

Personal Vehicle Ownership and Operating Cost Calculator

June 2018

A Research Report from the National Center
for Sustainable Transportation

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Personal Vehicle Ownership and Operating Cost Calculator

EXECUTIVE SUMMARY

The goal of this research is to develop a tool that can help students and the public better understand the total cost of owning and operating a personal vehicle over the lifetime of that vehicle, from vehicle purchase to vehicle disposal. Lifetime vehicle operating cost consists of the vehicle purchase cost, as well as costs that are less obvious to the user (e.g., financing, fuel, maintenance, insurance, etc.). Underestimating the hidden costs embedded in lifetime vehicle operating cost can lead people to choose vehicles that are unaffordable for their financial situations. Hence, educating transportation planners, students, and the public about lifetime vehicle operating costs is important.

Typical online websites, such as Edmunds® and Kelley Blue Book®, can help the public understand vehicle operating cost calculations. These sites typically provide users with simple five-year cost of ownership calculations, based upon average purchase price data, depreciation tables, average annual mileage accrual, fuel cost estimates, and average costs for items such as maintenance and insurance. However, actual purchase price and financing arrangements, annual insurance costs, parking and tolls, and a variety of other costs can vary widely across geographic regions (specifically, urban versus rural environments) and from household to household and individual to individual. Furthermore, the existing sites do not provide the level of detail needed by users to see how they might change their operating costs.

To provide a more personalized calculation approach, the National Center for Sustainable Transportation (NCST) research team developed the Lifetime Vehicle Ownership and Operating Cost Calculator (<http://costcalculator.ce.gatech.edu/>). The NCST website provides users with data entry flexibility and a clear, intuitive, and interactive user-interface through which users can better understand their vehicle ownership costs. Vehicle ownership costs are calculated using lookup data and user input for such elements as: purchase price, down payment, interest rates, loan term, annual insurance, maintenance, tire, smog check, parking, tolls, etc. All lookup data can be modified as desired by the user.

The cost calculator was developed using data from: 1) the USEPA Certification Test Result Database, for an assortment of vehicle make, model, model year, and fuel type data; 2) the State of Georgia Department of Revenue Motor Vehicle Division Database, for vehicle purchase price information; and 3) the US Department of Energy's Fuel Economy Database, for fuel economy data.

The NCST website is designed to provide students and the public with a tool that can be used in research and also at any educational level. Users can calculate the cent/mile and total cost of vehicle ownership over the life of the vehicle, with cost estimates for each component specifically identified so that users can weigh the impact of each cost element in their vehicle purchase and use decisions. From an educational perspective, this tool can be used as an

instructional aid to specific courses. For example, the tool has been used in the urban transportation planning course at Georgia Tech (CEE6602), where the students are asked to compare different vehicle choices based on a real-life case study. In addition, the NCST team plans to introduce this tool to high school consumer economics classes to help students make reasonable vehicle purchase decisions and to assess vehicle operating costs over entire vehicle life cycles.

As a part of this research, students taking the graduate level urban transportation planning course (CEE6602) were asked to complete a survey about their perception of lifetime vehicle operating costs before and after using the NCST Lifetime Vehicle Ownership and Operating Cost Calculator website. The results indicate that educating students about lifetime vehicle operating costs via the NCST website appears to change their perceptions of relative vehicle operating costs. For example, the students became more aware of the importance of depreciation in total lifetime vehicle ownership and operating costs.

Introduction

The average cost of owning and operating a private vehicle over the lifetime of the vehicle, from vehicle purchase to disposal, is significant. A recent American Automobile Association (AAA) report (2017a) suggests that the average five-year ownership of a vehicle used 15,000 miles per year is \$8,469 per year (AAA, 2017a). Lifetime vehicle operating cost varies considerably according to the type of vehicle and the driver's operating conditions. For example, AAA reports that lifetime vehicle operating cost per year varies from \$7,429 for a small sedan to \$11,835 for a pickup truck (AAA, 2017a). The annual vehicle operating cost for a small sedan varies by annual miles traveled, ranging from \$8,023 for 10,000 miles to \$10,543 for 20,000 miles. Lifetime vehicle operating costs includes insurance, which depends on driver characteristics, and fuel, which depends on the type and cost of fuel.

Consumers generally focus on vehicle purchase cost rather than lifetime vehicle operating cost in making vehicle purchase decisions. This may be because people do not understand how other costs contribute to the total lifetime vehicle operating cost. Dumortier, et al. (2015) demonstrated that providing users with lifetime vehicle operating cost can significantly affect vehicle purchase decisions. Thus, educating people about how to calculate lifetime vehicle operating cost may help them make more rational vehicle purchase decisions. For example, if people better understand lifetime vehicle operating cost, it is possible that they will choose to buy a hybrid or electric vehicle that is generally more expensive than a gasoline vehicle, but may have lower lifetime vehicle operating cost due to higher fuel efficiency (especially for those consumers that travel many miles per year).

Several websites have provided online tools to calculate lifetime vehicle operating cost. Edmunds® and Kelley Blue Book®, two of the most popular vehicle purchase websites, provide a five-year vehicle operating cost calculator based on the users' input of vehicle make, model, and model year. These websites provide users with an average five-year vehicle operating cost, using average purchase price data, depreciation tables, average mileage accrual, fuel cost estimates, and typical average values for ongoing costs such as maintenance and insurance. However, these websites do not allow entry of user-specific data in the calculations, such as actual miles of driving, insurance, interest, parking, and other costs. Because individual vehicle purchase costs and operating patterns vary significantly, it is likely that the actual lifetime operating cost is different from the five-year costs calculated by these websites. One particular website by FinancialMentor.com allows users to input specific vehicle operating costs into the calculations; however, the website does not provide any support resources (e.g., vehicle purchase cost) so it requires a huge effort on the part of users to gather that information. Therefore, a tool that allows user-specific inputs and provides such useful resources seems needed to help users obtain a better lifetime vehicle operating cost result.

The National Center for Sustainable Transportation (NCST) lifetime vehicle ownership and operating cost calculator (<http://costcalculator.ce.gatech.edu/index.html>) supports individualized user inputs for each cost component. A large database also contains data for vehicle makes, models, model years, fuel economy, etc. Hence, users can obtain lifetime vehicle operating costs for a diverse fleet of vehicles. Intuitive charts and tables also provided

as calculator outputs help users figure out how each cost component contributes to the lifetime cost.

A primary goal of developing the NCST lifetime vehicle ownership and operating cost calculator is to help users better understand the lifetime vehicle operating cost calculation. With simple user-interface, users can easily find out a list of factors affecting lifetime vehicle operating cost and understand how the cost of each cost component is calculated. The NCST cost calculator is useful for a variety of research and education purposes. For example, the public can use the NCST cost calculator to help them to make more rational purchase decisions. The NCST cost calculator can also be used as an educational tool in transportation-related or economics-related courses in high schools and universities.

Review of Literature and Existing Websites

This chapter summarizes previous research related to the development of lifetime vehicle ownership and operating cost calculators and existing on-line and off-line cost calculators. The main objectives of the literature review are to summarize essential operating cost components that should be included in the NCST lifetime vehicle ownership and operating cost calculator. The primary objective of this activity is to summarize the pros and cons of existing calculators and to establish the strategies to develop a better calculator.

Literature Review

Previous research efforts describe the various factors affecting the lifetime cost of vehicle ownership and operating cost. The Victoria Transport Policy Institute (VTPI) divides lifetime vehicle operating cost into fixed and variable costs (Litman, 2009). The fixed costs are defined as the costs that are unaffected by annual vehicle mileage, such as vehicle purchase or lease cost, insurance (although some policies do differentiate between low, medium, and high-mileage categories), registration fees, and vehicle taxes. On the other hands, variable costs typically increase with vehicle mileage, such as fuel, fuel taxes, maintenance, repair, paid parking, tolls, etc.

Specifically, the VTPI (Litman, 2009) research suggested an average of \$0.055 per mile for capital depreciation for a five-year-old vehicle (higher for low-mileage newer vehicles), and \$0.10 per mile for excess mileage charges for vehicle leases. In addition, the research suggested an average of \$0.15 to \$0.20 per mile for vehicle operating costs (fuel, oil, and tire wear) and \$0.10 to \$0.20 per mile for distance-based costs (maintenance, depreciation, and additional crash and citation costs).

The Transportation Economics Committee of the Transportation Research Board developed and currently maintains the “Transportation Benefit-Cost Analysis”¹ website (Transportation Economics Committee, 2017). In particular, the webpage describes the variety of specific factors affecting total vehicle operating cost. The factors include vehicle speed, speed changes, gradient, curvature, and road surface. For example, the website describes vehicle speed (which affects fuel economy) as a dominant factor affecting total vehicle operating cost. The website suggests the importance of vehicle operating conditions in the vehicle operating cost calculation.

The AAA publishes reports that show what factors affect vehicle ownership and operating costs (AAA, 2017a; AAA, 2017b). The cost components considered by the AAA in their reports include fuel, maintenance, repair and tires, insurance, license, registration and taxes, depreciation, and finance costs. AAA reports develop average per-mile costs based on their annual survey of members, using top-selling vehicle models in their calculations. The costs summarized in the 2017 report vary by vehicle mileage and type of vehicles as shown in Table 1, 2 and 3.

¹ The website is found at <http://bca.transportationeconomics.org/benefits/vehicle-operating-cost>.

Table 1. AAA Average Costs (\$) per Mile for 2017 Model Year Vehicles

Cost Components	Small Sedan	Medium Sedan	Large Sedan	Small SUV	Medium SUV	Minivan	½-Ton, Crew-Cab Pickup	Hybrid	Electric
Fuel	0.070	0.090	0.110	0.090	0.120	0.110	0.140	0.060	0.040
Maintenance, repair, tires	0.070	0.080	0.080	0.080	0.080	0.080	0.080	0.070	0.070
Insurance	0.086	0.080	0.080	0.072	0.073	0.072	0.082	0.081	0.079
License, registration, taxes	0.030	0.043	0.050	0.040	0.055	0.048	0.066	0.044	-0.044
Depreciation	0.141	0.212	0.253	0.189	0.248	0.256	0.239	0.220	0.380
Finance charge	0.026	0.040	0.047	0.038	0.054	0.046	0.061	0.042	0.045

Note: the values are assumed 15,000 miles driven per year.

Sources: AAA (2017a)

Table 2. AAA Average Costs (\$) per Year for 2017 Model Year Vehicles

Cost Components	Small Sedan	Medium Sedan	Large Sedan	Small SUV	Medium SUV	Minivan	½-Ton, Crew-Cab Pickup	Hybrid	Electric
Fuel	1,050	1,350	1,650	1,350	1,800	1,650	2,100	900	600
Maintenance, repair, tires	1,050	1,200	1,200	1,200	1,200	1,200	1,200	1,050	1,050
Insurance	1,288	1,202	1,200	1,076	1,089	1,075	1,229	1,208	1,185
License, registration, taxes	454	639	757	607	831	726	984	667	-656
Depreciation	2,114	3,187	3,799	2,840	3,720	3,839	3,587	3,301	5,704
Finance charge	396	597	706	567	806	692	922	624	671

Note: the values are assumed 15,000 miles driven per year.

Sources: AAA (2017a)

Table 3. AAA Total Cost (\$) Per Mile by Annual Vehicle Miles Traveled for 2017 Model Year Vehicles

Vehicle miles traveled	Operating Cost (\$/mile)								
	Small Sedan	Medium Sedan	Large Sedan	Small SUV	Medium SUV	Minivan	½-Ton, Crew-Cab Pickup	Hybrid	Electric
10,000	0.55	0.71	0.82	0.65	0.82	0.80	0.86	0.68	0.77
15,000	0.42	0.54	0.62	0.50	0.63	0.60	0.67	0.51	0.56
20,000	0.37	0.47	0.54	0.44	0.55	0.52	0.59	0.43	0.47

Sources: AAA (2017a)

A report by Wheels.com shows that vehicle ownership cost is composed of several cost components as shown in Figure 1 (Wheels.com, 2017), where the most significant factor is depreciation, accounting for 45% of the total cost of vehicle ownership. This report also showed that the second most important factor is fuel, accounting for 33%. Although this chart does not reflect the characteristics of individual vehicles and drivers, decomposing lifetime vehicle operating cost in graphic form helps users understand the component costs.

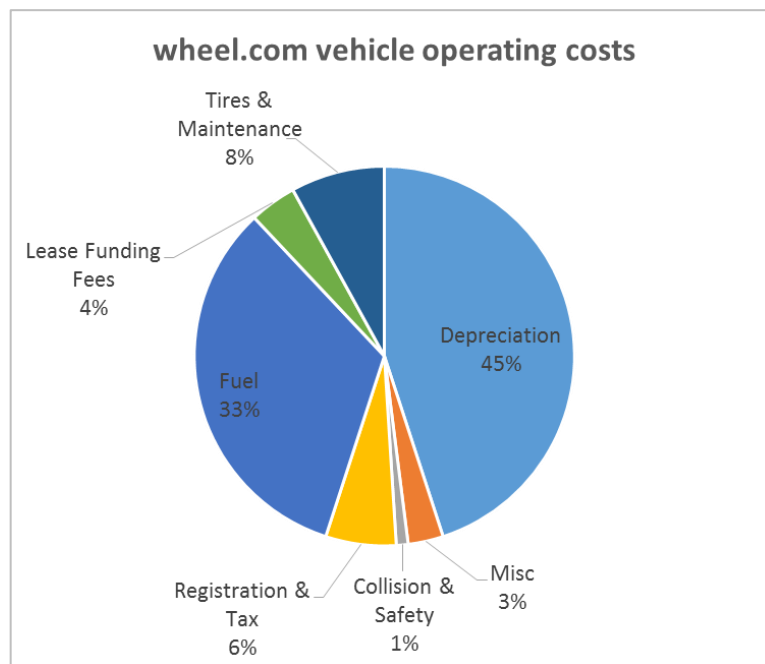


Figure 1. Factors Affecting Fleet Costs Addressed by Wheel.Com

An article by Delbridge (2017) summarized the various factors affecting the cost of car insurance. The factors are divided into vehicle, driver, and insurance company factors. Table 4 summarizes the factors demonstrated in the article; there are a number of factors that determine car insurance costs. For example, a foreign make car typically costs more to insure because the parts can be harder to obtain and fewer body shops repair these vehicles. Also,

although it varies by insurance company, persons older than twenty-five years old generally are eligible for preferred rates.

Table 4. Factors Affecting the Cost of Car Insurance

Classification	Factors
Vehicle factors	Model year, make, model, vehicle safety features (e.g., air bags), car alarm, coverage purchased, number of vehicles insured, etc.
Driver factors	Age, driving record, number of drivers, financial stability, primary health insurance coverage, home ownership, garage and operating location, education/good student discount, prior limits of liability, etc.
Insurance company	Profitability, payment plans, length of time insured, state laws, etc.

Reference: Delbridge (2017)

Existing Websites and Tools

This section delineates the characteristics of several existing online vehicle operating cost calculators.

Edmunds True Cost to Own®

Edmunds®, one of the most popular vehicle websites, provides an online tool to estimate a five-year total cost of vehicle ownership (Edmunds, 2017). The Edmunds tool has some great advantages: 1) the tool incorporates a large number of different new and used vehicle makes and models so that users can easily choose a vehicle of interest, 2) the system includes current market price data for these vehicles, 3) the tool is simple and easy-to-understand, and 4) the outputs are designed to provide users with a good understanding of how total costs are estimated (see Figure A-1 in Appendix A). For the vehicle operating cost calculation, the Edmunds “True Cost to Own” tool uses the following assumptions:

- Ownership expenses are estimated for a five-year period
- Users drive 15,000 miles per year
- The vehicle is purchased with traditional financing, not lease financing
- Users have an above-average credit rating for the purpose of interest rates
- A 10% down payment is paid at vehicle purchase
- The loan term is 60 months

While the Edmunds tool is simple to use and can compare five-year vehicle ownership costs, it has some drawbacks due to the pre-set assumptions used in the calculations. The tool only allows a five-year period of calculations and does not allow its users to integrate their own ownership and operating characteristics; hence, the system does not provide lifetime ownership costs from purchase to disposal. As reviewed in the previous section, because vehicle operating cost can significantly vary by the operating characteristics, user-specified

options that reflect the individual drivers' operating characteristics need to be included to improve accuracy.

KBB Cost to Own Calculator®

Kelley Blue Book® (KBB), also one of the most popular vehicle information websites, provides a five-year cost to own calculator through their website as shown in Figure A-2 in Appendix A (KBB, 2017). Similar to the Edmunds tool, the KBB tool also has some great advantages, but the KBB tool provides users with more options and flexibility than the Edmunds tool. For instance, the KBB tool enables users to choose more vehicle specifications (e.g., color, engine, powertrain, wheels, tires, fees and incentives, etc.) which affect the vehicle purchase price. However, KBB tool also has many of the same drawbacks of the Edmunds tool, with respect to assumptions used in vehicle operating cost calculations. The KBB cost functions assumptions include:

- A five-year period for calculating ownership expenses
- 15,000 miles per year
- 45% highway/55% city driving for fuel economy estimation
- An APR of 3.19% for 60 months and a 10% down payment
- An average insurance premium, including collision and liability, for the user's state

NADA Guides

NADA Guides (2017a), a popular vehicle price website, also provides a Cost of Ownership calculation tool (see Figure A-3 in Appendix A).² Unlike the previous tools, the NADA Guides tool only provides a car payment calculator to estimate total vehicle purchase cost. The calculations include vehicle price, interest, and sales tax, while also considering down payment, interest rate, loan term, etc. Despite the limited calculations, one of the benefits of using this website is that users can specify the vehicle purchase price for their own finance options.

Financial Mentor Car Cost Calculator

The Financial Mentor (2017) Car Cost Calculator is another online cost calculator available to the public (see Figure A-4 in Appendix A).³ One advantage of using this tool is that it helps users to easily figure out the list of factors affecting lifetime vehicle operating cost and understand how each of the individual factors contributes to the lifetime vehicle operating cost. Also, the tool allows users to reflect their own vehicle purchase and operation characteristics. For instance, the tool allows users to enter the amount of down payment, financing term, etc. Therefore, it is easy for users to test different vehicle purchase and operation scenarios. Also, the tool provides a comparison mode, allowing users to compare the lifetime vehicle operating cost for two different vehicles (or scenarios), so the users see cost differences at a glance. Despite these advantages, the disadvantage of this tool is that it does not provide any external

² NADA Guide Cost of Ownership tool is found at <http://www.nadaguides.com/Cars/Finance/Cost-Of-Ownership>.

³ The tool is found at <https://financialmentor.com/calculator/car-cost-calculator>.

resources to the user. Thus, the tool is not a convenient tool because users need to search for and enter individual cost components on their own.

Reed and Arata's Total Monthly Car Cost Calculator

The online Total Monthly Car Cost Calculator (TMCCC) created by Reed and Arata (Reed and Arata, 2017) via their blog performs a simple cost calculation.⁴ The TMCCC calculates costs using some of the same basic inputs of other calculators, including car payment, insurance, gas, etc. Although this tool is as simple and easy-to-use tool as the Financial Mentor Car Cost Calculator, it has the same limitations in that the tool does not provide any resources.

CHOOSEFI's True Cost of Car Ownership Calculator

The CHOOSEFI website provides an excel-spreadsheet version of a cost calculator that users can download (see Figure A-5 in Appendix A).⁵ One of the benefits of using this tool is that users can understand how the Excel-spreadsheet calculates costs by looking through the equations. However, it is difficult for users to understand the structure of the calculator, and similar to some of the previous tools, it does not support any resources.

Review of Literature and Existing Websites Conclusion

The literature review identified many factors affecting the lifetime cost of vehicle ownership and operation. Costs can be divided into fixed costs, which are unaffected by vehicle miles driven, and variable costs, which are affected by vehicle mileage. Table 5 summarizes all of the cost factors identified in the literature and considered in developing the NCST Lifetime Vehicle Ownership and Operating Cost Calculator.

Table 5. Summary of Factors Affecting Lifetime Vehicle Operating Cost

Classification	Items
Fixed cost	Vehicle purchase or lease, finance, insurance, license, registration and vehicle taxes
Variable cost	Depreciation, maintenance and repair, tires, fuel, fuel taxes and oil, paid parking, and tolls

Table 6 summarizes the advantages and disadvantages of existing lifetime vehicle operating cost tools identified online. As discussed earlier, some of the tools appear to be useful to estimate the true cost of owning a vehicle, helping the users to purchase a proper vehicle given their financial status. Some tools educate users about lifetime vehicle operating costs. However, given that the main purpose of the NCST lifetime vehicle ownership and operating cost calculator is to educate people about lifetime cost, the existing tools have some limitations. Most tools provided by popular websites (e.g., Edmunds) do not support individualized user inputs, thus limiting the user's ability to understand how a change in any

⁴ The Reed and Arata's tool is found at <https://www.nerdwallet.com/blog/loans/total-cost-owning-car/#methodology>.

⁵ The CHOOSEFI's tool is found at <https://www.choosefi.com/022-true-cost-car-ownership/>.

individual cost component affects lifetime vehicle operating cost. Those tools that do allow user inputs do not provide support with any external resources; hence, users must search for input data manually. Therefore, the NCST cost calculator aims to compensate for these limitations.

Table 6. Advantages and Disadvantages of Existing Cost Calculators

Tools	Advantages	Disadvantages
Edmunds® & KBB®	<ul style="list-style-type: none"> - Many vehicle makes, models, and model years are supported with vehicle pricing information - Simple and easy-to-understand web user interface - Clear outputs for five-year cost 	<ul style="list-style-type: none"> - Only allows five-year costs - User inputs are not allowed (e.g., 15,000 miles per year is fixed in the calculation)
NADA Guides	<ul style="list-style-type: none"> - Provides useful information about the cost calculations 	<ul style="list-style-type: none"> - Only provides a car payment calculator
Financial Mentor	<ul style="list-style-type: none"> - Simple and easy-to-understand web user interface - Allows user inputs to calculate costs that reflect user operating conditions - A good tool for educating people about cost calculation 	<ul style="list-style-type: none"> - Does not support any external resources (e.g., vehicle purchasing cost), so users have to search for and enter individual cost data on their own
Reed & Arata	<ul style="list-style-type: none"> - Much simpler than any other tools - A fair tool for educating people about operating costs 	<ul style="list-style-type: none"> - A limited number of items can be entered by the user, but vehicle operating conditions are not reflected - No input data support or links to external resources
CHOOSEFI	<ul style="list-style-type: none"> - Provides an excel-spreadsheet version of a cost calculator, so users can better understand the calculations 	<ul style="list-style-type: none"> - A limited number of items can be entered by the user - Not supported by data from external resources

Methodology

The NCST Lifetime Vehicle Ownership and Operating Cost Calculator (the NCST cost calculator) is designed to help users understand lifetime cost calculations. The NCST cost calculator incorporates simple user-interfaces, supported by a database that provides users with relevant information, default calculation data, and data for use in individualized scenarios. This chapter describes the development of the NCST cost calculator, overall process flow of the calculations, database development, and cost calculation methods for each cost component.

Framework

This section describes the structure of the NCST cost calculator. Figure 2 shows the calculator process, including the database, inputs, and each calculation module. More detailed descriptions of the development of NCST database and functions included in the NCST cost calculator are described in the applicable sections that follow.

As shown in the flowchart, the NCST cost calculator begins with the selection of a vehicle. To do this, the database contains an assortment of vehicle make, model, and model year so that the users can easily find their vehicles of interest. The vehicle model entries were created based on USEPA certification test results database. Then, users need to enter vehicle-related data (e.g., year purchased, purchase price, finance information, etc.). The database for current vehicle values is provided by the Georgia Department of Revenue (GDOR). Next part is to enter vehicle driving data, which are annual vehicle miles traveled (VMT) and fuel economy. To provide users with the fuel economy of the vehicle, fuel economy data from the US Department of Energy (USDOE) is integrated into NCST database.

Once the main inputs were entered, the baseline lifetime vehicle operating cost can be calculated using embedded default settings. Then, users can modify the default settings to reflect their own vehicle purchasing and operating options. For example, by updating plate fee option, users can adjust the registration fee. In addition, users can re-enter the actual car insurance cost they are spending, thereby re-calculating the lifetime vehicle operating cost.

Figure 2 also shows how each cost component related to other cost components. For example, annual VMT is used in determining the remaining useful life, thereby calculating the salvage and depreciation values. In addition, fuel type input determines which fuel cost calculation module is used for calculating fuel cost. For example, if a user chooses gasoline vehicles, the gasoline price calculation functions are used. Vehicle purchase value is one of the critical factors in lifetime vehicle operating cost calculation. As shown, vehicle purchase value is used in calculating interest paid and depreciation.

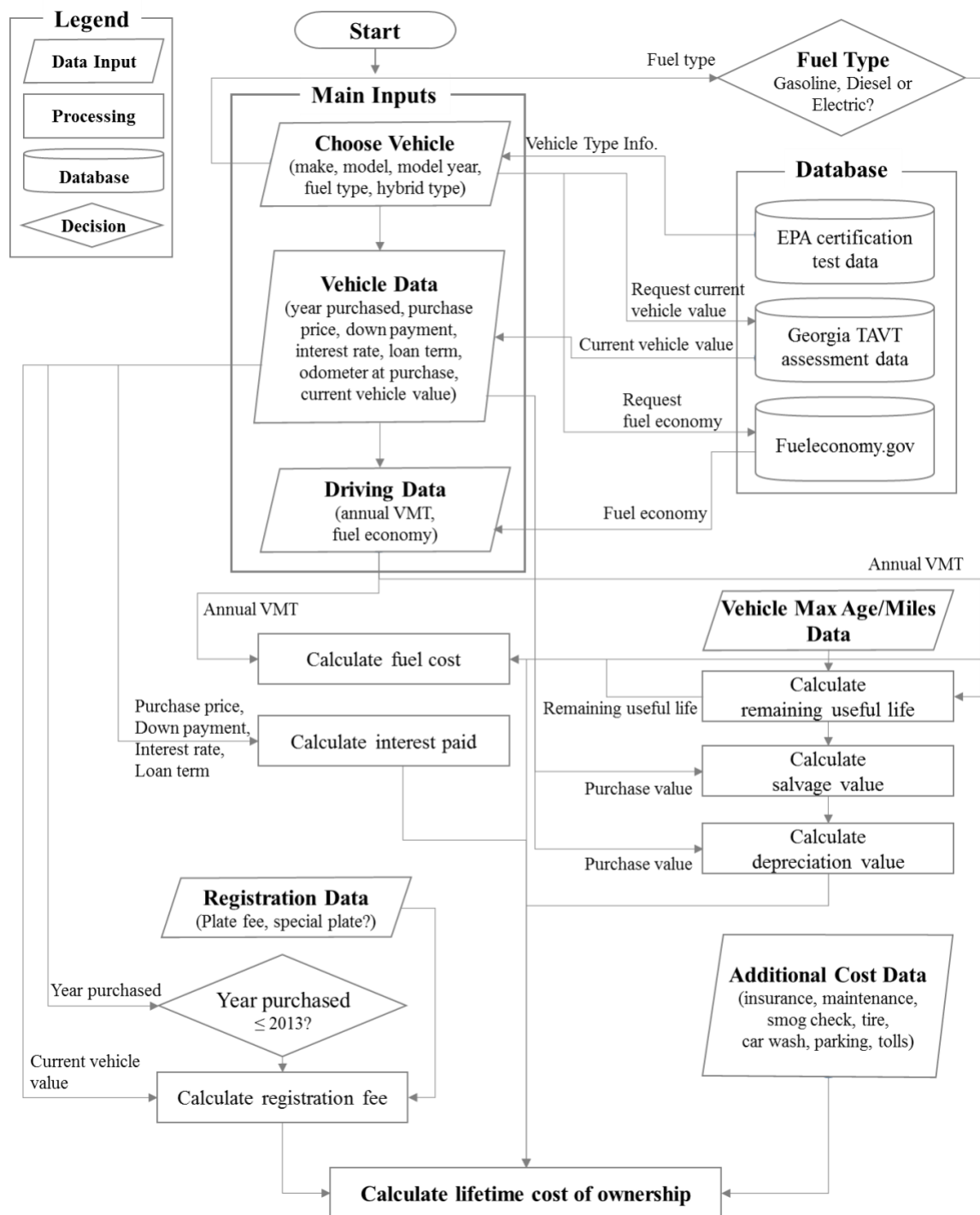


Figure 2. NCST Cost Calculator Flowchart

Database Development

This section describes the development and integration of a complete database into the NCST cost calculator, providing users with the data needed for their individual cost calculations.

Vehicle Entry

Database entries for vehicle make, model, and model year are based on USEPA vehicle certification and compliance testing database (USEPA, 2017).⁶ The USEPA database contains all vehicles that are tested by National Vehicle and Fuel Emissions Laboratory for compliance with the USEPA's exhaust emissions standards. The USEPA provides annual certification test results data for every year since 1979, however, only the data from 1997 and later years are machine-readable. Thus, the vehicle database begins with 1997 model years. One of the benefits of using the USEPA database is that it is updated several times a year with ongoing vehicle emissions standard test results.

Unique database entries for vehicle make, model, model year, and fuel type were extracted from the USEPA database. The vehicle database contains a total of 9,068 unique vehicles as of December 2017. The Georgia Tech research team periodically updates the vehicle entries used in the NCST cost calculator as the USEPA certification test database is updated.

Present Vehicle Value

Present vehicle value is the monetary value of the vehicle at the present time. Many useful websites, such as Edmunds®, provide present vehicle values. All of these websites provide present vehicle values that consider present market conditions. For example, vehicle values increased immediately after devastating hurricanes reduced the used car supply (New York daily news, 2017).

The NCST cost calculator currently uses 2017 Georgia Motor Vehicle Assessment Manual for Title Ad Valorem Tax (TAVT) database, provided by State of Georgia Department of Revenue (GDOR) Motor Vehicle Division.⁷ One of the benefits of using the Georgia database is that such vehicle websites only provide the vehicle values of the vehicles currently sold in the Georgia market. The Georgia database includes vehicle values for all vehicles registered in Georgia; thus, the present value for almost every vehicle make, model, and model year can be found in the database. Another benefit is that vehicle tax calculation is based on the TAVT values. Therefore, the users can better estimate their vehicle taxes using the present vehicle values from the Georgia database.

To provide vehicle values in the NCST cost calculator, the USEPA's vehicle make, model, and model year entries were matched with GDOR database entries. Because the USEPA and GDOR

⁶ EPA certification test data is found at <https://www.epa.gov/compliance-and-fuel-economy-data/annual-certification-data-vehicles-and-engines>.

⁷ The Georgia Department of Revenue provides a tool for users to calculate their vehicle's current vehicle values (see the website at <https://dor.georgia.gov/tavt-calculator>).

often use different names for vehicle make and model combinations, the Levenshtein Distance algorithm, one of approximate string matching algorithms, was used to identify similarities between different data strings (Wikipedia, 2017a; Wikipedia, 2017b).⁸ As a result, about 90% of the USEPA's vehicle entries were initially matched with the vehicle values from the Georgia database. The remaining 10% were manually matched across the databases.

Fuel Economy

Fuel economy is one of the key factors determining fuel cost. Although several existing websites can provide fuel economy data, the USDOE database was selected for its open accessibility and reliability.⁹ The fuel economy data are also reliable, coming from vehicle testing performed by the Environmental Protection Agency (USEPA)'s National Vehicle and Fuel Emissions Laboratory in Ann Arbor, Michigan, and by vehicle manufacturers with oversight by the USEPA. The USDOE also periodically updates the data, thereby updating the database for the NCST cost calculator.

The USDOE data provides three types of fuel economy for each vehicle: 1) city-driving fuel economy, 2) highway-driving fuel economy, and 3) combined (city and highway) fuel economy. Three types of fuel economy data were integrated with the NCST cost calculator database based on the key values consisting of vehicle make, model, and model year. However, as noted in matching present vehicle values, the names of vehicle make and model of USEPA certification test data and fuel economy data do not match exactly. The Levenshtein Distance algorithm was used to automatically match the different names of vehicle make and model of the datasets (Wikipedia, 2017a; Wikipedia, 2017b).

The current NCST cost calculator provides users with the combined fuel economy of vehicles as a default. However, a future option will enable users to enter their driving patterns, including the ratio of driving on city roads and highways, so that the NCST cost calculator can more reliably estimate their fuel economy.

Fuel Cost

Because vehicle fuel price varies from day to day and from region to region, it can be difficult for people to know the current fuel price for their vehicle. To assist users, fuel price information is retrieved from the EIA (Energy Information Administration) and embedded in the database (EIA, 2017a).¹⁰ The EIA provides users with an API (Application Programming Interface) so that its users can access the EIA's open access database. Using the API key, the NCST cost calculator website server connects and downloads EIA's fuel prices information.

The EIA database stores weekly gasoline and diesel prices and monthly electricity prices for use in transportation by region. The EIA provides the national average and average regional fuel prices by Defense District, states, and for some US cities. Given the high quality of the data, the

⁸ The tool used in this project is found at GitHub, <https://github.com/seatgeek/fuzzywuzzy>.

⁹ Fuel economy database is found at <https://www.fueleconomy.gov/feg/download.shtml>.

¹⁰ The EIA fuel prices website is found at https://www.eia.gov/dnav/pet/pet_pri_gnd_a_epmm_pte_dpgal_w.htm.

NCST cost calculator downloads the data into the NCST database and uses these data in all cost calculations.

Cost Calculations

This section describes how the NCST system calculates each cost component, provides the equations and assumptions embedded in the NCST cost calculator, and shows user interfaces screenshots for each module. The calculations embedded in the NCST cost calculator include: depreciation, interest, fuel cost, insurance, registration, registration, smog check, tires, maintenance, car washes, parking, and tolls.

Main Inputs

To calculate lifetime vehicle operating cost, users firstly need to select their vehicle by choosing through selecting option boxes as shown in Figure 3. Once users find their vehicle, present vehicle value is pulled from NCST database, and the value will be used in salvage value calculation. In the main input section, the system automatically calculates finance cost (interest paid) using the vehicle purchase price, down payment, interest rate, and loan term. The more detailed description on calculating financial cost will be explained later in this section.

Choose Your Vehicle	
Vehicle Make:	FORD ▼
Vehicle Model:	EXPLORER AWD ▼
Model Year:	2016 ▼
Fuel Type:	Gasoline ▼
Hybrid Type:	Conventional Vehicle ▼

Vehicle Data	
Year Purchased:	2017 ▼
Purchase Price (\$)∗:	30,088
Down Payment (\$):	1000
Interest Rate (%):	4.5
Loan Term (months):	48
Odometer at Purchase (miles):	0
Current Vehicle Value (\$)∗∗:	30,088
Financed:	29,088
Interest Rate (%):	4.5
Monthly Interest Rate (%):	0.38
Loan Term (months):	48
Interest Paid:	2,751

∗ Please provide the purchase price including all fees (e.g. TAVT and all relevant registration fees)
 ∗, ∗∗ The purchase price and current vehicle value provided in this website is based on Georgia TAVT assessment database, but it can be different from a real value. To get the more correct vehicle owning cost, please search by other websites such as [KBB](#) or [Edmunds](#)

Figure 3. NCST Cost Calculator Primary Inputs

Depreciation

Depreciation is the diminishment of vehicle value over time (a function of vehicle remaining life, expected durability, vehicle desirability, etc.). Typically, depreciation is the largest cost of lifetime vehicle operating cost. Depreciation is a function of present vehicle value, the vehicle value at the time the users disposes of the vehicle, and the number of years the vehicle is owned in the interim period. The depreciation rate, defined as an annual average reduction rate of the vehicle value, varies by numerous factors. A literature review was conducted to find an appropriate depreciation rate to represent an average vehicle or specific make and model combinations; however, no representative values were identified.

The NCST cost calculator assumes straight-line depreciation (from present vehicle value, at current year, to salvage value, at end of vehicle life). Hence, annual depreciation costs are constant over the calculated ownership period. In the default setting, the calculator applies

10% of annual depreciation, as shown in Figure 4, based on a naïve estimation (assuming that 10% of present vehicle value will remain after 10 years). However, the NCST cost calculator also allows users to override the default rate, and enter user-specified inputs for their own salvage value.

Salvage Data (Depreciation)

Please Select One among Salvage Value Options below, and Enter Salvage Value Information as Needed.

☒ End of Life Salvage (%)*: 10.0

→ 1,088

☐ Provide Manual Input (\$): 0.00

* The end of life salvage percentage is calculated by assuming 10% of depreciation for each year (e.g. 8 years of useful remaining life leads to 20% of EOL salvage (10 years - 8 years) X 10%), and minimum value of salvage is set to 10% or \$500.

Figure 4. NCST Cost Calculator Depreciation Inputs

Once the depreciation rate is determined, users need to specify the number of years or miles that they believe they will continue driving that vehicle before they decide to sell or scrap the vehicle. The “remaining useful vehicle life” calculation window is illustrated Figure 5. The remaining useful vehicle life is the lower of two values: 1) the number of years the owner could continue to drive the vehicle, given their annual mileage accrual and the maximum total miles they are willing to allow the vehicle to accrue, and 2) the number of additional years they say they are willing to drive this vehicle. The example in Figure 5 shows 10 years of the remaining useful vehicle life because the number of additional years the users are willing to drive the vehicle is 10 years and the maximum number of years the users would allow on the vehicle is 11.7 years (150,000 miles divided by 12,828 miles, default annual VMT).

Note that annual VMT plays a role in determining the remaining useful vehicle life, but also affects many other cost components. For example, annual VMT is used in calculating fuel cost, maintenance, tires, etc. Thus, annual VMT is one of the most important inputs in the lifetime vehicle operating cost calculation. The NCST lifetime vehicle operating cost calculator sets the default annual mileage accrual to 12,828 miles per year, which is an average annual VMT for the citizens of Georgia (Megna, 2016). However, VMT significantly varies per person, and users need to enter their best estimate of annual VMT to calculate more accurate cost estimates.

Driving Data	
Annual VMT (miles)*:	<input type="text" value="12,828"/>
Fuel Economy (miles per gallon):	<input type="text" value="19"/>
* The default value of 12,828 miles is an average VMT of Georgia State citizens (click here to see the reference)	
Vehicle Max Age/Miles Data	
To calculate the remaining useful life of this vehicle, please tell us the maximum number of years and maximum mileage you would allow on this vehicle. That is, if either value exceeded, you would get rid of this vehicle.	
Number of additional years you are willing to drive this vehicle:	<input type="text" value="10"/>
Maximum miles (odometer reading) you would allow on this vehicle:	<input type="text" value="150,000"/>
Remaining useful vehicle life based upon your statements above:	<input type="text" value="10.00"/>

Figure 5. NCST Cost Calculator Driving and Retention Inputs

The salvage value is determined by the equation below:

$$\text{Salvage value (\$)} = \text{Current vehicle value (\$)} \times \text{End of life salvage (\%)}$$

Where:

$$\begin{aligned} \text{End of life salvage (\%)} = \\ 100\% - \text{Annual average depreciation rate (\%)} \times \\ \text{Remaining useful vehicle life (years)} \end{aligned}$$

Finance Cost (Interest paid)

Finance cost is the interest expense for the vehicle purchase loan. Interest rates may vary by lender, loan term, borrower credit score, etc. (NADA Guides, 2017b; ValuePenguin.com, 2017a). Although average interest rates were available in the literature by credit score and loan term, these data were published a long time ago and were not embedded in the NCST cost calculator. Instead, the NCST cost calculator set a 3.5% interest rate as a default (most recent literature set around 3.5% of interest for above-average credit scores). The NCST cost calculator provides links relevant interest rate literature so that users can identify a personalized interest rate. Once the interest rate is entered, the financing cost is calculated by the equation below.

$$\text{Pay}_m = P_f \times \frac{\frac{r}{12}(1 + \frac{r}{12})^n}{(1 + \frac{r}{12})^n - 1}$$

$$\text{Interest paid} = \text{Pay}_m \times n - P_f$$

Where Pay_m is the monthly payment, P_f is the financial amount of the payment, r is the annual interest rate, and n is the loan terms.

Fuel Cost

The NCST cost calculator currently supports fuel cost calculations for gasoline, diesel, and electric vehicles. Once users choose the vehicle make, model, and model year, the fuel type of the vehicles is determined. Almost all individual vehicle make, model, and model year combinations employ a single fuel. When more than one fuel type applies to the make, model, and model year selected, the user is prompted to select the fuel type from the available fuel options (i.e., the program option for fuel type is only activated when more than one fuel applies). Once fuel type is determined or entered, the fuel data interface is activated for that fuel (see Figure 6). As described in database development section, the NCST cost calculator provides EIA's weekly (gasoline or diesel) or monthly (electricity) fuel cost data. Thus, users can search the average fuel price in their region. Also, the fuel cost module provides a historical fuel data over the past five years, so it helps users to identify the trends in past fuel prices, thereby helping them to choose an actual average fuel price they might expect to pay. For user convenience, the NCST cost calculator embeds a function to select the fuel price by clicking on the line graph displaying the historical fuel data.

Once the fuel price is entered, the annual fuel cost is calculated using the equation below. Annual fuel cost is a function of annual VMT, fuel price, and fuel economy. Fuel economy for the vehicle selected is already in the database, streamed from USDOE fuel economy data as mentioned in database development section. The default fuel economy value of the NCST cost calculator is a combined fuel economy of city and highway driving. Because the driving patterns of individual drivers vary, the system allows users to calculate fuel economy given their own driving patterns.

$$\text{Annual fuel cost (\$)} = \frac{\text{Annual VMT (miles)} * \text{Fuel price (\$/gallon)}}{\text{Fuel economy (miles/gallon)}}$$

To help users to understand the fuel cost calculation, the NCST cost calculator breaks down the fuel cost into fuel rack price and fuel taxes. The fuel taxes calculated in the NCST cost calculator are based on Federal and Georgia State laws and include the federal excise tax, Georgia State excise tax, and County sales tax. The Federal excise tax is \$0.184 per gallon for gasoline and \$0.244 per gallon for diesel as of July 2017 (EIA, 2017b). Based on GDOR (2017a), Georgia State excise tax is \$0.268 for gasoline and \$0.300 per gallon for diesel. County sales tax is then calculated by applying 3% to the county taxable portion, where the taxable county portion is calculated by the equation below:

$$\begin{aligned} \text{County taxable portion} \\ = \min(\$3.00, \text{sales price} - \text{federal excise tax} - \text{Georgia state excise tax}) \end{aligned}$$

Fuel Data

Fuel Type: Gasoline

Fuel Cost (\$/gallon):

☐ Provide manual input (\$/gallon): 2.30

☒ Search the average gas price in your area (\$/gallon)*: 2.31

* Gas price as of 12/25/2017 has been selected and applied to fuel cost calculation.

Search Average Gas Price in Your Area

Choose Grade: Regular (87 Octane) ▼

Choose District (see figure below): Lower Atlantic (East Coast) ▼



Average Fuel Prices (Regular) in Lower Atlantic (East Coast) in the last 5 years.



— Price

Hide Figure

Fuel Rack Price**: 1.81

Federal Excise Tax**: 0.18

Georgia Excise Tax**: 0.26

County Sales Tax**: 0.05

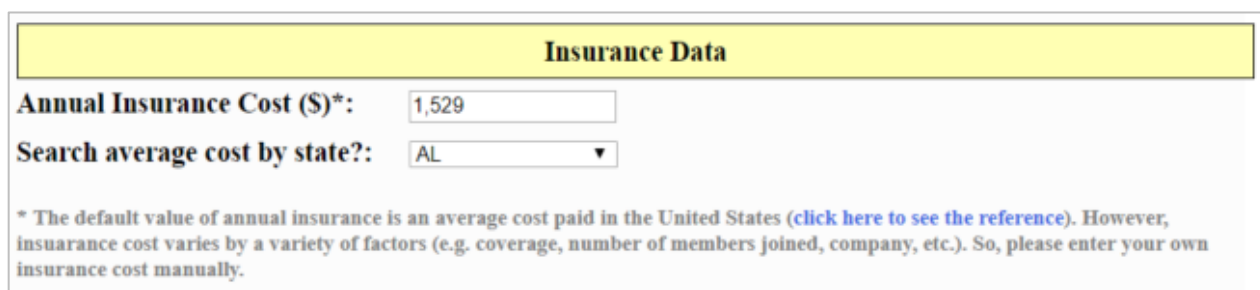
* The value is weekly retail gasoline and diesel prices from [EIA \(Energy Information Administration\)](http://www.eia.doe.gov).

** Fuel tax calculation in this website is based on Georgia State rules.

Figure 6. NCST Cost Calculator Fuel Inputs

Insurance

As discussed previously, insurance costs vary significantly across vehicle (make, model, and model year, etc.), driver (age, driving record, home ownership, etc.), and insurance company factors. However, providing users with an estimate of insurance cost is challenging. The current NCST cost calculator uses the national average insurance cost in the US of \$907 per year as a default value (ValuePenguin.com, 2017b). In addition, the NCST cost calculator embeds an option to select the average insurance cost by US states as shown in Figure 7. However, users can also override the average and enter their own insurance cost, which can be obtained via a call to their insurance company.



Insurance Data

Annual Insurance Cost (\$)*:

Search average cost by state?:

* The default value of annual insurance is an average cost paid in the United States ([click here to see the reference](#)). However, insurance cost varies by a variety of factors (e.g. coverage, number of members joined, company, etc.). So, please enter your own insurance cost manually.

Figure 7. NCST Cost Calculator Insurance Inputs

Registration

Vehicle registration costs in the NCST cost calculator include plate fees, special plate fees, and annual vehicle value taxes (ad valorem) as shown in Figure 8. The registration cost calculation is currently based on Georgia State regulations (GDOR, 2017b). Accordingly, the annual plate fee is \$20 per year, and a special plate fee is \$35 per year. With respect to vehicle registration ad valorem taxes, Georgia State tax law changed on March 1, 2013. Vehicles purchased after March 1, 2013 do not pay ad valorem taxes. These fees are now paid at the time of initial new vehicle purchase and are excluded from this cost element (users are asked to include the registration cost in the initial vehicle purchase price elements). For vehicles purchased before March 1, 2013, the registration cost is calculated by the equation below:

$$\text{Annual fee (\$)} = \text{fair market value (\$)} \times 40\% \times \text{mileage rate (\$)}$$

Where fair market values are present vehicle values as determined by GDOR (see database development section for more details), and millage rate (dollars paid per thousand dollars of calculated vehicle value) is currently set \$27.754 for Forsyth County in Georgia as a default.

Registration Data*	
Plate Fee (\$):	<input type="text" value="20.00"/>
Do you have a special plate?:	<input type="button" value="Yes"/>
Was vehicle purchased before 2013:	<input type="button" value="No"/>
Special Plate Fee:	<input type="text" value="35.00"/>
TAVT value:	<input type="text" value="0.00"/>
TAVT Millage/1000:	<input type="text" value="27.75"/>
Ad Valorem Tax:	<input type="text" value="0"/>
Total Registration:	<input type="text" value="55.00"/>

* Registration cost calculation in this website is built for vehicles registered in Georgia State.

Figure 8. NCST Cost Calculator Registration Inputs

Maintenance

The maintenance cost embedded in the NCST cost calculator includes annual vehicle maintenance except for the tires, smog check, and car washing fees. The current NCST cost calculator sets \$766.50 per year for an average maintenance cost as a default based on AAA report (AAA, 2017a) as shown in Figure 9. However, maintenance costs also vary significantly across many factors, such as driving habits, pavement condition, make, model, model year, etc. To assist the users, the NCST team plans to integrate an option to select average maintenance costs by vehicle size using data from the 2017 AAA report.

Maintenance Data	
Choose Maintenance Cost Option:	
<input checked="" type="radio"/> Average Maintenance Cost:	<input type="text" value="766.50"/> \$/year → <input type="text" value="0.060"/> \$/mile
<input type="radio"/> Provide Manual Input :	<input type="text" value="0.00"/> \$/year → <input type="text" value="0.000"/> \$/mile

* The average value of \$766.50 per year is based on reference ([Click here to see the reference.](#))

Figure 9. NCST Cost Calculator Maintenance Inputs

Other Costs

Other costs defined in the NCST cost calculator include annual smog checks, tire replacement, parking costs, car washes, and tolls. One of the benefits of using the NCST cost calculator is that these cost component calculations are included (no other online tools currently support the cost calculations). Thus, users can benefit from identifying the influence of other costs, such as parking, on total lifetime vehicle operating costs.

Specifically, the cost of smog check is set \$20 as a default considering the smog check cost of general shops in Georgia. Tire replacement cost is a function of the price of tires and tire

warranty, and it is calculated by the equation below. The default values are set \$120 per tire for the price of the tire, four for the number of tires, and 50,000 miles of tire warranty.

$$\text{Tire cost (\$/mile)} = \frac{\text{cost per tire (\$)} \times \text{number of tires}}{\text{tire warranty (mile)}}$$

Users can also specify the number of times per year they take their car to a car wash and the cost per wash to calculate the total cost of car washes per year. Users enter monthly parking costs at home and at work. Finally, the NCST cost calculator embeds a module to incorporate monthly tolls payment.

User Interface

This chapter describes how to use the NCST Lifetime Vehicle Ownership and Operating Cost Calculator (the NCST cost calculator), from selecting vehicle to obtaining output results. Also, this section describes some additional features that are embedded in the NCST cost calculator to assist users.

User Guide

The NCST cost calculator provides convenient user interfaces that provide access to default data and other information in associated database tables. However, users need to exercise caution in using the NCST cost calculator. Accurate input data are required to obtain accurate outputs. The following list describes the NCST cost calculator steps and cautionary notes (illustrated in Figure 10).

1. Select Vehicle: Users select a vehicle make, model, and model year, using the drop-down menus. Once selected, the fuel and hybrid type options are queried from the database. Users need to select the fuel type, if more than one option is available for that make, model, and model year (e.g., the 2017 Toyota RAV4 comes in a gasoline or hybrid option).
2. Enter Primary Input Data: Once the vehicle is selected, vehicle purchase price, present vehicle value, and fuel economy data are pulled from NCST database. Users also need to enter the year purchased. There are some cases where data are missing. In such cases, the applicable values in the calculator are empty (or set to zero).
3. Modify Default Values as Needed: Once the main input data are entered, the NCST cost calculator can be executed. However, users are prompted to look through the inputs and modify the default values as needed to obtain more accurate results.
4. Get Results: Once all inputs are entered, users can obtain the cost calculation results by clicking the “Get Results” button located at the bottom of the input page. The NCST cost calculator outputs cent per mile cost results, along with a pie chart and table as shown in Figures 11 and 12. The example outputs show a lifetime vehicle operating cost of 47.6 cents per mile, and total cost of \$57,081 for the 12 years of remaining useful life. Appendix B contains the details associated with the example run for these results.

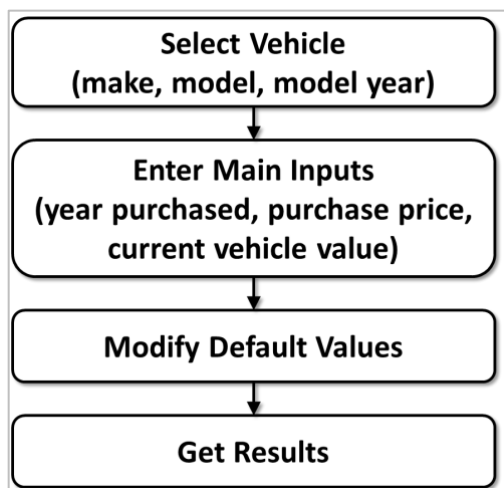


Figure 10. Steps to Run NCST Cost Calculator

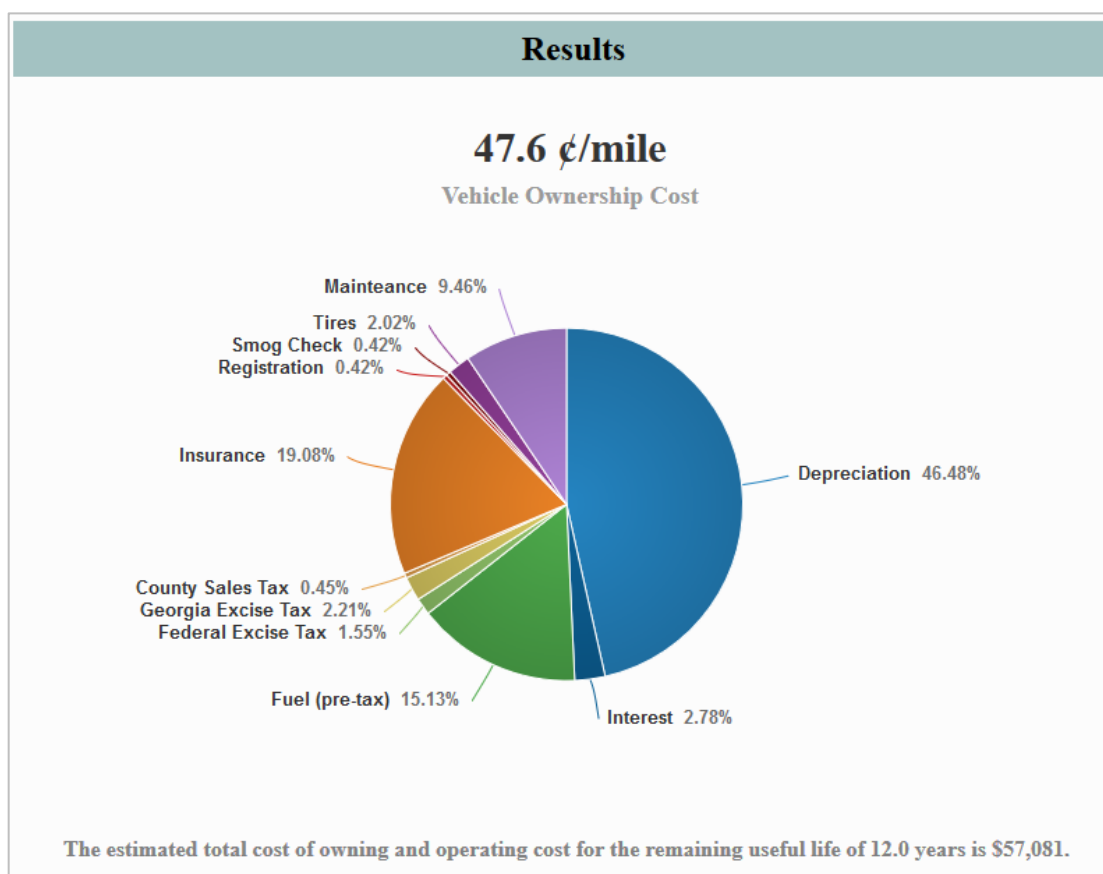


Figure 11. Example of NCST Cost Calculator Pie Chart Outputs

	Component	Value (¢/mile)	Percentage (%)
1	Depreciation	22.110	46.48
2	Interest	1.324	2.78
3	Fuel (pre-tax)	7.196	15.13
4	Federal Excise Tax	0.736	1.55
5	Georgia Excise Tax	1.052	2.21
6	County Sales Tax	0.216	0.45
7	Insurance	9.074	19.08
8	Registration	0.200	0.42
9	Smog Check	0.200	0.42
10	Tires	0.960	2.02
11	Maintenance	4.500	9.46
12	Car Washes	0.000	0.00
13	Parking	0.000	0.00
14	Tolls	0.000	0.00

Figure 12. Example of NCST Cost Calculator Output Tables

Useful Functions Embedded in the NCST Cost Calculator

The NCST cost calculator embeds some useful functions to make it easier for users to understand the model calculation. The features are described below:

Sidebar Menus

Sidebar menus located on the left side of the NCST cost calculator provide navigation and execution buttons as shown Figure 13. By clicking the “Get Results” button, users can instantly obtain the results based on the inputs entered. By clicking the “Start Over” button, users refresh the web page. However, this action deletes previously-entered input data, so the calculator asks users if the user is sure that they want to restart the website. If users select “Cancel”, the previously-entered entered inputs remain.

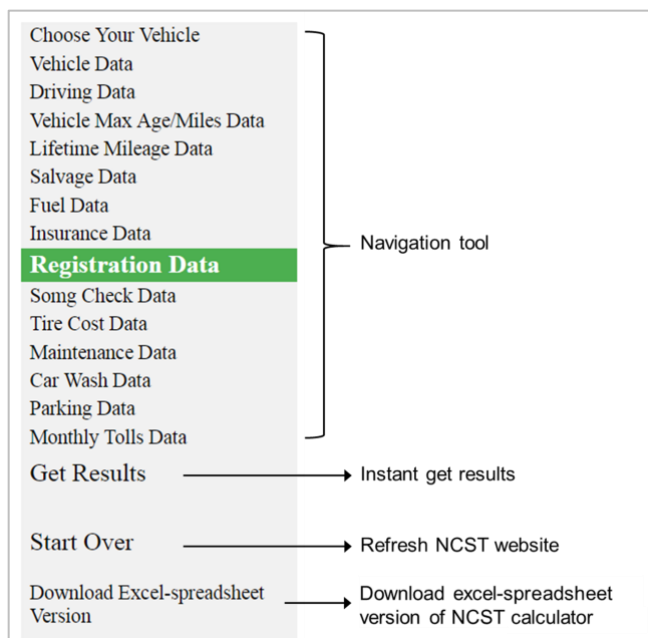


Figure 13. NCST Cost Calculator Sidebar Menus

Excel Spreadsheet Version

If users click the “Download Excel-spreadsheet Version” button, the excel-spreadsheet version of the NCST cost calculator downloads to the users’ local computer. The excel-spreadsheet employs the same functions embedded in the NCST cost calculator, so users can see exactly how all of the calculations work. However, spreadsheet users cannot access the continuously-updated databases that provide the elements such as fuel cost that is embedded in the online calculator.

Links to References

The NCST cost calculator provides links to the references that were used to develop the online system. By clicking on the links, users can read the references. The NCST cost calculator opens a new window to display the resource so that data already entered are not lost.

Model Verification

To test that the NCST cost calculator functions properly, and to ensure that the results are within the reasonable ranges, the NCST cost calculation results were compared with the results from the Edmunds calculator. To do this, 30 vehicles were randomly selected and five-year vehicle operating costs were calculated using both tools. Both calculations employed the same basic assumptions. Because the Edmunds assumes that people own their vehicle for five years, drive 15,000 miles annually, and purchase the vehicle with a 10% down payment, with a 3.5% interest rate, and 60 months of the loan term, the NCST calculations used the same values. Vehicle purchase costs on the Edmunds website were multiplied by 7% to add registration fees. In this particular comparative analysis of five years of ownership, 65% of depreciation rate at the end of five years is assumed based on the reference from FinancialMentor.com website. For the other cost components, default values set in NCST cost calculator were used:

- 5 years of vehicle ownership
- 15,000 miles of annual driving
- 10% of down payment on the vehicle at purchase, 3.5% of interest rate, and 60 months of the loan term
- Vehicle purchase values found on Edmunds website are used, and 7% of registration fee is applied
- 65% of depreciation rate at the end of five years
- Use the default values of NCST website for other variables:
 - \$907.38 of annual insurance cost
 - \$766.50 of annual maintenance cost
 - \$120 per tire of tire cost and 50,000 miles of tire warranty
 - \$20 of plate fee, no special plate, and \$20 of smog check fee
 - No costs for car wash, parking, and tolls

The scatter plot in Figure 14 shows that the Edmunds and NCST cost calculator results are similar, with some variability.

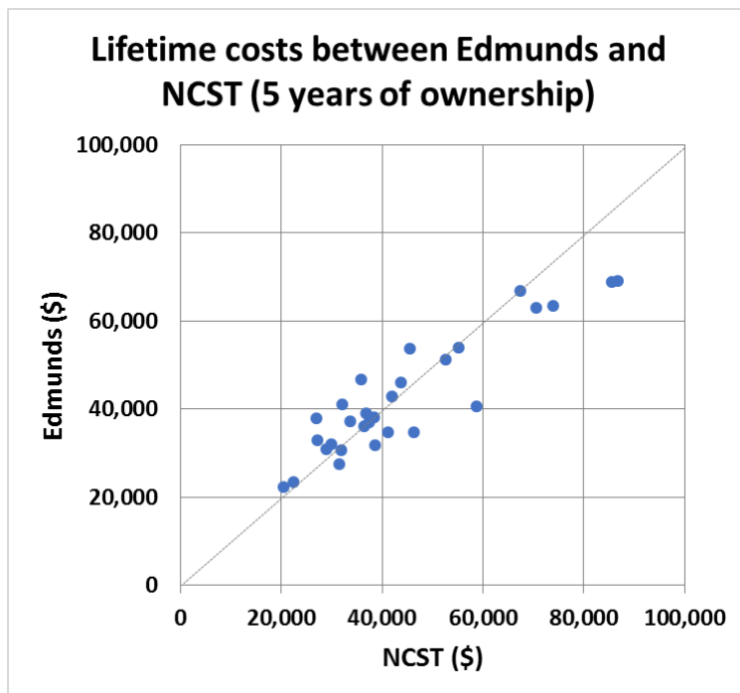


Figure 14. Comparison of Edmunds® and NCST Cost Calculator Results (Five-Year Ownership)

The results for each cost component, provided in Figure 15, also show that the Edmunds and NCST cost calculators obtain similar outcomes. The fuel cost, however, shows a greater difference, likely because the Edmunds and NCST cost calculators use different fuel economy assumptions. Despite some differences between the outcomes, the NCST cost calculator functions properly and the results seem reasonable.

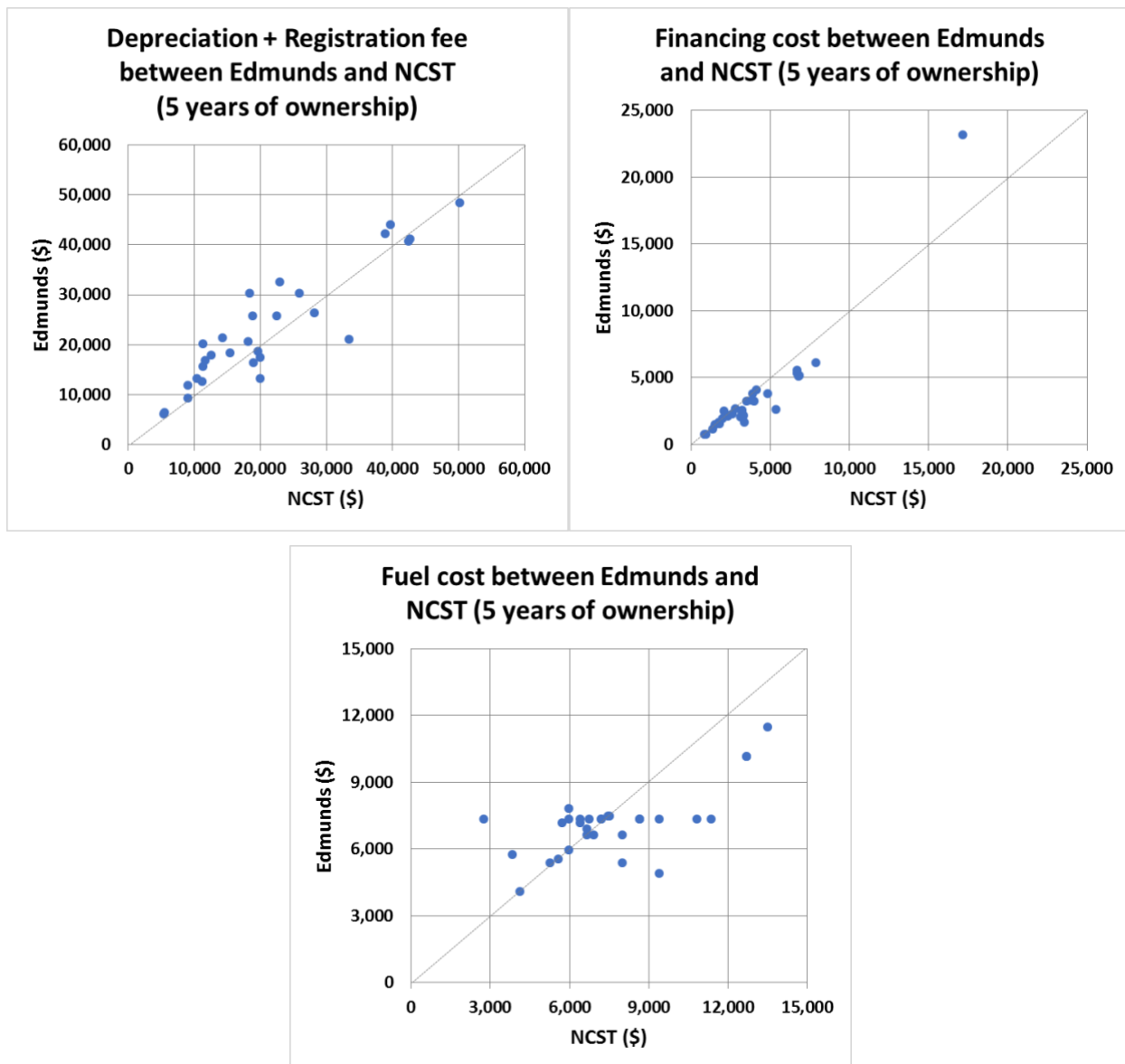


Figure 15. Comparison of Edmunds® and NCST Cost Calculator Results by Cost Component (Five-Year Ownership)

Contributions

Contributions to Education

One of the main purposes of the NCST Lifetime Vehicle Ownership and Operating Cost Calculator (the NCST cost calculator) is to help people better understand the variables that affect vehicle ownership and operating costs. The online NCST cost calculator can be used by the public and students for a variety of education purposes.

NCST Cost Calculator Education Uses

Members of the public interested in buying a vehicle can use the NCST cost calculator in making their purchase decision. Buying a vehicle is not easy, and requires a great deal of effort to obtain relevant information. Despite such efforts, people often choose vehicles that are not well-suited for their financial situation. Consumers often do not realize that vehicles often have high hidden costs. For example, many people may not fully consider vehicle operating costs (e.g., fuel, maintenance, parking, tolls, etc.) when they purchase a vehicle. These costs, however, actually account for a significant portion of the total cost of vehicle ownership as shown in previous sections. Thus, the NCST cost calculator can help the public to better understand total operating costs and make a more rational decision. The NCST cost calculator can help people to compare costs of different vehicles side-by-side.

The NCST cost calculator can be used in university transportation planning, policy, and resource economics courses. Vehicle ownership costs are an important part of sustainable transportation. Educating students on total ownership costs will help them better understand how personal transportation options impact sustainable transportation policies. The NCST cost calculator is now used in the Georgia Institute of Technology Urban Transportation Planning course (CEE6602), as a tool to support a cost of vehicle ownership lab assignment. A further discussion on the adoption will be addressed in the following section.

Lastly, the NCST cost calculator can also be used in high school consumer economics classes. Educating high school students about lifetime vehicle ownership and operating costs is important, because they are likely to purchase a vehicle in the relatively near future. Teaching high school students about total ownership costs is likely to help them make educated first-time vehicle purchases. The high school classes can use a teaching format similar to the university lab assignment.

Practical Implementation in an Urban Transportation Planning Course

The NCST cost calculator is used in the Georgia Tech urban transportation planning course (CEE6602). In this lab assignment, students use the NCST cost calculator to assess lifetime vehicle operating cost for 10 different vehicle scenarios in a real-life case study (see Appendix C). Before doing the lab assignment in 2017, the 41 students were asked to complete the survey before they used the NCST cost calculator for their assignment (pre-lab survey). After they completed the assignment, the students were asked to fill out the same survey again (post-lab survey). The post-lab survey was completed by 33 students (at the end of the

semester, some students were not able to conduct the survey). The survey asked several questions related to their experiences in performing the calculations, vehicle ownership preferences, and understanding of the calculations, along with their socio-demographic information. The survey results are provided in Appendix C.

Figure C-1 in Appendix C shows the socio-demographic distributions of the pre-survey and post-survey respondents. The demographics across samples are not identical due to sample size differences (not every person took the pre-survey took the post-survey, and the pairing of surveys was not allowed to ensure respondent privacy); however, the demographics are similar enough for a reasonable comparison. The results in Figure C-2 indicate that the lab assignment using NCST cost calculator may have increased the students' perception of the five-year total cost of ownership and their potential decision-making process for making a vehicle purchase. For example, Figure C-3 indicates that the lab assignment may have changed the students' vehicle ownership preferences in that students indicated that they planned to own their vehicles longer after completing the assignment. Finally, Figure C-4 and C-5 show changes in the students' understanding of the importance of each cost component to the total cost of ownership. For example, the students became more aware of the importance of depreciation in the total cost of ownership.

Contributions to Research

The NCST cost calculator can also contribute to any related research that could benefit from embedding the NCST cost calculator in their tools and applications. For instance, the NCST cost calculator can be used to support travel activity tracking applications such as Commute Warrior, which is invented by Georgia Tech research team¹¹, by providing cost estimates for each trip. Since the Commute Warrior tracks second-by-second travel activities of its users, the application will be able to provide the users with the travel cost information of each travel by calculating the travel cost based on the users' vehicle information and travel activities through NCST cost calculator.

In addition, the team plans to embed the NCST cost calculator into one of ARPA-E (Advanced Research Projects Agency-Energy) projects, "Assessing the time, monetary, and energy costs of alternative modes" which has been conducted by Georgia Tech research team. In particular, the team plans to embed the NCST databases and cost calculation functions into the cost modules of the project in calculating vehicles' fuel cost, maintenance, etc.

To support this research, the team plans to develop an API that provides same functions and databases embedded in the NCST cost calculator. To do this, the team has developed Python scripts to calculate lifetime vehicle operating costs on the Georgia Tech server and provide the results back to other models while developing a REST API by Python and Flask that connects the Python scripts and the other models through simple API calls.

¹¹ The Commute Warrior app is found at <https://ce.gatech.edu/node/6386>.

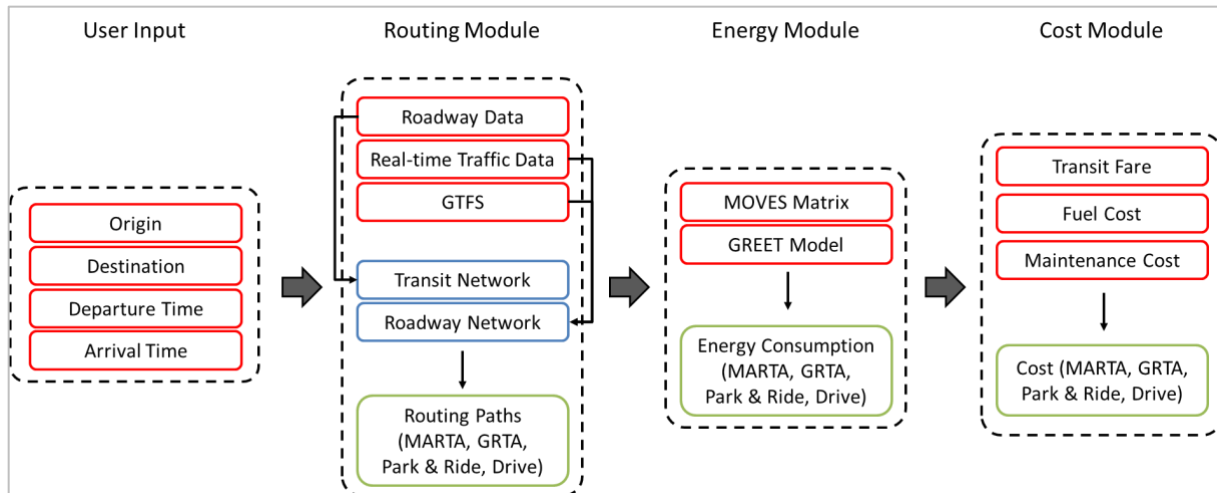


Figure 16. ARPA-E Project Framework

Conclusions and Future Work

This report describes the development of the NCST Lifetime Vehicle Ownership and Operating Cost Calculator (the NCST cost calculator) website. The NCST website aims to provide a more personalized calculation approach, by providing users with data entry flexibility, as well as a clear, intuitive, interactive, user-interface through which users can better understand vehicle ownership costs. To be specific, the NCST website calculates lifetime vehicle operating cost using lookup data and user input data for such elements as: purchase price, down payment, interest rates, loan term, annual insurance, maintenance, tire, smog check, parking, tolls, etc. The database supporting the NCST cost calculator uses various resources to provide users with useful information including: 1) the assortment of vehicle make, model, model year and fuel type data, 2) vehicle purchase price information, and 3) vehicle fuel economy data. Users can develop much more personalized outputs using the NCST cost calculator than with other online systems.

A primary goal of developing the NCST cost calculator website is to provide students and the public with a tool that can be used at any educational level. Students and the public can use the tool to calculate the cent/mile and total cost of vehicle ownership over the life of the vehicle, with cost estimates for each component specifically identified so that users can weigh these important elements in their vehicle purchase and use decisions. From an education perspective, this tool can be used as an instructional aid to specific courses. For example, the tool is currently employed in the urban transportation planning course (CEE6602) at Georgia Tech, where students are asked to compare different vehicle choices based on a real-life case study problem. The pre-lab and post-lab surveys conducted in the course indicate that the lab assignment using the NCST cost calculator did have a positive impact on the students' understanding of total operating costs. In particular, the students indicated that they planned to own their vehicles longer after they became more aware of the large contribution of depreciation to total operating cost. In addition, the NCST research team plans to introduce this tool to high school consumer economics classes in the fall to help students make reasonable vehicle purchase choices by considering the total cost of vehicle ownership, and not just the obvious portions.

The current NCST website includes all the essential elements needed for lifetime ownership and operating cost calculations; however, some future work is needed to support additional cost calculations and enhance the user experience. To make comparisons easier, the NCST team plans to improve the user interface by allowing users to specify several different vehicle alternatives during the input process and provide side-by-side cost outputs, rather than saving results for each choice separately. The current NCST cost calculator does not support city/highway fuel consumption calculations for hybrid vehicles. The next version of NCST website will include a hybrid vehicle fuel economy module. The team is currently assessing relevant models, such as "My Plug-in Hybrid Calculator," developed by the USDOE (fuelconomy.gov, 2017) to develop this new feature.

The research team will continue to add useful information into the NCST database. The search for more reasonable depreciation rate data is ongoing (current default rate is 10% of

depreciation per year). Second, an enhanced insurance cost calculator is needed, which could be implemented through partnerships with one or more insurance companies. Third, the team plans to integrate a feature that will allow users to set the ratio of the city- and highway-driving, or collect and process their own vehicle activity data (Guensler, et al., 2018) to develop individualized fuel economy estimates. Finally, to support any related research, the team plans to develop an API that provides same functions and databases embedded in the NCST cost calculator. To do this, the team has developed Python scripts to calculate lifetime vehicle operating costs on the Georgia Tech server and provide the results back to other models while developing a REST API by Python and Flask that connects the Python scripts and the other models through simple API calls.

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Appendices

Appendix A - Existing Cost Calculators

The figures mentioned in Literature Review are shown in this section. These figures will show the examples of using the existing lifetime vehicle operating cost calculators.

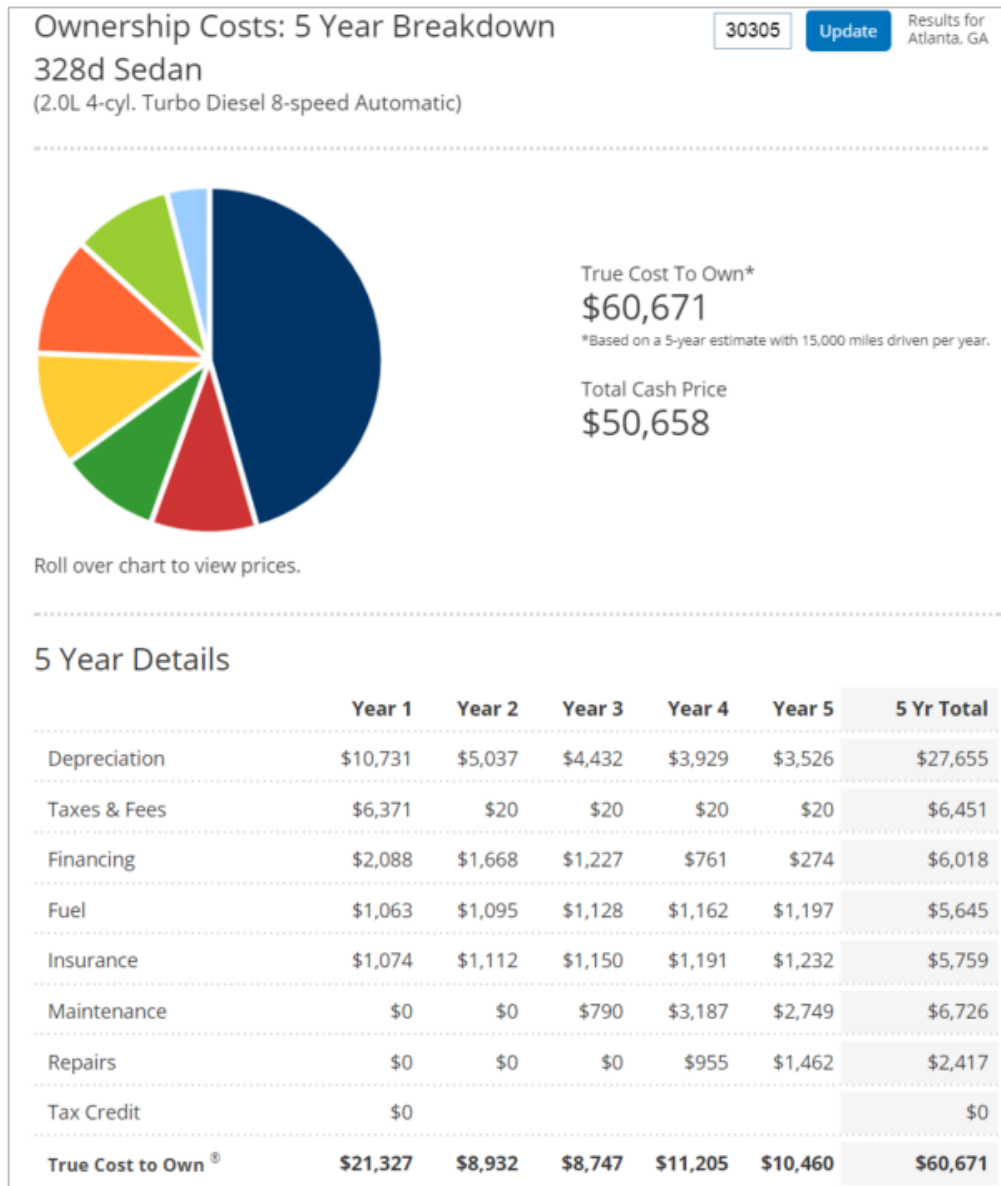


Figure A-1. Example Result from Edmunds® “True Cost to Own” Calculator



Figure A-2. Example Result from KBB® Five-Year Ownership Cost Calculator

Monthly Payments [What Can I Afford?](#)

- Vehicle Price**¹
Enter the MSRP, sales, asking or retail price of your vehicle
[Look up the price of your car](#)
- Trade-in Value**¹
What is the NADAguides trade-in value of your current vehicle? Note: make sure to deduct any remaining loan balance if you have one.
[Get your NADAguides trade-in](#)
- Down Payment**¹
Will you be putting money "down" on the purchase? If so, how much?
- Interest Rate**¹
What finance/car loan interest rate do you qualify for? 3.75% is based on average credit score.
- Loan Term**¹
How quickly (in months) do you plan to pay off the car loan? Typically loan terms are offered at 36, 48 and 60 months.
- Sales Tax**¹
Sales tax is a combination of your local and state sales tax rates. This figure is not represented in the sticker price of a vehicle, but contributes to the total cost of purchasing a vehicle. Sales tax may vary by county.

Your monthly payment:
\$ 0

Note: Based on the information given, we have calculated that you can afford a vehicle with a monthly payment of up to the figure listed above.

Cost factors included in your monthly payment.

Vehicle Price:	\$ 0
Interest Paid:	\$ 0
Sales Tax:	\$ 0
Total Cost:	\$ 0

[See Cars at this Price](#)

[Get Approved for a Car Loan](#)

Figure A-3. NADA Guides Car Payment Calculator

☐ Single Car Calculation
 ☒ Double Car Calculation

Copy Car #1 Entries to Car #2

Entry Descriptions	Car #1	Car #2
Purchase price:	25000	25000
Enter sales-tax percentage:	7.35	7.35
Enter annual license cost:	137	137
Enter extended warranty cost:	0	0
Will you be financing this car?:	Yes	Yes
Enter down payment amount:	1000	1000
Enter financing rate (APR):	7.9	7.9
Enter financing term (# months):	60	60
Enter annual insurance cost:	850	850
Enter expected annual driving mileage:	20000	20000
Enter car Miles Per Gallon rating:	22	22
Enter cost of one gallon of gasoline:	2.45	2.45
How many years old is the car?:	0	0
How many years do you expect to own this car?:	3	3
Enter estimated monthly maintenance/ repair cost:	35	35

[Email My Results
Click Here](#)

	Car #1	Car #2
Tax, License, and Warranty Costs:	\$2,248.50	\$2,248.50
Depreciation Costs:	\$16,000.00	\$16,000.00
Finance Costs:	\$4,570.07	\$4,570.07
Insurance Costs:	\$2,550.00	\$2,550.00
Fuel Costs:	\$6,681.82	\$6,681.82
Maintenance & Repair Costs:	\$1,260.00	\$1,260.00
Total cost of owning the car:	\$33,310.39	\$33,310.39
Annual cost to own this car:	\$11,103.46	\$11,103.46
Cost per mile:	\$0.56	\$0.56

Figure A-4. Financial Mentor Car Cost Calculator

Assumptions					
NEW CAR	\$30,000	5 YEAR OLD CAR	\$15,000	10 YEAR OLD CAR	\$5,000
10 year old car Trade in Value	\$5,000	15 year old Car Trade in Value	\$1,500	20 year old car Trade in Value	\$0
10 Year Depreciation Cost	\$25,000	10 year Depreciation Cost	\$13,500	10 year Depreciation Cost	\$5,000
Average Annual Cost	\$2,500	Average Annual Cost	\$1,350	Average Annual Cost	\$500

Annual Opportunity Cost 8%					
NEW CAR	\$30,000	5 YEAR OLD CAR	\$15,000	10 YEAR OLD CAR	\$5,000
Average Annual Cost	\$2,400	Average Annual Cost	\$1,200	Average Annual Cost	\$400

For Simplicity I assume that as Taxes go down Maintenance goes up (\$500) annual combined					
Maintenance		Taxes and Inspection Annual Cost		Average Cost of Insurance	
New Car (\$16 per Month)	\$200	New	\$200	New Car - Comprehensive (\$100 per month)	\$1,200
5 year Old Car (\$25 per Month)	\$300	Old Car	\$100	Old Car - Liability (\$50 per month)	\$600
10 Year Old Car (\$33 per Month)	\$400	Old Car	\$100		

Calculating the Cost of Gas					
Assumptions		SUV / Truck		Econo Hatchback	
Miles to Work (one way)	15	Gas Economy (MPG)	15	Gas Economy (MPG)	30
Annual Mileage (Assumes 5 days a week 50 weeks per year 10% discretionary)	8,250	Number of Gallons per Year	550	Number of Gallons per Year	275
Cost of gas per Gallon	\$2.20	Annual Cost of Gas	\$1,210	Annual Cost of Gas	\$605

Figure A-5. CHOOSEFI's Cost of Car Ownership Calculator

Appendix B - Example NCST Cost Calculator Run

An example will be run using the NCST website as a demonstration. A new 2017 Subaru Forester AWD purchased in Georgia will be used as the test example vehicle. For this example, when users choose the vehicle make, model, and model year, the following data will be used for the calculation using the NCST website:

1. \$28,251 purchase price with 7% sales tax in Georgia included.
2. Down payment of \$500.00 as the default.
3. 36-month financing at an annual interest rate of 3.5%.
4. Annual mileage accrual of 12,828 miles per year as default, but the user decides to use 10,000 instead.
5. 25 miles/gallon fuel economy, which is shown in the window box as soon as user chose the vehicle make, model, and model year.
6. Fuel costs of \$2.30 per gallon for gasoline.
7. \$450.00 per year for annual maintenance, which is the default value in the website.
8. The user specifies that the plan to keep the vehicle for 12 years or 150,000 miles, whichever comes first (in this case, the 12-year lifespan controls the calculation, given the specified annual mileage accrual rate).
9. The salvage value is set to 10% of the purchase price at the end of life.

The total operating cost over the 12-year lifespan of the vehicle is \$57,081, which translates to 47.6 cents/mile. Figures B.1 provides model input screenshots and model results. Users will obtain the same result by using the Excel tool, which also is provided on the NCST website and can be downloaded directly.

Enter Information

Choose Your Vehicle

Vehicle Make:

Vehicle Model:

Model Year:

Fuel Type:

Hybrid Type:

Vehicle Data

Year Purchased:

Purchase Price (\$)*:

Down Payment (\$):

Interest Rate (%):

Loan Term (months):

Odometer at Purchase (miles):

Current Vehicle Value (\$):**

Financed:

Interest Rate (%):

Monthly Interest Rate (%):

Loan Term (months):

Interest Paid:

* Please provide the purchase price including all fees (e.g. TAVT and all relevant registration fees)

** The purchase price and current vehicle value provided in this website is based on Georgia TAVT assessment database, but it can be different from a real value. To get the more correct vehicle owning cost, please search by other websites such as [KBB](#) or [Edmunds](#)

Driving Data

Annual VMT (miles)*:

Fuel Economy (miles per gallon):

* The default value of 12,828 miles is an average VMT of Georgia State citizens ([click here to see the reference](#))

Vehicle Max Age/Miles Data

To calculate the remaining useful life of this vehicle, please tell us the maximum number of years and maximum mileage you would allow on this vehicle. That is, if either value exceeded, you would get rid of this vehicle.

Number of additional years you are willing to drive this vehicle:

Maximum miles (odometer reading) you would allow on this vehicle:

Remaining useful vehicle life based upon your statements above:

Lifetime Mileage Data

Current Year:

Miles Accrued prior to Purchase:

Owner-Accrued Miles since Purchase:

Owner-accrued Mileage to End of Life:

Owner's Lifetime Mileage Accrual:

Total Lifetime Vehicle Mileage:

Salvage Data (Depreciation)

Please Select One among Salvage Value Options below, and Enter Salvage Value Information as Needed.

☒ End of Life Salvage (%)*: →

☐ Provide Manual Input (\$):

* The end of life salvage percentage is calculated by assuming 10% of depreciation for each year (e.g. 8 years of useful remaining life leads to 20% of EOL salvage (10 years - 8 years) X 10%), and minimum value of salvage is set to 10% or \$500.

Fuel Data

Fuel Type:

Fuel Cost (\$/gallon):

☒ Provide manual input (\$/gallon):

☐ Fuel cost near your place, please enter your ZIP code*:

Fuel Rack Price:**

Federal Excise Tax:**

Georgia Excise Tax:**

County Sales Tax:**

* Currently this option is unavailable.

** Fuel tax calculation in this website is based on Georgia State rules.

Insurance Data

Annual Insurance Cost (\$)*:

* The average value of annual insurance is an average cost paid in the United States ([click here to see the reference](#)). However, insurance cost varies by a variety of factors (e.g. coverage, number of members joined, company, etc.). So, please enter your own insurance cost manually.

Registration Data*

Plate Fee (\$):	<input type="text" value="20.00"/>
Do you have a special plate?:	<input type="text" value="No"/>
Was vehicle purchased before 2013:	<input type="text" value="No"/>
Special Plate Fee:	<input type="text" value="0.00"/>
TAVT value:	<input type="text" value="0.00"/>
TAVT Millage/1000:	<input type="text" value="27.75"/>
Ad Valorem Tax:	<input type="text" value="0"/>
Total Registration:	<input type="text" value="20.00"/>

* Registration cost calculation in this website is built for vehicles registered in Georgia State.

Smog Check Data

Smog Check Fee (\$):	<input type="text" value="20.00"/>
----------------------	------------------------------------

Tire Cost Data

Cost per Tire (\$):	<input type="text" value="120.00"/>
Total Tire Cost:	<input type="text" value="480.00"/>
Tire Warranty (miles):	<input type="text" value="50,000"/>

Maintenance Data

Choose Maintenance Cost Option:

<input type="radio"/> Average Maintenance Cost:	<input type="text" value="766.50"/>	\$/year →	<input type="text" value="0.077"/>	\$/mile
<input checked="" type="radio"/> Provide Manual Input :	<input type="text" value="450"/>	\$/year →	<input type="text" value="0.045"/>	\$/mile

* The average value of \$766.50 per year is based on reference ([Click here to see the reference.](#))

Car Wash Data

Cost per wash (\$):	<input type="text" value="0.00"/>
Number of washes per year:	<input type="text" value="0"/>
Annual Car Wash Cost:	<input type="text" value="0.00"/>

Parking Data

Monthly Parking Cost - Home (\$):	<input type="text" value="0.00"/>
Monthly Parking Cost - Work (\$):	<input type="text" value="0.00"/>
Monthly Parking Cost - Total (\$):	<input type="text" value="0.00"/>

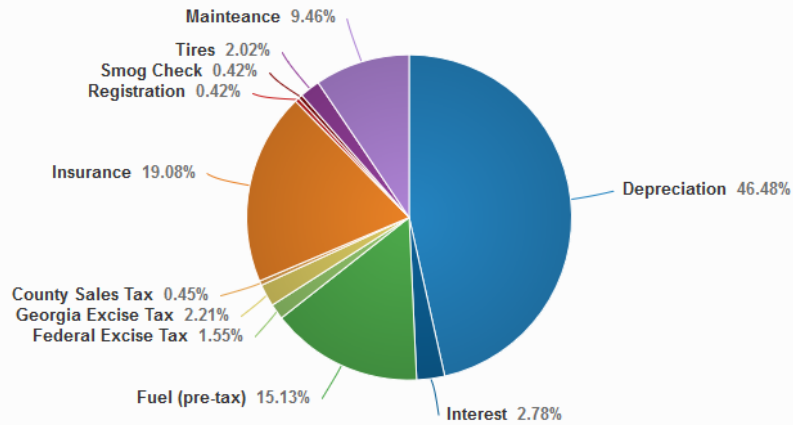
Monthly Tolls Data

Monthly Tolls Paid (\$):	<input type="text" value="0.00"/>
--------------------------	-----------------------------------

Results

47.6 ¢/mile

Vehicle Ownership Cost



The estimated total cost of owning and operating cost for the remaining useful life of 12.0 years is \$57,081.

	Component	Value (¢/mile)	Percentage (%)
1	Depreciation	22.110	46.48
2	Interest	1.324	2.78
3	Fuel (pre-tax)	7.196	15.13
4	Federal Excise Tax	0.736	1.55
5	Georgia Excise Tax	1.052	2.21
6	County Sales Tax	0.216	0.45
7	Insurance	9.074	19.08
8	Registration	0.200	0.42
9	Smog Check	0.200	0.42
10	Tires	0.960	2.02
11	Maintenance	4.500	9.46
12	Car Washes	0.000	0.00
13	Parking	0.000	0.00
14	Tolls	0.000	0.00

Figure B-1. Example NCST Cost Calculator Run Results

Appendix C - CEE 6602 Lab Assignment Results

This chapter includes the Georgia Tech Urban Transportation Planning course (CEE6602) lab assignment instruction and the pre-lab and post-lab survey results.

Cost of Owning and Operating Personal Vehicles

Work in Final Project Groups for this Lab

Dr. Guensler lives in Atlanta's Virginia-Highland neighborhood (30306), one block from MARTA's 16 and 36 lines, and walking distance from Virginia and North Highland. The family of four includes Dr. Guensler, his wife (also employed full-time downtown), and two children: a 19-year-old male with a driver's license who lives at college out of state, and a 16-year-old female who is currently learning to drive on a learner's permit. The family currently owns a 1999 Ford Explorer and a 2004 Honda Pilot, which they purchased new. The family plans to purchase a vehicle. The new driver will learn on the Explorer, which will also serve as a backup vehicle. Both adults can take transit to their work (Georgia Tech and Downtown Federal Building), but they generally do not. The 16-year old attends the Howard School; her extracurricular activities begin at 7:00 am and end at 4:00 PM. The family likes the room provided by a sport utility vehicle. However, now that the family no longer needs to fit multiple car seats in a vehicle (two kids, plus friends), moving to a smaller vehicle might be a reasonable option. The family is fairly 'green' and has expressed an interest in electric and hybrid vehicles.

Interview Dr. Guensler at the beginning of the lab session to establish factors that you suspect the family will be taking into consideration in their vehicle purchase decision. Use the online NCST Vehicle Ownership and Operating Cost Calculator (<http://fec.ce.gatech.edu/autoOwershipCost.html>) to analyze the cost of owning their existing vehicles, as well as new and used replacement vehicles as outlined below:

- | | |
|--------------------------------------|--|
| 1) Ford Explorer, 1999
(existing) | 6) Nissan Leaf, 2018 (electric) |
| 2) Honda Pilot, 2004 (existing) | 7) Tesla, Model X, 2018 |
| 3) Toyota RAV4, 2017
(gasoline) | 8) Chevy Spark, Used 2015 |
| 4) Toyota RAV4, 2017 (hybrid) | 9) Toyota Prius, Used 2014
(Hybrid) |
| 5) Subaru Forester Touring,
2018 | 10) An alternative that you
provide |

Construct a spreadsheet to present lifetime (10-year) vehicle ownership and operating costs for each vehicle on a cent/mile basis, and the total household outlay

for each vehicle. Put each cost element in a separate row (e.g., capital purchase, interest, gasoline, registration, insurance, etc.). For the cost of gasoline, break out the embedded federal, state, and local sales taxes as separate line items. To estimate the capital cost of each vehicle, go ahead and upgrade the interior, but do not upgrade to a high-end stereo/video system ... use your best judgment. Assume that children 16+ are, and always will be, good drivers and good students when you are estimating the insurance costs. Use a separate column for each vehicle purchase decision so that you can easily make comparisons by cost component.

Develop a lab report in MS Word that describes the various costs of owning and operating a personal vehicle. Outline all of the assumptions used in your analyses to estimate each cost element. Cite the sources for all of your assumptions. Write a report section that compares each cost element across vehicles (explain why it is higher or lower for certain vehicle choices) and provide graphics. Compare the lifetime fuel costs of each alternative. Compare and contrast the RAV4 hybrid and non-hybrid costs and estimate a payback period in years where fuel savings pay for the increase in capital and other costs. Discuss the overall cost and convenience tradeoffs across the alternatives. If the family were to decide not to purchase a replacement vehicle, discuss how much travel they could undertake by Uber/Lyft, taxi, and rental car given their annual vehicle cost savings (make sure these costs are included in your spreadsheet for that alternative). Summarize your findings in a conclusions section and provide input to the family on the pros and cons of various options. Make a recommendation, but recognize that they will be making their own decision based upon your report given their personal preferences and valuation of pros and cons.

Assumptions:

The family drives their current vehicles 5,000 (Ford) and 8,500 (Honda) miles/year. Remember that alternative fuel vehicles may have tax credits available. For the purposes of straight-line depreciation, assume the family will own and use the new vehicle for 10 years and their current vehicle for 10 more years and that the salvage value of each vehicle (remaining value at the end of useful life) will equal 12% of the purchase cost. Parking at the worksite costs \$4.50 per day per vehicle at each work location. Assume that gasoline costs \$2.36/gallon. Assume zero inflation. All drivers are good drivers and have had no crashes or points on their driving records and the family has excellent credit.

The Survey questions are appended below:

Pre-Lab Survey and Post-Lab Survey

Q1. Do you currently own or lease a vehicle?

(check all that apply)

- ☐ Yes, I own a vehicle
- ☐ Yes, I lease a vehicle
- ☐ No, I do not own or lease a vehicle
- ☐ Prefer not to answer

Q2. How many years' of driving experience do you have, including the time that you only had a learner's permit?

- ☐ Less than 1 year
- ☐ 1 to 5 years
- ☐ More than 5 years
- ☐ Prefer not to answer

Q3. Do you compare gas prices online or through a cell phone app before selecting a station to refuel your vehicle?

- ☐ Yes
- ☐ No
- ☐ N/A
- ☐ I compare gas prices another way

Please indicate how you compare prices:

-
- ☐ Prefer not to answer

Q4. Have you ever seen a comparison of five-year total cost of ownership data for personal vehicles?

- ☐ Yes
- ☐ No
- ☐ Prefer not to answer

Q5. A number of websites offer information on total cost of vehicle ownership. Please identify the websites that you have visited. Check all that apply

- ☐ CarComplaints.com
- ☐ CarGurus.com
- ☐ Edmunds.com
- ☐ KelleyBlueBook.com
- ☐ TrueDelta.com
- ☐ Please list any other websites here. _____
- ☐ Prefer not to answer

Q6. How likely are you to visit one or more of the sites listed above to review the five-year cost of vehicle ownership or total cost of vehicle ownership prior to purchasing or leasing a vehicle? (Given a scale of 1-5, where 1 is very unlikely to review as a reference, and 5 is very likely to review as a reference.)

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5

Q7. On average, for how many years do you think most people keep a vehicle?

- ☐ Less than 2 years
- ☐ 2 years or longer, but less than 4 years
- ☐ 4 years or longer, but less than 6 years
- ☐ 6 years or longer, but less than 8 years
- ☐ 8 years or longer, but less than 10 years
- ☐ 10 years or longer, but less than 12 years
- ☐ 12 or more years
- ☐ Prefer not to answer

Q8. If you were to obtain a vehicle, what age do you think the vehicle would be?

- ☐ Less than 2 years
- ☐ 2 years or longer, but less than 4 years
- ☐ 4 years or longer, but less than 6 years
- ☐ 6 years or longer, but less than 8 years
- ☐ 8 years or longer, but less than 10 years
- ☐ 10 years or longer, but less than 12 years
- ☐ 12 or more years
- ☐ Prefer not to answer

Q9. If you were to obtain a vehicle, for how many years do you think you would keep your vehicle?

- ☐ Less than 2 years
- ☐ 2 years or longer, but less than 4 years
- ☐ 4 years or longer, but less than 6 years
- ☐ 6 years or longer, but less than 8 years
- ☐ 8 years or longer, but less than 10 years
- ☐ 10 years or longer, but less than 12 years
- ☐ 12 or more years
- ☐ Prefer not to answer

Q10. How many different makes and models of new electric vehicles do you think are currently available for sale?

_____.

- ☐ I don't know
- ☐ Prefer not to answer

Q11. Suppose you are buying a 2014 sedan with manufacturer's suggested retail price (MSRP) of around \$15,000; how many years do you think you will need to keep it to be most cost effective?

- ☐ Less than 2 years
- ☐ 2 years or longer, but less than 4 years
- ☐ 4 years or longer, but less than 6 years
- ☐ 6 years or longer, but less than 8 years
- ☐ 8 years or longer, but less than 10 years
- ☐ 10 years or longer, but less than 12 years
- ☐ 12 or more years
- ☐ Prefer not to answer

Q12. Suppose you are buying a used 2013 Sedan with a purchase price of about \$10,000, with a 10% down payment and 4% annual interest rate. Assume that you will pay \$800/year for insurance. Without consulting the Internet, please rank-order (1-6) the following cost elements, from the largest contribution (1) to the five-year total cost of ownership to the smallest contribution (6) to the five-year total cost of ownership.

- _____ Depreciation
- _____ Fuel
- _____ Interest
- _____ Insurance
- _____ Maintenance
- _____ Other costs

Q13. Suppose you are buying a new 2017 Sedan with MSRP of around \$25,000, with a 10% down payment and 4% annual interest rate. Assume that you will pay \$1,200/year for insurance. Without consulting the Internet, which of the following do you think is the most costly part for five-year total cost of ownership (assuming a 10% down payment and a 4% annual interest rate)?

- _____ Depreciation
- _____ Fuel
- _____ Interest
- _____ Insurance
- _____ Maintenance
- _____ Other costs

Q14. What is your gender?

- ☐ Male
- ☐ Female
- ☐ Prefer not to answer

Q15. What is your age?

_____.

☐ Prefer not to answer

Q16. How many people are there in your household, yourself included?

_____.

☐ Prefer not to answer

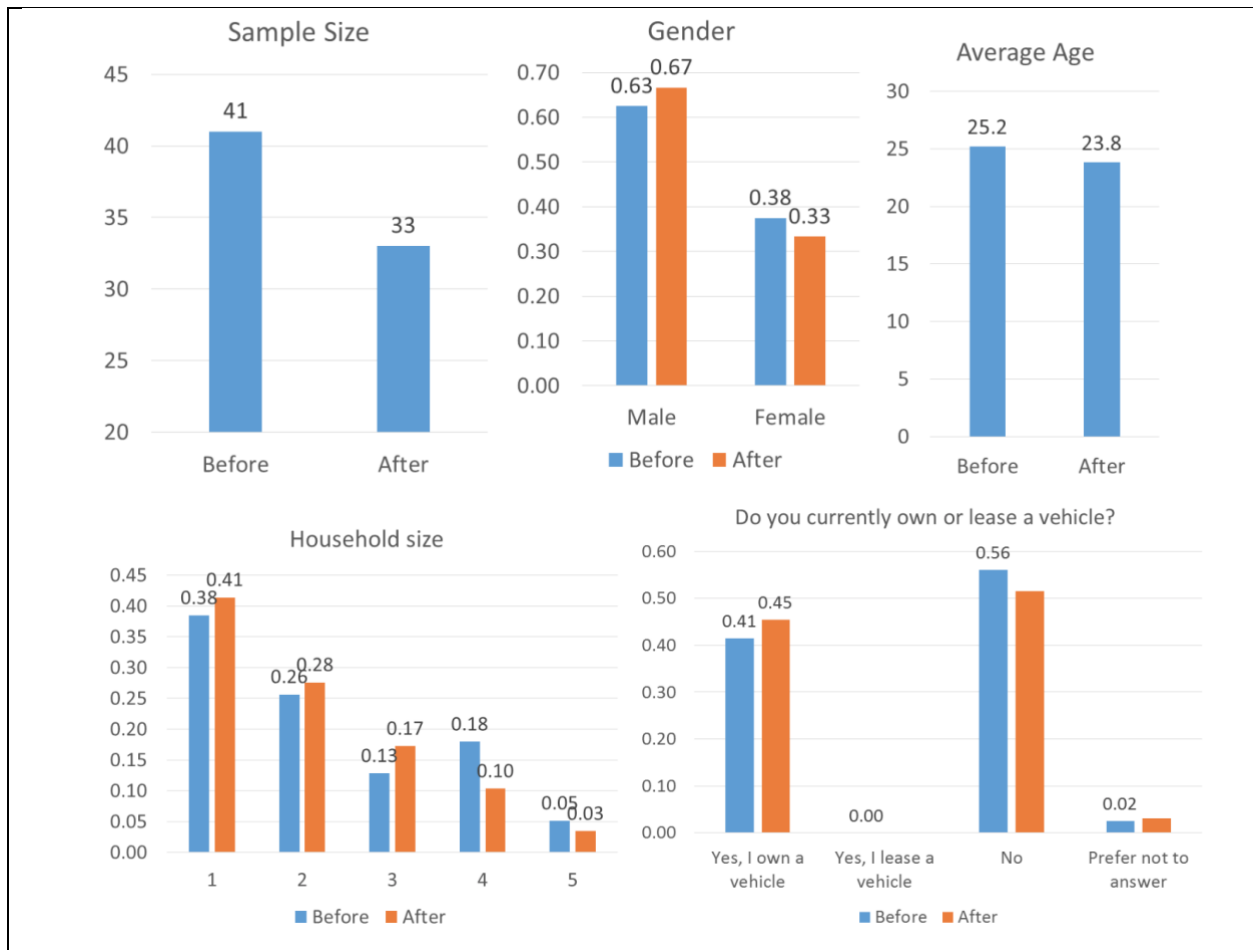
Q17. In what country/ies did you grow up?

Q18. Any other comments for this survey?

_____.

Thank you for taking this survey!

The following figures show the prior- and post-survey results. Figure C-1 shows the socio-demographic distributions of the pre-survey and post-survey respondents. It shows that the demographics are similar enough for a reasonable comparison.



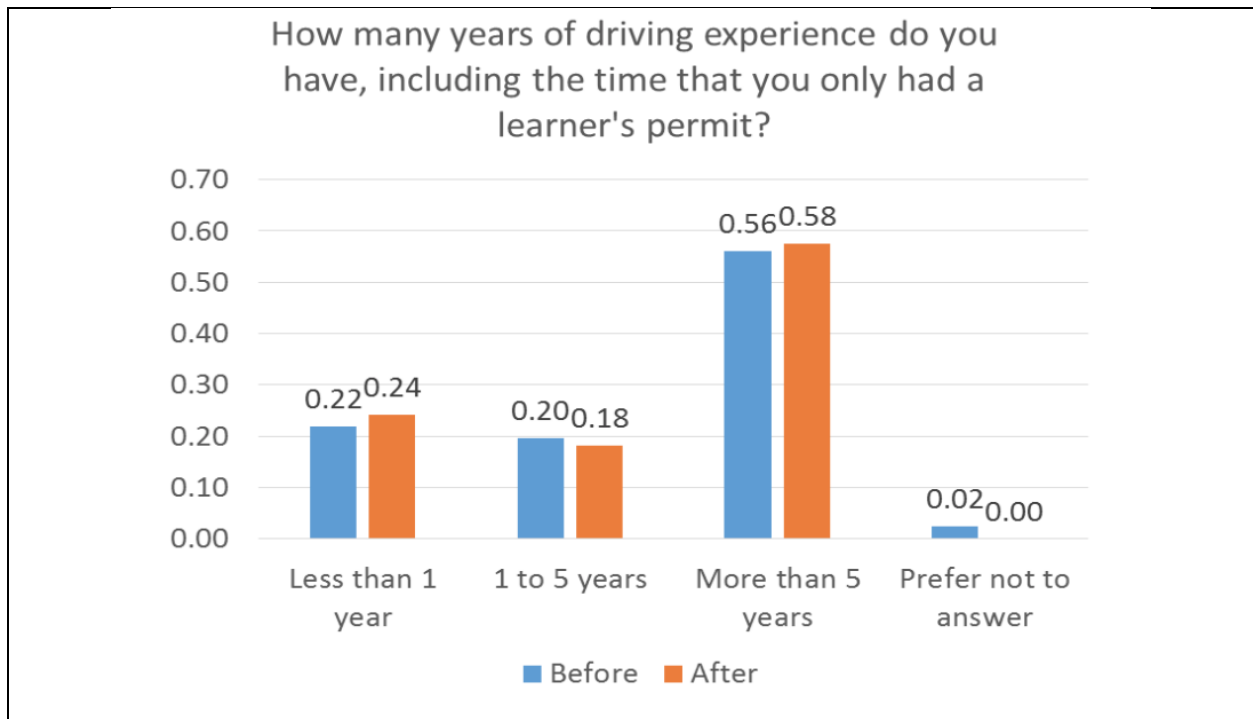


Figure C-1. Survey Sample Distribution

Figure C-2 shows the experiences of the survey respondents of using the NCST cost calculator. It indicates that the lab assignment using NCST cost calculator may have increased the students' perception of the five-year total cost of ownership and their potential decision-making process for making a vehicle purchase.

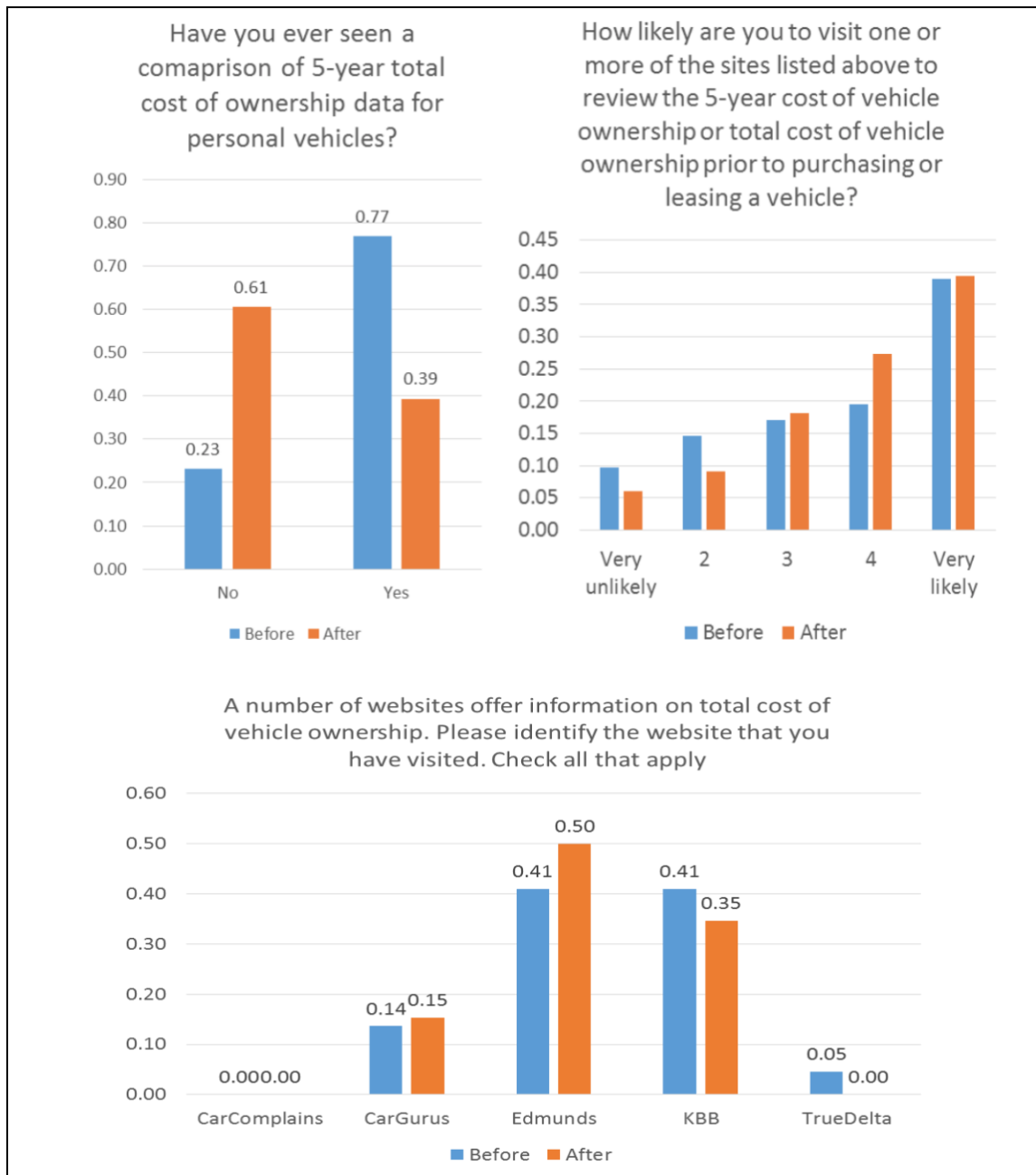
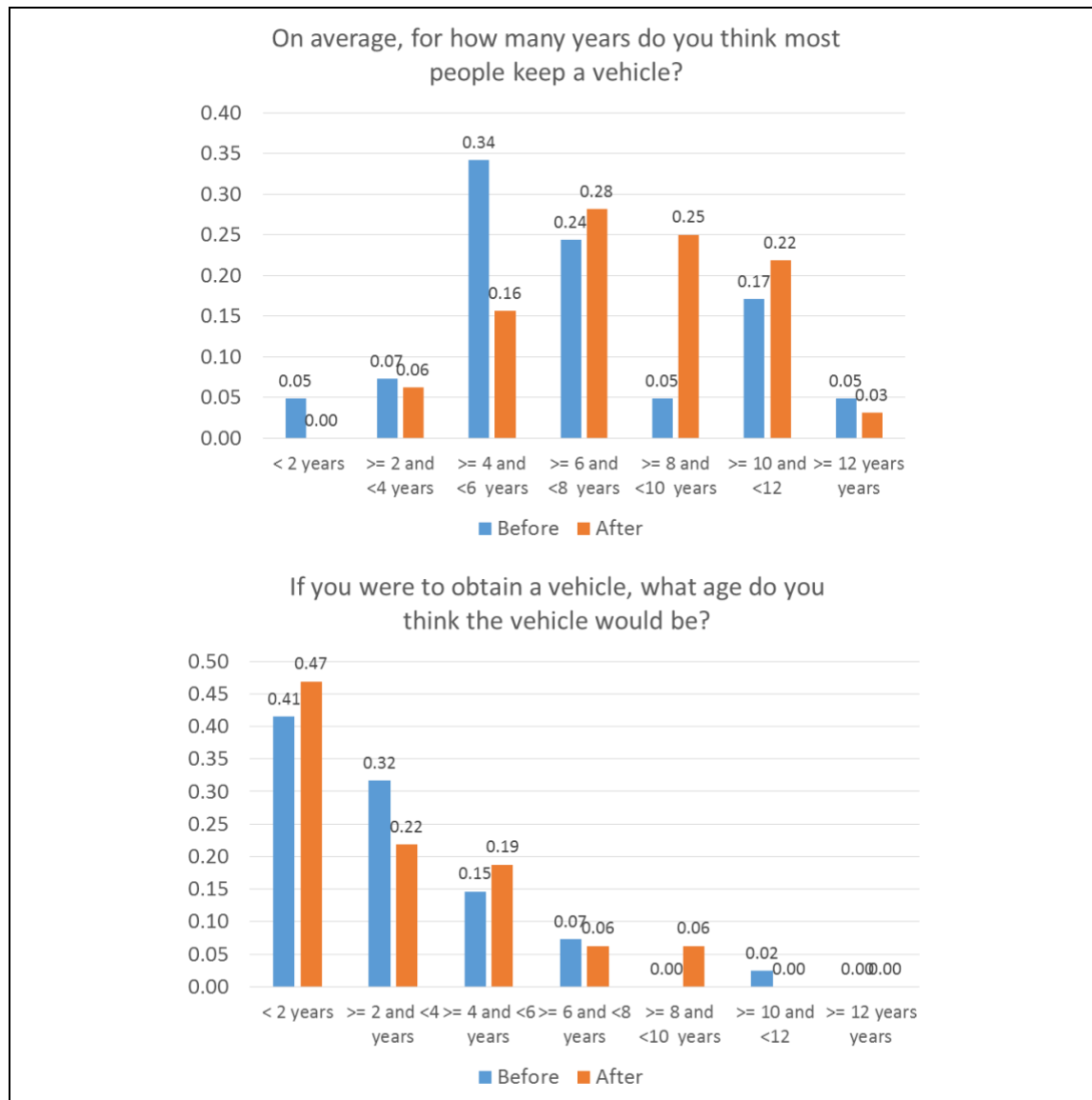


Figure C-2 Experiences Using the NCST Cost Calculator

Figure C-3 shows the survey respondents' vehicle ownership preferences. It indicates that the lab assignment may have changed the students' vehicle ownership preferences in that students indicated that they planned to own their vehicles longer after completing the assignment.



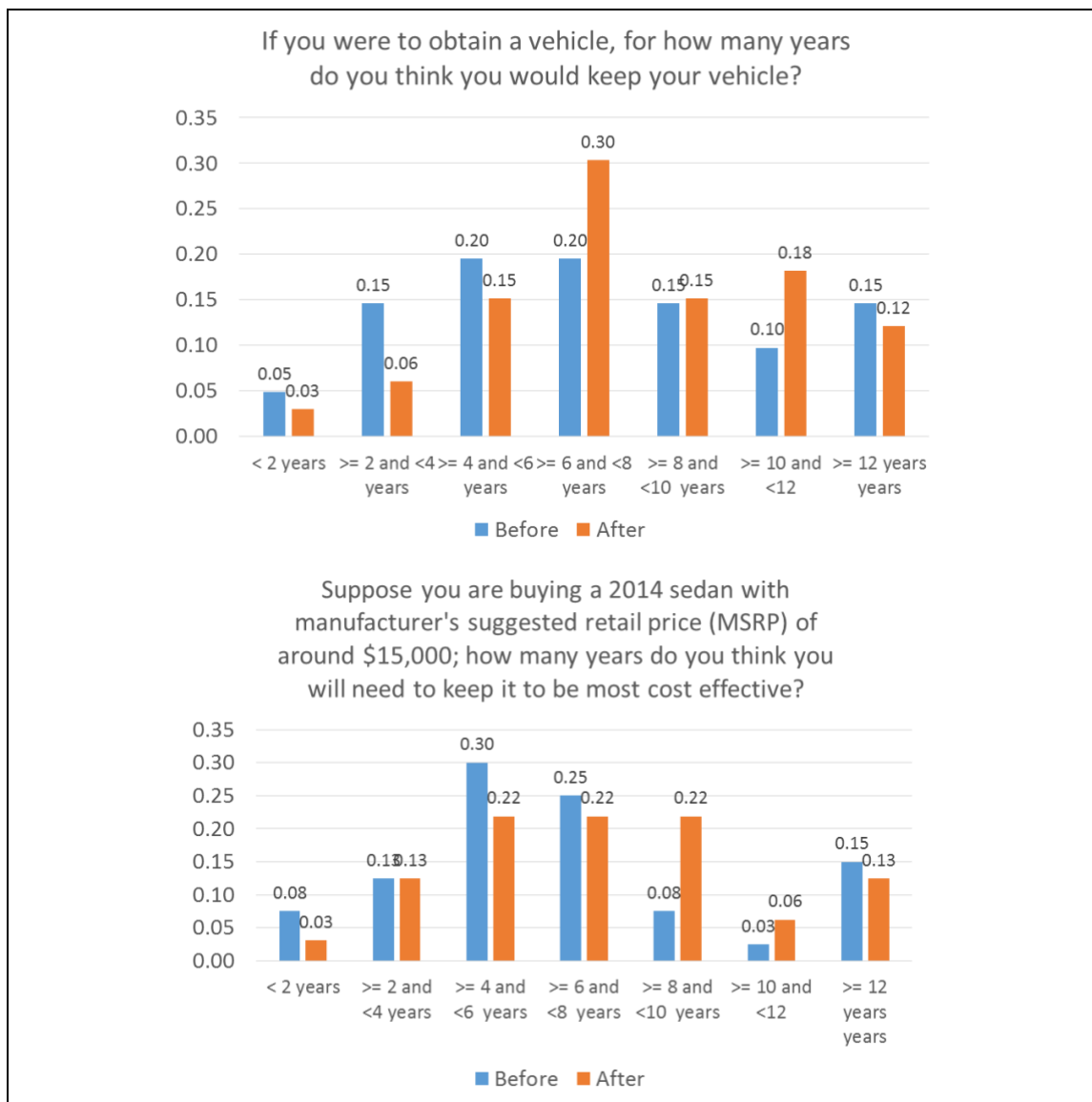
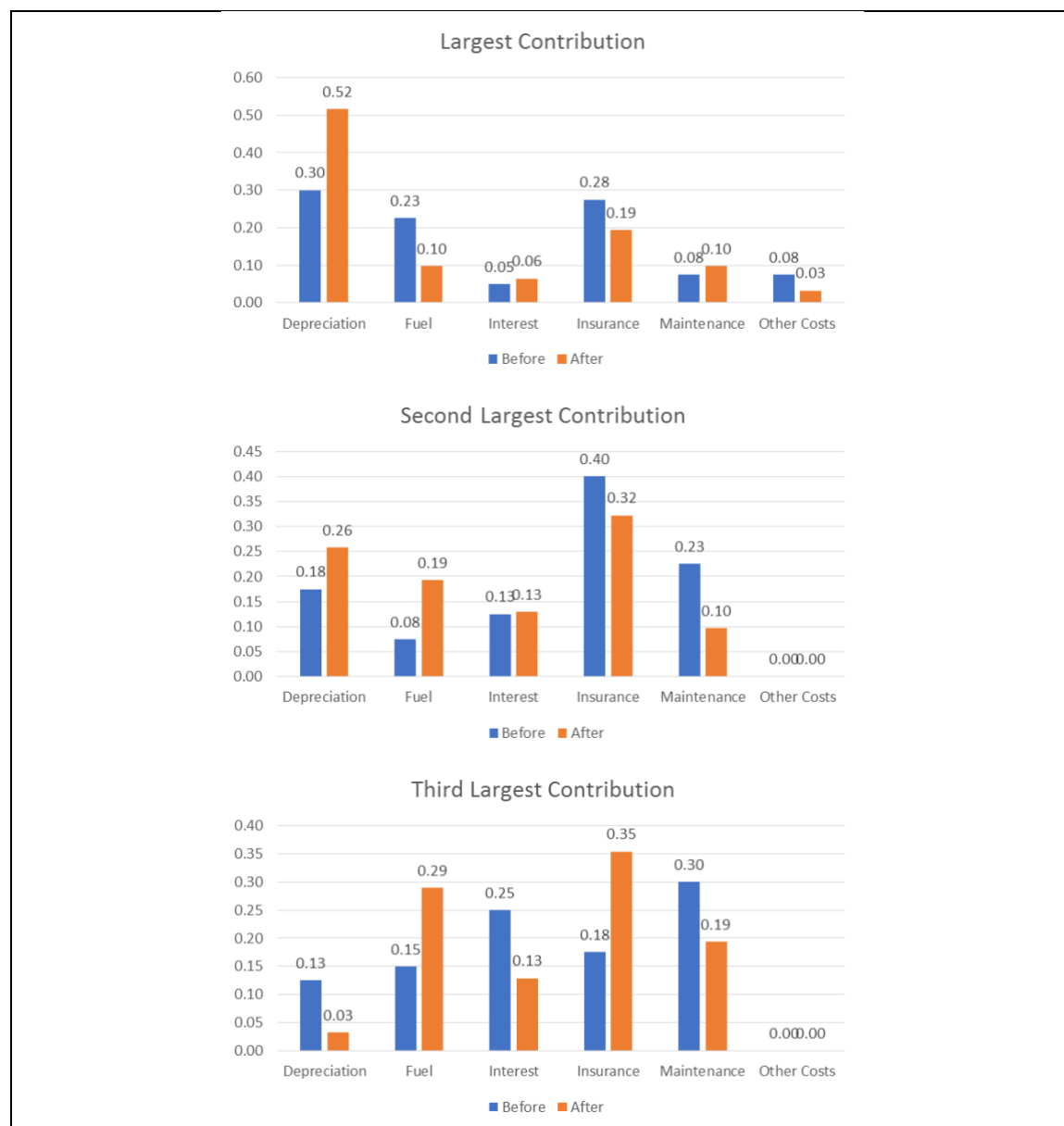


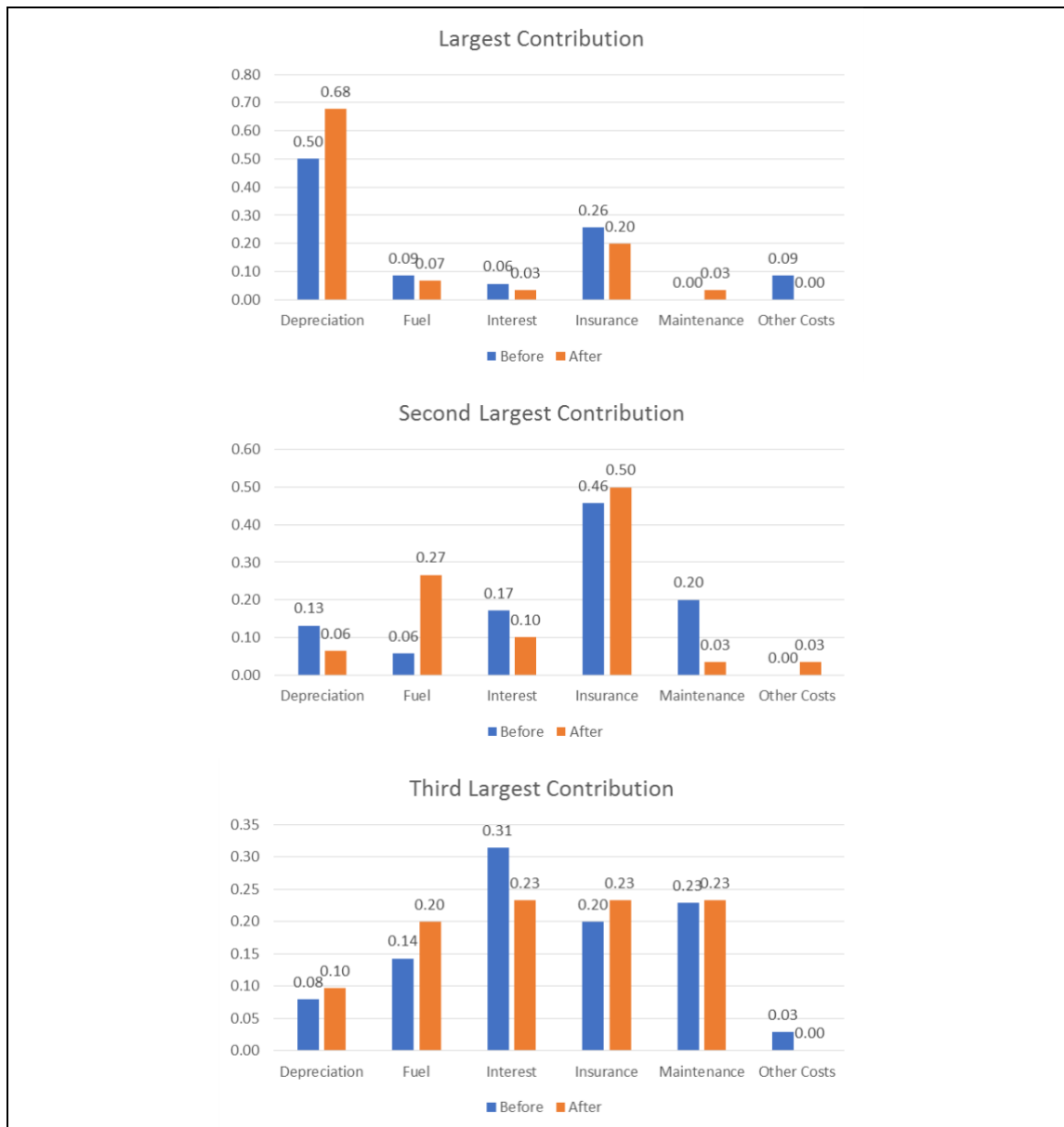
Figure C-3. Vehicle Ownership Preferences

Figure C-4 and C-5 show changes in the students' understanding of the importance of each cost component to the total cost of ownership. In particular, it shows that the students became more aware of the importance of depreciation in the total cost of ownership.



Question "Suppose you are buying a used 2013 Sedan with a purchase price of about \$10,000, with a 10% down payment, and a 4% annual interest rate. Assume that you will pay \$800/year for insurance. Without consulting the internet, please rank-order (1-6) the following cost elements, contribution (6) to the five-year total cost of ownership."

Figure C-4. Cost Rank-order Responses for Used Vehicle Purchase



Question: “Suppose you are buying a new 2017 Sedan with a purchase price of about \$25,000, with a 10% down payment, and a 4% annual interest rate. Assume that you will pay \$1,200/year for insurance. Without consulting the internet, please rank-order (1-6) the following cost elements, contribution (6) to the five-year total cost of ownership.”

Figure C-5. Cost Rank-order Responses for New Vehicle Purchase