SAND2018-13600R

I Modeling and Simulation

I.1 ParaChoice Model

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Start Date: FY14
End Date: Project continuation determined annually
Total Project Cost: $1,130k
DOE share: $1,130k
Non-DOE share: $0

Project Introduction

ParaChoice supports the VTO mission using early-stage research to help in the development of technology that will improve affordability of transportation, while encouraging innovation and reducing dependence on petroleum. Analysis with the ParaChoice model enables exploration of key factors that influence consumer choice, and technology, fuel, and infrastructure development for the vehicle mix. Because of the distinct differences between requirements, needs, and use patterns for light duty vehicles (LDVs) relative to heavy duty vehicles (HDVs), this project models the dynamics of each of these segments to characterize the factors that influence technology adoption.

Objectives

The lifetime project objective is to provide system-level analysis of the dynamics among the LDV and HDV fleets, fuels, infrastructure mix, and emissions. These capabilities have been instantiated in the ParaChoice model, a parametric vehicle choice model that can be used to identify trade spaces, tipping points, and sensitivities. Furthermore, parametric analyses can help quantify the effects of and mitigate uncertainty introduced by data sources and assumptions.

LDV analysis goal: Determine the potential for alternative fuel vehicles to penetrate the market, reduce LDV petroleum consumption and emissions, and impact energy use. Determine factors that influence alternative energy vehicle penetration and impact, the path to more efficient vehicles, tipping points for impactful market penetration, and system sensitivities.

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HDV analysis goal: Evaluate the potential for alternative fuel vehicles to increase freight hauling efficiency and reduce pollution, similarly to LDV. The capability to handle vocational HDVs were added to ParaChoice to facilitate these analyses this year.

Approach

ParaChoice is a system dynamics model incorporating energy sources, fuels, and LD or HD vehicles; see Figure 1. Simulations begin with today's energy, fuel, and vehicle stock and projects out to 2050. At each time step, vehicles compete for share in the sales fleet based on value to consumers. The simulation assesses generalized vehicle cost for each vehicle at every time step. A nested multinomial logit choice function assigns sales fractions based on these costs and updates the vehicle stock accordingly.

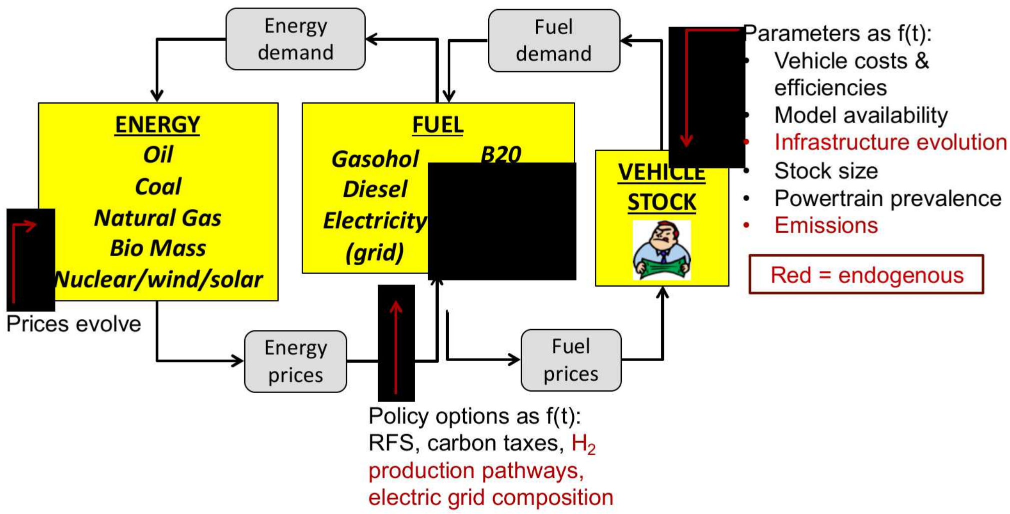

Figure 1. Visualization of the ParaChoice system dynamics model structure that demonstrates how energy, fuel, and vehicle-stock effect each other iteratively. Allows for parameters and policy options to act as functions of time.

ParaChoice is designed to enable parameterization that can be used to explore uncertainty and trade spaces, easily allowing identification of tipping points and system sensitivities. Uncertainty analyses possible using ParaChoice include trade space analyses where two parameters are varied, generating 100s of scenarios; and sensitivity analyses where many parameters can be varied at once, generating 1,000s of scenarios. Parameter ranges are selected to explore plausible and "what if" regimes, and provide thorough coverage of possible future states. Analysis products using ParaChoice provide insights into: (1) perspectives in uncertain energy and technology futures; (2) sensitivities and tradeoffs between technology investments, market incentives, and modeling uncertainty; and (3) the set of conditions that must be true to reach performance goals.

Vehicles, fuels, and populations are segmented to study the competition between powertrains and market niches; see Figure 2. Baseline inputs into the ParaChoice model include the following data and modeling outputs: AEO 2016 (energy prices); GREET (emissions); NHTS (LDV fleet segmentation); Polk (HDV fleet segmentation); Autonomie (LDV price projections); National Petroleum Council (HDV price projections); and AFDC (2010-2017 fueling stations and policies (by state)).

Results

To visualize results from ParaChoice runs and to help understand the impact of various parameters on modeling outputs, the results are made available through an interactive, online Results Viewer at https://h2-msm-vm.sandia.gov/parachoice. This year the Results Viewer for the LDV analyses was updated based on feedback from the VTO program office, and viewer plots and tables for powertrains no longer of interest were removed.

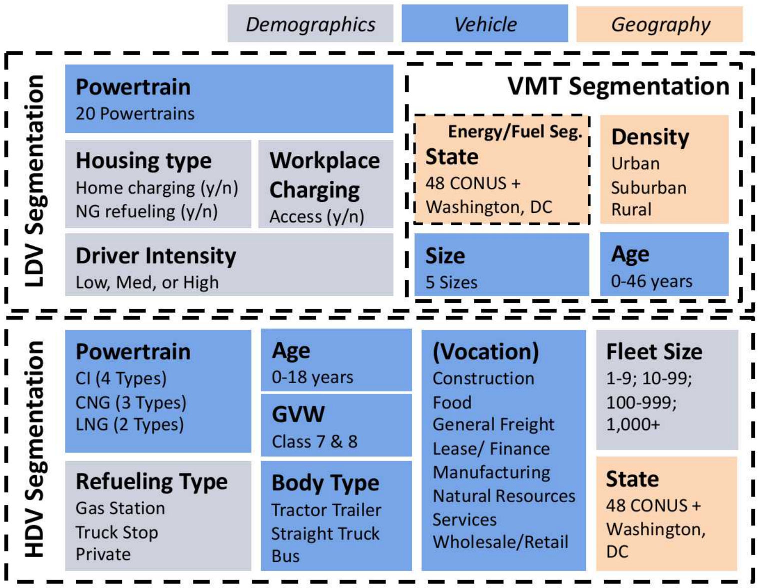

Figure 2. LDV and HDV segmentation options grouped into themes of buyer demographics (e.g., access to workplace charging or truck stop versus gas station refueling), vehicle options (e.g., powertrain or body type) and geography (e.g., State or population density).

To identify the combination(s) of HDV fleet segments and novel technologies that have the potential to significantly decrease petroleum use or criteria air pollutants, we quantitatively characterized the fleet of HDVs by elucidating the taxonomy of the Class 7 & 8 HDVs according to count (informing OEM manufacture decision), annual VMT and annual fuel consumption. Fuel consumption was broken down further by truck (informs buyer purchase decision, and when compared to VMT, informs the potential for technology improvements that affect efficiency or accessories), by typical fleet size for segment (informs buyer purchase decision and risk tolerance of buyers) and for segment (informs OEM manufacture decision and potential petrol and environmental impacts).

The number of registered Class 7 & 8 vehicles for each truck type was determined using data from the Polk 2011 data set [1], the U.S. Department of Transportation's Federal Transit Administration 2011 Annual Vehicle Inventory [2] and the Federal Highway Administration Highway Statistics Series for bus registrations [3]. The vehicle numbers were compared across all sources, and the final values are presented in Figure 3. The vehicle body or trailer fraction for each vehicle type came from the 2002 Vehicle Inventory and Use Survey (VIUS) [4] where the body/trailer represents ≥5% of the total for each vehicle type; else, the body/trailer was grouped into the "Other" category.

The average annual VMT by truck-tractors and single-unit trucks were determined from VIUS 2002 [4]. The annual VMT for transit and school buses were determined to be 34,053 miles/year and 12,000 miles/year, respectively, from the U.S. Department of Energy's Alternative Fuels Data Center [5]. Motor home annual VMT was determined to be 2,546.71 miles/year from the 2009 National Household Travel Survey (NHTS) [6].

The short- vs. long-haul split fraction was determined for each body or trailer type by applying a mileage threshold (100k) to the annual miles from VIUS 2002. For analysis purposes, long-haulers travel 110,000 miles annually, and short-hauling trucks with "day cabs" travelling approximately 80,000 miles annually [7]. Histograms of annual VMT for truck-tractors and single-unit trucks are shown in Figures 4 and 5, respectively. The short- vs. long-haul split fractions for the five truck-tractor segments are shown in Table 1. Essentially all single-unit trucks travel less than 110,000 mi annually, and therefore, are short-haulers by definition.

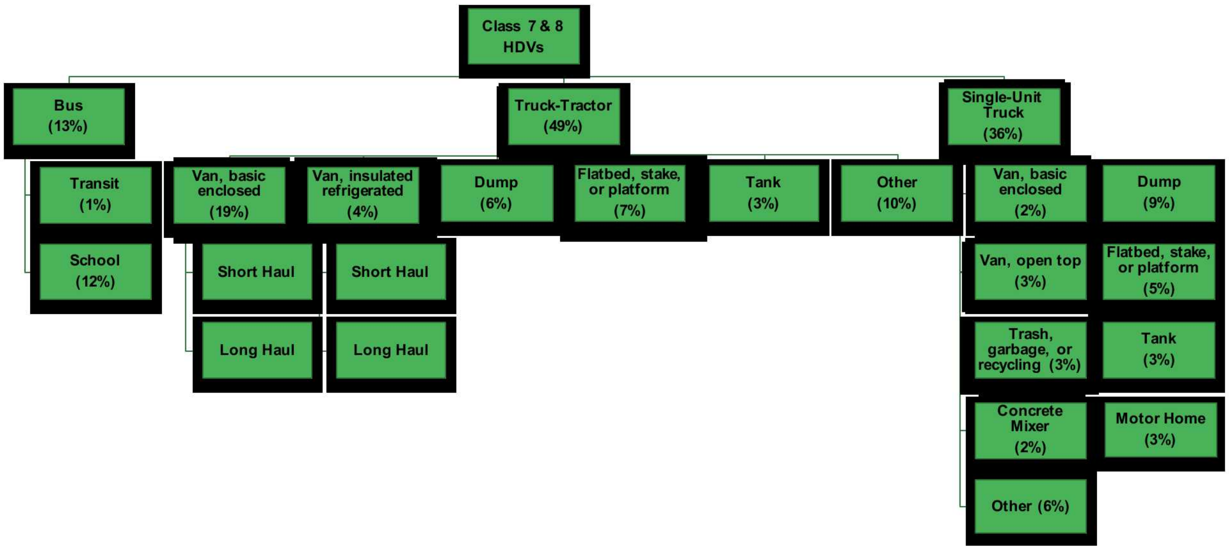

Figure 3. Segmentation of the HDV (Class 7 & 8) vehicles into subcategories using a tree structure that elucidates the percent vehicle fraction. The first segmentation is buses (13%), truck-tractor (49%) and single-unit trucks (36%).

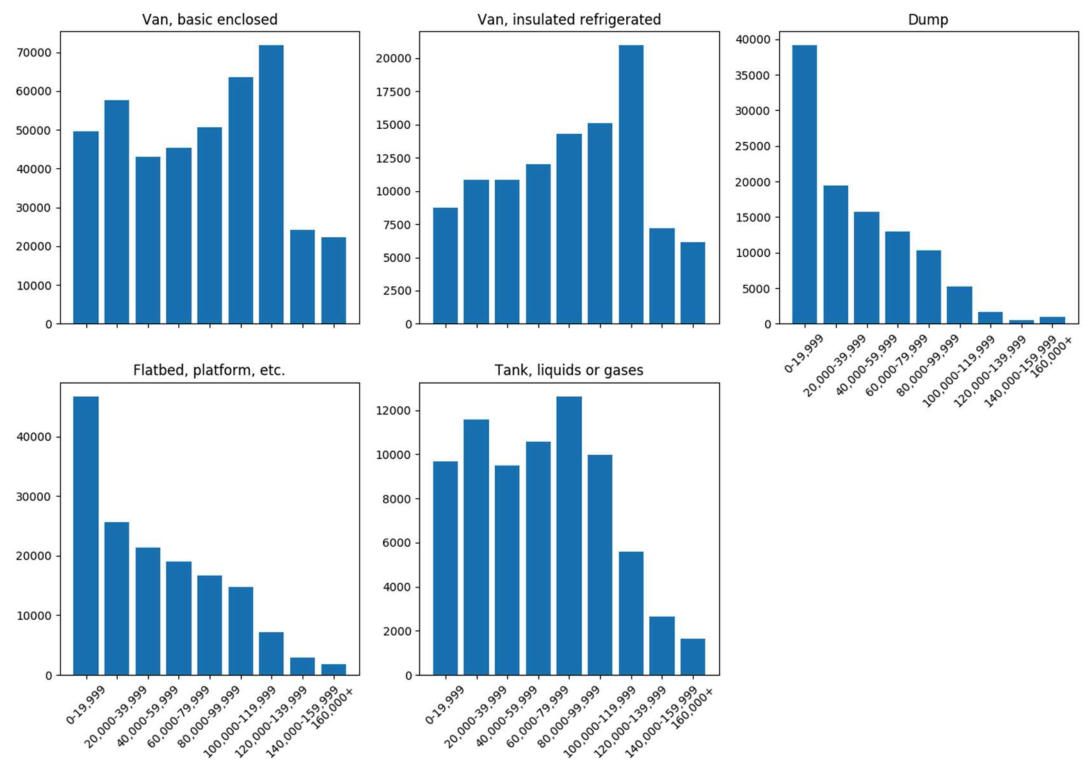

Figure 4. Bar graphs showing the VMT for five subsections of truck tractors (van-basic, van-insulated, dump, flatbed, tank). VMT ranges are broken into 9 bins distributed equally from 0-160k+ miles per year.

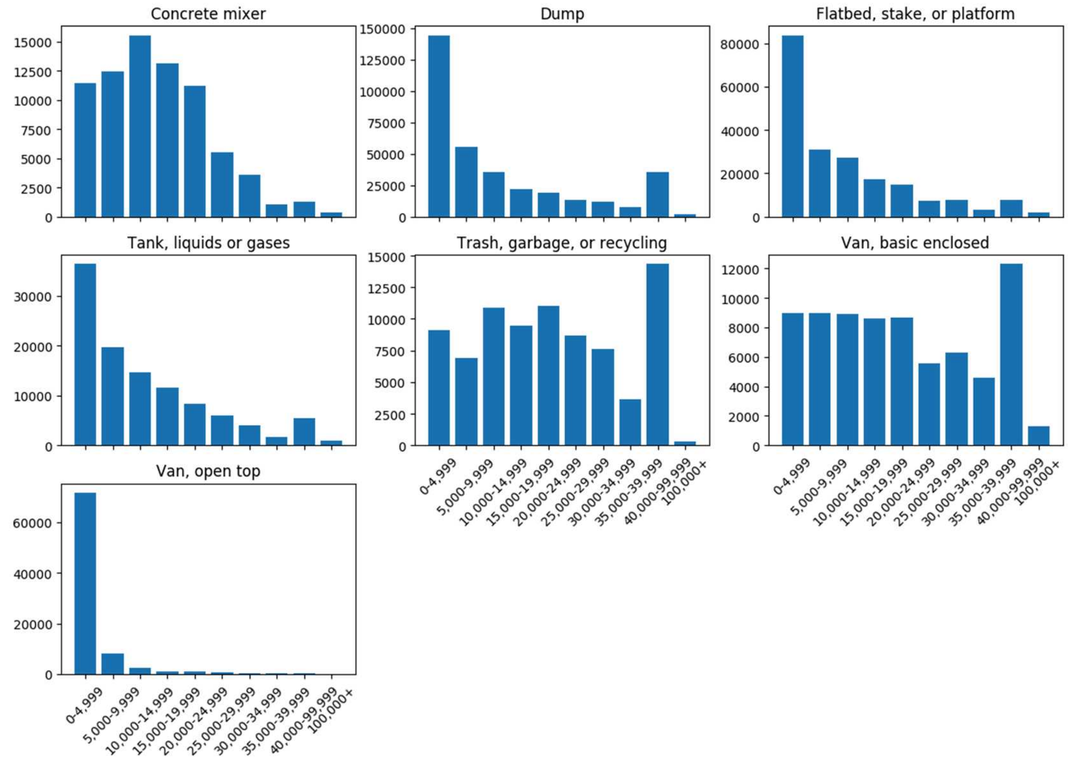

Figure 5. Bar graphs showing the VMT for seven subsections of single-unit trucks (concrete mixer, dump, flatbed, tank, trash, van-basic, van-open). VMT ranges are broken into 10 bins distributed from 0-100k+ miles per year.

Table 1 Truck-tractor short- vs. long-haul split fractions

	Van, basic	Van, refrigerated	Dump	Flatbed	Tank
Short-haul	0.58	0.53	0.92	0.83	0.73
Long-haul	0.42	0.47	0.08	0.17	0.27

Key findings from the HDV segmentation analysis are the following:

- HDV segmentation by count looks quite different than by annual VMT or fuel use (see Figure 7). Truck-tractors account for only half of Class 7 & 8 HDVs but travel three-quarters of the total annual miles and consume three-quarters of fuel. Of these, the long-haul trucks dominate.
- Sectors where alternative energy technologies have been successful are relatively small: refuse (e.g., CNG) is 2.2% by VMT, 2.8% by fuel use and 2.4% by count; and transit buses (e.g., hybrid/electric, CNG/LNG) is 1.2% by VMT, 2.1% by fuel use and 1.0% by count.
- Nearly all single-unit trucks are short-haulers. There are ~1.7M single-unit trucks on the road, and thus there may be a large enough market in a given body type of single-unit trucks for OEMs to be interested to make new, alternative powertrain versions. The short range of single-unit trucks may make them good candidates for electrification.

These and the other findings from the segmentation analysis will be combined with the fuel and emissions analysis in FY19 to determine where alternative powertrains have the potential be the most efficacious.

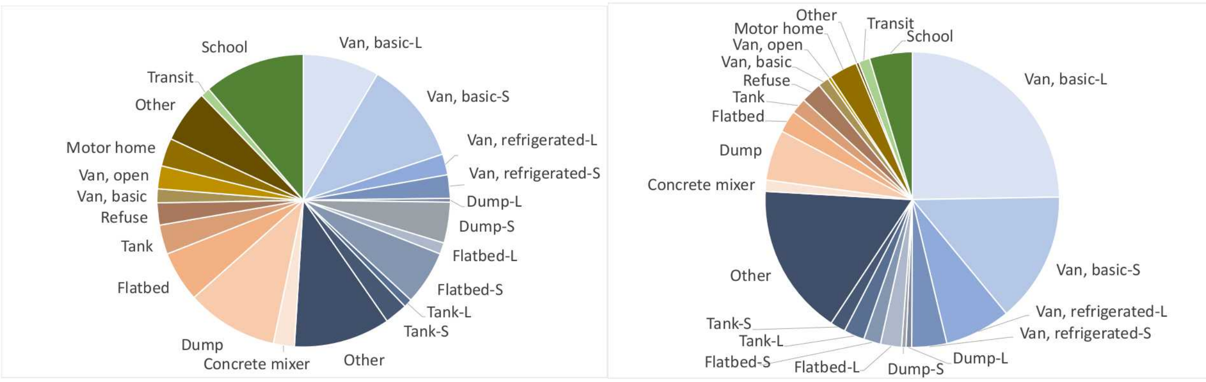

Figure 7. Pie charts of HDV fleet by vehicle count represented as a percentage of total fleet (left-hand plot) and by VMT as a percentage of total fleet miles (right-hand plot). The “-L” and “-S” suffixes indicate long- or short-haulers, respectively. Truck-tractor segments are shown in blue-gray, single-unit trucks in orange, and buses in green. Segmentation of HDV fleet by total fuel consumption is similar to the VMT segmentation.

Conclusions

ParaChoice is a validated, system-level model of the dynamics existing among vehicles, fuels, and infrastructure. It leverages other DOE models and inputs to simulate fuel production pathways that scale with demand from vehicles. It is designed for parametric analysis in order to understand and mitigate uncertainty introduced by data sources and assumptions. Native parametric capabilities are also useful for identifying trade spaces, tipping points and sensitivities. ParaChoice is not simply a tool for creating scenario sales projections; its results help analysts understand relationships among the LDV and HDV stocks, fuel use, and emissions.

Key Publications

Levinson, R.S. and West, T.H. (2018). “Impact of convenient away-from-home charging infrastructure,” *Transportation Research Part D,* 65, 288-299.

References

(1) R. Polk and Co., U.S. Vehicle Registration Data MY 2005-2016, Jan. 2015. Compiled by SRA International, Inc.

(2) U.S. Department of Transportation Federal Transit Administration 2011 Annual Vehicle Inventory; https://www.transit.dot.gov/ntd/data-product/2011-annual-database-revenue-vehicle-inventory

(3) Federal Highway Administration Highway Statistics Series for bus registrations; https://www.fhwa.dot.gov/policyinformation/statistics/2011/mv10.cfm

(4) U.S. Census Bureau Vehicle Inventory and Use Survey (VIUS), 2002; https://www.census.gov/library/publications/2002/econ/census/vehicle-inventory-and-use-survey.html

(5) U.S. Department of Energy’s Alternative Fuels Data Center; https://www.afdc.energy.gov/data/10309

(6) 2009 National Household Travel Survey (NHTS); https://nhts.ornl.gov/tables09/fatcat/2009/avmtvs_VEHAGE_VEHTYPE.html

(7) These approximations come from the North American Council for Freight Efficiency 2016 Annual Fleet Fuel Study. https://nacfe.org/wp-content/uploads/2018/01/NACFE-2016-Annual-Fleet-Fuel-Study-FINAL-Report-082316_0.pdf

Acknowledgements