Economic and Operational Impacts of Commercial Trucks on Florida Freeways and Multilane Highways

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Introduction

The PCE values in the Highway Capacity Manual (HCM) used for freeways and multilane highways are based on a study performed in the mid 1990s. Since that time, commercial truck performance technologies have changed. Furthermore, loading conditions are considerably different today given the tremendous growth in freight movement. In addition, the PCE values taken from that study for inclusion in the HCM correspond to just a single "typical" truck (although the study considered multiple categories of trucks), which was found not to be representative of a typical truck in Florida. Also, accounting for just a single truck type may lead to considerable error in LOS results in some situations. Therefore, the objective of this project was to develop truck PCE values appropriate for current commercial truck characteristics on Florida freeways and multilane highways.

Data Used to Obtain Truck Characteristics

The initial step of the data collection procedure was to obtain information on physical and power characteristics for multiple brands (Mack, Peterbilt, Volvo, Kenworth, etc.) of commercial heavy vehicles. In addition, the Florida Department of Transportation provided data from 24 Weigh-in-Motion (WIM) stations that are located on Florida freeways and multilane highways, for years 2008-2010, and part of 2011. Using these data, the project team was able to obtain AADT, truck classification, total truck volume and typical weight loadings for each of the 24 WIM stations per area type (rural, urban) and facility type (freeway, multilane highway). Figure 1 and Table 1 present a revised version of the Federal Highway Administration (FHWA) vehicle classification chart that is specific to the trucks analyzed in this study and the rural freeway yearly truck volume per class, respectively.

Figure 1.Revised FHWA Vehicle Classification (Source: TXDOT)

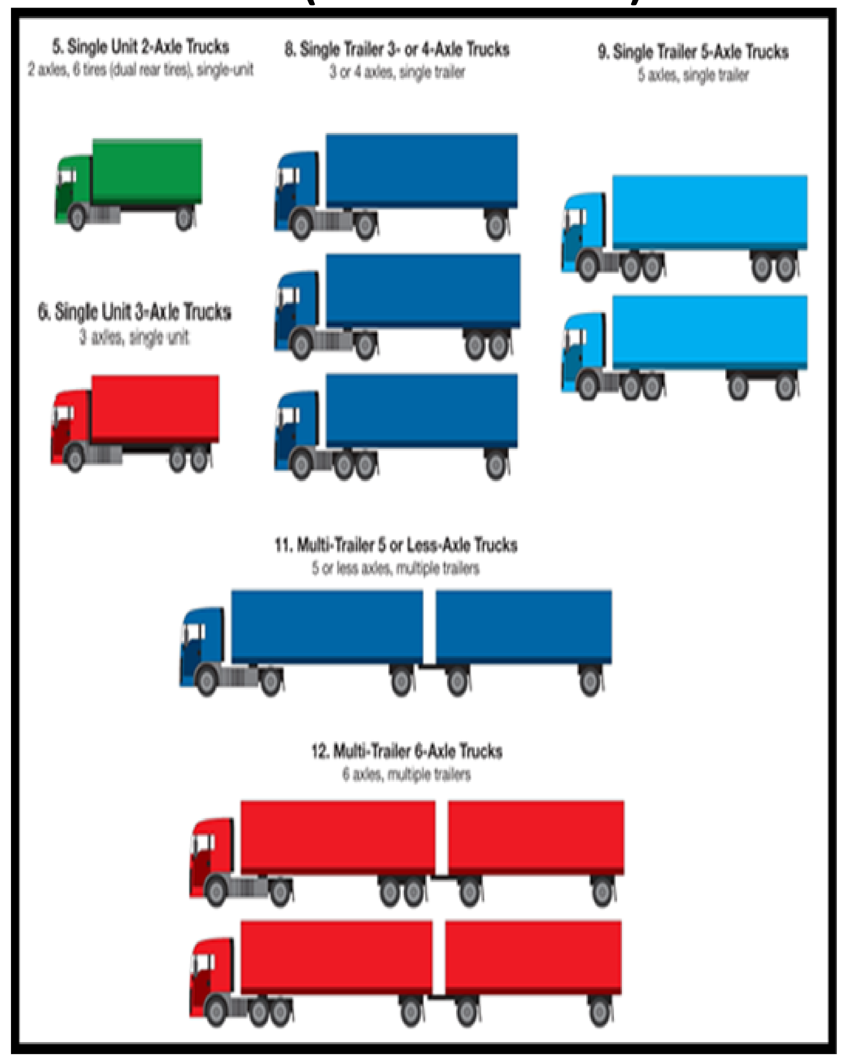


Table 1. Rural Freeway Yearly Truck Volume per Class

Rural Freeway	Total Volume Per Truck Class	% of Truck Volume
5	5122	17.03%
6	791	2.63%
7	45	0.15%
8	2407	8.00%
9	20100	66.83%
10	173	0.57%
11	862	2.87%
12	532	1.77%
13	46	0.15%
TOTAL %		100.00%

Classes 5&6 (SUT), Class 8 (Intermediate Semi-tractor+Trailer), Class 9 (Interstate Semi-tractor +Trailer), and Classes 11&12 (Semi-tractor+Double-trailer) were found to be the most prevalent in the Florida traffic stream. The truck characteristic conditions on Florida freeways and multilane highways are highlighted in Table 2.

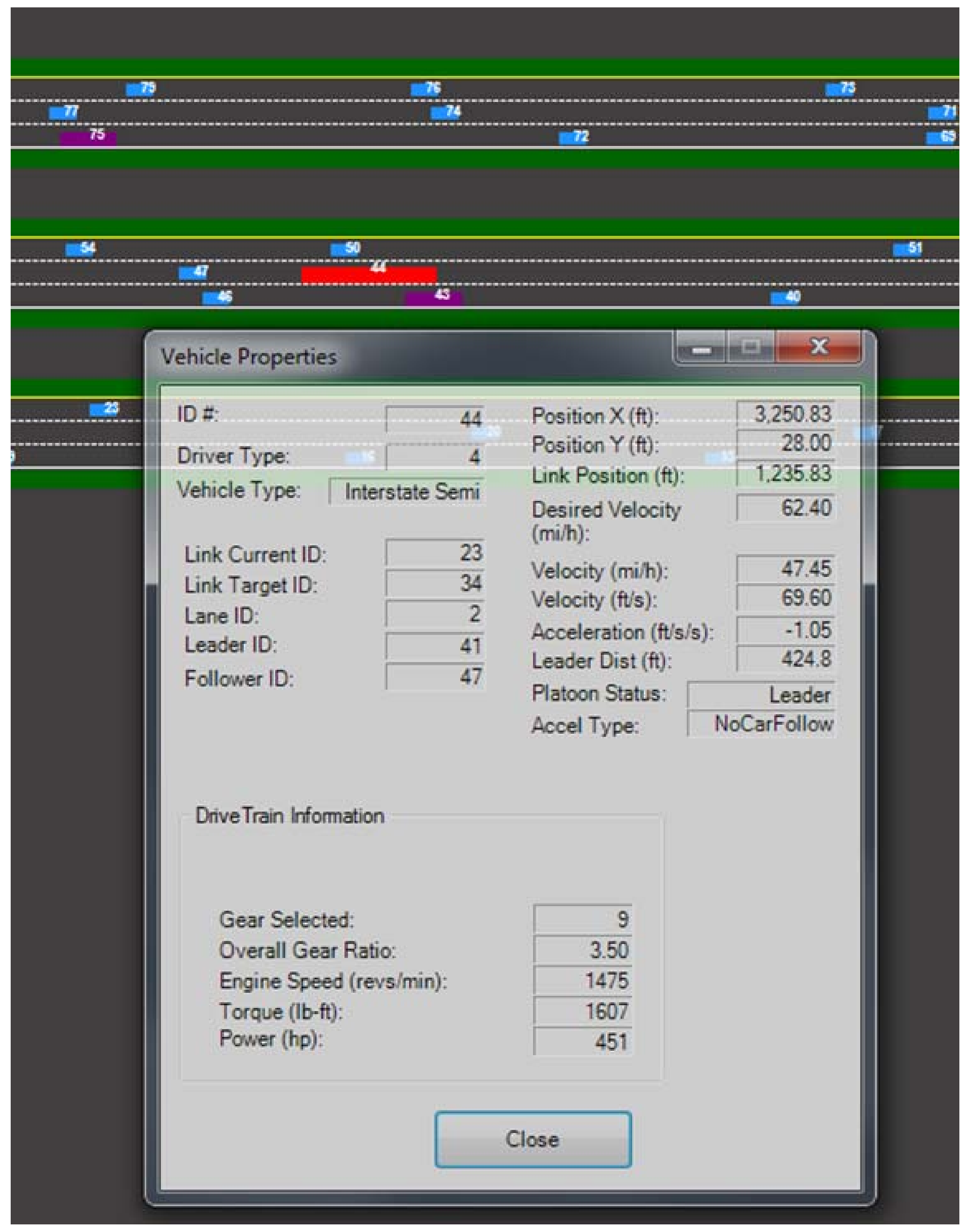
Table 2. Truck Characteristic Conditions

Truck Class	FHWA Class	Average Length (ft)	Average Weight (lb)	Average Horsepower (HP)	Frontal Area (ft^2)	Average Weight/Power Ratio (lb/HP)
Single Unit Truck (Small Truck - ST)	5&6	29	25000	300	80	83.3
Intermediate Semi-tractor+Trailer (Medium Truck - MT)	8	55	37000	485	85	76.3
Interstate Semi-tractor+Trailer (Medium Truck - MT)	9	68.5	53000	485	85	109.3
Semi-tractor+Double-trailer (Large Truck - LT)	11&12	74.6	55000	485	85	113.4

Simulation Platform and New Truck Performance Modeling Methodology

In order to obtain the analysis data, a custom simulation program, referred to as SwashSim, was used. One of the key features of SwashSim is its ability to model individual vehicle characteristics and dynamics in great detail, which was specifically used for this project to model truck characteristics and dynamics to replicate their behavior in the traffic stream. To further mimic the field characteristics, the heavy vehicle acceleration calculation model was built to account for truck gear shifting capabilities. For this effort, the research team calculated gear changing speeds for the passenger car and the four truck types of interest using vehicle dynamics equations. Figure 2 presents a simulation run with the vehicle properties window enabled to depict various properties including selected gear, desired velocity, velocity at current time step, acceleration at current time step, etc.

Figure 2. Custom Simulation Program Window



In order to validate the acceleration values obtained by the truck acceleration calculation methodology, the research team obtained a copy of the TruckSim software program, which provides detailed simulation of individual trucks, based on mathematical models of the truck's powertrain (engine, transmission) and physical characteristics. TruckSim was used to determine the acceleration capabilities of the four truck types on varying grade and its results were compared with the SwashSim acceleration results. These results show that by accounting for the gear changing capabilities of the vehicles into SwashSim, the acceleration performance of trucks modeled in SwashSim match very closely to TruckSim and therefore, the field conditions.

Results

The most suitable calculation approach to develop the Florida truck PCE values were found to be based on flow rate and density. This is due to traffic density being the measure of effectiveness (MOE) for freeways in the current HCM, therefore this calculation approach being the most consistent with the HCM methodology. Table 3 presents the variables used for the experimental design simulation runs.

Table 3. Variables Used for Experimental Design Simulation Runs

Variable	Setting Level
Number of lanes in analysis direction	2-lanes
	3-lanes
Roadway Grade	Level
	3%
	6%
Free-Flow-Speed (mi/h)	55
	65
	75
Segment Length (ft)	1320
	2640
	3960
	5280
HV Percentage	5%
	10%
	15%
	20%

Once the experimental design was executed, which resulted in a total of 311,040 simulation runs, the chosen PCE calculation methodology was applied to determine the PCE values for each specific truck class. From these PCE values, a regression analysis was used to develop equations to estimate the PCE values for each truck type as a function of several explanatory variables. From the analysis, it was determined that there was not much difference in the PCE values between Class 8 and Class 9 trucks. Therefore, it was decided to use three separate truck categories for PCEs. All variables in the PCE models were statistically significant (C.I. 95%) with logical coefficient signs.

$$PCE_{ST} = 0.966 + 0.0000154 \times (\mathrm{Min}(SegLen \times Prop.\ Grade, 300))^2 - 0.000101 \times (\mathrm{Min}(SegLen \times Prop.\ Grade, 300)) + 0.0037 \times \mathrm{Max}(FFS, 66) - 0.0801 \times NumLanes + 1.21 \times Prop.\ Small\ Trucks + 0.0031 \times \mathrm{Max}(Flow\ Rate, 100) \times Prop.\ Small\ Trucks$$

$$PCE_{MT} = 1.095 + 0.0000165 \times (\mathrm{Min}(SegLen \times Prop.\ Grade, 300))^2 - 0.000105 \times (\mathrm{Min}(SegLen \times Prop.\ Grade, 300)) + 0.00255 \times \mathrm{Max}(FFS, 66) - 0.07774 \times NumLanes + 2.148 \times Prop.\ Medium\ Trucks + 0.00244 \times \mathrm{Max}(Flow\ Rate, 100) \times Prop.\ Medium\ Trucks$$

$$PCE_{LT} = 1.246 + 0.0000171 \times (\mathrm{Min}(SegLen \times Prop.\ Grade, 300))^2 - 0.0000335 \times (\mathrm{Min}(SegLen \times Prop.\ Grade, 300)) + 0.00264 \times \mathrm{Max}(FFS, 66) - 0.10316 \times NumLanes + 1.98 \times Prop.\ Large\ Trucks + 0.00401 \times \mathrm{Max}(Flow\ Rate, 100) \times Prop.\ Large\ Trucks$$

where

SegLen	=	Segment/Link length in ft.
Prop. Grade	=	Proportion of grade (i.e., % grade/100)
FFS	=	Free-flow-speed in ft/s
NumLanes	=	Number of lanes in analysis direction
Prop. Small Trucks	=	Proportion of single unit trucks in traffic stream (i.e., % ST/100)
Prop. Medium Trucks	=	Proportion of medium trucks in traffic stream (i.e., % MT/100)
Prop. Large Trucks	=	Proportion of large trucks in traffic stream (i.e., % LT/100)
Flow rate	=	Measured volume in veh/h/ln

Conclusions

- The new PCE values calculated are generally lower than the HCM 2010 values, therefore the use of the HCM PCE values will overestimate the impact of trucks on traffic operations.
- This can lead to the estimation of a worse-than-observed freight bottleneck phenomenon, which negatively affects economic competitiveness due to its impact on travel time reliability.