Assessment of Prospective Mileage-Based Fee System to Replace Fuel Taxes for Passenger Vehicles in Pennsylvania

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EXECUTIVE SUMMARY

Historically, transportation infrastructure in the United States has been funded through a per-gallon fuel tax levied at the state- and federal-levels. The federal fuel tax has remained constant over the last thirty years, even as road construction and maintenance costs have risen steeply in that time. This funding gap is widened by advances in hybrid and electric vehicle technology, which have significantly improved fleet fuel-economy and reduced revenue from fuel tax. To address this, an increasing number of jurisdictions are considering programs where vehicles are taxed per-mile traveled, rather than per-gallon of fuel consumed. These mileage-based user fees (MBUFs) could replace federal and state fuel taxes and reduce the deficit in transportation infrastructure funding. To develop MBUF programs and design fair and equitable rates, jurisdictions typically develop a model estimating the number of vehicle miles traveled (VMT) by different types of vehicles in different parts of the jurisdiction.

In this proof-of-concept for Pennsylvania, we leverage about 120 million records from annual vehicle inspections across a fifteen-year period, to develop high-resolution estimates of annual vehicle miles travelled (VMT) per vehicle aggregated at the state, county, and ZIP code level. Web scraping was used to assess the fuel economy of each vehicle in these records, and to develop estimates for fleetwide fuel economy in each area. Based on these estimates of VMT and fuel economy, we estimate the annual cost to vehicle owners of the existing fuel tax, and compare this cost against the cost of MBUF's, at various rates. Based on these estimates, we find that the 'balance point' fees (i.e., the per-mile MBUF rate at which 50% of the jurisdiction would pay less or as much per year as they currently do in fuel taxes) would vary by county and ZIP code to be between 2.4 and 3.2 cents (¢) per mile. We also find that vehicles registered in urban areas travel 10-30% fewer miles per year and tend to consume about 10% less fuel per year than average. Our results show that a shift to MBUF's will in general lead to drivers in urban areas, and drivers of hybrid electric vehicles, paying a higher amount than they currently do, while drivers in suburban and rural counties will spend less each year.

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1 INTRODUCTION

Since being introduced in 1932, fuel taxes at the federal and state level have been the primary means of funding transportation infrastructure in the United States. The price of fuel paid by road-users at the pump includes state and federal fuel taxes (referred to hereafter as a 'gas tax'), plus any associated sales tax, and is a fixed per gallon rate. This system does not require user identification or the collection of mileage data and ensures that the tax is paid with the purchase of gas. The gas tax is collected by a small number of fuel wholesalers, and is reallocated back to the respective state and federal DOTs, although states may receive slightly more or less back than they paid in [1]. There are modest administrative costs associated with the collection and disbursement of gas taxes, which come primarily from implementation, operation, enforcement, and compliance costs. Gas taxes are attractive to jurisdictions as they have "low administrative and compliance costs", as well as "ease of implementation" according to the National Surface Transportation Policy and Revenue Study Commission [2].

The federal fuel tax has been stagnant for nearly three decades ($0.185/gal since 1993) and has not been adjusted for inflation despite a 240% increase in the construction cost index over that period [3]. The significant decline in the purchasing power of fuel taxes has been compounded by fuel-efficient (and electric) vehicles, which effectively pay lower (or no) taxes per mile driven [4]. Several concerns have been raised around the lower funding levels, most notably that it may lead to deferred or delayed maintenance, which would in turn lead to reduced safety, and lower resilience of infrastructure over time.

1.1 MILEAGE BASED USER FEES

As state DOT expenditures increase and the fuel tax revenue decreases, government agencies are looking for alternative methods of revenue generation. Vehicle miles traveled (VMT) fees, road user charges (RUCs), or mileage-based user fees (MBUFs) have been proposed as a successor to fuel taxes. Despite some differences in implementation, in the rest of this paper we refer to these interchangeably as MBUFs. The federal government has completed studies on MBUF's, which would the per gallon tax with a per-mile tax for each vehicle--but has not taken large-scale action [5]. The stated benefits of MBUFs include increased cost recovery for new facilities, congestion management and traffic reduction, the ability to privately finance roadways, possible incentives for fuel efficient vehicles through lower rates, and a greater wealth of data for use in improving planning models [6].

1.2 VMT ESTIMATION

Jurisdictions develop statistical models of fleet fuel-economy and mileage, to assess the potential impact of transitioning to MBUF's, and of specific MBUF rates (per mile). Historically, jurisdictions have applied a variety of methods to estimate VMT in the development of these models. Top-down methods like randomized surveys, such as the National Household Transportation Survey (NHTS) have been conducted for about 50 years [7]. However, these methods rely on relatively small sample sizes (in some cases as few as 200 for an entire state) and may result in uncertain estimates. Travel diaries have also been used to build bottom-up estimates of VMT and contain additional information such as trip types. Some studies have also evaluated registration data, but these studies can suffer from time lags.

1.2.1 Pennsylvania Vehicle Inspection Programs

Other emerging methods seek to scavenge data from existing datasets such as inspection records [8]. In this paper, we leverage odometer readings from consecutive annual safety and emissions inspections for passenger vehicles in Pennsylvania to estimate miles driven during that period. The Commonwealth has decentralized inspection and maintenance programs (I/M programs), which require annual safety inspections for all light-duty vehicles (LDV's), in addition to annual emissions inspections for LDV's registered in a subset of counties, mostly near urban areas [9]. Since millions of vehicles from across the state receive these inspections each year (during which the vehicles' odometer readings are recorded), it is possible to have large sample sizes that allow for improved and higher resolution VMT estimates across the jurisdiction. Pennsylvania is one of over thirty states with active I/M programs for LDV's, and while we demonstrate this method for one state in this study, the tools and process described here may be applied to inspection records and data from any state or jurisdiction.

1.2.2 Utilizing Inspection Data to Inform MBUF Policy

In this study, we seek to apply these high-resolution estimates of VMT to produce vehicle-level comparisons of what drivers are currently paying in fuel taxes versus what they may pay in hypothetical MBUFs. Specifically, we first aggregate inspection records for each individual vehicle (after conducting data cleaning and filtering as described below), to estimate vehicle-level VMT. Next, we estimate VMT distribution at the state, county, and ZIP level. Based on this, we calculate the annual fuel tax that each vehicle is likely currently paying, based on these VMT estimates and fuel economy data scraped from numerous websites as described below. Finally, we provide balance points between fuel taxes and MBUFs for each county, and each ZIP code area. To show these results at a vehicle-level, we also provide eight example cases and discuss their circumstances under a transition from fuel tax to different MBUF rate settings.

2 DATA

In addition to analyzing emissions and safety inspection data (to develop high-resolution estimates of VMT) over a fifteen-year period, we assessed state-level transportation spending and revenue data from publicly available sources (to assess the current funding gap and to forecast Pennsylvania's future transportation funding needs).

2.1 I/M DATA

We gathered 110 million inspection records representing a period of nearly two decades. Records for Pennsylvania's annual LDV emissions I/M programs were provided by the state Department of Transportation (PennDOT). PennDOT's emissions I/M data (2000-2016) consist of two types of records: Emissions (for all vehicles in the state that underwent an emissions inspection), Exempt (for all vehicles that were exempted from an emissions test due to age or lack of mileage, but some information is still collected). Safety inspection records were provided by PennDOT and by a private safety inspection software company, CompuSpections Inc. Table 1 shows a summary of all raw records by year and source. While emissions inspection and exemption records are assumed to be exhaustive, safety inspection data from PennDOT was only available for vehicles receiving a safety inspection at a station that voluntarily paid a fee to report the inspection result to the state. As shown in Table 1, very few safety inspections are voluntarily reported to the State. CompuSpections does not serve all safety inspection stations in the state, so data is a sample of vehicle inspection records from 1999 to 2018. In recent years, a significant share of the safety inspection records for the state's 6 million vehicles are recorded. While all datasets contain many variables for our analysis, we require only the Vehicle Identification Number (VIN), inspection date, and the vehicle's odometer reading on that date. We augmented station addresses not provided in the data with supplemental information from PennDOT.

Table 1: Over 100 million inspection records were provided by PennDOT and CompuSpections.

Year	CompuSpections	Exempt	Safety	Emissions	Total
1999	2	/	/	/	2
2000	1	780,800	/	3,000,804	3,781,605
2001	1	728,400	/	3,057,150	3,785,551
2002	7	658,378	/	3,103,306	3,761,691
2003	5	662,381	/	3,151,591	3,813,977
2004	15	984,715	/	5,562,887	6,547,617
2005	17,324	1,172,051	/	5,611,680	6,801,055
2006	59,622	1,243,627	/	5,494,224	6,797,473
2007	143,859	1,078,123	28,336	5,450,212	6,700,530
2008	193,770	1,382,762	215,787	5,511,450	7,303,769
2009	308,012	1,465,220	288,678	5,544,118	7,606,028
2010	655,482	1,687,027	315,102	5,599,702	8,257,313
2011	857,507	1,705,361	353,423	5,507,609	8,423,900
2012	1,040,980	1,736,269	372,393	5,479,813	8,629,455
2013	1,183,380	1,781,218	570,497	5,558,013	9,093,108
2014	1,320,397	1,831,794	602,998	5,578,552	9,333,741
2015	1,548,213	/	625,877	5,250,120	7,424,210
2016	1,680,438	/	637,209	6,477,578	8,795,225
2017	1,639,841	/	/	/	1,639,841
2018	660,365	/	/	/	660,365
Invalid Date	286,278	-	-	-	286,278
Total	11,595,499	18,898,126	4,010,300	84,938,809	119,442,734

2.2 Fuel Economy Data

For vehicle-level analyses, we also gathered fuel economy data for each inspected vehicles. Since inspection records do not include this information, four website sources were scraped to 'decode' the vehicle identification numbers (VIN's) for each inspected vehicle, to acquire details (such as fuel economy) for specific make/model/year/trim levels of vehicles in the inspection records—decodethis.com [10], vinquery.com [11], fueleconomy.gov [12], and the National Highway Traffic Safety Administration (NHTSA) API [13].

2.3 Transport Spending and Revenue Data

With the intent of informing MBUF fee structures and rates, we also studied the availability of state-level data on collections and disbursements of transportation funding. One of the best-known data sources about highways and funding is US DOT's Highway Statistics (HS) series of data releases. HS has been produced on a nearly annual basis from 1992-2018, with annual reports containing information on motor fuel, motor vehicle registrations, driver licenses, highway user taxation, highway mileage, revenues, and disbursements [14]. The data are collected and reported to US DOT by state DOTs.

We studied several tables in the HS and created connections between tables to cross-validate entries (e.g., ensuring total entries in one table matched corresponding values in another, matching federal funds distributed to those spent, etc.) and to perform other quality checks. This task is further complicated by that table counts and formats vary over time: some tables (e.g., SF-12) are not reported for some years. In terms of data on revenues, disbursements, and VMT as needed for MBUF studies, we made four conclusions:

- HS data alone do not provide a clear picture of the flow of dollars between revenue sources and disbursements.
- HS data are biased towards primary road systems of federal interest (i.e., federal-aid highways or Interstates, etc.)
- It is challenging, if even possible, to track revenue flows from a source through different level of roadway ownership (federal, state and local) and functional systems.
- Connecting revenues, disbursements, and VMT at higher resolution is challenging because there is a mismatch between estimates of VMT and mileage between tables, e.g., state level disbursement for different roads exists, but not corresponding VMT at state level on different roads.

Therefore, while HS appears to contain data of interest (as highlighted in Table *2*), relying solely on the nationally organized HS data could be problematic for any type of detailed MBUF setting exercise.

3 Methodology

Inspection data were collected from numerous sources (each with slightly different data formats) and over a long duration. The same vehicle may appear in more than one of the datasets, and in each dataset on multiple occasions (one corresponding to each safety or emissions inspection). Therefore, we collated and cleaned data from each source, before developing annualized VMT estimates for each inspected vehicle, or aggregates at the county- and state-level. Fuel-economy data were then combined with these estimates to make inferences regarding potential MBUF policies.

Table 2: Available State-Level Highway Statistics Revenue, Disbursement and VMT Data [14].

Name	Description of Table Contents and Detail
Revenue Tables (units: thousands of dollars)	
HDF	Highway-user revenue sources (e.g., federal fuel tax, state fuel tax, state, and local tolls) and their disposition (e.g., for highways, for mass transit) for all levels of government (federal, state, and local)
HF-1	Disposition of highway-user revenues for highways, all levels of government
SF-1	Revenues used by the state for highways, from all sources (e.g., state fuel taxes, vehicle taxes, and federal funds, etc.).
SF-3	Revenues used by state for only state administered highways (same columns as SF-1)
Disbursement Tables (units: thousands of dollars)	
HF-2	Disbursement (e.g., capital outlay, maintenance outlay, administration, etc.) of transportation revenues across all units of government. Capital and maintenance include the disbursement on state-administered, local-administered, and federal roads, respectively
SF-2	Disbursement (e.g., capital, maintenance, administration, etc.) of state government funds on state administered highways and local roads and streets
SF-21	State receipts and disbursements for highways detailed in Tables SF-1 (receipts) and SF-2 (disbursements). A key difference between state results is the presence of toll roads.
LGF-2	Disbursement (e.g., capital, maintenance, administration, etc.) from local government
SF-4	Disbursement (e.g., capital, maintenance, administration, etc.) of state administered highways, not including local roads and streets (SF-2 includes this).
SF-12	State capital and maintenance outlays, classified by functional system and rural/urban/urbanized area
VMT Tables (units: millions of miles)	
VM-1	Annual vehicle distance traveled by highway functional system and vehicle type, a national scale table
VM-2	Annual vehicle traveled by functional system for each state

3.1 I/M Data Cleaning and Sub-setting

In the datasets described above, inspection records for each vehicle are distributed irregularly over time. While inspections are required to be annual, it is exceedingly rare for consequent records to be exactly one year apart. To estimate VMT for each vehicle, we use Python's dictionary data structure (key-value pair) to store each vehicle's VIN as a key and store this key's odometer readings and inspection dates as value pairs in a list. In other words, we transform four datasets into a single VIN-based database, so each vehicle's odometer readings and inspection dates can be retrieved by its unique VIN. The raw datasets contain several records with invalid or inconsistent data. Therefore, prior to the development of a vehicle-level key-value database, it was necessary to filter out a small percentage of records which included corrupted or invalid data, based on the criteria listed below:

- Records with missing, manually entered, or corrupted data, and records with typographical errors (for VINs and inspection dates were excluded.

- We filtered data for the interval between subsequent inspections to be less than a threshold, to ensure that VMT for each pair of records were assigned to an appropriate year. We estimated the distribution of day intervals between all inspection dates in the database. The 5th percentile of day difference is 146 days, and the 25th-50th-75th to be 347, 369, and 395, respectively (the average is 391 days). We find inspection date gaps are inconsistent, and large date intervals account for a small number of records but may be far away from the median value, so we use the interquartile range (IQR) measure of statistical dispersion, which can be calculated by the difference between the third and first quartiles (Q3 – Q1). We treat large day differences as outliers if a value is larger than Q3 + 1.5 IQR. Consequently, a date difference value of 467 (about 90th percentile) is picked as a threshold for large inspection dates (outliers).
- For some inspection records, the odometer reading on later dates is recorded as being lower than on earlier dates, indicating a likely error either in the odometer reading or date on record (e.g., from manual data entry). These records were exempted from our analyses.

3.2 VMT Estimation

After the erroneous records were removed, the cleaned dataset still included over 22 million inspection records over time. Using this database, we estimate a distribution for vehicle-level VMT for the state of Pennsylvania. Each vehicle's annual VMT was calculated through normalized daily VMT using equation 1, which requires a unique VIN to have (at least) two (odometer reading; inspection date) value pairs. However, we consider vehicles that have more than 3 pairs, as two pairs can generate only one VMT estimate. There were 14 million vehicles with ≥3 pairs (64% of all in dataset), 12 million with ≥ 4 (54%), 10 million with ≥5 (45%), and 8.5 million with ≥6 (40%). To ensure every vehicle has sufficient inspection data, the subsequent analysis will use a threshold of ≥3 pairs, meaning every vehicle has at least three pairs, to generate two annual VMT estimates using Equation 1.

$$Annual\ VMT = 365\ days \times \frac{Odometer\ Reading_{latter} - Odometer\ Reading_{former}}{Inspection\ Date_{latter} - Inspection\ Date_{former}} \qquad (1)$$

Although we have defined a method to calculate daily VMT, each vehicle's inspection records generally straddle calendar years, so differences in odometer readings provide estimates of driving across two years, which need to be allocated to derive estimates per calendar year. For instance, given an odometer reading R1 in calendar year Y1, and an odometer reading R2 in calendar year Y2 (Y1 < Y2), we can calculate daily VMT using Equation 1, but does this VMT belong to Y1 or Y2? We set four allocation options here and discuss the difference among them:

- Assumption 1 – Calculate annual VMT, then allocate it to Y1 (former year).
- Assumption 2 – Calculate annual VMT, then allocate it to Y2 (latter year).
- Assumption 3 – Allocate VMT on both years. First calculate daily VMT, then multiply this daily VMT by number of days in each year.
- Assumption 4 – Similar to Assumption 3 but add a supplementary assumption: if an inspection date is less than 30 days from the beginning or end of a year, we do not include these days' miles within that year.

Using these assumptions, we generate four versions of annual VMT estimates, for several years. Figure 1 show histograms after filtering out outliers larger than 3IQR for the four allocation methods, using year 2005 and 2015 as examples. The density plots in Figure 1 show that the distribution of VMT under each of the four allocations are remarkably like each other. However, the plots with Assumption 3 and Assumption 4 are smoother and always in between the lines of Assumption 1 and 2. Adding a 30-day threshold in Assumption 4 seems not to bring any difference. Consequently, we conclude that the allocating method used in Assumption 3 can better reflect how VMT estimates distribute from 2000 to 2018 and use this assumption for the remaining work.

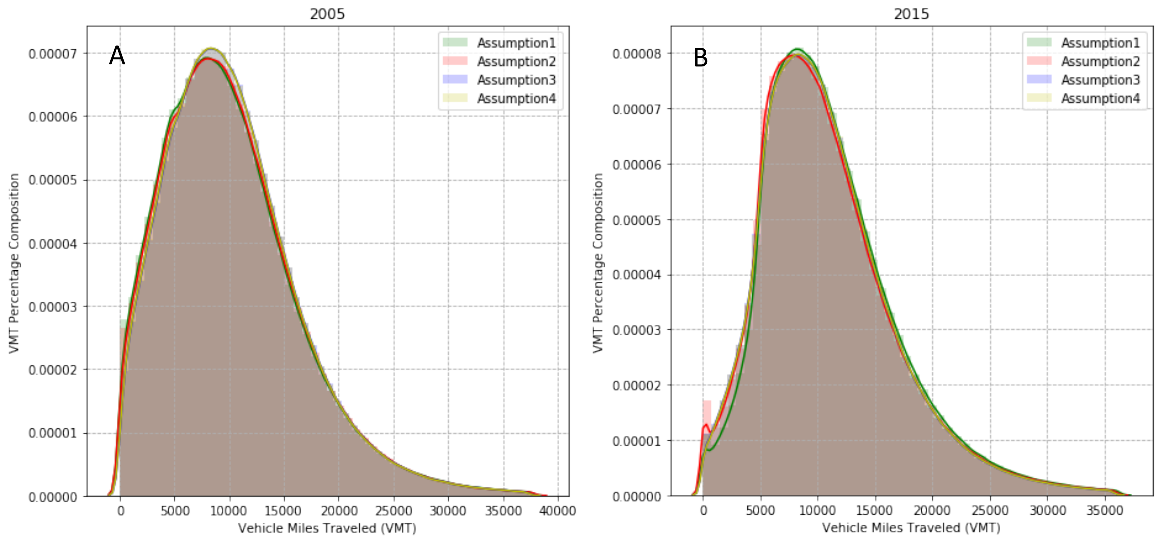

Figure 1: VMT distribution for vehicles in Pennsylvania, (A) 2005, (B) 2015.

3.3 SETTING A REVENUE NEUTRAL MILEAGE BASED USER FEE

To better understand the differences between fuel taxes and MBUFs, and their impact on vehicle owners, we compared the annual consumer cost of the two. We chose to conduct our analyses on data from the year 2014, but updated estimates can easily be derived by applying these methods by re-running code to new data as it becomes available. In contrast to a flat fuel tax per gallon, the equity of MBUF programs is an ongoing concern, especially when considering their disparate effects on rural or urban drivers, and the potential penalization of lower income households.

We show this effect by calculating “balance points”—i.e., the MBUF rate at which 50% of drivers in a region would pay less under an MBUF system, while the other half would pay more, than they currently spend in fuel taxes. Additionally, we compared county and ZIP code level estimates of VMT and fuel consumption with the statewide average estimates.

4 RESULTS

4.1 VMT ESTIMATES

We developed estimates for annual miles traveled per LDV, at various resolutions and for numerous timeframes.

4.1.1 Changes Over the Duration of Analysis

Figure 2 shows density plots of VMT and number of vehicles used for calculation from 2000 to 2016, showing an explicit interpretation of distribution for all years analyzed. The VMT appears to have an average of around 10,000 miles (per vehicle, per year), with a left-skewed distribution.

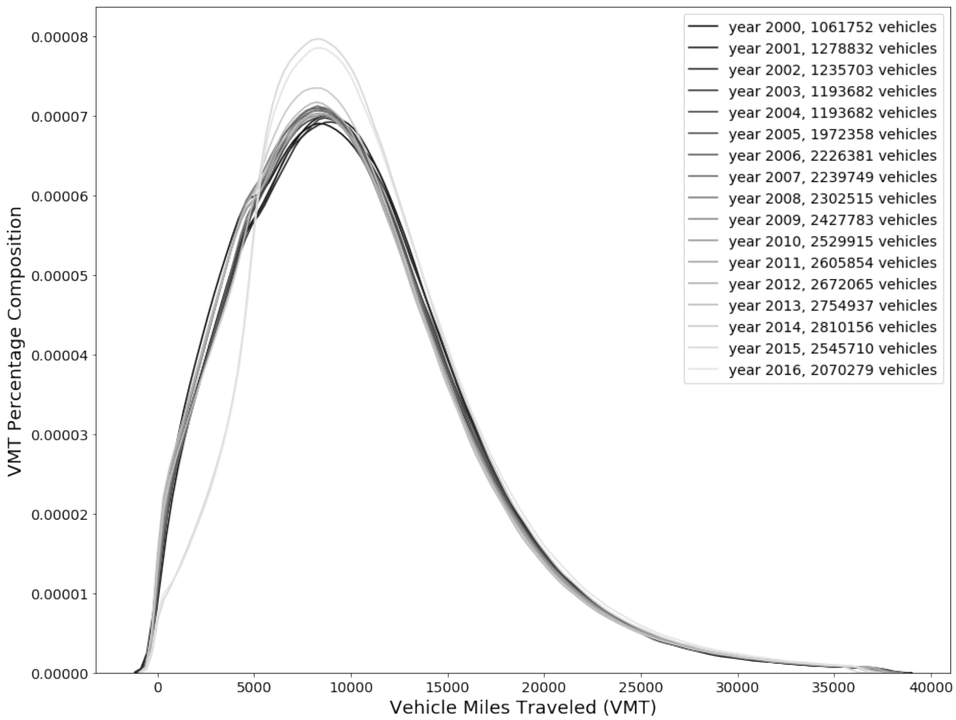

Figure 2: Annual statewide VMT Distribution from 2000 to 2016.

4.2 MBUF RATES AND THEIR IMPLICATIONS

Figure 4 illustrates the effect of changing the MBUF rate (i.e., the $/mile traveled) on the number of passenger vehicles in Pennsylvania which would spend more taxes per year in Pennsylvania and shows how the statewide-"balance point" is around $0.027 per mile.

4.2.1 County-level Estimates

Next, we applied a similar calculation to study the "balance point" for each county. Figure 5 shows how these estimates vary between each county and the statewide mean. In urban and suburban counties (denoted by grey borders), VMT and fuel consumption are at, or slightly less than, average. However, in rural areas, the situation differs by county. Rural counties like Schuylkill, Venango, Greene and Northumberland county have an average VMT and fuel consumed significantly below average. However, other rural counties remain at average, or slightly higher. Figure 6 shows the "balance points" for each county.

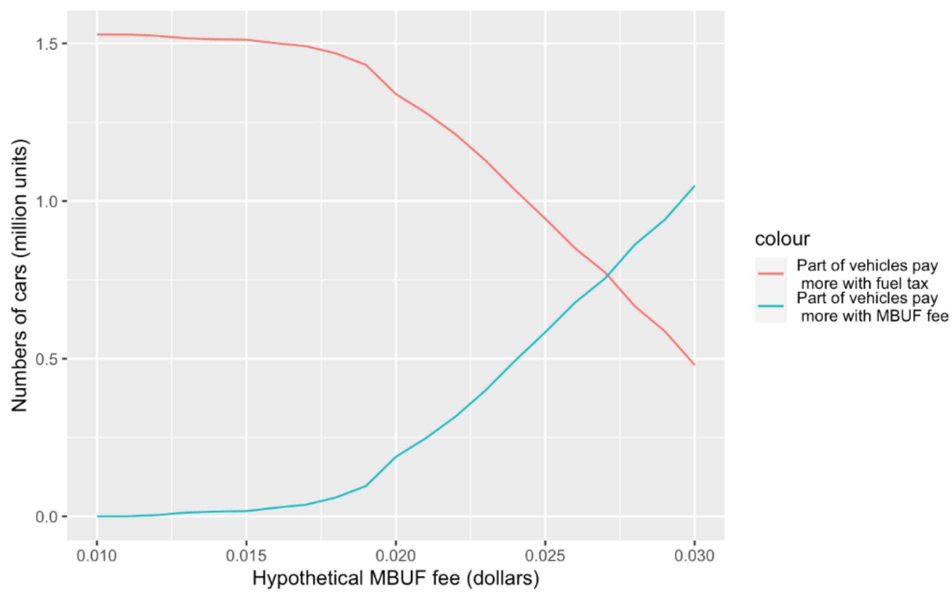

Figure 3: Comparison of fuel tax and hypothetical MBUF fee with combined fuel tax in state level.

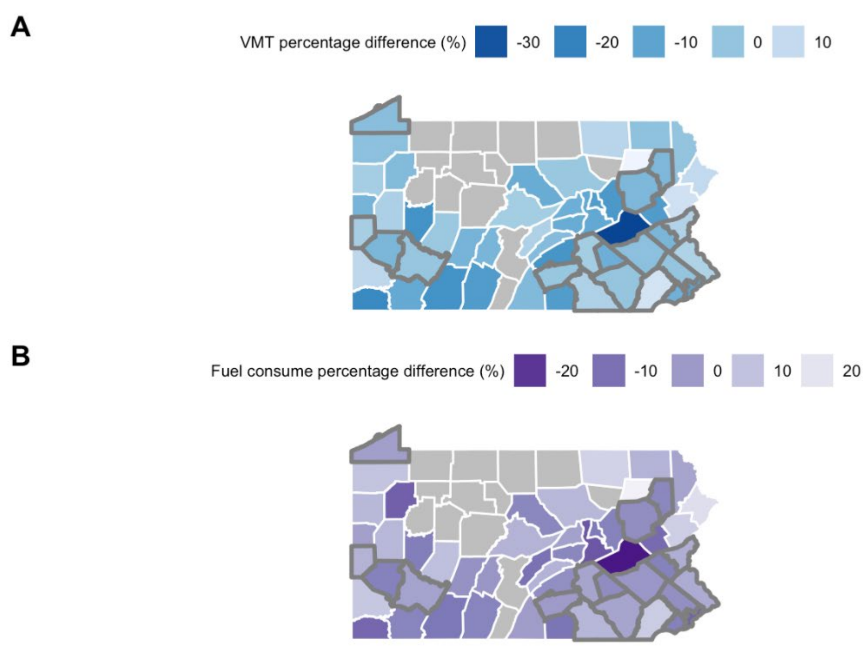

Figure 4: CMT and fuel tax percentage differences in each county in Pennsylvania in year 2014, A: VMT percentage difference (%), B: Fuel consumed percentage difference (%)

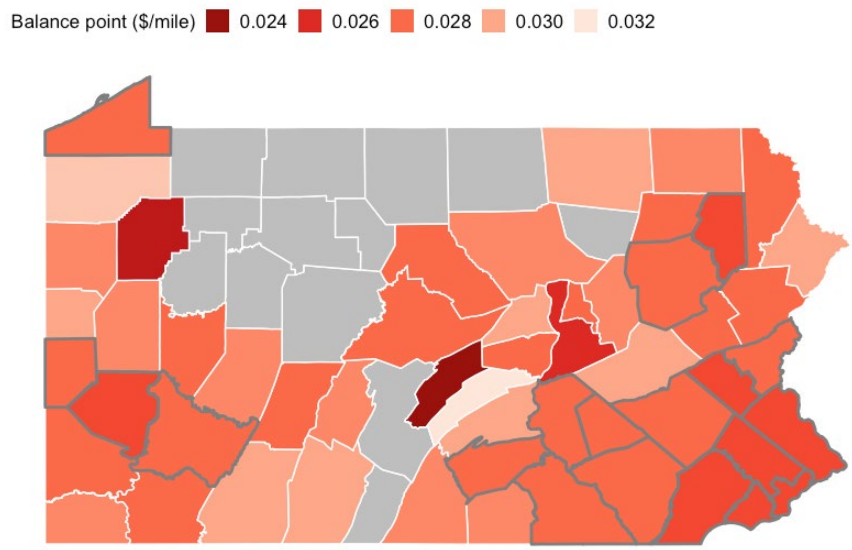

Figure 5: Balance point between MBUF and fuel tax in each county in Pennsylvania.

4.2.2 ZIP-Level Estimates

As a proof-of-concept for even more granular estimates, we also estimated ZIP code level VMT, fuel economy, and MBUF balance points, for Allegheny County (which includes the city of Pittsburgh in the center, and several suburban and rural areas). In 2014, the county had a mean VMT of 10,100 miles, and estimated fuel consumption of 492 gallons per vehicle. Figure 7 shows that, most urban ZIP code areas in the county (surrounded by bold grey lines), have VMT and fuel consumption below the county average, whereas in suburban and rural areas in the county, VMT and fuel consumption are higher than average. In Figure 8, we see that in some urban areas such as downtown and the east suburbs, the balance points of fuel tax and MBUF are lower than $0.0275 per mile, whereas in the relatively more rural northeastern part of the county, the balance points are as high as $0.0325 per mile.

4.2.3 Vehicle-Level Estimates

The state, county, and ZIP code level analysis shows the high geographical variation between counties, in estimated annual VMT, fuel economy, and MBUF "balance point". This can also be demonstrated by example at the individual vehicle level. Eight vehicles of four types with high and low VMT have been selected as examples; Table 4 shows how much more or less their owners would spend if transitioning from the current fuel tax to an MBUF at various rates.

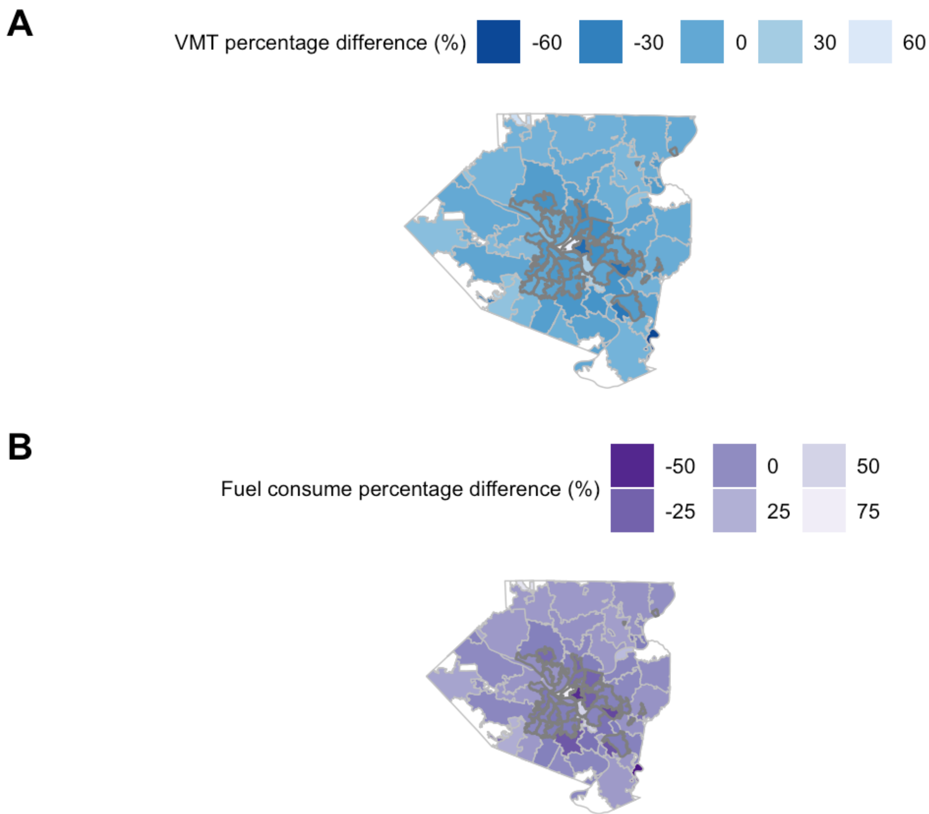

Figure 6: VMT and fuel tax percentage differences in each ZIP code area in Allegheny County in year 2014, A VMT percentage difference (%), B Fuel consumed percentage difference (%).

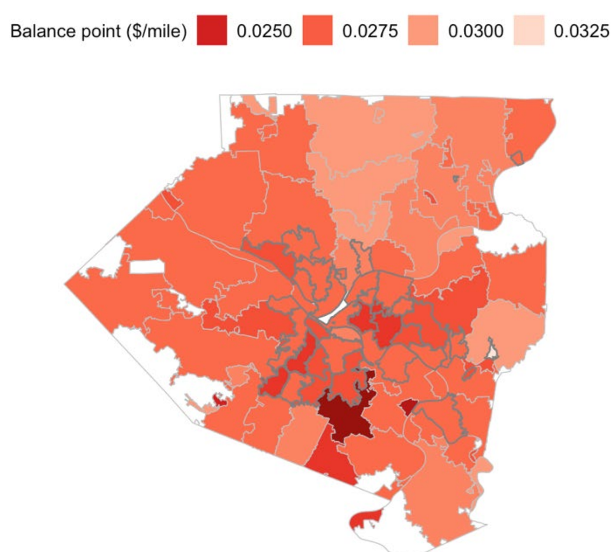

Figure 7: Balance point between MBUF and fuel tax in each ZIP code area in Allegheny County (urban area border in County drawn in bold grey line).

Table 3 Vehicle level analyses show that hybrid electric vehicles may be penalized by MBUFs.

Make/Model	Vehicle Type	VMT (miles/year)	Fuel economy (MPG)	Annual Fuel Tax ($)	Change in cost between fuel tax and MBUF of:		
					¢1/mi	¢2/mi	¢3/mi
2013 Chevrolet Malibu	Sedan	13,277	26	292	-55%	-9%	36%
2013 Ford Fusion	Sedan	33,399	36	541	-38%	23%	85%
2013 Honda Insight	Hybrid Sedan	16,323	42	222	-27%	47%	120%
2010 Toyota Prius	Hybrid Sedan	6,364	50	74	-14%	72%	158%
2008 Honda Pilot	SUV	35,348	18	1159	-70%	-39%	-8%
2011 Toyota RAV4	SUV	8,121	24	196	-59%	-17%	24%
2012 Ford F-150	Pickup	27,162	16	985	-72%	-45%	-17%
2010 Dodge Ram 1500	Pickup	9,266	15	359	-74%	-48%	-23%

5 DISCUSSION & CONCLUSIONS

5.1 VMT ESTIMATES AND IMPLICATIONS FOR MBUF

Our analyses estimate the "balance point" MBUF rate at the county and ZIP code level by leveraging 100+ million inspection records to assess variations in annual VMT and fleet fuel economy. As a result, we found the "balance point" MBUF to be about $0.0275 per mile for the state of Pennsylvania, but to vary substantially (from $0.024 to $0.032 per mile) between counties. From these results, it also appears that drivers in rural counties will generally pay a higher per-mile fee for this balance point to be achieved. This was true in both the county and ZIP code level results. We also show that these analyses can be conducted for individual vehicles, and quantify how hybrid vehicles, and those with higher fuel economy will likely pay more in taxes annually, with a flat MBUF than with per-gallon fuel taxes. Such results would be useful to present to the public in informational materials about such a transition. These results also demonstrate the complexities embedded in the transition from fuel taxes to MBUFs. There are various other challenges associated with setting rates, such as out-of-state drivers and privacy considerations. Even if states set rates as demonstrated above, they would be challenged to fully collect these revenues, as, for example, out-of-state vehicles under a different MBUF regime would not be paying into a state's programs.

It is also evident from these results that jurisdictions will require to carefully tailor marketing around an MBUF program, to ensure that vehicle owners' perceptions are not swayed by generalized statements about specific types of counties or ZIP codes paying a higher cost. Our results show that the difference between fuel tax and MBUF costs vary significantly based on the individual driving characteristics of each vehicle, and that these broad generalizations are likely to be misleading.

5.2 SCOPE FOR FUTURE WORK

As fuel-efficient hybrids and electric vehicles constitute an increasing proportion of Pennsylvania's fleet, it is inevitable that gasoline taxes will be replaced by some form of 'per mile' tax. As we outline in this study, DOT's may use inspection records to develop a first order estimate of their programs' designs. However, several additional design challenges exist and warrant further consideration. The equity considerations that were mentioned briefly in this study warrant further investigation. Jurisdictions will need to understand the income and racial inequity in the distribution of costs under an MBUF regime, and to test the effect on these inequities of various rate structure designs. Consumer perception and messaging surrounding what many vehicle owners may see as a new 'fee' must also be studied before any large-scale rollout of an MBUF program. We also anticipate that studies to assess the availability at the state and federal level, and into what specific data gaps currently exist in terms of transport revenue and spending will be of particular interest to DOT's. In addition to the intricacies of program design, several technological challenges also exist. For example, DOT's must collect mileage data from each vehicle, for each type of road that vehicle travels on, but would still require to do so in a manner that protects the privacy of drivers.

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