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NATIONAL RENEWABLE ENERGY LABORATORY

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Statistical Characterization of Medium-Duty Electric Vehicle Drive Cycles

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BACKGROUND

With funding from the U.S. Department of Energy's Vehicle Technologies Office, the National Renewable Energy Laboratory (NREL) conducts real-world performance evaluations of advanced medium- and heavy-duty fleet vehicles. Evaluation results can help vehicle manufacturers fine-tune their designs and assist fleet managers in selecting fuel-efficient, low-emission vehicles that meet their economic and operational goals.

In 2011, NREL launched a large-scale performance evaluation of medium-duty electric vehicles. With support from vehicle manufacturers Smith and Navistar, NREL research focused on characterizing vehicle operation and drive cycles for electric delivery vehicles operating in commercial service across the nation.

Participating companies tapped into American Recovery and Reinvestment Act funding to cover part of the purchase cost of the new vehicles. These vehicle deployment efforts are designed to help commercialize electric vehicles and the electric charging infrastructure.

TEST VEHICLE SPECIFICATIONS

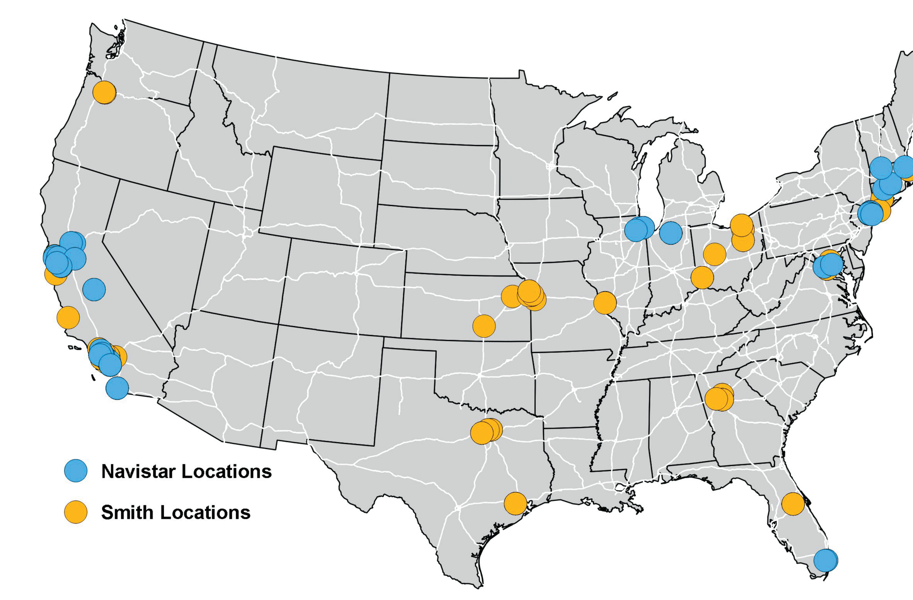
Smith Newton	
Weight Class	Classes 4–6
Gross Vehicle Weight Rating	9,980–11,793 kg
Payload	5,590–7,348 kg
Battery Capacity	80 kWh
Motor Power	134 kW
Top Speed	80.5 km/h
Advertised Range	Up to 160 km
Total Distance	4,529,790 km
Number of Vehicles	200

Photo from Smith, NREL 22851

Navistar eStar	
Weight Class	Class 3
Gross Vehicle Weight Rating	5,488 kg
Payload	2,313 kg
Battery Capacity	80 kWh
Motor Power	70 kW
Top Speed	80.5 km/h
Advertised Range	Up to 160 km
Total Distance	558,987 km
Number of Vehicles	101

Photo from Navistar, NREL 18624

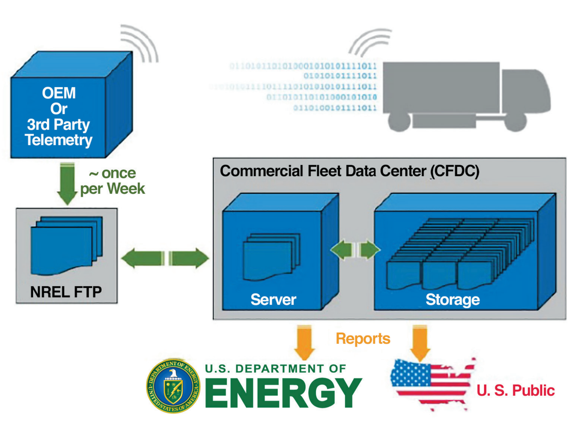
CHARGING LOCATIONS



This map shows the charging locations—which range in population density and climate—for the vehicles under study. There are 35 charging locations for the Navistar vehicles and 81 for the Smith vehicles.

DATA COLLECTION, ANALYSIS, AND REPORTING

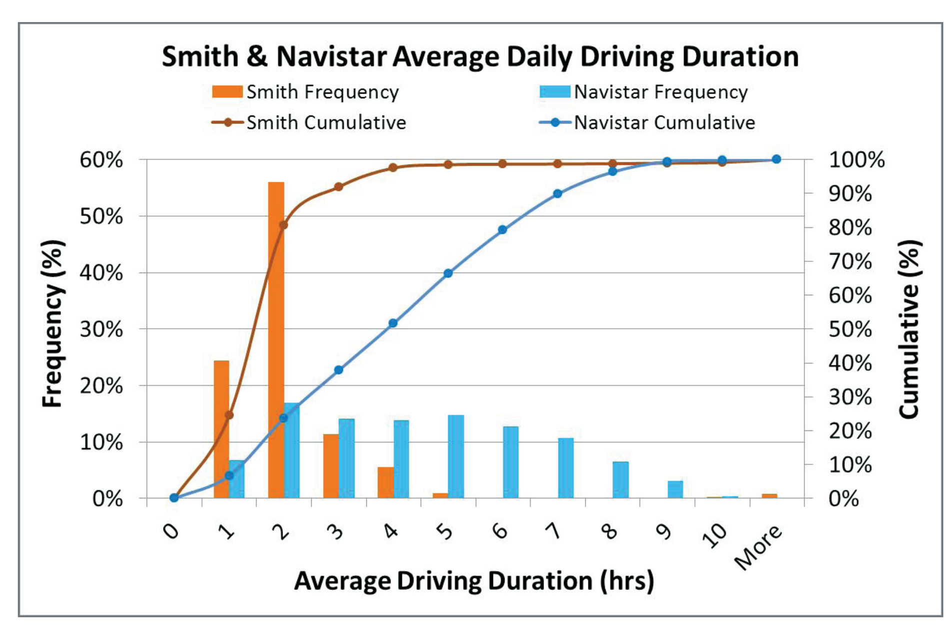
Data collected via onboard logging devices are transmitted wirelessly to the original equipment manufacturer (OEM) and then transferred via a secure file transfer protocol (FTP) site to NREL's Commercial Fleet Data Center for processing and storage.

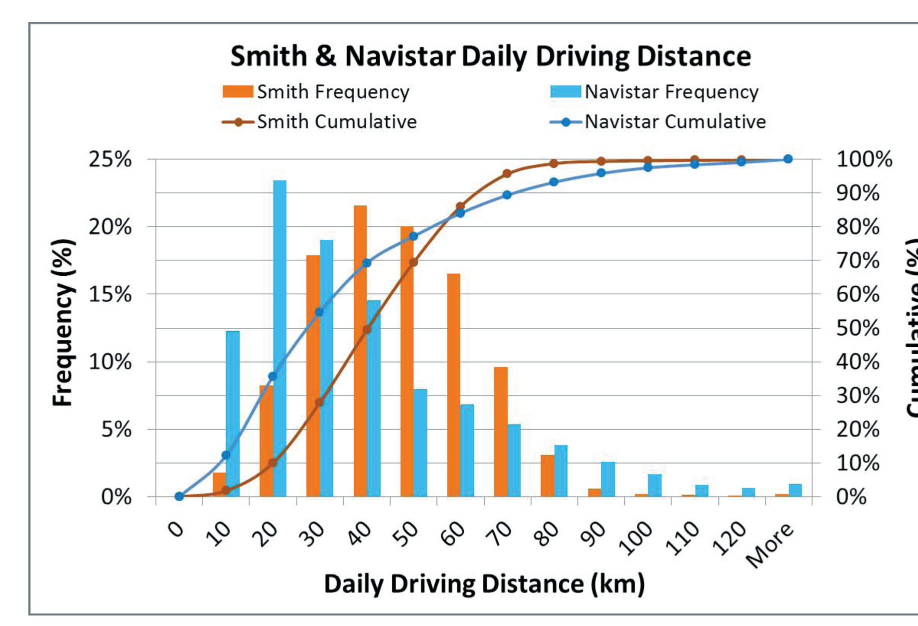


NREL's data analysis results are published in technical reports, conference papers, and online at *www.nrel.gov/transportation/fleettest.html*. The data from the project are stored in the Fleet DNA clearinghouse at *www.nrel.gov/fleetdna*, allowing for comparison of vehicle performance across platforms, vocations, and projects.

DRIVING DURATION AND DISTANCE

Although the average daily driving duration of the Navistar vehicles (4 hours) is more than double that of the Smith vehicles (1.6 hours), both drive only a small portion of the time they are away from the depot due to the nature of their delivery routes.



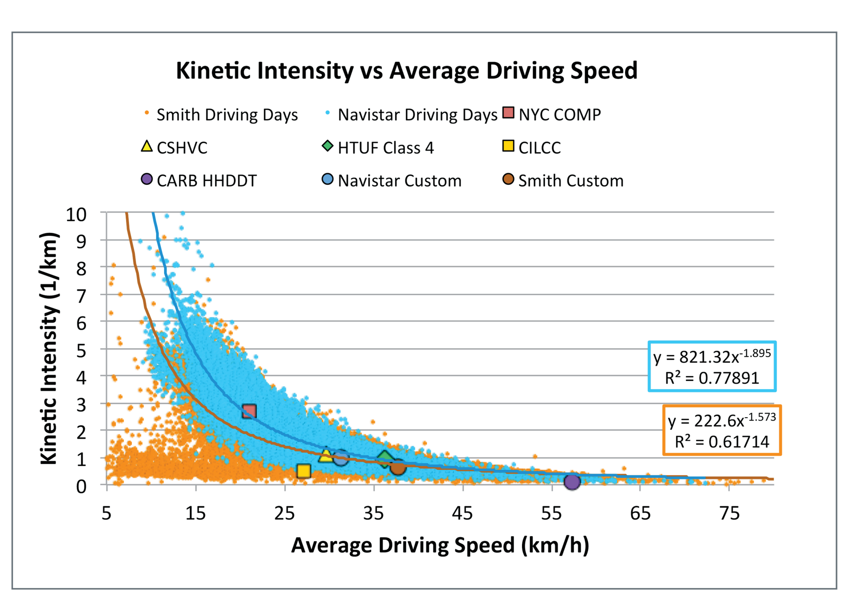


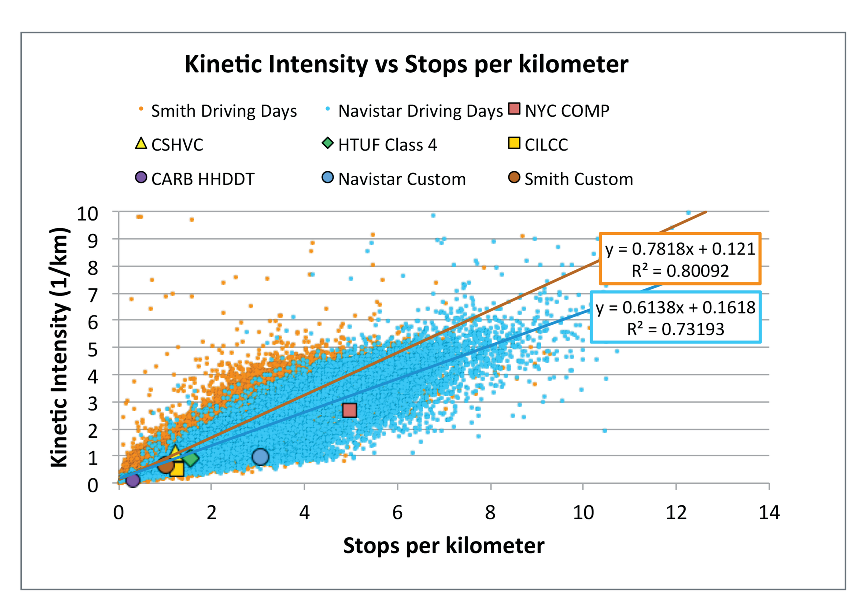
The advertised driving range of the Navistar and Smith vehicles is 80 km; with an average daily driving distance of 34.9 km for the Navistar vehicles and 41.3 km for the Smith vehicles. This disparity suggests opportunities to reduce costs by downsizing the batteries or by delaying or staggering charging times to minimize peak-demand charges. Alternatively, this finding suggests the potential for increased utilization of the vehicles as owners and operators become more familiar with the new technology.

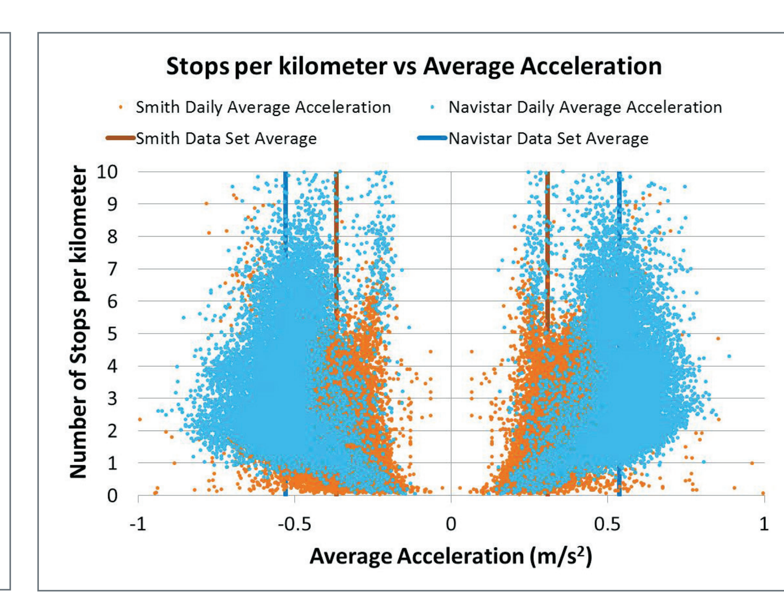
CHARACTERIZING DRIVE CYCLES

For a given average speed, the kinetic intensity is consistently greater for the Navistar vehicles than for the Smith vehicles, indicating a more aggressive drive cycle. Both vehicle types also show a strong correlation between kinetic intensity and average driving speed, which suggests that average driving speed is a strong indicator of the drive cycle's aggressiveness across the range of vocational applications.

For a given kinetic intensity, the Navistar vehicles on average stop more often than the Smith vehicles. Both vehicle types also show a strong correlation between kinetic intensity and stops per kilometer, which suggests that the number of stops per kilometer is a strong indicator of the drive cycle's aggressiveness.







Further examining the relationship between acceleration rates and the number of stops per kilometer, the lighter Navistar vehicles on average exhibit greater acceleration and deceleration rates than the Smith vehicles.

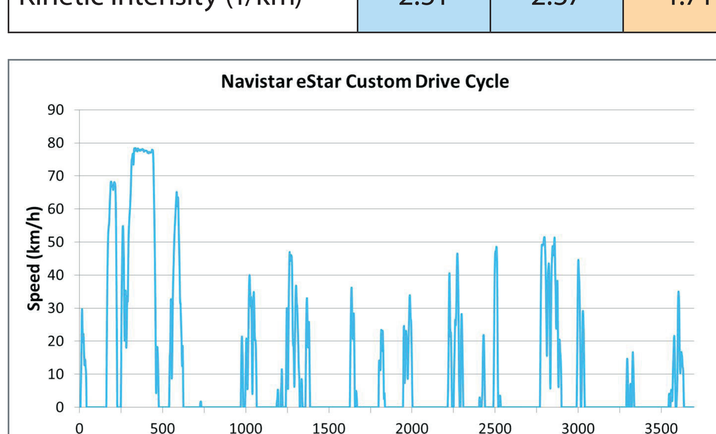
STANDARD AND CUSTOM DRIVE CYCLES

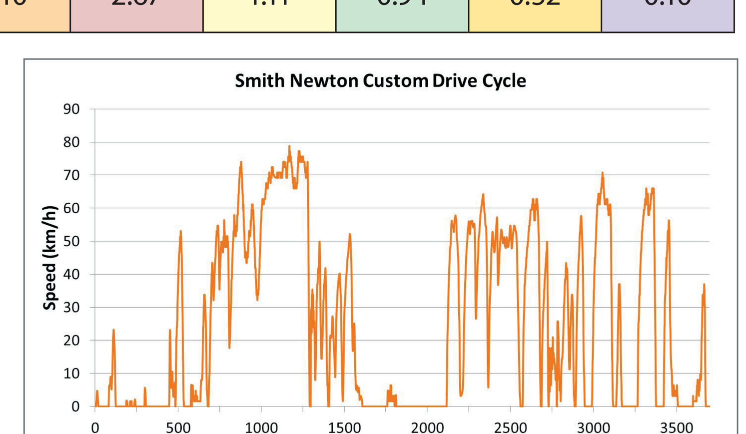
NREL used its Drive-Cycle Rapid Investigation, Visualization, and Evaluation (DRIVE) analysis tool to generate custom drive cycles based on the aggregated in-use data. Additionally, the tool was used to identify standard chassis test cycles that matched the range of observed vehicle operation.

As listed in the table, the custom drive cycle statistics show a strong correlation to the average values.

These statistics can be used to better quantify and understand the typical performance characteristics of medium-duty electric vehicles that operate in commercial service.

Metric	Navistar eStar		Smith Newton		NYC COMP	CSHVC	HTUF Class 4	CILCC	CARB HHDDT
	Custom	Average	Custom	Average					
Maximum Driving Speed (km/h)	78.4	68.9	78.9	82.5	57.94	70.49	91.08	88.51	95.43
Average Driving Speed (km/h)	31.3	25.1	36.3	34.8	21.10	29.68	36.19	27.13	57.27
Standard Deviation of Speed (km/h)	19.7	15.5	25.3	19.9	15.23	21.02	22.40	19.98	39.40
Stops per km	3.04	3.60	1.00	1.26	4.96	1.21	1.56	1.26	0.31
Characteristic Acceleration (m/s²)	0.22	0.23	0.15	0.13	0.23	0.17	0.17	0.09	0.05
Aerodynamic Speed (m/s)	14.99	11.16	15.05	11.95	9.27	12.39	13.57	12.83	22.67
Kinetic Intensity (1/km)	2.51	2.37	1.71	1.10	2.67	1.11	0.94	0.52	0.10





SUMMARY

This evaluation identified typical driving patterns and drive cycles for two types of medium-duty electric vehicles that operate in commercial service across the nation. Results indicate that the vehicles under study are used on highly aggressive urban delivery routes with frequent stops per kilometer and low average driving speeds. Such routes are ideal for electric vehicles because they take advantage of the vehicles' regenerative braking functionality and the high energy efficiency of electric motors at low speed.

The study also revealed opportunities to increase the use of electric vehicles and to optimize battery pack size based on real-world usage patterns.

The data collected as part of this study in conjunction with the Fleet DNA database of commercial fleet vehicle operating data provide researchers with the opportunity to accurately quantify and compare the operational characteristics of Smith and Navistar electric vehicles.

FUTURE WORK

While NREL's analysis provides a statistical characterization of medium-duty electric vehicle drive cycles, further research is needed to better understand the long-term benefits of operating such vehicles under varying conditions. Additionally, the study's extensive drive cycle data can be used to further explore real-world operation through testing, modeling, and simulation activities.

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