North Carolina Highway Cost Allocation and Revenue Attribution Study

SEPTEMBER 2021

NC STATE UNIVERSITY

Department of
Civil, Construction, & Environmental ENGINEERING

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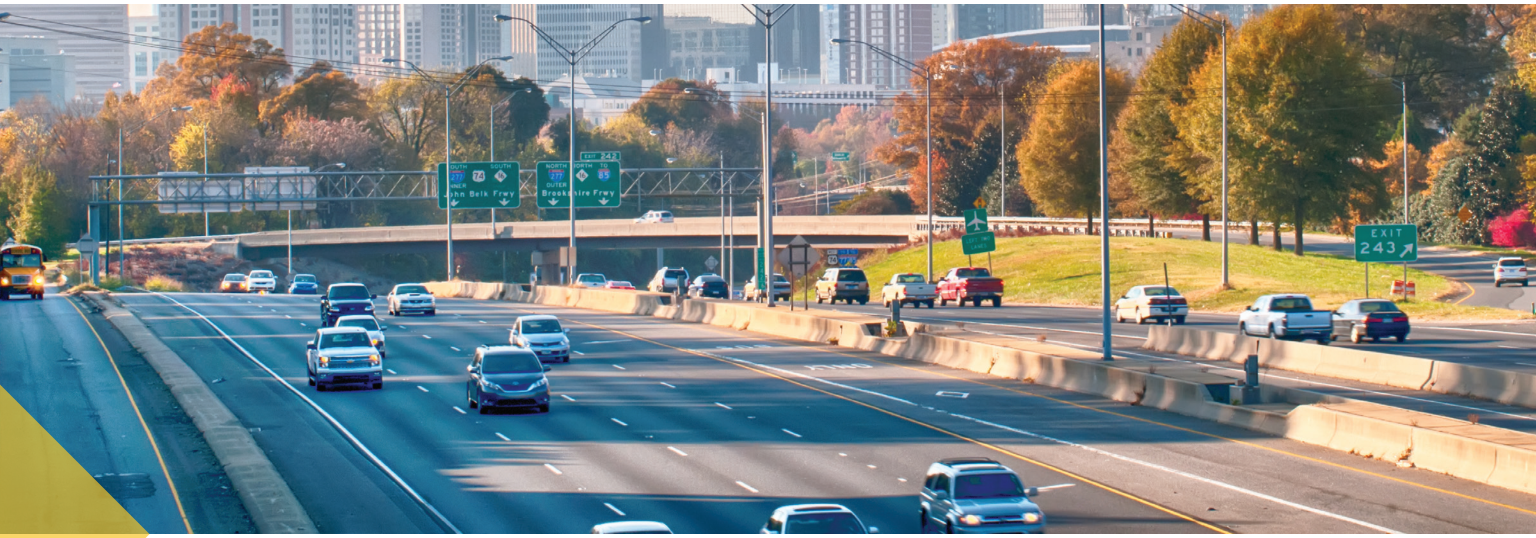


Executive Summary

This research was conducted for the North Carolina Department of Transportation (NCDOT) with the objective to estimate and compare the highway infrastructure cost responsibility and revenue contribution of highway users in North Carolina. The study adopted the FHWA 13 vehicle classification system and analyzed data on highway infrastructure expenditures and federal and state revenue for the years 2014-2017.

The results of this research indicate that lightweight vehicles, including motorcycles and passenger cars, contribute more to the revenue than their share of cost responsibility. Specifically, it was found that motorcycles, passenger cars, and FHWA class 3 vehicles overpay by 30%, 26%, and 8%, respectively. On the other hand, single-unit trucks with four or more axles (FHWA class 7) and all multi-unit trucks classes (FHWA classes 8-13) underpay by 37%-92% for highway infrastructure compared to the damage they cause. In summary, lightweight vehicles are currently subsidizing the cost responsibility of most trucks on North Carolina's highway system.

The results of this study reveal that NCDOT should explore ways to increase the share of revenue contributions from trucks to improve equity in revenue generation. Several revenue scenarios were analyzed as part of this study, such as increasing the rates of current sources of revenue as well as investigating new sources, such as mileage-based user fees and dedicating state sales tax revenue to transportation. Although most of the revenue scenarios explored as part of this research are implementable and reasonable when compared to the tax and fee structures in other states, none of these scenarios was found to lead to substantial equity improvements. Future research should focus on a detailed exploration of tax and fee structures that can significantly enhance equity in NC's transportation infrastructure revenue generation process.

Introduction

Research Motivation

North Carolina (NC) finances highway infrastructure mainly with the motor fuels tax, highway use tax, and motor vehicle fees. Highway users contribute to these revenue sources based on either how much they use the infrastructure or the transportation mode that they own. Ideally, each highway user contributes to the revenue an amount equal to the cost of consuming the state's infrastructure. However, this is challenging to achieve in practice, and in the majority of states, users of lighter vehicles overpay for highway infrastructure. To enable policymakers to plan and implement more equitable tax and fee systems, it is necessary to periodically assess the cost responsibility of highway users and compare it with their contribution to the revenue.

To date, no study of highway cost allocation and revenue attribution has been completed for NC. It is therefore not clear how much certain highway users overpay or underpay for highway infrastructure. This hinders the North Carolina Department of Transportation (NCDOT) from exploring more equitable mechanisms for collecting revenue and funding future infrastructure projects. In addition, due to the continuous improvements in vehicle fuel efficiency and the increasing market penetration of electric vehicles, traditional revenue sources such as the motor fuels tax will be unable to provide sustainable revenue for funding highway infrastructure in the near future. Thus, identifying alternative funding mechanisms that are equitable but can also sustain revenue has become a pressing need.

The objective of this research is to estimate and compare the cost responsibility and revenue contribution of individual vehicle classes for North Carolina's highway infrastructure. This comparison is based on highway infrastructure expenditures and federal and state revenue sources between 2014 and 2017. The study also includes an analysis of future revenue scenarios and assesses alternative infrastructure funding mechanisms based on revenue potential, financial sustainability, ease of implementation, and public perception. As the federal government and other states evaluate innovative policies to secure the financial sustainability of highway infrastructure, this study is paramount to ensure NCDOT and the state legislature can make informed decisions in the near future.

Report Organization

This report (Volume I) summarizes the methodology, results, and conclusions of our study. Volume II discusses in detail the different study components, including literature review, methodology, traffic, expenditure, and revenue data, study assumptions and limitations, analysis, and results.

Summary of Analysis Inputs and Data Sources

This project combines data from multiple sources. The main inputs to the highway cost allocation and revenue attribution study, and their respective source are summarized in Table 1.

Table 1: Summary of inputs to the highway cost allocation and revenue attribution study

Analysis	Data Description		Data Source
Cost Allocation	Traffic Data	Annual VMT estimates by FHWA vehicle class and roadway functional class	Traffic Survey Group, Transportation Planning Division, NCDOT
		Traffic segment GIS shapefiles with annual AADT estimates	Traffic Survey GIS Data Products & Documents, Connect NCDOT
		Gross vehicle weight distributions from different locations around NC	Traffic Survey Group, Transportation Planning Division, NCDOT
	Project Data	Expenditure data for contracted projects	HiCAMS, Connect NCDOT
		Expenditure data for in-house maintenance projects	State Maintenance Operations, NCDOT
Revenue Attribution	Traffic Data	Same as above	Same as above
	Vehicle Registration Data	Number of registered vehicles by vehicle type	Department of Motor Vehicles, NCDOT
		Number of registered vehicles by vehicle weight	Department of Motor Vehicles, NCDOT
	State Revenue	Revenue by source and year	Office of Strategic Initiatives & Program Support, NCDOT
	Federal Revenue	Revenue by source and year	Office of Highway Policy Information, Policy and Governmental Affairs, USDOT

Highway System Use and Classification

This study adopts the FHWA vehicle classification system shown in Figure 1. This system classifies vehicles into 13 categories on the basis of size and axle configuration. Highway system usage was measured in terms of vehicle-miles traveled (VMT) based on the 13 FHWA vehicle classes. We used the annual VMT that is reported to the FHWA highway performance monitoring system (HPMS) by NCDOT. This annual VMT was initially categorized using the FHWA functional classifications of roadways that is comprised of 14 roadway classes (FHWA, 2013). For the purposes of this study, the reported VMT was redistributed from the FHWA functional classes to NCDOT's four route system, i.e., Interstate, US highways, State/NC routes, and secondary routes (SR). This is because the highway project contract information collected as part of this research provided the route information in the NCDOT's four route classes and not in the FHWA functional classes. Table 2 presents the annual VMT by route class, and Table 3 presents the average VMT distribution for our study period by FHWA vehicle class.

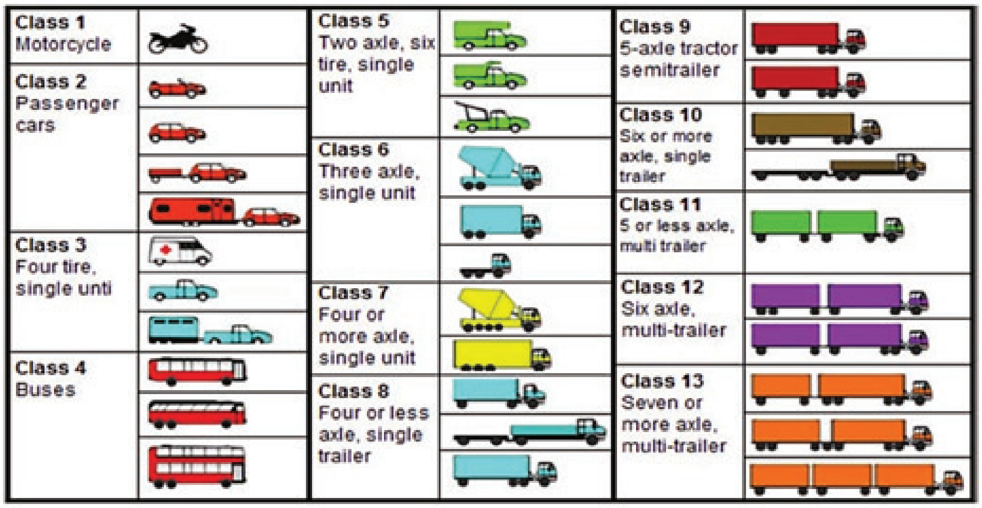


Figure 1: FHWA vehicle classification (Source: FHWA, 2017a).

Table 2: Annual VMT (billions) by road functional class.

	2014	2015	2016	2017
Interstate	23.65	24.47	25.60	27.12
US	26.06	27.02	28.18	28.72
NC	18.75	19.37	20.04	20.20
SR	39.57	41.02	42.61	43.06
Total	108.04	111.87	116.44	119.10

Table 3: Percentage share of VMT by vehicle class, 2014-2017.

FHWA Vehicle Class	Name	Description	Average Percentage Share of VMT, 2014-2017
1	MC	Motorcycle	0.60%
2	Cars	Passenger car	73.57%
3	2A4T	Four tire single unit	18.03%
4	Bus	Bus	0.68%
5	2ASU	Two axle, six tire, single unit	2.44%
6	3ASU	Three axle, single unit	0.67%
7	4ASU	Four or more axle, single unit	0.06%
8	4AST	Four or less axle, single trailer	0.66%
9	5AST	5-axle tractor semitrailer	3.05%
10	6AST	Six or more axle, single trailer	0.14%
11	5AMT	Five or more axle, multi-trailer	0.05%
12	6AMT	Six axle, multi-trailer	0.02%
13	7AMT	Seven or more axle, multi-trailer	0.03%

Highway Cost Allocation

Expenditures

NCDOT provided the list of contracted projects completed between 2014 and 2017. NCDOT's database divides projects into three major categories: design and build, resurfacing, and other. During the analysis period, 50 design and build, 754 resurfacing and 1580 other projects were completed and therefore analyzed as part of this research. We categorized these projects according to the facility type (i.e., pavement, bridge, or both) and type of work (widening, grading, signal and intelligent transportation system, and others). This allowed us to apply appropriate cost allocation methods based on the type of facility and suitable measures of highway usage based on the type of work. Figure 2 shows the number of projects by year, project type, and facility type, and Figure 3 presents the cost associated with these projects in a similar manner.

Approximately 600 projects are completed by NCDOT on an annual basis, with most projects being pavement related. Regarding total expenditure, 2015 had the highest amount of expenditure, $1.48 billion in 594 contracted projects.

In addition, we analyzed expenditures related to NCDOT's in-house maintenance projects. These projects were categorized under pavement related, bridge related, and other in-house maintenance work. The average annual expenditure of the in-house maintenance projects from 2014 to 2017 was approximately $39 million.

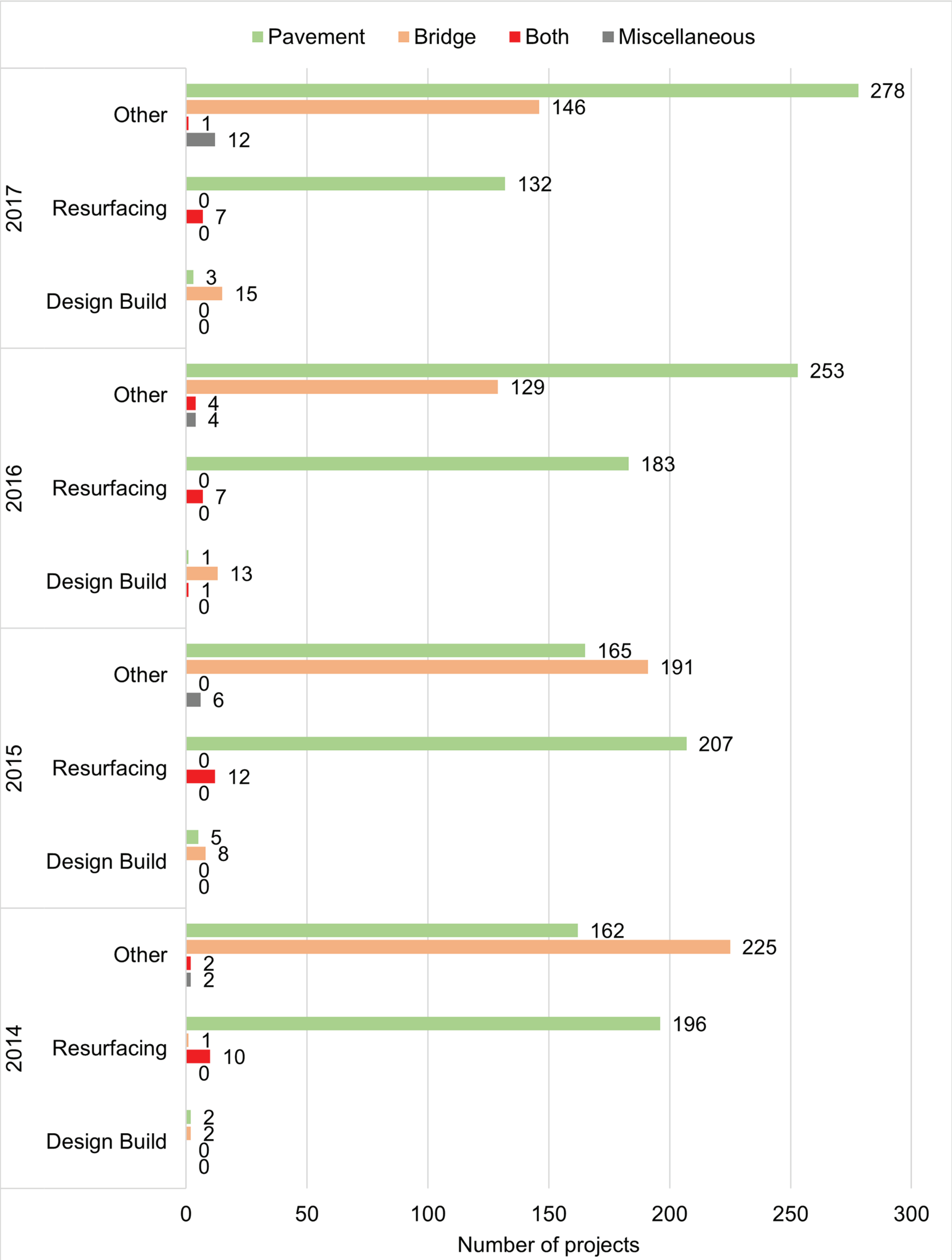


Figure 2: Number of projects by year, project type, and facility type.

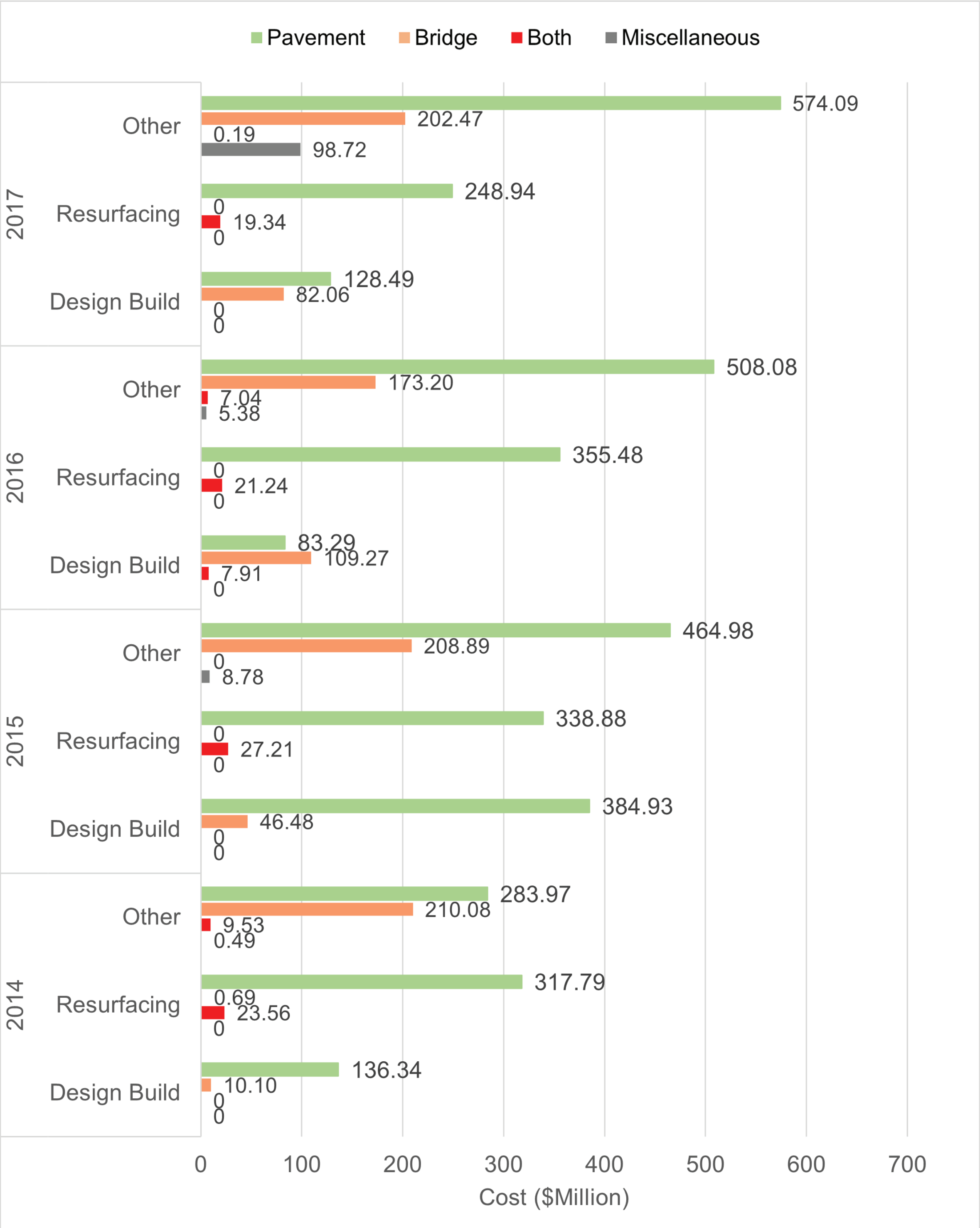


Figure 3: Project costs by year, project type, and facility type.

Allocation of Pavement Expenditures

NEW PAVEMENT CONSTRUCTION

The highway cost allocation study (HCAS) tool developed by FHWA to help states complete HCAS analyses (FHWA, 1997) was used to allocate expenditures from new pavement construction and pavement reconstruction projects. The thickness-based approach (also known as the incremental approach) was used, where new pavement construction costs are separated into two components: cost of the base facility and cost of the remaining facility. The base facility design is considered adequate for light vehicles and is viewed as a common cost for all vehicle classes. We allocated the base facility cost using PCE-adjusted VMT, which is a non-load related allocator. Passenger car equivalent (PCE) factors represent the capacity and congestion impact of truck traffic on the roadways relative to the passenger car. We used the average PCE factors suggested by the Highway Capacity Manual 2000 (TRB, 2000).

Additional pavement thickness is required to accommodate the VMT from different vehicle classes (ECONorthwest, 2021; Volovski et al., 2015). A higher portion of the remaining facility cost is therefore allocated to the successively larger and heavier vehicles (ECONorthwest, 2019). The number and configuration of axles also plays a significant role on the amount of damage to the pavement. A small number of axles carrying higher loads will impart more damage to the pavement, while increasing the number of axles for the same total load will reduce the amount of damage to the pavement (Salama et al., 2006). To this end, the cost of the remaining facility is allocated based on the operating weights and axles of each vehicle class, using the AASHTO pavement design procedures (AASHTO, 1993a).

PAVEMENT REHABILITATION

Pavement rehabilitation costs were allocated using the National Pavement Cost Model (NAPCOM). NAPCOM includes models for different types of distresses in flexible and rigid pavement. For flexible pavement, the method includes individual distress models for fatigue cracking, thermal cracking, rutting, loss of skid resistance, and loss in pavement serviceability rating (PSR). For rigid pavements, the types of distresses introduced in the model include fatigue cracking, spalling, and soil-induced swelling, depression, faulting, loss skid resistance, and traffic-related PSR loss. These models were used to estimate the rate of progression of individual types of distresses under given pavement design, traffic, and environmental conditions (FHWA, 1997).

The cost associated with pavement rehabilitation projects was categorized into a load related portion, which accounts for the damage caused by different vehicle classes, and a non-load related portion, which accounts for the damage caused by climatic conditions. We followed the FHWA guidelines to distribute the rehabilitation project costs into a load and non-load related portion (FHWA, 1997). The non-load related cost was allocated to vehicle classes on the basis of VMT while the load-related cost was allocated based on the NAPCOM equations.

PAVEMENT IN-HOUSE MAINTENANCE

Pavement in-house maintenance costs were categorized into a load and a non-load portion using the load-related factors developed by Sinha et al. (1984). The non-load related cost was allocated to vehicle classes on the basis of VMT while the load-related cost was allocated based on the NAPCOM equations. Maintenance expenditures that are unrelated to pavement preservation and resurfacing were allocated to vehicle classes on the basis of VMT.

RESULTS

The combined results of the allocation of pavement expenditures are shown in Figure 4. The lowest unit cost ($/VMT) is found for the lightest vehicles (vehicle classes 1, 2, and 3), while trucks in vehicle classes 7, 9, 10, and 13 exhibit the highest unit costs. The highest cost responsibility of pavement expenditures is found for passenger vehicles (vehicle class 2) because of their large VMT share.

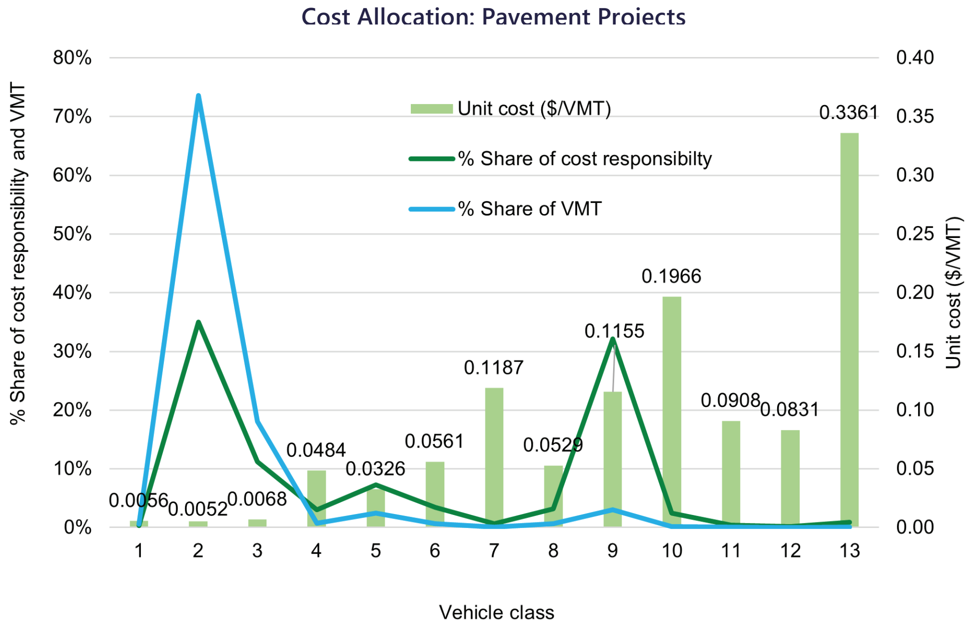


Figure 4: Cost allocation by vehicle class for pavement related projects.

Allocation of Bridge Expenditures

NEW BRIDGE CONSTRUCTION AND REPLACEMENT

The costs of new bridge construction and bridge replacement projects were allocated using the incremental method developed by FHWA (1997). The live-load moments in the load-bearing members of a bridge depend on vehicle size, weight, axle-spacing, and distribution of weights among the axles. To allocate cost increments to highway users, the live-load moments from each vehicle class were compared with the design live-load moments. The first cost increment is associated with the lightest design loading and was allocated to all vehicle classes based on their VMT share. The subsequent cost increments were shared by the heavier vehicle classes. For bridge replacement projects, the percentage of the cost that occurs due to structural deficiencies was first defined based on FHWA's bridge sufficiency rating formula (FHWA, 1995).

BRIDGE REHABILITATION

Bridge rehabilitation costs were allocated to vehicle classes based on the method developed by FHWA (1997). The bridge rehabilitation projects were divided into major and minor rehabilitation work.

It was assumed that minor rehabilitation projects for bridges are not related to weight damage. Therefore, these costs were allocated to vehicle classes on the basis of VMT. Major rehabilitation projects include load-related costs which were allocated using the FHWA approach described in the previous section.

BRIDGE IN-HOUSE MAINTENANCE

Bridge in-house maintenance costs were categorized into a load and a non-load portion based on FHWA guidance (FHWA, 1997). The non-load related cost was allocated to vehicle classes on the basis of VMT while the load-related cost was allocated using the cost allocation method of bridge rehabilitation expenditures.

RESULTS

The combined results of the allocation of bridge expenditures are shown in Figure 5. Low unit costs (approximately $0.002/VMT) are found for vehicle classes 1-3. For the truck classes, class 13 has the highest unit cost at $0.4/VMT. The cost responsibility of passenger vehicles (class 2) is high due to their large VMT share.

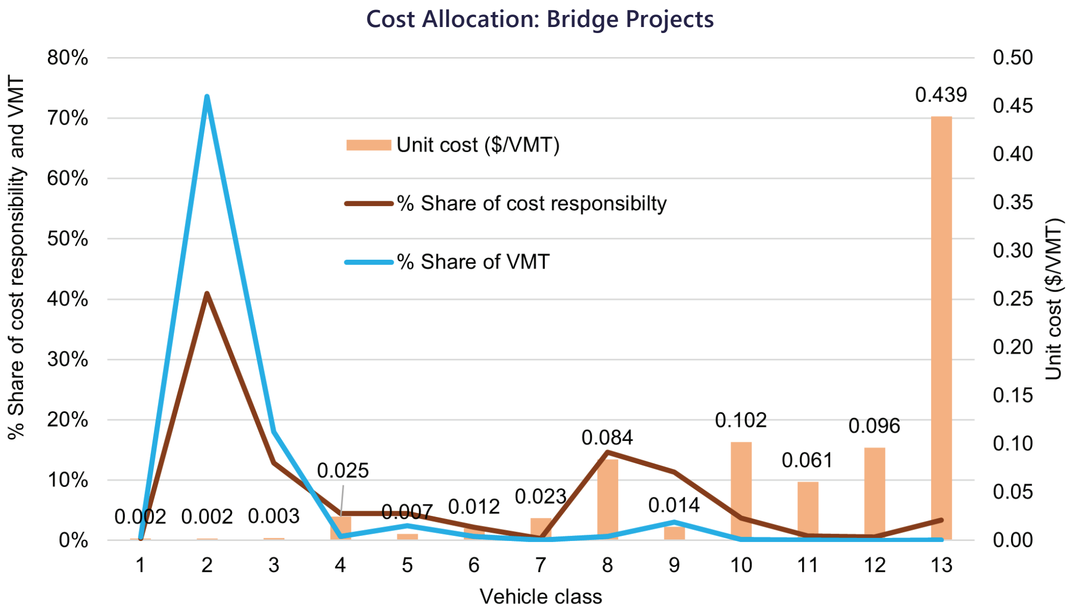


Figure 5: Cost allocation by vehicle class for bridge related projects, 2014-2017.

Allocation of Other Highway Expenditures

Other highway infrastructure expenditures include projects related to traffic operation, weight stations, safety, traffic signs, other maintenance projects, and right of way (RoW) purchases. The RoW expenditures were extracted for each fiscal year from NCDOT's monthly financial update documents. Because many of these expenditures are associated with vehicle size, they were distributed to vehicle classes based on the PCE-miles on respective facilities. The results of the allocation of other highway expenditures are shown in Figure 6.

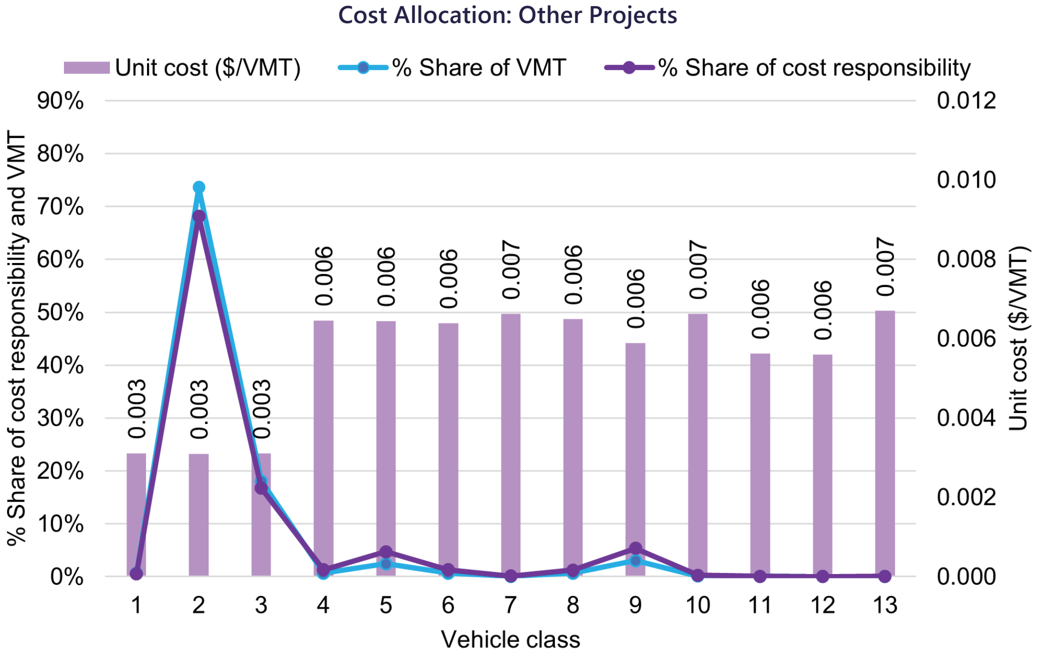


Figure 6: Cost allocation by vehicle class for Other projects, 2014-2017.

Summary of Highway Cost Allocation Results

Figure 7 presents the combined results of the allocation of pavement, bridge, and other highway expenditures of projects completed between 2014 and 2017 in NC. Figure 8 also shows the unit cost ($/VMT) by vehicle class and expenditure type. As expected, passenger cars (vehicle class 2) have the highest percentage of cost responsibility (42%). Among the trucks, FHWA class 9 (5-axle tractor semitrailer) has the highest cost responsibility at 23%. Similar trends have been found in HCASs conducted by other states, including Indiana (Volovski et al., 2015), Minnesota (Gupta, 2012), and Nevada (Balducci et al., 2009). In addition, the unit cost for the non-truck classes, i.e., motorcycles, passenger vehicles, and pickup trucks, is approximately $0.01/VMT, which is very small compared to the truck classes. Among the single unit trucks (vehicle classes 4-7), vehicle class 7 has the highest unit cost in pavement projects, and vehicle class 8 has the highest unit cost in bridge projects. Regarding multi-unit trucks, class 13 vehicles have a very low cost responsibility share (due to their low VMT share) but the highest unit cost. Previous HCASs have also reported the highest unit cost for FHWA class 13 vehicles.

The primary limitations of this cost allocation analysis pertain to the lack of detail in project contract information and up-to-date data on vehicle weight and axle distributions. First, the contract description of several projects did not include information about the type of pavement structure (flexible or rigid) or the types of structural layers and their thickness. In addition, a substantial portion

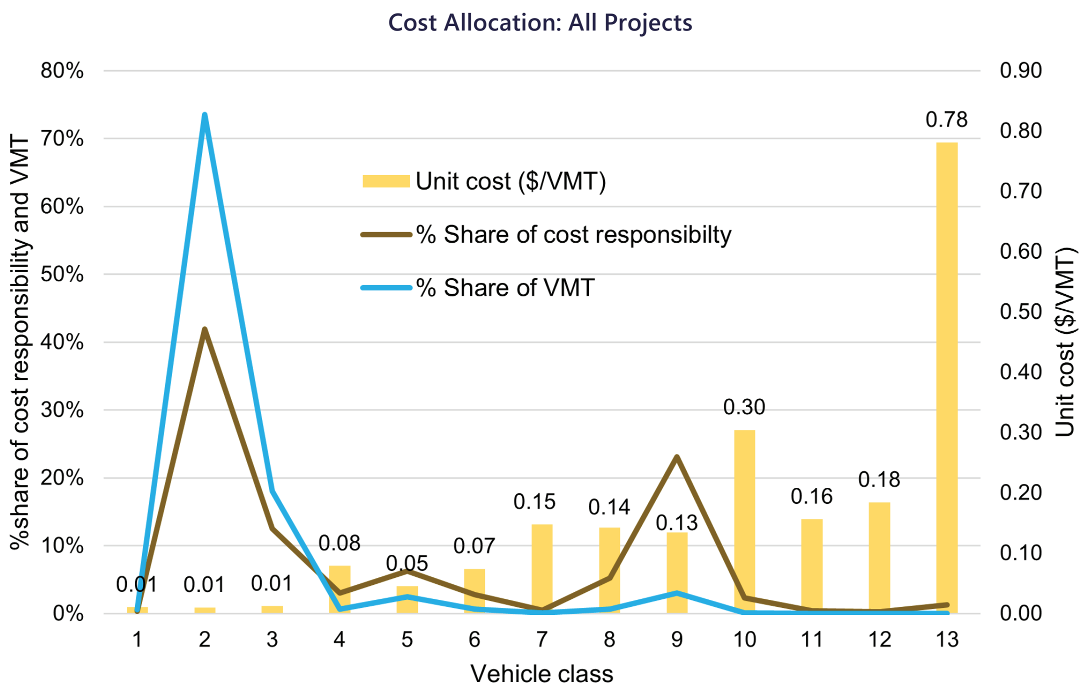


Figure 7: Cost allocation by vehicle class for all projects, 2014-2017.

of the contract data did not include detailed work items that would allow us to separate the load-related and non-load related costs of the project. For these reasons, several simplifying assumptions had to be made (discussed in Volume II). Furthermore, the location description in the contract data is in interstate, US, NC or secondary route format while the annual VMT data provided by NCDOT were classified based on the FHWA roadway functional class system. As a result, the research team had to use route-mile information and make several assumptions to distribute the VMTs from one roadway system to the other. Lastly, the weight-in-motion (WIM) data provided by NCDOT included a limited number of weight distributions from interstates and US routes and only one distribution for NC and secondary routes. We used the weight distributions provided by NCDOT for interstate and US routes. However, this data is based on a limited sample and is not up to date; it is not clear whether the data is representative of the current system and how this issue may impact our results. For NC and secondary routes, the default FHWA operating gross vehicle weight distribution was used due to the lack of local data. FHWA developed this distribution using WIM data from a few sample sites located on several western states. Therefore, this data may not be representative of North Carolina. Axle weight distributions for the highway facilities of North Carolina were also not available. Therefore, the default axle weight distribution included in the FHWA HCAS tool was used to complete the cost allocation study.

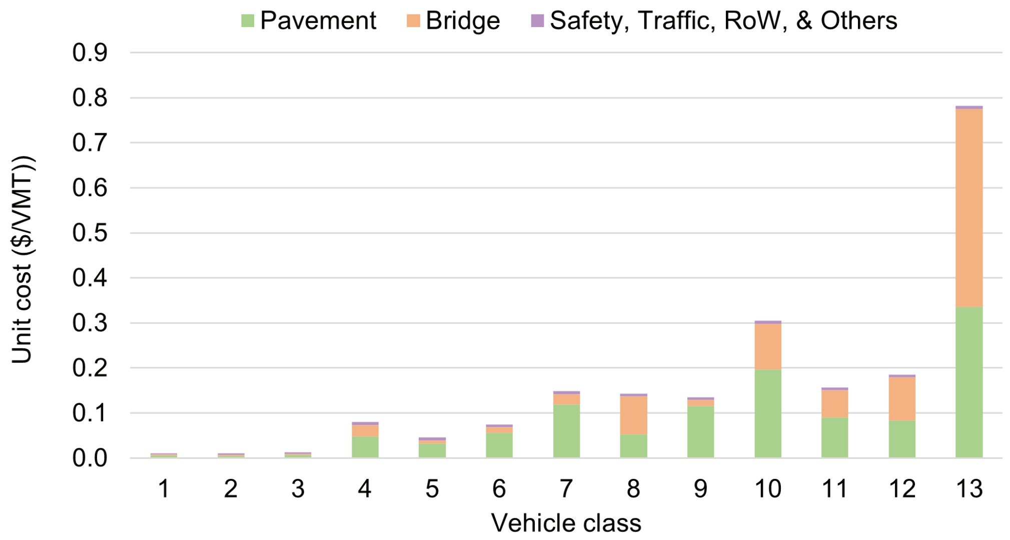


Figure 8: Average unit cost of all expenditures for all routes combined, 2014–2017.

Revenue Attribution

Sources of Revenue for Transportation Infrastructure

Seventy-five percent of the funding for transportation expenses covered by NCDOT comes from state revenue sources. The remaining 25% comes from federal revenue sources, which were generated in NC, collected by the federal government, and a portion was returned to NC. The NCDOT has two main funds to cover the transportation financing needs of the state: the Highway Fund, which includes approximately 60% of the total revenue, and the Trust Fund, which includes approximately 40% of the revenue. The Highway Fund finances operation and maintenance projects, the DMV, and administrative costs. The Trust Fund finances capital construction projects, debt/GAP fund, work related to NC Ports, and administrative costs. Federal revenue can only be allocated to the Trust Fund, while state revenue contributes to both funds.

Federal revenue sources include:

i. Gasoline and special fuel tax: Federal gas taxes are collected at a rate of 18.4 cents per gallon of gasoline and 24.4 cents per gallon of diesel.

ii. Federal use tax: This tax is charged on top of the sales tax for new vehicles. Sales taxes are collected at a rate of 12% of retail price for trucks over 33,000 lbs. of gross vehicle weight (GVW) and for trailers over 26,000 lbs. of GVW. On top of the sales tax, the trucks over 55,000 lbs. are charged with a federal use tax. The rate is $100 for every truck over 55,000 lbs. plus additional $22 for each 1,000 lbs. but not exceeding $550.

iii. Tax on trucks and trailers

iv. Tire tax: Tire tax is charged at a rate of 9.45 cents ($.04725 in the case of a biasply tire or super single tire) for each 10 lbs. of the maximum rated load capacity over 3,500 lbs.

The three main sources of state revenue are motor fuel tax (50%), DMV fees (30%), and highway use tax (HUT; 20%). The state motor fuels tax includes a fixed amount of tax charged per gallon of fuel (both gasoline and diesel) and an additional 0.0025 cents per gallon inspection fee. The motor fuel tax and inspection fee contribute approximately 50% of the total state revenue. During the study period (2014-2017), the fuel tax rate fluctuated between 34.3 cents per gallon to 37.5 cents per gallon.

Motor vehicle fees mainly consist of registration fees, license fees, title fees, and other miscellaneous fees. The various types of registration fees collected by NCDOT include staggered registration fee (fees for vehicles in FHWA classes 1-3), truck license fees (registration fees for trucks, i.e., FHWA classes 4-13), international registration plan fees, highway usage registration fees, and miscellaneous registration fees.

North Carolina charges a highway use tax (HUT) on vehicle purchases rather than a sales tax. This tax applies to all retail and casual sales of motor vehicles at the rate of 3% of purchase price. For new residents moving to North Carolina, the maximum HUT is $250, and for commercial (weighing more than 26,000 lbs.) and recreational vehicles, the maximum HUT is $2,000 (NC First Commission, 2020). The HUT contributes approximately 20% of the state revenue and covers 16% of NCDOT's annual budget.

The total revenue collected from 2014 to 2017 was $17.93 billion, with an average annual revenue of $4.48 billion. Table 4 presents the transportation revenue by source for the analysis period.

Table 4: Revenue ($Million) for transportation infrastructure in North Carolina, 2014-2017.

	Revenue Source	2014	2015	2016	2017	Average
State Highway Fund	Gas Tax	1,404.34	1,396.99	1,329.11	1,355.56	1,371.5
	Staggered Registration	204.95	208.42	274.15	280.78	242.08
	Truck Licenses	139.7	143.54	195.54	197.21	169
	Driver License Fees	111.08	122.28	133.9	124.24	122.88
	International Registration Plan Fees	59.1	62.93	115.68	100.09	84.45
	Exhaust Emission Inspection	28.46	25.63	25.31	25.49	26.22
	Gasoline Inspection Tax	14.07	14.73	15.13	15.65	14.9
	Overweight/Size Permits	5.91	6.32	6.64	7.04	6.48
	Process Service Fees_	4.49	4.67	4.08	4.51	4.44
	Registration Fees	3.76	4.04	5.7	5.99	4.87
	Financial Security Restoration Fees	3.35	1.46	0.44	0.73	1.5
	DMV Other Fees	2.99	5.27	3.03	6.36	4.41
	Auto Safety Equip. Inspection Fees	1.63	1.93	2.13	2.09	1.95
	Dealers' Manufacturers' License Fees	1.27	1.28	1.73	1.74	1.51
	Title Fee	0.77	0.82	0.76	0.76	0.78
	Highway Usage Registration Fees	0.18	0.37	0.18	0.36	1.96
	Motor Carrier Safety Fees	0.1	0.07	0.06	0.07	0.08
	Lien Recording Fees	0.09	0.26	0.28	0.33	0.24
	Subtotal	**1,986.24**	**2,000.99**	**2,113.86**	**2,128.99**	**2,059.21**
State Trust Fund	Highway use Tax	620.14	692.35	760.6	785.31	714.6
	Gas Tax	470.99	525.3	554.05	564.03	528.59
	Title Fee	84.41	89.44	121.13	123.17	104.54
	Miscellaneous Registration Fees	11.17	12.1	15.57	15.65	13.62
	Lien Recording	3.87	3.57	4.07	3.89	3.85
	Subtotal	**1,190.57**	**1,322.76**	**1,455.42**	**1,492.05**	**1,365.20**
Federal	Gasoline Tax	662.61	668.04	707.66	729.61	691.98
	Special Fuels Tax	214.58	221.11	223.08	238.19	224.24
	Tax on Trucks and Trailers	93.75	118.11	112.48	84.03	102.09
	Federal Use Tax	24.31	29.82	31.32	32.51	29.49
	Tire Tax	11.45	12.99	12.61	12.82	12.47
	Subtotal	**1,006.73**	**1,050.07**	**1,087.15**	**1,097.16**	**1060.28**
	Total	**4,183.54**	**4,373.81**	**4,656.43**	**4,718.20**	**4,482.99**

Methodology for Revenue Attribution

Revenues are allocated by vehicle class using either the proportion of VMT or the number of registered vehicles. For instance, to distribute fuel tax revenue, the proportion of fuel used by vehicle class is determined based on VMT and average fuel efficiencies. Table 5 presents the method used to attribute each source of revenue to the 13 FHWA vehicle classes.

Table 5: Attribution method and average collected revenue ($Millions) for the period 2014-2017 by revenue source.

Source of Revenue	HF/TF* or Federal	Collected Revenue	Attribution Method
State Gasoline Tax	HF & TF	1539.08	By VMT to non-trucks (FHWA vehicle class 1 – 3)
Highway Use Tax	TF	714.60	By number of registered vehicles
Federal Gasoline Tax	Federal	691.98	By VMT to non-trucks (FHWA vehicle class 1 – 3)
State Diesel Tax	HF & TF	361.02	By VMT to trucks (FHWA class 4 –13)
Staggered Registration	HF	242.07	By number of registered vehicles in FHWA class 1-3 and accounting for higher fees for classes 2 and 3 (~1.52 times higher compared to class 1)
Federal Special Fuel Tax	Federal	224.24	By VMT to trucks (FHWA class 4 –13)
Truck Licenses	HF	169.00	By vehicle registered weight to FHWA class 4-13.
Driver License Fees	HF	122.88	By number of registered vehicles (regular license to vehicles FHWA class 1-3, commercial license to vehicles FHWA class 4-13.)
Title Fee	TF & HF	105.32	By number of registered vehicles
Federal Truck & Trailers Fee	Federal	102.09	By number of registered vehicles in FHWA class 4-13.
International Registration Plan Fees	HF	84.45	By VMT to trucks (FHWA class 4 –13)
Federal Heavy Vehicle Use Tax	Federal	29.49	By number of trucks with registered weight over 55,000 lbs.
Exhaust Emission Inspection	HF	26.22	By number of registered vehicles
Gas inspection tax	HF	14.90	By VMT
Miscellaneous Registration Fees	TF	13.62	By number of registered vehicles in FHWA class 1-3
Federal Tire Tax	Federal	12.48	By number of registered vehicles in FHWA class 4-13.
Overweight/Size Permits	HF	6.48	By vehicle registered weight to trucks (FHWA class 4-13).

**HF and TF correspond to Highway Fund and Trust Fund, respectively.*

Source of Revenue	HF/TF* or Federal	Collected Revenue	Attribution Method
Registration Fees	HF	4.87	By number of registered vehicles
Process Service Fees	HF	4.44	
DMV Other Fees	HF	4.41	
Lien Recording Fee	HF	4.09	
Auto Safety Equipment Fee	HF	1.95	
Dealers' Manufacturers' License Fees	HF	1.51	By number of registered vehicles in FHWA class 1-3
Financial Security Restoration Fees	HF	1.50	By number of registered vehicles
Highway Usage Registration Fees	HF	0.28	By number of registered vehicles
Motor Carrier Safety Fees	HF	0.07	By VMT to multi-unit trucks (FHWA class 8 –13)

**HF and TF correspond to Highway Fund and Trust Fund, respectively.*

Due to a lack of data, a number of assumptions had to be made to distribute the revenue from certain sources. For some vehicle classes, vehicle registration data were not available by FHWA vehicle class but based on aggregate vehicle categories (e.g., single-unit trucks); in those cases, the VMT distribution was used to approximate the distribution of vehicle registrations within an aggregate vehicle category. In addition, average vehicle purchase prices had to be assumed to attribute the highway use tax revenue. Furthermore, to attribute the revenue from truck licenses, overweight/size permits, and federal heavy vehicle use tax, data on the number of registered vehicles by weight was converted to the 13 FHWA vehicle classes based on expert opinion; this was due to lack of data on registered weight distributions by vehicle class.

Results

Table 6 presents the revenue contribution by vehicle class. The highest percentage share of revenue (56.68%) was attributed to passenger cars. FHWA class 3 vehicles have the second highest share of revenues at 13.59%. Among the multi-unit trucks, class 9 vehicles contributed the highest amount to the revenue (9.93% of the total revenue). Similar trends were reported by HCASs conducted for Indiana, Minnesota, and Nevada.

Among the single-unit trucks, class 5 vehicles contributed the highest amount to the revenue (11.06% of the total revenue). This amount is higher than what has been reported in the other state HCASs. During field data collection at the vehicle classification stations, NCDOT allots all the misclassified trucks under FHWA class 5. As a result, class 5 trucks have a higher VMT proportion among the single-unit trucks. Because the VMT distribution plays a significant role in revenue attribution, this issue related to class 5 vehicles has affected our results.

Equity Ratios

The equity ratio for each roadway user compares the portion of revenues attributed to the portion of expenditures allocated. It is defined as the ratio of the percentage of revenue contribution to the percentage share of cost responsibility.

$$\textit{Equity ratio} = \frac{\text{\% Share of Revenue}}{\text{\% Share of Cost Responsibility}}$$

A vehicle with an equity ratio greater than one pays more than their cost-responsible share, while a vehicle with an equity ratio of less than one pays less than its cost-responsible share (ECONorthwest, 2019). Table 6 presents the equity ratios for the 13 FHWA vehicle classes. Figure 9 also compares the percentage share of cost responsibility and revenue contribution by FHWA vehicle class.

Table 6: Revenue contribution, cost responsibility, and equity ratio for NC highway infrastructure, 2014-2017.

Vehicle Class	VMT (%)	Revenue Contribution ($Million)	% Revenue Contribution	Cost Responsibility ($Million)	% Cost Responsibility	Equity Ratio
1	0.60%	82.77	0.46%	28.72	0.35%	1.30
2	73.57%	9,470.22	52.81%	3394.78	41.93%	1.26
3	18.03%	2,423.45	13.51%	1010.92	12.49%	1.08
4	0.68%	616.63	3.44%	245.69	3.03%	1.13
5	2.44%	1,984.02	11.06%	504.35	6.23%	1.78
6	0.67%	607.47	3.39%	227.84	2.81%	1.20
7	0.06%	55.34	0.31%	39.85	0.49%	0.63
8	0.66%	497.25	2.77%	426.48	5.27%	0.53
9	3.05%	2,029.61	11.32%	1872.71	23.13%	0.49
10	0.14%	90.48	0.50%	188.56	2.33%	0.22
11	0.05%	38.16	0.21%	34.66	0.43%	0.50
12	0.02%	17.28	0.10%	18.47	0.23%	0.42
13	0.03%	19.29	0.11%	103.44	1.28%	0.08

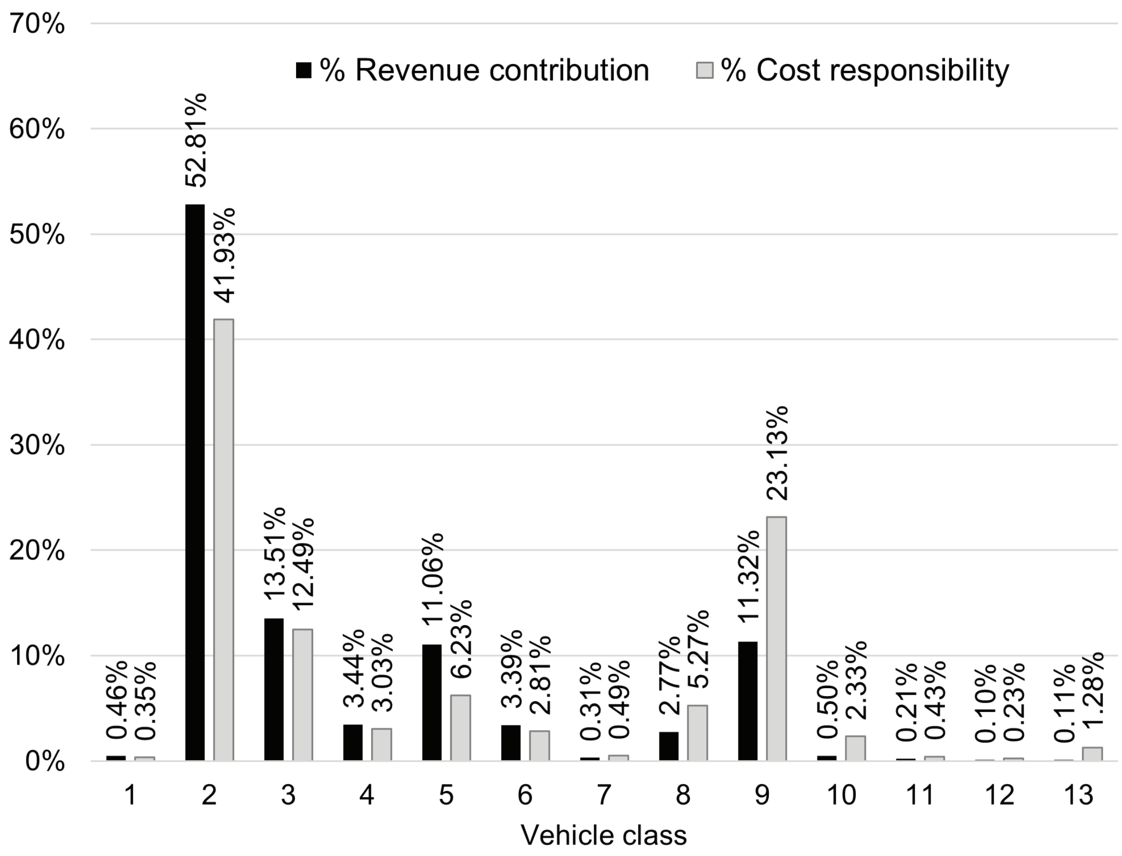


Figure 9: Revenue contribution and cost responsibility by vehicle class, 2014-2017.

Our results indicate that FHWA vehicle classes 1-3 have an equity ratio greater than one. According to the results, motorcycles, passenger cars and four tire single unit vehicles overpay by 30%, 26%, and 8%, respectively. Similar trends are reported in HCAS studies from other states including Indiana, Minnesota, Nevada and Idaho (Balducci et al., 2010; Balducci et al., 2009; Gupta, 2012; Volovski et al., 2015). Equity ratios for passenger cars in these studies varied from 1.10 to 1.43. Among the single-unit trucks, the only vehicles that underpaid were the FHWA class 7 trucks, at 37% of their cost responsibility. Other single-unit trucks have an equity ratio above 1.0, indicating that the amount of revenue collected from these vehicles is higher in proportion to their cost-responsible share. Class 5 vehicles have an equity ratio of 1.78; we attribute this unusual result to issues related to the VMT estimation for class 5 vehicles, discussed above. However, HCASs in other states have also reported equity ratios above one for several truck classes. For buses, Indiana and Minnesota reported equity ratios of 1.03 and 1.47, respectively. Minnesota's HCAS reported equity ratio of 1.12 and 1.10 for FHWA vehicle class 5 and class 6, respectively (Gupta, 2012).

We also find that the multi-unit trucks in FHWA vehicle classes 8-13 underpay by 47% to 92% of their cost responsibility. Combined, the multi-unit trucks paid 54% less than their cost-responsible share. FHWA class 13 vehicles have NC's lowest equity ratio, 0.08, meaning they underpaid by 92% from 2014 to 2017. Minnesota and Nevada reported that class 13 trucks underpaid by 87% and 73%, respectively (Balducci et al., 2009; Gupta, 2012). Overall, the findings suggest that the lightweight vehicles are paying more than their fair share and the trucks (except vehicle class 4-6) are paying less than their fair share. Lightweight vehicles are subsidizing the cost responsibilities of most trucks on North Carolina's highway system. Figure 10 compares equity ratios found by past HCASs that used the 13 FHWA vehicle classification, including the current study for NC.

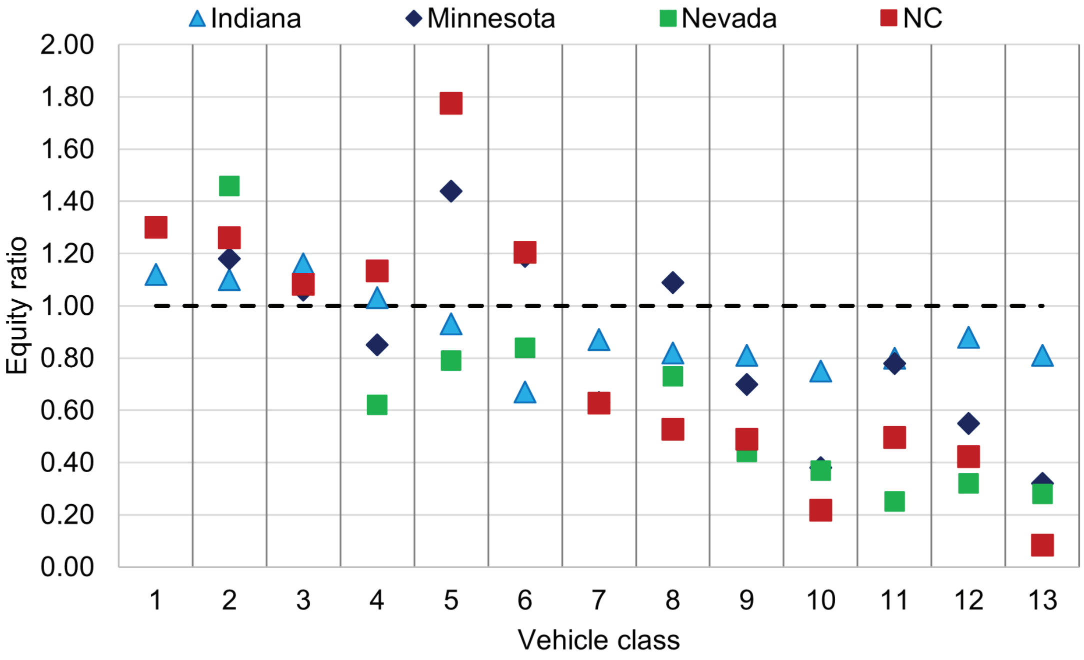


Figure 10: Equity ratios by FHWA vehicle classes across states.

Revenue Scenarios

Safe and efficient transportation infrastructure plays a vital role in the successful operation of household activities, businesses, and the overall economy. Significant research effort has been devoted to the study of revenue generation mechanisms, their long-term effectiveness in raising adequate funds, and their acceptance by the public (Agrawal and Nixon, 2018; Dill and Weinstein, 2007; Dumortier et al., 2017; Norboge et al., 2019; Tonn et al., 2021). Multiple studies have emphasized the inability of the gas tax to sustain transportation revenue due to continuous improvements in vehicle fuel efficiency and the expected widespread adoption of electric vehicles (Dumortier et al., 2017; Duncan et al., 2020, 2017). In response, several states have conducted pilot studies and have explored altering and diversifying their revenue streams during the last decade (CalSTA, 2017; Mcmullen et al., 2010; Nordland et al., 2013; Thapa et al., 2020; WSTC, 2020). We investigate whether increasing state revenue by 10-30% by modifying existing tax rates or introducing new revenue generation sources for NC is reasonable compared to common practices in other states. We also explore whether these changes lead to improved equity ratios for the 13 FHWA vehicle classes.

Increasing the State Motor Fuels Tax

Currently, the state fuel tax is 36.1 cents/gallon, which is 25% higher than the national average of 24.65 cents. NC has the 9th highest motor fuel tax rate in US; Pennsylvania has the highest per gallon fuel tax of 58.6 cents, followed by California (53.3 cents), Washington (52 cents), New Jersey (41.4 cents), New York (40.45 cents), Illinois (39.1 cents), Ohio (38.5 cents), and Maryland (36.89 cents) (WPR, 2021). Compared to its neighbors, NC has a substantially higher fuel tax. Georgia, Tennessee, South Carolina, and Virginia have a state fuel tax of 27.9, 27.4, 22.75, and 16.2 cents/gallon, respectively. However, even with a higher fuel tax rate, the revenue generated would fall short of increasing revenues sufficiently (unless it was raised higher than any other state), in comparison with the changing travel behavior trends and the increasing adoption rate of fuel-efficient vehicles. From 2009 to 2019, the fuel efficiency for an average NC motorist increased by 2.2 miles per gallon (mpg) (Bert et al., 2020). In addition, from FY 2018 to FY 2019, the sales of electric vehicles (EVs) and hybrid vehicles increased by 69% and 4.4%, respectively (NC FIRST Commission, 2019). The combined effect of fuel efficiency improvements and increased adoption of EVs will continue to decrease the contribution of motor fuel tax.

To increase the state revenue by 10%, NCDOT would have had to increase the revenue from state fuels tax by 18.01%. A long-run price elasticity for VMT of -0.241 (Hymel et al., 2010) is used to account for the reduction in VMT from non-trucks (vehicle class 1-3) as a response to the rising fuel tax. For trucks, we assumed zero elasticity because single-unit and combination truck travel in the US have near zero elasticity with respect to fuel cost (Winebrake et al., 2015a, 2015b).

The increased tax rate ranges from 35.59 cents per gallon to 53.00 cents per gallon. To increase the state revenue by 10%, NCDOT would have had to raise the fuel tax by only 4.49%. For per mile travel, vehicles with higher fuel efficiency contribute less than the vehicle with lower fuel efficiency. Therefore, even with a lower percentage increase in per mile fuel tax, we find a higher increase in overall revenue from fuel tax. The highest estimated fuels tax of 53 cents per gallon for a 30% increase in state revenue is nearly equivalent to California's rate of 53.3 cents per gallon, currently the second highest state fuel tax in the US. The estimated tax rates for a 10% and 20% increase in total state revenue are equivalent to current state fuel tax of 36.89 cents per gallon in Maryland (8th highest in the US) and 41.4 cents per gallon in New Jersey (4^{th} highest in the US), respectively.

To increase the state revenue by 30%, passenger cars (class 2 vehicles) would have to pay an additional 0.96 cents per mile, 25.41% higher than the current base case. According to Federal Highway Statistics, from 2014 to 2017, a single passenger car traveled on average 11,303 miles (FHWA, 2019, 2018). With an average fuel efficiency of 23.8 mpg and fuel tax of 35.59 cents per gallon, a single passenger car paid $169 annually in fuel tax. To increase the collection of state revenue by 10%, 20%, and 30% a passenger car user would have to pay a total of $175, $199.95, and $226.89, respectively. In other words, an average passenger car user would have to pay 3.55%, 18.31%, and 57.89% more, respectively, in annual fuel tax.

In addition, increasing the state fuel tax rate would improve equity for motorcycles and passenger vehicles (classes 1 and 2) by reducing their share of revenue contribution. Equity would also improve for multi-unit trucks due to an increase in their proportion of revenue attribution. We note though that these changes to equity ratios are small (within 0.04 points).

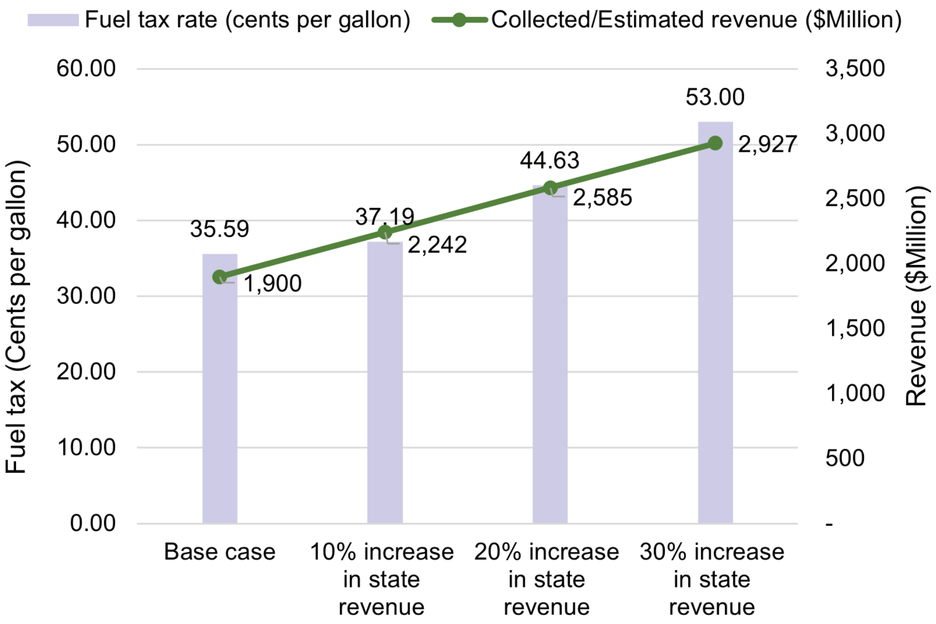


Figure 11: Average annual revenue from increased state fuel tax by revenue scenario, 2014-2017.

Increasing the Highway Use Tax

HUT is responsible for approximately 20% of the state revenue and covers 16% of NCDOT's annual budget. From 2014 to 2017, the HUT on average contributed $714.60 million in revenue. NC has the lowest rate of HUT among the states that collect any form of sales tax on vehicle purchase, currently 3% of the vehicle purchase price. States with lower HUTs (though still higher than NC) include Hawaii (4.5%), Maine (5.5%), and Wisconsin (5.6%). NC's neighboring states (Tennessee, South Carolina, Georgia, and Virginia) have HUT rates between 7% and 10%.

The estimated HUT rate for increasing state revenues ranges from 4.38% to 7.61%. The highest rate (for a 30% increase in state revenue) is close to the HUT rates of Alaska and Nebraska (7.5%), and well below the highest rate of 11.5% in Louisiana and Oklahoma (Bert et al., 2020). To increase the state revenue by 10%, NCDOT would have had to raise the HUT to 4.44%, an increase of 47.90% from the current rate. Figure 12 shows the estimated HUT rates required to collect the additional revenue.

An increase in HUT would lead to improved equity for motorcycles, passenger cars, and multi-unit trucks, but not substantially.

Vehicle sales might decrease, or individuals might choose to buy more affordable vehicles in response to increased an HUT rate. It has been reported that an increase in vehicle property tax could lead to a reduction in vehicle capital (Craft and Schmidt, 2005). Another study estimated a decrease in greenhouse gas emissions from an increase in vehicle sales tax, which implies a reduction in VMT (Liu and Cirillo, 2015). Additional research is needed to better understand the short-term and long-term impacts of changes in vehicle sales tax and how they would affect revenue. For the analysis, we have ignored the possible changes in vehicle sales due to the rise in HUT rates.

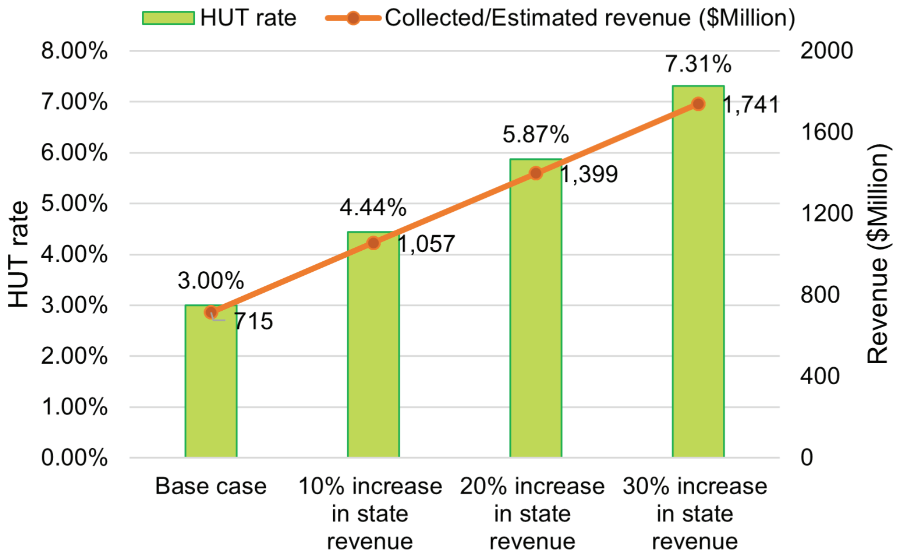


Figure 12: Average annual revenue from increased HUT rates by revenue scenario, 2014-2017.

Increasing Motor Vehicle Fees

From 2014 to 2017, motor vehicle fees contributed on average $808.03 million to the annual revenue in NC. NC vehicle fees are not considered competitive compared to other states. The annual vehicle registration fee and driver's license fee for a private passenger car is $38.75 and $5.00/year, respectively, both below the national average of $54.69 and $6.70/year (NCDMV, 2020; WPR, 2020a, 2020b). Currently, Florida has the highest annual registration fee of $225 and Massachusetts has the highest driver's license fee of $21.25/year (WPR, 2020c). In addition, NC currently charges a $130 flat registration fee for EVs, whereas its neighbor, Georgia, charges $214 and $320 for non-commercial and commercial alternative fuel vehicles, respectively (NCDMV, 2020).

The results suggest that to ensure additional revenue equivalent to 30% of the collected state revenues on average, the current rate of vehicle registration fee would need to increase from $38.75 to $87.99 (127.1% increase). This is equivalent to the current vehicle registration fee in Connecticut ($88, 9th highest rate in the US) (WPR, 2020c). This would also increase the driver's license fee from $5 to $11.35, close to current rate in Nevada ($10.56, 5th highest in the US), as well as increase the EV registration fee from $130 to $295.20. We also find that even a large increase in motor vehicle fees does not lead to substantial changes or improvements in the equity ratios.

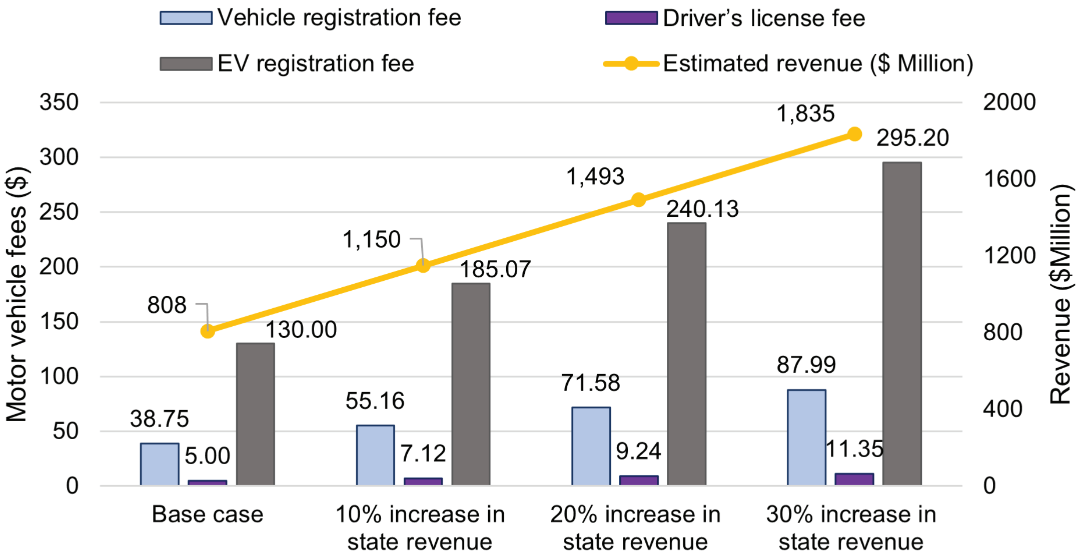


Figure 13: Average annual revenue from increased motor vehicle fees by revenue scenario, 2014-2017.

Dedicated Sales Tax

At least 19 states in the US use sales tax revenue for funding transportation infrastructure. Among them, at least 12 states (including NC) collect local sales tax at the county level for transportation-related uses, while the rest dedicate a portion of the statewide sales tax to transportation. In NC, no sales tax revenue is allocated to roadway infrastructure. The state sales tax is 4.75%; 72 out the 100 counties collect an additional 2% sales tax. Three counties (Durham, Mecklenburg, and Wake) have imposed another 0.5% sales tax, which is directed towards funding their respective public transportation systems. North Carolina ranks 26th in the US in terms of total (state and local) sales tax rate. Tennessee, Louisiana, and Arizona have three of the highest total sales tax rates (approximately 9.5%), while California has the highest state sales tax rate (7.25%) (Cammenga, 2020).

We have estimated the percentage of additional sales tax on all taxable sales and purchases that could have generated an additional 10-30% state revenue (Figure 14). For the revenue scenarios examined herein, the average maximum state sales tax rate would need to be 5.55%. This is close to the current state sales tax of Nebraska 5.50%, which is the 29th highest state sales tax in the US (Cammenga, 2020).

We also collected the annual per capita personal consumption expenditures (PCE) for NC from 2014 to 2017 (U.S. Bureau of Economic Analysis, 2020) to understand the impact of potentially increasing the state sales tax in $ per user. Residents of NC, on average, made $32,525 in PCEs per year from 2014 to 2017. The average annual spending in sales tax was $1,544.90 during this period, based on the current sales tax rate of 4.75%. To collect an additional 10-30% of state revenue, the average individual taxpayer would have to spend $86.40-$259 more on state sales tax.

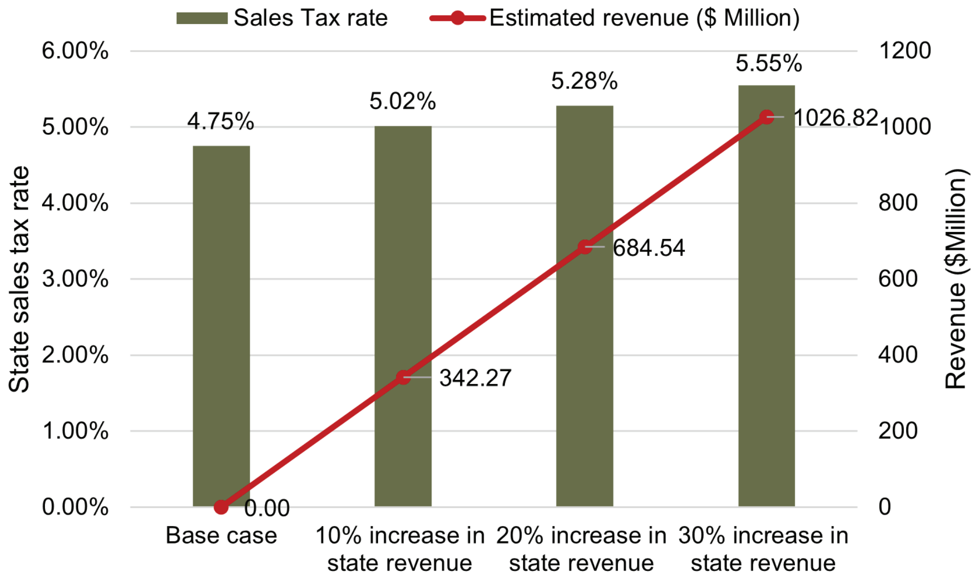


Figure 14: Average annual revenue from increased state sales tax by revenue scenario, 2014-2017.

Mileage-Based User Fee

As an effort to diversify the transportation revenue structure, several states have tested and some have implemented mileage-based user fee (MBUF) systems (CalSTA, 2017; ODOT, 2020; WSTC, 2020). Eight states are currently planning or have completed MBUF pilot programs, while Oregon and Utah have fully operational, voluntary MBUF systems (ODOT, 2020). The rates being applied and/or tested in other states range from 1.8 cents/mile to 2.4 cents/mile for passenger vehicles.

For this analysis, we first estimated the per-mile fee needed to replace the existing state fuels tax to generate the same revenue collected from state fuels tax during 2014-2017. A flat rate MBUF was estimated for FHWA vehicle class 2 (passenger cars) and class 3 (2-axle 4-tire vehicles). Higher fees are introduced for trucks. Higher rates for trucks are justifiable given the greater damage they cause to road and bridge infrastructure compared to passenger vehicles (AASHTO, 1993b; Luskin and Walton, 2001; Vaidyanathan and Langer, 2011). Oregon has the only functioning MBUF program with different fee structures for trucks and passenger cars. The truck MBUF system in Oregon imposes a base fee of 6.2 cents/mile on trucks with gross weight over 26,000 lbs; the fee increases at a rate of 0.3 cents/mile for every 2,000 lbs up to 60,000 lbs, and 0.9 cents/mile for every 2,000 lbs up to 80,000 lbs (CBO, 2019). The highest rate for trucks can reach up to 28.8 cents/mile based on weight and axle configuration (CBO, 2019). For this case study, the starting rate of mileage-based fee for trucks (FHWA class 4-13) weighing over 26,000 lbs. has been selected to be 3.4 times the rate of the passenger cars, following the base rate for passenger cars and trucks in Oregon's MBUF system. We did not include motorcycles in the MBUF, as no state has either implemented or tested MBUF for this class.

The highest estimated fee is 2.46 cents/mile for class 2 and 3 vehicles (Figure 15), whereas the current highest rate suggested in the US is 2.4 cents/mile by the Washington State Transportation Commission to replace the current state fuels tax of 49.4 cents/gallon (WSTC, 2020). Similar to the state fuels tax analysis, we have adopted a long-run price elasticity of -0.241 (Hymel et al., 2010) to adjust the VMT in response to the changes in travel cost

In the base case (traditional system of fuels tax-based revenues), the single-unit and multi-unit trucks were contributing about 8.41% and 10.51% of the total state fuels tax, respectively. However, replacing the fuels tax with mileage-based fee would have collected about 12% of the total revenues from the trucks (class 4-13). This is also reflected in the equity ratios for the vehicle classes. Replacing the current state fuels tax with an MBUF system slightly improves equity because the truck revenue share increases compared to the state fuel tax system. Overall, by implementing an MBUF system with fee structures similar to existing MBUF systems results in minor changes in the equity ratios.

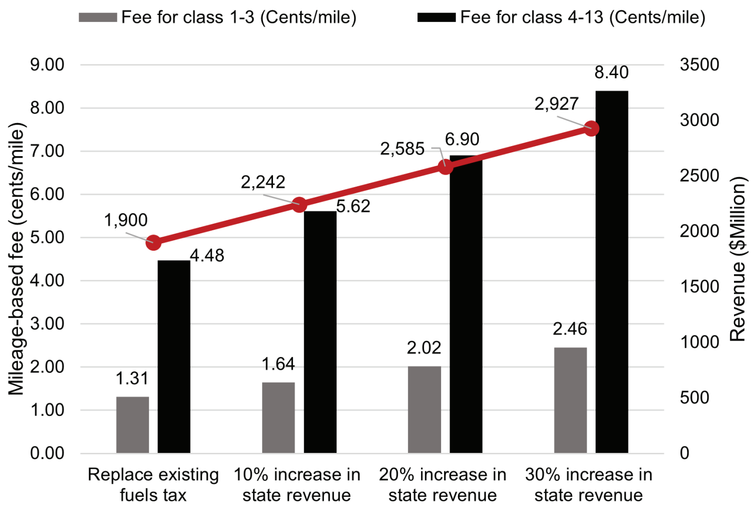


Figure 15: Average annual revenue from MBUF system by revenue scenario, 2014-2017.

Conclusions

This research estimated the cost responsibility and revenue contribution of individual vehicle classes for North Carolina's highway infrastructure. Results are reported in terms of equity ratios, which measure the percentage contribution to the revenue over the cost responsibility of each vehicle class. Our results suggest that lightweight vehicles, i.e., motorcycle (class 1), passenger cars (class 2), and class 3 vehicles contribute more to the revenue than their share of cost responsibilities. Specifically, it was found that the motorcycles, passenger cars, and class 3 vehicles overpay by 30%, 26%, and 8%, respectively. Among the single-unit trucks, buses (class 4) and three-axle single-unit trucks (class 6) are found to overpay by 13% and 20%, respectively, of their cost-responsible shares. Vehicles in FHWA class 5 (two-axle six tire single-unit trucks) are reported to have an equity ratio of 1.78, meaning they overpay by 78% of their cost-responsible share. This high equity ratio can be attributed to the fact that NCDOT allots misclassified trucks under FHWA class 5 during field data collection at the vehicle classification stations, which may not accurately reflect actual traffic volumes and VMT. As a result, class 5 trucks have a higher VMT share, that led to a higher percentage share of revenue and a higher equity ratio. Single unit trucks with four or more axles (class 7) and all the multi-unit trucks (class 8-13) have equity ratios below one indicating these vehicles did not contribute to the revenue stream in proportion to their cost responsibilities. Specifically, multi-unit trucks in class 10, class 12, and class 13 underpay by 78%, 58%, and 92%, respectively, of their cost-responsible shares. In summary, lightweight vehicles contribute more to the revenue compared to the damage they cause on highway infrastructure and subsidize the cost responsibility of the heavier truck classes.

The results of this study reveal that NCDOT should explore ways to increase the share of revenue contributions from trucks. Several revenue generation mechanisms were analyzed as part of this study, such as increasing the rates of current sources of revenue and investigating new sources of revenue. The feasibility of the proposed revenue generation scenarios was evaluated in terms of their revenue generation potential, public perception, and the practicality of their application. However, an in-depth analysis of funding mechanism scenarios was not within the scope of this study. Such future research is important for identifying feasible approaches that will increase equity in revenue generation for transportation infrastructure.

Increasing the state motor fuels tax would be a feasible approach for raising additional transportation revenue. From 2014 to 2017, the average state fuels tax in NC was 35.59 cents per gallon. During this period, it would have been possible to increase the state revenue by 10%, 20%, and 30% by increasing the fuels tax by 4.49%, 25.40%, and 48.91%, respectively; this would correspond to a state motor fuels tax of 37.19, 44.63, and 53 cents per gallon, respectively. These rates are close to the current 8th highest (36.89 cents per gallon in Maryland), fourth-highest (41.4 cents per gallon in New Jersey), and second-highest (53.3 cents per gallon in California) gas tax, respectively, across the US (API, 2021). In addition, public perception studies across the US suggest increasing support towards raising the state fuels tax. Studies carried out in Rhode Island, Arkansas, Georgia, and Mississippi during 2015 suggested that 27%-38% of the respondents favored increasing the state fuels tax (AJC, 2015; Brawner, 2015; Gregg, 2015). In a more recent public perception study, it was found that half or more of the respondents from Tennessee, Montana, New Hampshire, California, Utah, Iowa, New Jersey, and Virginia supported an increase in state fuel tax (Agrawal and Nixon, 2018). The most recent public perception study in NC reported that over half of the residents consider the amount they pay in state gas tax as a fair price for driving on NC roads (McCaleb et al., 2021). In addition, about a third of the NC residents would prefer an increase in the state gas tax, compared to other means of raising additional transportation revenue (McCaleb et al., 2021).

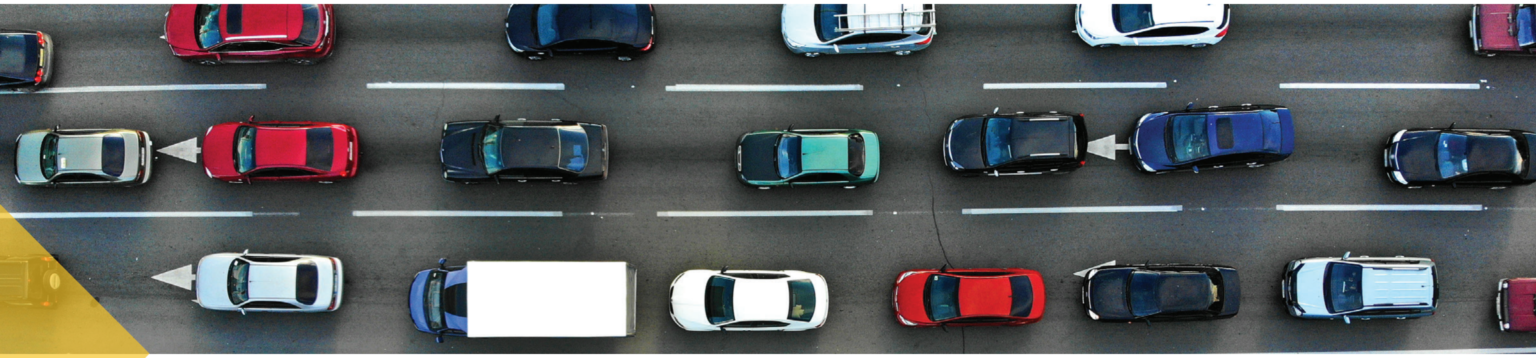
Implementing a higher rate of HUT would also be a feasible solution for collecting additional revenue. The current HUT rate in NC is 3% which is the lowest among the states that collect sales tax on vehicle purchases. An up to 30% increase in state revenue could be accomplished by raising HUT at around 7%. This HUT rate is still considered reasonable, given the substantially higher HUT rates in other states, such as 11.5% in Louisiana and Oklahoma (Bert et al., 2020).

Furthermore, ensuring an additional revenue of 10-30% of the state revenue by only increasing motor vehicle fees may not be a reasonable solution because it would require a 42.36-127.08% increase in fees. A uniform increase in the motor vehicle fees would also imply an increase in the registration fees for electric vehicles from $130 to a maximum of $295.20. The final report of the NC FIRST commission has suggested increasing the fees for electric vehicles and impose additional fees on hybrid vehicles (NCDOT, 2021). Increasing motor vehicle fees could ensure a larger share of revenues from single-unit and multi-unit trucks. The NC FIRST commission also stressed the need to establish competitive trucking fees and ensure that the tax and fees collected from the trucks are proportionate to the amount of damage caused (NCDOT, 2021).

As a new source of revenue, this study explored the potential of dedicating revenues from state sales and use tax to transportation use. The current state and local sales and use tax rate in NC is 4.75% and 6.75%–7.0%, respectively. Increasing the state revenue by 30% would require a less than one percentage point increase in the state sales tax rate. This is considered feasible, given that the current highest state sales tax in the US is 7.25% (in California). Using personal consumption expenditure data, it was found that an average individual taxpayer would have to spend up to $259 more on state sales tax to collect an additional 30% state revenue. Public perception studies across the US have suggested that people overall support dedicating state sales tax for general transportation use (Agrawal and Nixon, 2018). Separate studies in Texas, Michigan, Georgia, California, Wisconsin, and Colorado reported that people would support a 0.5-1% increase in state sales tax over a fixed period to fund specific transportation projects (Baldassare et al., 2017; Magellan Strategies and Public Policy Polling, 2018; Nixon and Agrawal, 2018). Similarly in NC, there seems to be substantial support for increasing the sales tax to fund transportation infrastructure (McCaleb et al., 2021). The NC FIRST commission has recommending diverting the state sales tax from transportation-related goods and services to NCDOT, ensuring immediate additional revenue (NCDOT, 2021).

Lastly, this study investigated the potential of replacing the state fuel tax with a mileage-based user fee system. Trucks (FHWA classes 4-13) were assumed to pay higher rates than other vehicles, similar to Oregon's MBUF system. Our results indicate that a rate of 2.46 cents per mile for passenger vehicles is needed for a 30% increase in state revenue this is close to the current highest rate of 2.4 cents/mile proposed by the Washington State Transportation Commission to replace the current state fuels tax of 49.4 cents/gallon (WSTC, 2020). MBUF systems are becoming more popular across the US as studies have suggested that public support for 1 cent/mile MBUF has increased from 33% in 2010 to 50% more recently (Agrawal and Nixon, 2020; Nixon and Agrawal, 2018). A state-wide survey of 2,200 NC residents found that 30% of the residents supported MBUF as their most preferred method to fund the state's transportation projects, while 36% and 34% of the respondents preferred fuel-based fees and weight-based fees, respectively (Norboge et al., 2019). More recently, it was found that the introduction of a fee based on miles driven is the least preferred option for NC residents, compared to increasing the state gas tax or the general state sales tax (McCaleb et al., 2021). The NC FIRST commission has also suggested implementing an MBUF system as a long-term solution to modernizing NCDOT's funding structure (NCDOT, 2021).

Although most of the revenue scenarios explored as part of this research are implementable and reasonable when compared to the tax and fee structures in other states, none of these scenarios was found to lead to substantial improvements in the reported equity ratios. Future research should focus on a detailed exploration of tax and fee structures that can significantly enhance equity in NC's transportation infrastructure revenue generation process.



References

AASHTO, 1993a. AASHTO Guide for design of pavement structures. Washington, DC.

AASHTO, 1993b. AASHTO Guide for Design of Pavement Structures. Washington D.C.

Agrawal, A.W., Nixon, H., 2020. What Do Americans Think About Federal Tax Options to Support Transportation? Results from Year Eleven of a National Survey.

Agrawal, A.W., Nixon, H., 2018. What Do Americans Think About Federal Tax Options to Support Transportation? Results from Year Nine of a National Survey.

AJC, 2015. Poll of Georgia voters, January 2015 [WWW Document]. Atlanta Journal-Constitution. URL https://www.ajc.com/news/jan-2015-poll/ (accessed 12.21.20).

API, 2021. Gasoline Taxes, American Petroleum Institute.

Baldassare, M., Bonner, D., Kordus, D., Lopes, L., 2017. PPIC Statewide Survey: Californians and Their Government.

Balducci, P., Mingo, R., Wolff, H., Stowers, J., Cohen, H., 2009. 2009 Nevada Highway Cost Allocation Study: Final Report.

Balducci, P., Stowers, J., Mingo, R., Cohen, H., Wolff, H., 2010. 2010 Idaho Highway Cost Allocation Study Final Report.

Bert, S., Head, W., Norboge, N., Odom, S., Dorn, L., Findley, D., 2020. Modernizing North Carolina's Infrastructure Through Sustainable and Diversified Revenue Streams.

Brawner, S., 2015. AFP Poll: 64% Oppose Raising Gas Tax For Arkansas Highway Needs [WWW Document]. Talk Bus. Polit. URL https://talkbusiness.net/2015/10/afp-poll-64-oppose-raising-gas-tax-for-arkansas-highway-needs/ (accessed 12.21.20).

CalSTA, 2017. California Road Charge Pilot Program.

Cammenga, J., 2020. State and Local Sales Tax Rates, 2020.

CBO, 2019. Issues and Options for a Tax on Vehicle Miles Traveled by Commercial Trucks.

Craft, E.D., Schmidt, R.M., 2005. An Analysis of the Effects of Vehicle Property Taxes on Vehicle Demand. Natl. Tax J. 58, 697–720.

Dill, J., Weinstein, A., 2007. How to pay for transportation? A survey of public preferences in California. Transp. Policy 14, 346–356. https://doi.org/10.1016/j.tranpol.2007.04.001

Dumortier, J., Zhang, F., Marron, J., 2017. State and federal fuel taxes: The road ahead for U.S. infrastructure funding. Transp. Policy 53, 39–49. https://doi.org/10.1016/j.tranpol.2016.08.013

Duncan, D., Li, D., Graham, J.D., 2020. Tax rate design and support for mileage user-fees. Transp. Policy 93, 17–26. https://doi.org/10.1016/j.tranpol.2020.04.017

Duncan, D., Nadella, V., Giroux, S., Bowers, A., Graham, J.D., 2017. The road mileage user-fee: Level, intensity, and predictors of public support. Transp. Policy 53, 70–78. https://doi.org/10.1016/J.TRANPOL.2016.09.002

ECONorthwest, 2021. Oregon Highway Cost Allocation Study. 2019-2021 Biennium.

ECONorthwest, 2019. Oregon Highway Cost Allocation Study. 2017-2019 Biennium.

FHWA, 2019. Annual Vehicle Distance Traveled in Miles and Related Data - 2017 by Highway Category and Vehicle Type [WWW Document]. Highw. Stat. - 2017. URL https://www.fhwa.dot.gov/policyinformation/statistics/2017/vm1.cfm (accessed 7.17.21).

FHWA, 2018. Annual Vehicle Distance Traveled in Miles and Related Data - 2015 by Highway Category and Vehicle Type [WWW Document]. Highw. Stat. 2015. URL https://www.fhwa.dot.gov/policyinformation/statistics/2015/vm1.cfm (accessed 7.17.21).

FHWA, 2014. Traffic Monitoring Guide: Appendix C. Vehicle Types [WWW Document].

FHWA, 2013. Highway Functional Classification Concepts, Criteria and Procedures.

FHWA, 1997. 1997 Federal Highway Cost Allocation Study Final Report [WWW Document]. Policy Gov. Aff. FHWA. URL https://www.fhwa.dot.gov/policy/hcas/final/toc.cfm (accessed 3.28.19).

FHWA, 1995. Recording and coding guide for the structure inventory and appraisal of the nation's bridges. Rep. No. FHWA-PD-96-001.

Gregg, K., 2015. Poll: Truck toll favored over gas-tax hike to fund R.I. road-bridge repairs [WWW Document]. Provid. J. URL https://www.providencejournal.com/article/20151006/NEWS/151009606 (accessed 12.21.20).

Gupta, D., 2012. Highway Cost Allocation and Determination of Heavy Freight Truck Permit Fees.

Hymel, K.M., Small, K.A., Van Dender, K., 2010. Induced demand and rebound effects in road transport. Transp. Res. Part B 44, 1220–1241. https://doi.org/10.1016/j.trb.2010.02.007

Liu, Y., Cirillo, C., 2015. Model System to Evaluate Impacts of Vehicle Purchase Tax and Fuel Tax on Household Greenhouse Gas Emissions. Transp. Res. Rec. 2503, 51–59. https://doi.org/10.3141/2503-06

Luskin, D.M., Walton, C.M., 2001. Effects of Truck Size and Weights on Highway Infrastructure and Operations: A Synthesis Report (FHWA/TX-0-2122-1).

Magellan Strategies, Public Policy Polling, 2018. Colorado Transportation Funding Survey Topline Results.

McCaleb, E., Norboge, N.D., Head, W., Findley, D., Cobb, M., Goode, L., Bardaka, E., 2021. Public Perceptions of Transportation Fees and Taxes in North Carolina 2020.

Mcmullen, B.S., Zhang, L., Nakahara, K., 2010. Distributional impacts of changing from a gasoline tax to a vehicle-mile tax for light vehicles: A case study of Oregon. Transp. Policy 17. https://doi.org/10.1016/j.tranpol.2010.04.002

NC First Commission, 2020. The North Carolina Highway Use Tax.

NC FIRST Commission, 2019. The NC Motor Fuels Tax-2019.

NCDMV, 2020. Vehicle Title & Registration Fees [WWW Document]. North Carolina Dep. Mot. Veh. URL https://www.ncdot.gov/dmv/title-registration/vehicle/Pages/fees.aspx (accessed 12.17.20).

NCDOT, 2021. Final Commission Report: North Carolina Future Investment Resources for Sustainable Transportation (NC FIRST) Commission.

Nixon, H., Agrawal, A.W., 2018. Would Americans pay more in taxes for better transportation? Answers from seven years of national survey data. Transportation (Amst). https://doi.org/10.1007/s11116-018-9855-x

Norboge, N.D., Head, W., Findley, D., Ravi, P.E., Chittilla, K., Broussard, P., Cobb, M., Goode, L., Bardaka, E., 2019. Public Perceptions of Transportation Fees and Taxes in North Carolina.

Nordland, A., Paz, A., Khan, A., 2013. Vehicle Miles Traveled Fee System in Nevada. Transp. Res. Rec. J. Transp. Res. Board 2345, 39–47. https://doi.org/10.3141/2345-06

ODOT, 2020. Oregon's Road Usage Charge Program [WWW Document]. Oregon Dep. Transp. URL https://www.oregon.gov/ODOT/Programs/Pages/OReGO.aspx (accessed 12.21.20).

Salama, H.K., Chatti, ; Karim, Lyles, R.W., 2006. Effect of Heavy Multiple Axle Trucks on Flexible Pavement Damage Using In-Service Pavement Performance Data. J. Transp. Eng. 132, 763–770. https://doi.org/10.1061/ASCE0733-947X2006132:10763

Sinha, K.C., Fwa, T.F., Sharaf, E.A., Tee, A.B., Michael, H.., 1984. Indiana Highway Cost-Allocation Study (Project Number:C-36-54PP). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284314083

Thapa, R., Zeringue, K., Codjoe, J., 2020. Literature Review of Mileage-Based Road User Fees.

Tonn, G., Reilly, A., Czajkowski, J., Ghaedi, H., Kunreuther, H., 2021. U.S. transportation infrastructure resilience: Influences of insurance, incentives, and public assistance. Transp. Policy 100, 108–119. https://doi.org/10.1016/j.tranpol.2020.10.011

TRB, 2000. Highway capacity manual.

U.S. Bureau of Economic Analysis, 2020. Annual per capita personal consumption expenditures (PCE) in North Carolina from 2000 to 2019 [WWW Document]. Stat. Res. Dep. URL https://www.statista.com/statistics/1128241/north-carolina-per-capita-personal-consumption-expenditures/ (accessed 7.15.21).

Vaidyanathan, S., Langer, T., 2011. Rating the Environmental Impacts of Motor Vehicles: ACEEE'S Green Book Methodology.

Volovski, M., Bardaka, E., Zhang, Z., Agbelie, B., Labi, S., Sinha, K.C., 2015. Indiana State Highway Cost Allocation and Revenue Attribution Study and Estimation of Travel by Out-of-State Vehicles on Indiana Highways. https://doi.org/10.5703/1288284315709

Winebrake, J.J., Green, E.H., Comer, B., Li, C., Froman, S., Shelby, M., 2015a. Fuel price elasticities in the U.S. combination trucking sector. Transp. Res. Part D Transp. Environ. 38, 166–177. https://doi.org/10.1016/j.trd.2015.04.006

Winebrake, J.J., Green, E.H., Comer, B., Li, C., Froman, S., Shelby, M., 2015b. Fuel price elasticities for single-unit truck operations in the United States. Transp. Res. Part D Transp. Environ. 38, 178–187. https://doi.org/10.1016/j.trd.2015.05.003

WPR, 2021. Gas Taxes By State 2021 [WWW Document]. World Popul. Rev. URL https://worldpopulationreview.com/state-rankings/gas-taxes-by-state (accessed 7.24.21).

WPR, 2020a. Drivers License Cost by State [WWW Document]. World Popul. Rev. URL https://worldpopulationreview.com/state-rankings/drivers-license-cost-by-state (accessed 12.17.20).

WPR, 2020b. Gas Taxes by State [WWW Document]. World Popul. Rev. URL https://worldpopulationreview.com/state-rankings/gas-taxes-by-state (accessed 12.13.20).

WPR, 2020c. Car Registration Fees by State [WWW Document]. World Popul. Rev. URL https://worldpopulationreview.com/state-rankings/car-registration-fees-by-state (accessed 12.17.20).

WSTC, 2020. Washington State Road Usage Charge Assessment.

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