Rehabilitation • Category 6: Structures Replacement and Rehabilitation • Category 8: Safety • Category 11: District Discretionary	• Category 9: Transportation Enhancement • Category 10: Supplemental Transportation Projects • Category 10: Earmarks—Fed. Share • Railroad • Transit

Source: Burris et al. (2013)

Table 2: Total Predicted Expenditures by Category from 2012 to 2021

Category	Rural	Urban	Total
Maintenance	$5,935,011,162 (20.1%)	$9,403,068,838 (31.9%)	$15,338,080,000 (52.0%)
Construction	$562,715,400 (1.9%)	$10,470,364,600 (35.5%)	$11,033,080,000 (37.4%)
Environmental	$106,509,360 (0.4%)	$3,020,145,640 (10.2%)	$3,126,655,000 (10.6%)
Total	$6,604,235,921 (22.4%)	$22,893,579,079 (77.6%)	$29,497,815,000 (100.0%)

Source: Burris et al. (2013)

The estimates in Table 2 only include the funds for fully approved future projects. The UTP report also includes a total expense forecast. This provides the total future cash flows based on department operations, financial participation by others, and the dollar value of project commitments (Texas Department of Transportation 2012a). Thus, the UTP future spending estimates in Table 2 do not include expenses and projected costs for project development, maintenance, operations, and debt service for new construction projects, and do not take into account all the expenditures and expected payouts from previous projects. However, the UTP does include an item called the total expense forecast. The total expense forecast accounts for these expenditures and is therefore closer to actual future transportation spending estimates. Since a detailed distribution plan for the total expense forecast is not provided, the total expense forecast cannot be directly classified into the six categories used in this research. Therefore, this research allocated the total expense forecast into the six categories in the proportions found in the future spending estimates derived from the UTP. Since the amount spent each year is different, the proportions for 2012 to 2021 are not exactly the same. Next, these proportions were multiplied by the total expenses as outlined in the total expense forecast to determine the total expenditures in each category. Table 3 provides the results of the classification of the total expense forecast into the six categories. Note that these estimates were used in the analysis as the future transportation spending in the six categories.

Table 3: Classification of the Total Expense Forecast into Our Six Categories

Category	2012-2021		
	Rural	Urban	Total
Maintenance	$13,919,430,410 (20.4%)	$22,095,662,077 (32.5%)	$36,015,092,487 (52.9%)
Construction	$1,238,103,049 (1.8%)	$23,523,074,460 (34.6%)	$24,761,177,509 (36.4%)
Environmental	$246,568,254 (0.4%)	$7,032,393,559 (10.3%)	$7,278,961,813 (10.7%)
Total	$15,404,101,713 (22.6%)	$52,651,130,096 (77.4%)	$68,055,231,809 (100.0%)

TRAVEL DATA

The NHTS is a large-scale, nationwide survey that provides planners and researchers with information regarding the travel behavior of Americans, as well as demographic information that may affect travel (U.S. Department of Transportation 2010). The most recent survey (the 2009 NHTS) was conducted from March 2008 to May 2009 and includes over 150,000 households nationwide. One unique feature of the survey is that the data include VMT and fuel efficiency information by household. This feature can be used to estimate each household's tax burden, either under the current gas tax or if an MBUF is implemented. Therefore, gas tax revenue collected either in a specific location (rural or urban area) or from a specific household income class can also be estimated. As a result, the geographical equity and vertical equity of the current gas tax and an MBUF can be estimated. Therefore, this research used data from the 2009 NHTS.

Weighting the 2009 NHTS Data Set

The 2009 NHTS data include a weighting variable that can be used to adjust the new data to better reflect all Texas vehicle-owning households. However, the weights cannot be used in this research without modification because the geographic boundary used by NHTS to divide rural and urban households is different from the boundary that was used to classify transportation spending. This may result in inaccurate analysis of geographical equity when considering a change in the tax system. The 2009 NHTS data set includes a household location variable with households classified as either rural or urban. This variable was categorized by the cartographic boundary that only considers urbanized areas, which consist of the built-up area surrounding a central city with a population density of at least 1,000 people per square mile (U.S. Department of Transportation 2012). This boundary was not consistent with the county boundary used to divide the rural and urban area households for funding as noted in the previous section. Thus, each data set was analyzed to identify the number of households in rural and urban areas.

The 54 urban counties, as defined in the previous section, had a 2010 Census population of 7,676,751 households (86%), while the 200 rural counties had 1,246,182 households (14%) (Texas State Data Center 2013a). Based on the 2009 NHTS data, there were 6,199,869 urban Texas households (78%) and 1,714,454 rural Texas households (22%). The total number of households in the 2010 Census (7,676,751+1,246,182=8,922,933) is also different from the total number of households in the 2009 NHTS data set (6,199,869+1,714,454=7,914,323). The main reason for this difference is that the households in the 2009 NHTS data set modified for this research only represent vehicle-owning households, while the households in the 2010 Census represent all households regardless of vehicle ownership. The two-year difference in when the data were collected may also produce additional differences in the total number of households. The 2010 Census data were the most reliable source and matched the spending data set based on county boundaries, and were therefore used as the true total population. However, the difference in the percentage of rural and urban households between both data sets needs to be considered because the difference is caused by the use of the different boundaries in both data sets. The most ideal method to adjust the difference is to recategorize one data set based on the boundary of the other data set. However, this method could not be applied because the 2009 NHTS data set only mentions whether the household was rural or urban, and not the specific address of a household. Therefore, this research adjusted the ratios of rural and urban NHTS households to match the 2010 Census. For this, the weight variable included in the 2009 NHTS data was adjusted using Equations 1 and 2:

(1) $$\text{Adjusted Weight of Urban HH}$$
$$= \text{NHTS Weight of Urban HH} \times \frac{\text{Total Number of HHs in NHTS} \times 86\%}{\text{Number of HHs in NHTS in Urban Areas}}$$
$$= \text{NHTS Weight of Urban HH} \times \frac{7{,}914{,}323 \times 86\%}{6{,}199{,}869} = \text{Weight of Urban HH} \times 1.098$$

(2) $$\text{Adjusted Weight of Rural HH}$$
$$= \text{NHTS Weight of Rural HH} \times \frac{\text{Total Number of HHs in NHTS} \times 14\%}{\text{Number of HHs in NHTS in Rural Areas}}$$
$$= \text{NHTS Weight of Rural HH} \times \frac{7{,}914{,}323 \times 14\%}{1{,}714{,}454} = \text{Weight of Rural HH} \times 0.641$$

Where: HH implies household.

Estimating Future Travel Data from 2012 to 2021

The 2009 NHTS data only provided 2008 travel information for households. However, this research requires future travel data from 2012 to 2021 to estimate tax revenues from either the current gas tax or an MBUF.

Estimating NHTS Weights from 2012 to 2021. Each weight in the previous section reflects the number of vehicles that may have the same travel characteristics in 2008. Thus, the sum of the weights is the same as the total number of vehicles owned by Texas households. Those weights cannot be used for future estimation because the number of vehicles in Texas will change in the future. Thus, new weights for future travel need to be estimated. However, projections for vehicle increase rates classified by the household location (rural and urban areas) in Texas for the future are not available. Thus, to estimate the number of vehicles during 2012 to 2021, this research first estimates past vehicle increases in both rural and urban areas between 2001 and 2007 (Texas Department of Transportation 2013). Then, this research also considered past population increases in both rural and urban areas between 2001 and 2007 (Texas State Data Center 2013b) because the change in population generally reflects the change in the number of vehicles. From these two estimations, the relationship between population growth and the increase in the number of vehicles between 2001 and 2007 was estimated (see Table 4). Using this relationship and projected future populations (Texas State Data Center 2013c), the projection for vehicle increase rates was estimated. This projection was applied to the NHTS weighting factors.

Table 4: Relationship Between Vehicle Increase and Population Increase

	(a) Vehicle Increase Rate	(b) Population Increase Rate	Ratio (a/b)
Rural areas	17.30%	3.90%	4.44
Urban areas	20.17%	13.57%	1.49
All of Texas	19.68%	12.10%	1.63

Estimating Fuel Efficiency Improvements. The current gas tax is charged in proportion to the amount of fuel consumed. The amount of fuel consumed in each household can be calculated by dividing the VMT of each household vehicle by the fuel efficiency (in MPG) of the vehicle. The 2009 NHTS data included these VMT and MPG estimates of each household vehicle in 2008. However, the average fuel efficiency is expected to increase in the future. This will reduce the gas tax burden of each household and Texas gas tax revenue because the amount of fuel consumed will decrease. Castiglione et al. (2011) provides the projections of average MPG for all vehicles in Texas that were used in the Transportation Revenue Estimator and Needs Determination System (TRENDS) model (Castiglione et al. 2011). The vehicle in the NHTS data set had its fuel efficiency increased using the projections.

Estimating Fuel Costs. The 2009 NHTS data included the cost of fuel (dollars per gallon) that each household paid for one gallon of gasoline in 2008. A shift to the MBUF will cause a change in fuel prices because the tax will be subtracted from the total fuel price. This change may also affect the VMT of households—as fuel price increases, VMT is generally reduced. This effect of fuel price change on VMT due to the shift to MBUFs was considered in this research. Thus, estimates of fuel cost for each household from 2012 to 2021 are also required. For the fuel cost estimates in 2012, historical data of average gasoline prices in Texas between 2008 and 2012 were used to estimate the increase (U.S. Energy Information Administration 2013). For the future fuel cost estimates from 2013 to 2021, this research assumes that the cost of fuel for each household will change at the same rate as nationwide gasoline prices. Thus, projected U.S. gasoline price changes from 2013 to 2021 were used (U.S. Department of Transportation 2009).

MBUF AND FUNDING DISBURSEMENT SCENARIOS

To evaluate the equity of an MBUF, this research considers the change in revenue collection as well as the disbursement of funds. Table 5 provides a brief description of the scenarios. Note that all monetary estimates in this section are expressed in 2012 dollars and apply a 4% inflation rate.

Table 5: Brief Description of the Scenarios

Scenario	Gas Tax System	Funding Disbursement
Scenario 1	Current state and fed. gas tax	Same as the current disbursement
Scenario 2 (static and dynamic)	Flat MBUF and fed. gas tax	Same as the current disbursement and increased revenue by the MBUF
Scenario 3 (static and dynamic)	Flat MBUF and fed. gas tax	More disbursement to maintenance spending
Scenario 4 (static and dynamic)	Flat MBUF and fed. gas tax	More disbursement to environmental spending

Static Versus Dynamic Scenarios

Revenue that will be collected from the MBUF in the future is estimated assuming no change in driver behavior due to the MBUF (static) and a change in VMT due to the MBUF (dynamic). To estimate the change in VMT due to the MBUF for the dynamic scenario, reasonable values of elasticity (ratio of percent change in VMT to percent change in total cost of gas and MBUF) are required. However, since MBUF research is still in the theoretical stage, empirical elasticities of VMT and the associated price of gas/MBUF cannot be directly estimated. Thus, this research adopted the values of elasticity used in previous MBUF research (Burris and Larsen 2012) (see Table 6). Note that these values were derived from Wadud et al. (2009) and are based on the price elasticity of gas. These elasticities were used to calculate the anticipated change in annual VMT for households within each subcategory disaggregated by household income level and geographic location. Elasticities are based on the percent change in the total price of gas, not just the change in the state gas tax portion of the price.

Table 6: Price Elasticities by Household Income Level and Geographic Location

Household Income Level ($1,000s)	Urban Households	Rural Households
<20	−0.447	−0.254
20–40	−0.280	−0.159
40–60	−0.259	−0.147
60–100	−0.335	−0.191
100+	−0.373	−0.212
Total (weighted average)	−0.339	−0.192

Source: Burris and Larsen (2012)

Scenario Structure

All scenarios are structured based on two perspectives, revenue collection and transportation funding disbursement. The revenue here implies the total expected Texas revenue from either the current gas tax (both state and federal) or the MBUF along with the federal gas tax. The disbursement of transportation funds reflects possible changes in future funding disbursement, including distribution of increased revenue due to the MBUF, additional disbursement to maintenance spending, and additional disbursement to environmental spending.

Scenario 1. Scenario 1 evaluates the equity of the current plans. This includes the revenue that will be collected from the current gas tax together with the current planned transportation funding disbursement from 2012 to 2021. To calculate the revenue estimates from 2012 to 2021, it is assumed that there will be no changes in the state (20 cents/gallon) or federal (18.4 cents/gallon) gas tax from 2012 to 2021. Annual revenues were calculated by multiplying the VMT of all Texas (adjusting for future growth) vehicles by 38.4 cents/gallon and dividing by each vehicle's fuel efficiency adjusting for the change in fuel efficiency. This scenario uses the current funding disbursement plan from 2012 to 2021 shown in Table 3.

Scenario 2. In Scenario 2, the state gas tax is replaced with a flat MBUF to estimate revenue. In addition, static models (no change in driver behavior due to the MBUF) and dynamic models (a change in VMT due to the MBUF) are considered. A shift from the current state gas tax to the MBUF will increase projected revenues since fuel efficiencies are increasing while total VMT is increasing. Thus, for the funding disbursement in this scenario, increased revenue due to the MBUF was distributed into our six categories. To estimate revenues from 2012 to 2021, this research first determined a flat MBUF that would generate roughly the same gross revenue in 2012 as the current state gas tax. The amount of revenue in 2012 from the current state gas tax was $1,662,386,960 based on the weighted NHTS data. The total VMT of the Texas households was 190,854,877,961 miles in 2012 based on the weighted NHTS data. Thus, the rate of flat MBUF in the static model was determined as $0.008710/mile ($1,662,386,960/190,854,877,961 miles). The next step was to determine an MBUF associated with the dynamic model. The change in total VMT in 2012 due to the MBUF was estimated to be -280,782,179 miles based on the elasticity of demand in Table 6. Thus, the flat MBUF in the dynamic model was determined to be $0.008723/mile ($1,662,386,960/190,574,095,782 miles). In addition, in dynamic Scenario 2, changes in VMT due to the MBUF ($0.008710/mile) were also considered for every year from 2013 to 2021 to estimate the revenue from 2013 to 2021 because the weights, fuel costs, and fuel efficiencies were different for each year. This research assumed that the rate of the federal gas tax will not change. In addition, similar to Burris and Larsen's research (2012), 80% of urban household travel was assumed to be on urban roadways, and 20% of urban household travel was assumed to be on rural roadways. Thus, 80% of the MBUF revenue collected from urban households was considered revenue for urban areas, and 20% of the MBUF revenue was considered revenue for rural areas. Conversely, 80% of the MBUF revenue collected from rural households was considered revenue for rural areas, and 20% of the MBUF revenue was considered revenue for urban areas. For funding disbursement scenarios, this research assumes that changes to funding disbursements begin in 2017 because planning for future transportation projects, including environmental reviews, public input, and funding allocation, takes many years. Table 7 provides the increased revenues from 2017 to 2021 due to the MBUF in the static model and in the dynamic model. The increased revenue each year was distributed to the six categories with the same average proportions from 2012 to 2021 found in Table 3. Finally, those additional revenues were then added to the annual spending amounts.

Table 7: Increased Revenues due to the MBUF

Model	2017	2018	2019	2020	2021
Static	$170,502,196	$204,966,508	$239,905,768	$275,517,439	$312,050,777
Dynamic	$165,612,994	$199,298,088	$233,544,599	$268,502,718	$303,825,899

Scenario 3. If the current transportation funding shortfalls are not improved, construction spending may be shifted to maintenance spending to maintain the current transportation infrastructure, rather than be used to construct new infrastructure. Scenario 3 was designed to consider this change in funding disbursement focus, whereas the same revenue structure as in Scenario 2 was applied to this scenario. This scenario also assumed that the funding disbursement focus can only be changed from 2017 to 2021. For the funding disbursement in this scenario, this research assumed that 50% of construction spending for each year from 2017 to 2021 estimated in Scenario 2 would be shifted to maintenance spending in the future. To distribute this shifted construction expenditure in each year into rural maintenance and urban maintenance expenditure for each year, the average proportions of rural maintenance and urban maintenance spending from 2012 to 2021 was used. The environmental funding disbursement is not changed in this scenario.

Scenario 4. This scenario was designed to be an environmentally friendly transportation spending policy change. Similar to Scenario 3, the same revenue structure as in Scenario 2 was applied to this scenario. If a transportation policy focus moves to an environmentally friendly policy, it stands to reason that transportation funding allocation will reflect this policy. Thus, for the funding disbursement in this scenario, this research assumed that 50% of planned construction spending for each year from 2017 to 2021 estimated in Scenario 2 would be shifted to environmental projects. To distribute the shifted construction funds in each year into rural environmental and urban environmental expenditure for each year, the average proportions of rural environmental and urban environmental spending from 2012 to 2021 were applied. The amount spent on maintenance was not changed in this scenario.

Results

Revenue. The total revenue estimates from 2012 to 2021 for rural and urban areas is provided in Table 8. As previously mentioned, the rate of the MBUF was set so that it would generate the same revenue in 2012 that was generated by the current gas tax. However, it was expected that the MBUF would generate more total revenue over all 10 years of analysis. This is primarily related to the expected fuel efficiency improvement of vehicles. Texas households will consume less fuel due to fuel efficiency improvements, thereby paying less in gas taxes under the current gas tax system. In addition, rural areas would contribute a higher percentage of total revenue under the MBUF system relative to the current tax system. These results were partially caused by the 80/20 assumption illustrated in Scenario 2. Since an MBUF charges based on miles driven, rural areas will generate more revenue, while urban areas will generate less. It is reasonable that the total revenue in the dynamic model is a little less than the revenue in the static model because the total VMT is reduced due to elasticity of demand.

In Scenario 4, as transit infrastructure increases due to the increased environmental spending, total VMT in Texas may decrease because automobile trips may be replaced by transit trips. However, most residents in Texas depend heavily on automobile trips. As a result, a relatively small amount of spending for transit service is currently planned for the next 10 years. This amount is $395,875,000 and this accounts for 12.7% of total predicted environmental expenditure in Table 2. Thus, even though the environmental spending will be increased, most spending will be allocated to reduce negative environmental impacts of automobile trips, such as the "Clean Technology Revolving Loan Program" in Dallas, rather than to increase transit service. Thus, reduction in total VMT due to the transit service would be minimal. For this reason, this research did not consider the reduction in total VMT to estimate revenue in Scenario 4.

Table 8: 2012 to 2021 Revenue Estimates for Each Scenario

Scenario	Rural	Urban	Total
Current tax (for Scenario 1)	$5,417,437,003 (20%)	$21,557,187,519 (80%)	$26,974,624,522
MBUF and fed. tax—static (for static Scenarios 2, 3, and 4)	$7,553,595,698 (26%)	$20,965,267,325 (74%)	$28,518,863,023
MBUF and fed. tax—dynamic (for dynamic Scenarios 2, 3, and 4)	$7,546,981,882 (27%)	$20,929,622,877 (73%)	$28,476,604,759

Disbursement. This research assumed that transportation funding will be distributed into six categories with different amounts allocated to each category based on the scenarios examined. Thus, the total funding disbursements from 2012 to 2021 for each category depend on the scenarios and are compared in Table 9. As expected, the biggest amount of rural maintenance and urban maintenance spending is allocated in both static and dynamic Scenario 3. Rural environmental spending does not largely increase even in Scenario 4, the environmentally friendly funding disbursement scenario, in terms of dollar amount. This is because environmental spending is mainly used for urban areas in the current transportation plan. Since the revenue does not largely increase due to the MBUF, the total amount of funds available in Scenario 1 is not much smaller than that in the other scenarios. Table 10 provides the total funding disbursement estimates from 2012 to 2021 in urban and rural areas. Allocating a greater percentage of funds to maintenance in Scenario 3 results in an increase in the amount of funds directed to rural areas. However, even if Scenario 4 has a greater percentage of environmental spending, the proportions of rural and urban disbursements are similar to Scenarios 1 and 2.

Table 9: Comparison of Funding Disbursements in Millions of Dollars

Category	R-M	U-M	R-C	U-C	R-E	U-E	Total
Scenario 1	13,919	22,096	1,238	23,523	247	7,032	68,055
Static Scenario 2	14,165	22,486	1,260	23,939	251	7,157	69,258
Dynamic Scenario 2	14,159	22,476	1,259	23,928	251	7,153	69,227
Static Scenario 3	15,688	24,903	1,125	20,134	251	7,157	69,258
Dynamic Scenario 3	15,679	24,890	1,125	20,129	251	7,153	69,227
Static Scenario 4	14,165	22,486	1,125	20,134	384	10,963	69,258
Dynamic Scenario 4	14,159	22,476	1,125	20,129	384	10,954	69,227

Note: R-M = rural maintenance spending. U-M = urban maintenance spending. R-C = rural construction spending. U-C = urban construction spending. R-E = rural environmental spending. U-E = urban environmental spending.

Table 10: Estimates of Funding Disbursement for Each Scenario

Scenario	Rural	Urban	Total
Scenario 1	$15,404,101,715 (23%)	$52,651,130,096 (77%)	$68,055,231,811
Static Scenario 2	$15,676,384,257 (23%)	$53,581,790,241 (77%)	$69,258,174,498
Dynamic Scenario 2	$15,669,251,996 (23%)	$53,557,412,215 (77%)	$69,226,664,211
Static Scenario 3	$17,063,880,985 (25%)	$52,194,293,513 (75%)	$69,258,174,498
Dynamic Scenario 3	$17,054,819,865 (25%)	$52,171,844,346 (75%)	$69,226,664,211
Static Scenario 4	$15,674,651,449 (23%)	$53,583,523,049 (77%)	$69,258,174,498
Dynamic Scenario 4	$15,667,611,638 (23%)	$53,559,052,573 (77%)	$69,226,664,211

Revenue Compared to Disbursement. The ratio of revenue (Table 8) to disbursement (Table 10) was estimated to simultaneously examine both the burden and the benefit for each area (see Table 11). For example, for static Scenario 2, the ratio of rural area was estimated by dividing $15,676,384,257 in Table 10 by $7,553,595,698 in Table 8 and the ratio of urban area was estimated by dividing $53,581,790,241 in Table 10 by $20,965,267,325 in Table 8. The ratios were 2.075 and 2.556, respectively. For dynamic Scenario 2, the ratio of rural area was estimated by dividing $15,669,251,996 in Table 10 by $7,546,981,882 in Table 8 and the ratio of urban area was estimated by dividing $53,557,412,215 in Table 10 by $20,929,622,877 in Table 8. The ratios were 2.076 and 2.559, respectively. Since differences between static and dynamic scenario ratios are very small, this research expresses them as a two-decimal-point value without distinguishing static and dynamic scenarios in Table 11. A larger ratio means that the area received more funding than its tax burden. This ratio should, in theory, be close to one. However, the revenue includes only the gas tax from household gasoline-run vehicles, while expenses are based on all kinds of revenue (such as gas tax, registration fee, fare revenue, and lubricant tax). Therefore, the ratio estimates were much greater than one. Comparison of the ratios across the areas gives a rough idea about the geographical equity of the gas tax and funding disbursement. That is, a smaller difference between the ratios in both areas implies more geographical equity. Thus, Scenario 3, where the MBUF combined with the federal tax focuses on maintenance funding disbursement, is the most geographically equitable transportation policy. Whereas, Scenarios 2 and 4 are the least geographically equitable. Across the scenarios, Scenario 1 is the most beneficial for rural areas.

Table 11: Ratios (Disbursement/Revenue) and Their Rank in Each Scenario

Scenario	a) Rural (Rank)	b) Urban (Rank)	Difference (b-a)
1	2.84 (1st)	2.44 (4th)	−0.40
2 (static and dynamic)	2.08 (4th)	2.56 (1st)	0.48
3 (static and dynamic)	2.26 (2nd)	2.49 (3rd)	0.23
4 (static and dynamic)	2.08 (4th)	2.56 (1st)	0.48

Note: The rank is ordered by the largest ratio across the scenarios.

Geographical Equity. This research estimated two types of geographical equity (equity between rural and urban areas) with respect to funding disbursements to reflect two perspectives of equity. The first one is equity based on the number of urban and rural households, and the second is equity based on the percentage of revenues collected from each area.

To begin, the percentage of funds spent on rural and urban areas was compared to the percentage of (vehicle owning) households in rural and urban areas. In this measure, the closer the ratio is to one, the more equitable the funds spent are. This is because one area receives an appropriate amount of funds corresponding to its number of households. Scenario 3, with its focus on maintenance, proved to be the least equitable (see Table 12). This is because a larger percentage of maintenance funding is used for rural areas compared with the percentage of rural households.

Secondly, the percentage of funds spent on rural and urban areas was compared to the percentage of revenues collected from rural and urban areas. When considering the percentage of revenue in each area instead of the percentage of households, the geographical equity of the disbursement was different from the results in Table 12. All scenarios are geographically equitable based on the values of the ratios — all the ratios are relatively close to one (see Table 13). Scenarios 2 and 4 are slightly less equitable than the current gas tax (Scenario 1). Scenario 3 was slightly more equitable than the current gas tax.

Table 12: Geographical Equity of the Disbursement Based on Percentage of Households

Scenario	Percentage of Funds Spent in Rural Areas	Percentage of HHs in Rural areas	Ratio of Funds to HHs (Rank, 1=Most and 4=Least Equitable)
1	22.6%	14.0%	1.6 (1st)
2 (static and dynamic)	22.6%	14.0%	1.6 (1st)
3 (static and dynamic)	24.6%	14.0%	1.8 (4th)
4 (static and dynamic)	22.6%	14.0%	1.6 (1st)

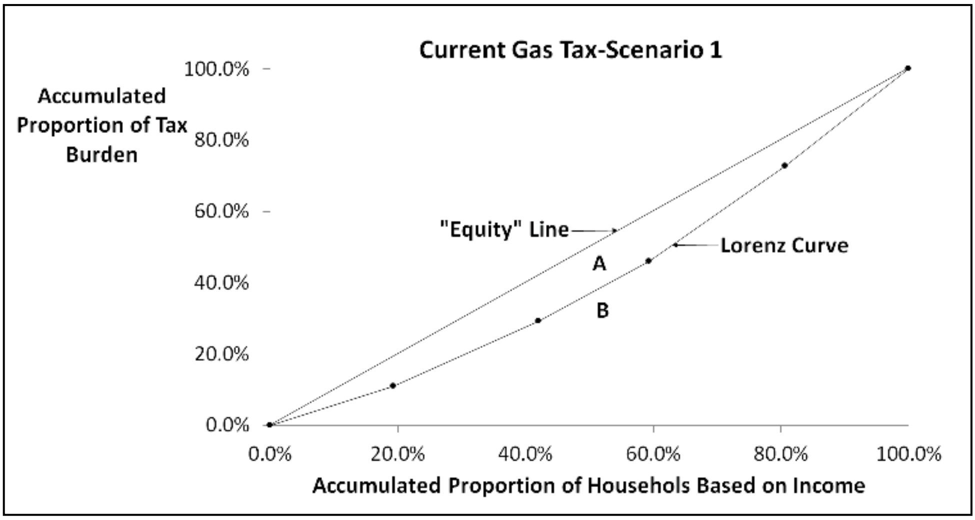
Table 13: Geographical Equity of the Disbursement Based on Percentage of Revenues

Scenario	Percentage of Funds Spent in Rural Areas	Percentage of Revenues Collected from Rural areas	Ratio of Funds to Revenues (Rank, 1=Most and 4=Least Equitable)
1	22.6%	20.1%	1.13 (2nd)
2 (static and dynamic)	22.6%	26.5%	0.85 (4th)
3 (static and dynamic)	24.6%	26.5%	0.93 (1st)
4 (static and dynamic)	22.6%	26.5%	0.85 (4th)

Vertical Equity. To estimate vertical equity of the revenues, Gini coefficients were calculated. Gini coefficients and Lorenz curves (see Figure 1) are common quantitative and visual methods, respectively, used to evaluate equity. The closer the Lorenz curve is to the equity line, the more equitable the tax is across household incomes. According to Drezner et al. (2009), "The Gini coefficient (G) is the ratio of the area between the Lorenz curve and the straight equity line to the entire area below the equity line." The value of a Gini coefficient can range from zero to one, with zero indicating complete equality and one indicating complete inequality (Rock 1982). Gini coefficients can be calculated using equation 3:

$$(3) \quad G = \frac{A}{A + B}$$

Figure 1: Lorenz Curve Plot for Tax Burden (Scenario 1)



The vertical equity of the current gas tax and the MBUF combined with the federal tax, without consideration of funding disbursement, was examined. To plot the Lorenz curves for the Gini coefficients, the percentage of households based on income class were plotted on the x-axis, and the percentage of tax burden in each household income class was plotted on the y-axis. The results in Table 14 show that the vertical equity of the current gas tax is basically identical to that of the MBUF. This is because the rate of the MBUF in this research was determined as a rate that would generate roughly the same net revenue in 2012 as the current gas tax.

Table 14: Gini Coefficients of Tax Burden Based on Household Income

Scenario	Gini Coefficients
Current tax (for Scenario 1)	0.1690
MBUF and fed. tax—static (for static Scenarios 2, 3, and 4)	0.1694
MBUF and fed. tax—dynamic (for dynamic Scenarios 2, 3, and 4)	0.1694

This research adopted the 2012 unified transportation program (UTP) for estimates of spending. In the UTP, each category has different projects, and therefore has been separated by TxDOT. However, some categories are highly related to each other in terms of their project characteristics, such as Category 2 and Category 5. Thus, in the future, there is a high possibility that spending for one category is shifted to another category. As a result, equity will be affected by this relationship.

In our research, Scenarios 3 and 4 assume that 50% of planned construction spending would be shifted to maintenance and environmental spending. The amount of the shifted funding was about $4 billion. Even though we shifted this large amount of funding, the equity of Scenarios 3 and 4 changed only a small amount (see Table 11). From these results, even if some spending for one category was shifted to its related category, equity will not be largely affected because the amount of the spending would be much less than the 50% of the construction spending.

CONCLUSIONS AND RESEARCH LIMITATIONS

Through this research, potential equity impacts of shifts in revenue collection and spending were examined. Four different scenarios were examined to evaluate equity impacts due to these changes during the years 2012 to 2021. The first scenario analyzed was the current state gas tax and the current funding disbursement. In the other scenarios, equity impacts of funding disbursement changes were analyzed under a situation where the MBUF replaces the state gas tax. Two types of geographical equity related to funding disbursements were examined. The first one is geographical equity of funding disbursement based on the percentage of urban and rural households. Scenario 3, where the MBUF is combined with the federal tax and focuses more on maintenance funding disbursement, was the least equitable because rural areas receive a larger percentage of the funding compared with the number of rural households. The second is geographical equity of funding disbursement based on the percentage of revenues collected from each area. In this measure, Scenario 3 was the most equitable. Through the results of these two measures, it was clear that the equity of a transportation funding disbursement policy depends on how it is measured. The first measure, the geographic equity of the funding disbursement based on the percentage of urban and rural households, can be used to examine a policy that aims to provide equal benefits based on the geographic location of the population. The second measure, the geographic equity of the funding disbursement based on the percentage of tax collected from each area, is useful to examine a policy that aims to distribute funding in relation to how much an area paid in taxes. Lastly, the vertical equity was examined using the Gini coefficient. The current state plus federal gas tax is similar in vertical equity to that of the MBUF combined with the federal tax for all scenarios.

Through these analyses, researchers found that considering funding disbursement when examining the effect of a shift to the MBUF may change the equity of different scenarios compared with when funding disbursement is not considered. If the MBUF rate is set at the same level as the current tax, a shift to the MBUF would have little impact on vertical equity. However, geographic equity would be reduced by the MBUF based on the revenue estimates because a shift to the MBUF increases the percentage of tax burden for rural areas. This negative impact can be alleviated by changing the funding disbursement focus; in this research, allocating more funding to maintenance improved geographical equity.

Due to the inherent difficulties of 10-year predictions for both revenue and funding disbursement estimates, several assumptions were made in performing this analysis. First, we assumed the decrease in construction spending to be 50% in Scenarios 3 and 4, but this was an arbitrary value and changing this value would affect the results. Additionally, the funding disbursement plan for the next 10 years is not perfectly clear because a few transportation plans for some categories/programs are not decided. In addition, since this research used the NHTS data set, only household gasoline-run vehicles were included in the analysis under the assumption that vehicles dependent on a different source of energy accounted for only a small portion of all household vehicles. Commercial vehicles registered in each area were not considered in this research. In the scenarios where the MBUF is implemented, the breakdown of road-type travel by both urban households and rural households was assumed to be 80/20 based on Burris and Larsen's (2012) research. This assumption can greatly affect the results. Thus, a more reliable value is required in future research. Lastly, the vertical equity of the gas taxes could not be considered together with funding disbursement because this research did not analyze how disbursement varies by income group. Based on the knowledge gained from this research, examining the vertical equity of the gas tax with consideration of funding disbursement to each income class may provide different results and be worth investigating.

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