A METHODOLOGY TO EVALUATE THE LOGISTICAL COMPETITIVENESS OF ELECTRIC TRUCKS IN THE LTL DELIVERY INDUSTRY

Brian A. Davis
Portland State University
Email: bdavis@pdx.edu

Miguel A. Figliozzi*
Portland State University
Email: figliozzi@pdx.edu
*Corresponding Author

Short Abstract

This paper examines the new generation of electric delivery trucks that has begun to enter the marketplace in mid-2010.The implications of routing constraints, route parameters, and electric truck characteristics are analyzed integrating three models: (a) a vehicle ownership cost minimization model, (b) a model to calculate the power consumption and maximum potential range of an electric or conventional truck as a function of velocity and weight, and (c) a continuous approximation model to estimate fleet size, distance traveled, and ensure that practical routing constraints are satisfied. The model is applied to the study the competitiveness of three vehicles of similar weight and size: a widely available conventional diesel truck and two electric trucks. Scenarios and breakeven points are calculated and analyzed for a large number of parameter combinations. The results provide new insights regarding the truck characteristics and logistical constraints that determine whether a conventional or electrical truck is more cost effective.

Keywords: urban deliveries, commercial electric vehicles, LTL deliveries, vehicle replacement

Modeling

Due to the 1000 word constrained we do not include details of the four parts of the optimization model but we include some illustrative figures and tables.

Real-world speed profiles

An innovative aspect of this research is to feed the optimization model with real-world energy/fuel consumption as well as idealistic uniform speeds; we compare results using both methods. Real world driving conditions of course deviate significantly from the ideal uninform speed conditions.

The well-known MOVES model developed by the US Environmental Protection Agency (2009)gives velocity-time curves for vehicles on several types of facilities (Koupal et al. 2010).These curves are widely available and provide a second-by-second descriptions of speeds for vehicles on several different types of facilities. For medium duty vehicles, the model provides eleven velocity-time curves in total, six of which apply to non-freeway roadways while the remaining five apply to freeways. As an example, **Figure 1** shows the velocity-time curve corresponding to drive schedule #204, which describes a medium truck on a non-freeway with an average speed of 20.8 mph (9.3 m/s).

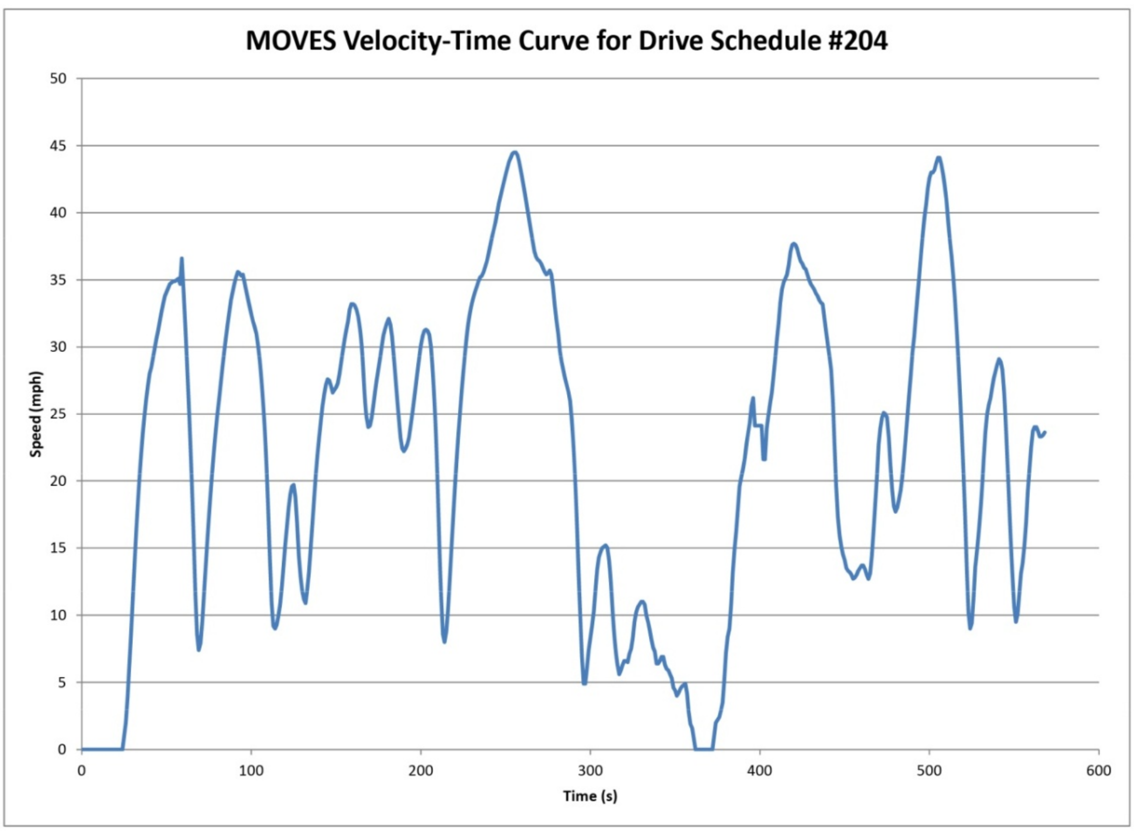

Figure 1: MOVES Drive Schedule #204 Velocity-Time Curve, illustrating a typical speed profile for a 20 mph non-freeway. ***Source:(US EPA 2009)***

The energy consumption is calculated according to the methodology described above, but on a second-by-second described by the time-speed curves given by the MOVES drive cycles.

We do not show the formulas for the sake of brevity but assuming a vehicle weight equal to the tare plus one-half the payload capacity (i.e., the truck is, on average, half full), energy factors can be calculated for each of the MOVES drives schedules. For example, Figure 2 graphs the power consumption of the Navistar E-Star for drive schedule #204, showing the proportions of the total power used for accelerating, and overcoming aerodynamic and rolling resistances, as well as the power returned to the battery via regenerative braking. The area under this curve represents the energy consumed, with each shaded area representing the energy consumed for that purpose (or returned to the battery, in the case of regenerative braking).

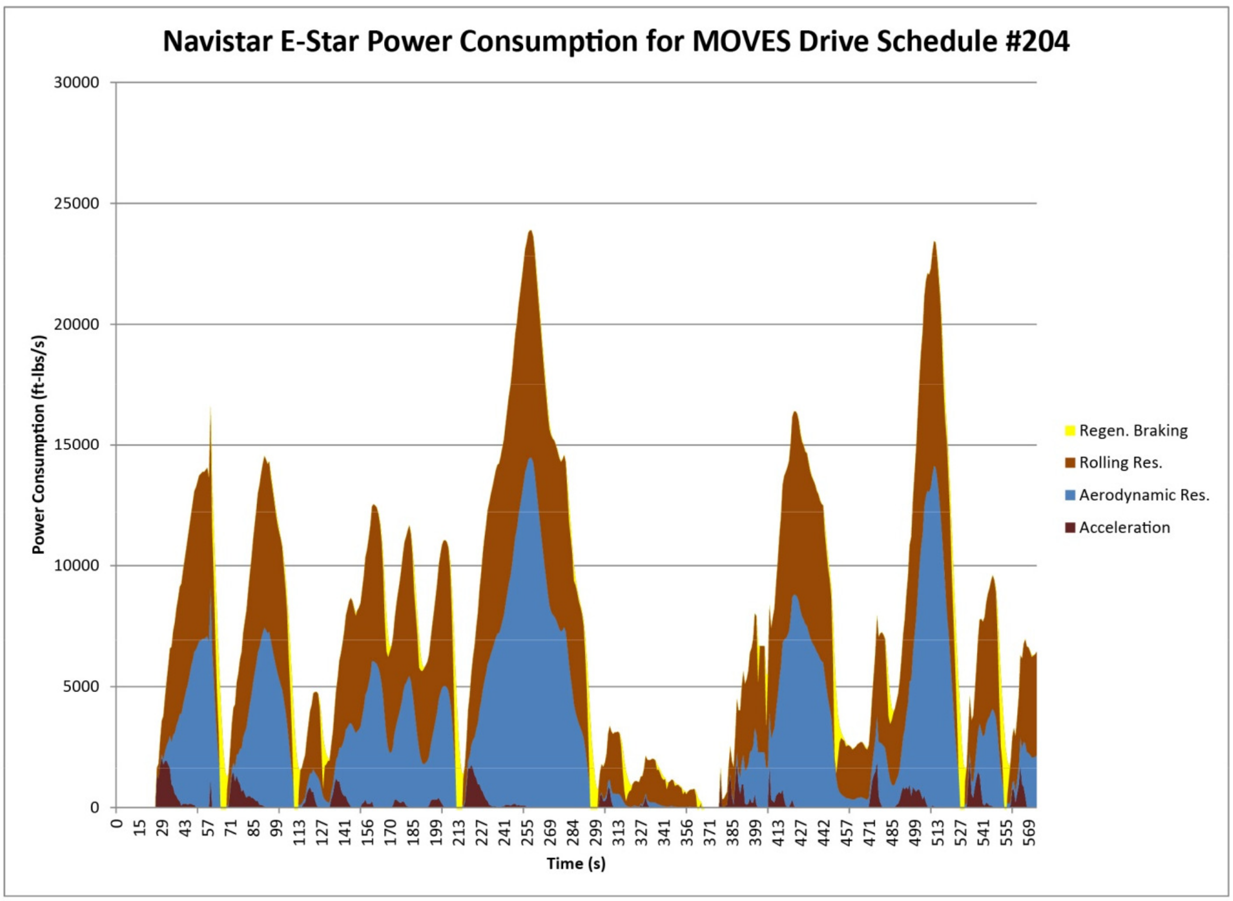

Figure 2: Power consumption of the Navistar E-Star electric truck when navigating MOVES Drive Schedule #204.

To model these effects for the conventional truck, an analogous methodology is applied to obtain a factor that increases fuel consumptions for profiles with a given average speed (a factor >1 with respect to the uniform average speed).

The electric and diesel vehicles not only have different energy consumption profiles but also significantly different cost structures (see Figure 3) which makes the comparison and vehicle selection problem even more interesting and relevant.

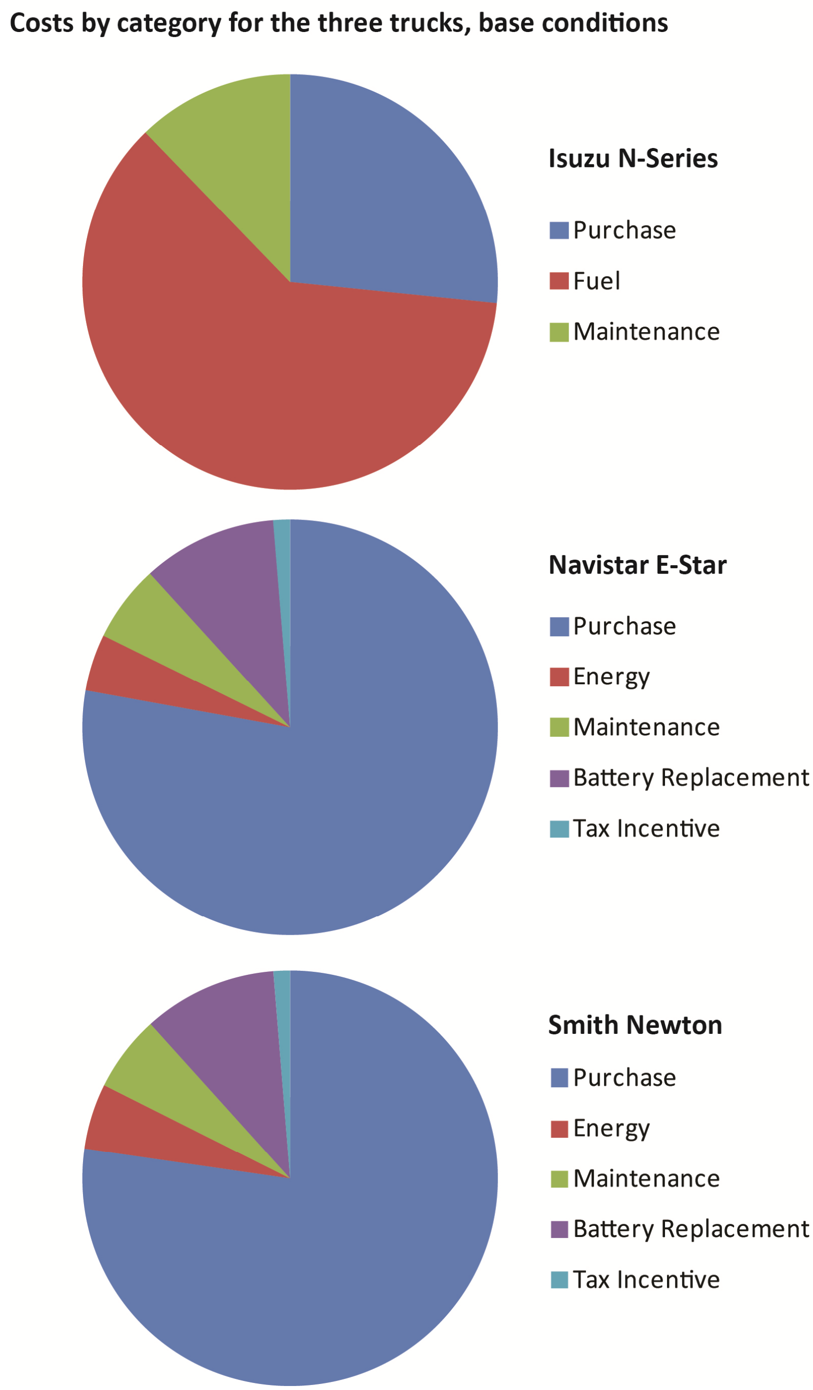

Figure 3: Proportion of total lifetime costs by category for each of the three trucks for the base conditions (medium value parameters)

Breakeven points

For several scenarios (different utilizations, future fuel prices, logistical and route patterns, battery replacement, etc.) we found the best vehicle type and calculate also the different cost elasticities. In addition, for some selected scenarios we found "breakeven points" as shown in Table 1. For example, for the base battery replacement scenario, the N-Series and the E-Star will have the same lifetime costs if the gas mileage of the conventional truck is 7.61 mpg, <u>or</u> the average diesel cost is $4.99 per gallon, <u>or</u> the fuel inflation rate is 6.56%, etc.

Table 1: Breakeven points for three battery replacement scenarios, where parameters are set as shown in Table 5.

		Base MPG	Diesel cost	E-truck purchase cost	Additional tax incentive per truck	Fuel Inflation Rate	CO^2 price per ton
Base Battery Replacement	E-Star	7.61	$4.99	$128,904.87	$21,095.13	6.5%	$68.00
	Newton	7.49	$5.05	$127,524.41	$22,475.59	6.7%	$72.00
No Battery Replacement	E-Star	9.86	$4.11	$149,064.87	$935.13	2.7%	$2.00
	Newton	9.67	$4.17	$147,684.41	$2,315.59	3.0%	$8.00
High Battery Replacement	E-Star	6.83	$5.43	$118,824.87	$31,175.13	8.1%	$100.00
	Newton	6.74	$5.49	$117,444.41	$32,555.59	8.3%	$104.00

Intuitively, it is seen that the breakeven points assuming no battery replacement are much closer to current values than those assuming expensive battery replacement. For instance, while the $5.43 diesel price or $31,175 increase in per-truck tax credit necessary for the E-Star and N-Series to break even is fairly unrealistic, the breakeven points in the scenario that assumes no battery replacement are very close to today's values. Additionally, some combination of, say, a slight rise is fuel cost and a slight decrease in e-truck purchase cost would result in a breakeven point. Therefore, while the e-trucks are currently a more expensive option in most situations, many situations exist where a confluence of rising energy costs and falling technology costs could create an environment where electric trucks prevail in far more scenarios.

Final Comments

This paper presents a logistical planning model to estimate the competitiveness of new generation trucks. This model is easily adaptable to include new trucks as information on them becomes available, or to tailor to the specific needs of particular routes or carriers since it models (a) energy consumption as a function of distance traveled, speed, and route/vehicle characteristics and (b) key logistical planning parameters such as customer density, demand weight, and depot-to-service area distance. In the paper we show the combination(s) of logistical and/or economical factors that are needed to ensure the electric truck competitiveness.