

An Innovative Approach to Truck Modeling

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Increasing truck traffic is becoming a major issue facing planners in many areas and the issue is only expected to grow in the future. The Federal Highway Administration's (FHWA) freight analysis framework forecasts that freight tonnage and truck VMT will double in the next twenty years. Traditionally, truck modeling has received very few resources due to the perceived high cost and low benefit of developing truck models. The traditional approach to creating a truck model has been to conduct a survey on truck movements to use to develop a model of truck trip rates, distribution patterns, and routes. This approach is generally too costly, however, due to the difficulty and high expense inherent in conducting a statistically valid truck survey. Consequently, the truck components of regional travel demand models have generally not been updated regularly. This has generally not been considered to be a problem; however, since truck traffic has been viewed as comprising a very low percentage of overall traffic. With truck traffic routinely now accounting for over 10% of all traffic on major roadways and using an even larger share of available road capacity, planners can no longer ignore the need to more accurately model truck traffic. The increased need for precision in air quality conformity modeling has also created a similar need. As a result, to meet these needs, an innovative, faster, less costly approach to developing a truck model has been developed using an approach called "adaptable assignment."

Adaptable assignment is a practical method of working backwards from count data to develop a model. This approach was used to develop new truck models for the Baltimore Metropolitan Council (BMC). The BMC maintains the regional travel demand model used for regional modeling for the Baltimore Region as shown in Figure 1. The BMC model is a traditional 4-step model within the framework of the TP+/VIPER software. Truck models were developed for two trip purposes: medium trucks and heavy trucks. Medium trucks were defined as vehicles with 2 axles and 6 tires (F5 in the FHWA classification scheme) and heavy trucks were defined as vehicles with 3+ axles (F4 and F6-F13) as shown in Figure 2. Detailed classification count data was available at over 600 locations throughout the BMC modeled network for the model's base year of 2000. Medium and heavy truck trip tables were synthesized from this count data for comparison with model truck trip tables.

The existing BMC truck models were developed in 1964-65 from survey data collected during the Baltimore Region Transportation Study of 1959-62. A review of these models found them to be unsuitable as a starting point. As a result, the Phoenix Truck Model from the FHWA Quick Freight Response Manual was chosen as a starting point. Adjustments to the Phoenix model were made using parameters from other urban areas to create initial models. This initial trip tables were modified by the adaptable assignment process, to produce new tables whose

Figure 1: Map of Baltimore Region

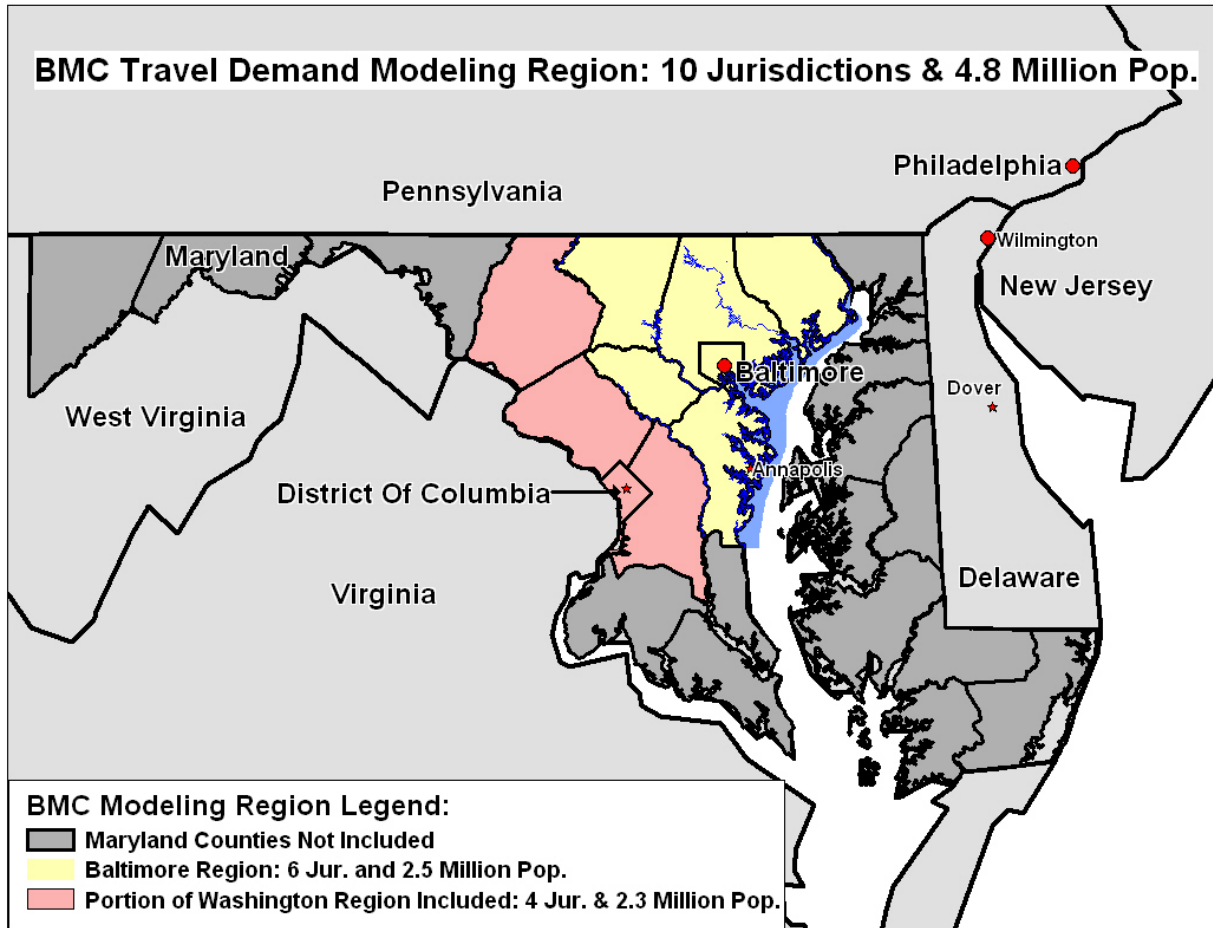


Figure 2: Truck Definitions

Heavy Truck: 3+ Axles



Medium Trucks: 2 Axles and 6 Tires (Box/Panel Trucks)



assignment much more closely matched the classified count data. The new models were based on retail, industrial, and office employment and households. The resulting trip table was systematically compared to the initial table to understand the differences. Several improvements to the initial models were then made to better reflect those differences:

1. Truck Special Generators
2. Truck Prohibitions
3. Truck Passenger Car Equivalents
4. Sensitivity for Land Use
5. Sensitivity for Jurisdiction
6. Improved method for estimating External Truck Trips

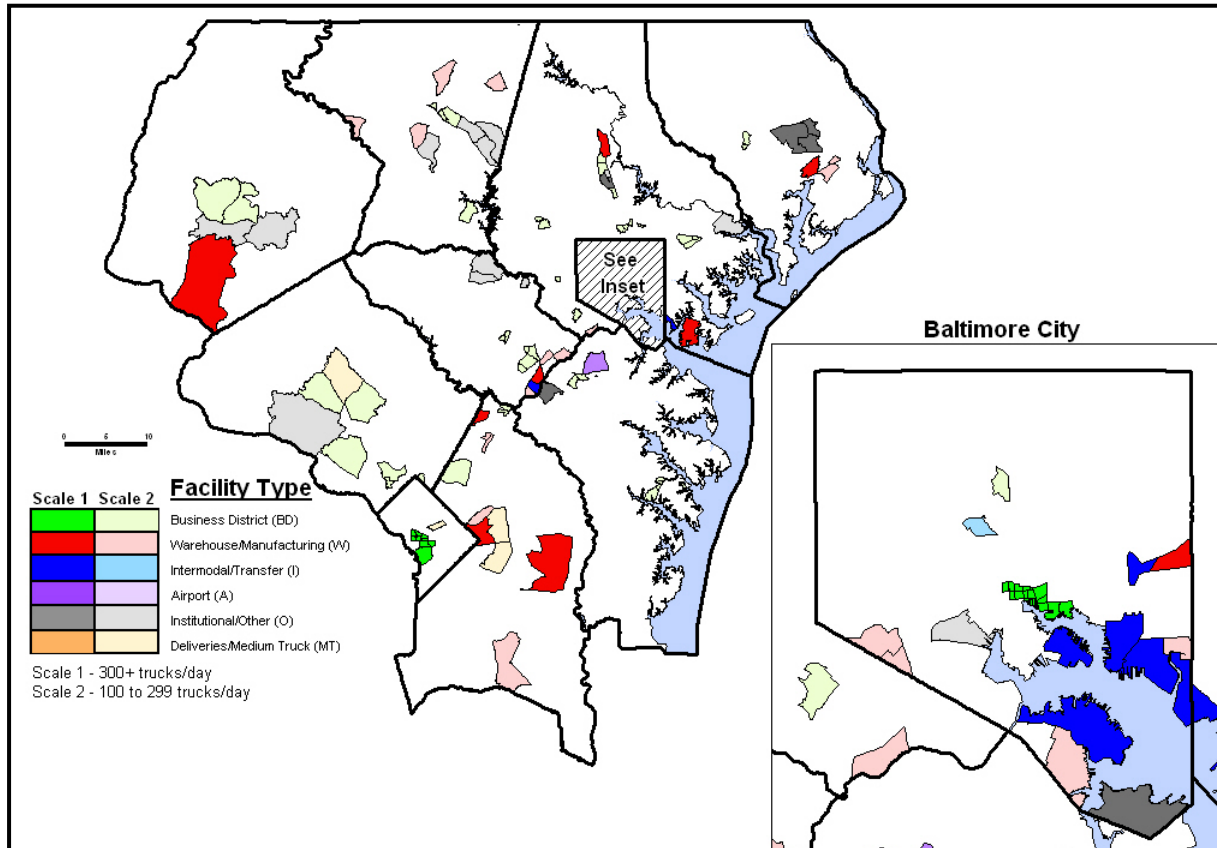
The truck special generators were added to address the problem of under simulation in areas of high truck activity. A total of 127 Transportation Analysis Zones (TAZs) were selected from the modeling region's 1,463 TAZs. The selection process was based on input from both Modeling/Technical and Freight/Policy staff and committees. This partnership proved invaluable to identifying potential truck special generators as it took advantage of the experience and expertise of both types of staff and committees. The truck special generator zones were categorized according to six different types and two different scales as shown in Table 1. Business district covered the CBD areas of cities and large suburban town centers and malls. Warehouse/Manufacturing were generally industrial parks and large warehouse areas associated with trucking. Intermodal/Transfer accounted for facilities where goods moved to/from truck including port terminals. Airport accounted for public airports with significant truck activity. Baltimore-Washington International Airport was the only such airport in the BMC model. Institutional/Other was a miscellaneous category to account for quarries and landfills which had significant trucking activity. Delivery/Medium Truck was used for zones with high levels of medium truck activity, e.g., FedEx facility, but little heavy truck activity. The two scales of large and small were used to indicate size. A threshold of 300 trucks per day was used to separate large from small zones for every category other than business district.

Table 1: Description of Truck Zone Categories

Truck TAZ Type	Scale (Trucks/Day)	
	Large	Small
Business District (BD): central business districts, major retail areas/large malls, colleges	Baltimore DC	Annapolis Columbia Towson
Warehouse/Manufacturing (W): warehouse, manufacturing, & processing facilities, industrial parks	300+	100-299
Intermodal/Transfer (I): facilities where freight transfers from truck to another mode	300+	100-299
Airport (A):	300+	100-299
Institutional/Other (O): quarries, landfills	300+	100-299
Delivery/Medium Truck (MT): facilities that process mail or primarily generate medium truck activity	300+	100-299

Figure 3 shows a map of the truck special generator zones. Although there was a concentration of truck zones in the Baltimore and Washington CBDs and around the Port of Baltimore, many of the zones were dispersed along freeways and major highways in outlying areas.

Figure 3: Map of Truck Special Generators



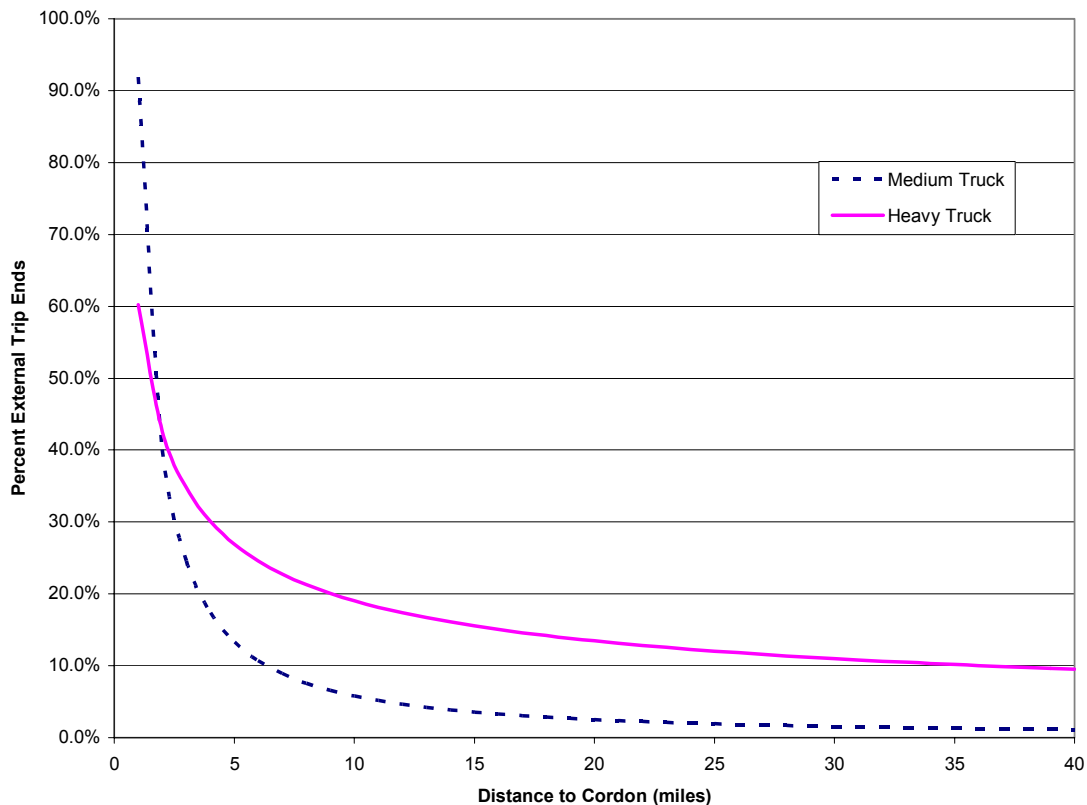
Truck prohibitions were placed on roadways with daily prohibitions only. Passenger car equivalencies (PCE) were added to better account for the extra capacity trucks use. After considerable research of potential PCEs, a decision was made to use the PCEs from the 2000 Highway Capacity Manual of one heavy truck equals 2.0 cars and one medium truck equals 1.5 cars. Sensitivity to the BMC model's 4 land use density codes: CBD, Urban, Suburban, and Rural and for each of the model's 10 jurisdictions was also added.

Lastly, an improved method of estimating external trips was developed. The old BMC model had grouped all external trips together for each of the model's 42 external stations. The new method separates external station trips into 4 categories: personal use automobiles, heavy trucks, medium trucks, and commercial vehicles. The external trip model assumes that the generation model estimates total trip ends. The external share of the total trip ends is modeled as a function of the zone's distance to the model's cordon, along the highway network. The external share model is shown in Figure 4, the equation of which is: Percent External (HT) = $0.602 * D^{-0.5}$ and Percent External (MT) = $0.919 * D^{-1.2}$ where D is the distance to the nearest external station in miles. The external trip ends at the internal zones are balanced to match the total external trip

ends at the external stations. Thus, the cordon volumes are preserved. At the external stations, both Heavy and Medium truck trips were split into external vs. through (X/X), based on 2000 total weekday volumes posted on the network and a total X/X trip table provided by BMC. First, the percentage of total X/X trips by station was determined, using a look-up table to estimate the external trip share (= 100% - through trip share) for each station.

For X/X trip patterns, external stations where X/X Heavy and Medium truck trips should be expected were examined. By making assumptions about likely X/X patterns, an “X/X pattern file” was developed. This was used to create a seed matrix, which was then Frated to match the estimated number of daily X/X Heavy and Medium truck trip ends at each station. The final X/X 2000 daily total for Heavy Truck is 7,730 and for Medium Truck is 1,831. These volumes are not significant in the context of the entire model, but are important for analyses that focus on the major regional roadways.

Figure 4: Truck External Share Model



Once the improvements to the initial truck models were complete, medium and heavy truck trip tables were estimated from the new models and compared to the observed truck trip tables developed from the counts. The adaptable assignment process was then used to systematically adjust the coefficients of the new truck models to better match the observed trip tables derived from the counts in an iterative process. Ten iterations of adaptable assignment were used for both the medium and heavy truck models. A calibration adjustment table called the delta table was developed to account for differences between the observed and estimated trip tables. Ideally, the delta table should be as small as possible. Tests were performed to ensure that no variables or

other changes could be made to better account for the differences between the observed and estimated tables. The final new medium and heavy truck models are shown in table 2.

Table 2: Final Medium and Heavy Truck Models

$$MT = 0.70 * (0.178 * INDEMP + 0.177 * RETEMP + 0.048 * OFFEMP + 0.069 * HH)$$

$$HT = 0.90 * (0.199 * INDEMP + 0.141 * RETEMP + 0.029 * OFFEMP + 0.068 * HH)$$

Special Generator TAZ Factors:

Type	Scale		Small	
	Large	HT	MT	HT
Business District	1.3	1.1	1.2	1.3
Warehouse/Mfgr.	1.0	1.9	1.0	1.8
Intermodal Transfer	1.0	3.8	1.0	3.0
Airport	1.0	1.0	1.0	1.0
Institutional/Other	1.0	2.7	1.0	1.4
Delivery/Medium Truck	1.3	2.0	1.0	1.6

Factor for density code:

Type	MT	HT
Rural	1.4	0.8
Suburban	0.9	0.9
Urban	0.8	1.0
City Center	0.8	0.5

Factor for jurisdiction:

Type	MT	HT
Baltimore City	1.1	1.2
Anne Arundel	1.2	1.2
Baltimore County	1.3	1.2
Carroll	1.3	1.1
Harford	1.5	1.7
Howard	1.2	1.2
D.C.	0.7	0.4
Montgomery	1.0	0.7
Prince George's	1.2	1.0
Frederick	0.6	0.6

The new truck models produced very different results from the old truck models as shown in Table 3. The new models had 71% fewer medium trucks and 133% more heavy trucks. Medium trucks declined dramatically for two reasons. First, the old medium truck model included some two axle 4 tire trucks which are now classified as commercial vehicles, a trip purpose which did not exist in the old model. Second, the old medium truck model, which was based on population

and retail employment, had a much higher coefficient on population than retail employment. As a result, medium trucks were being vastly over simulated and concentrated in residential areas. In contrast, the new medium truck model has a lower coefficient on households relative to employment. The new models also showed much greater future growth in truck traffic. Additionally, the accuracy of the new models was greatly superior to the old models as measured by the percent RMS error. The new models had percent RMS errors of 27% for heavy trucks and 24% for medium trucks. The improved assignment for the truck and commercial vehicle purposes contributed toward improving the overall assignment for all vehicles and for personal cars. The assignment for personal cars improved because of the improvements in external station modeling and the elimination of the medium truck over simulation problem in residential areas. Lastly, the new truck models much more closely matched the count volumes by facility type.

Table 3: Differences between New versus Old Truck Models

Measure	Heavy Truck	Medium Truck	Commercial Vehicle	Personal Car	All Vehicles
2000 Vehicle Trip %					
Old	0.9%	7.2%	N/A	91.9%	100.0%
New	2.1%	2.1%	7.0%	88.8%	100.0%
% Growth: 2000-2025					
Old	25.7%	19.6%	N/A	22.0%	21.9%
New	41.1%	22.1%	33.3%	22.6%	23.8%
% RMSE					
Old	394%	138%	N/A	45%	43%
New	27%	24%	13%	36%	34%

Facility Type	Heavy Truck Traffic Percentages			Medium Truck Traffic Percentages		
	Count	New Model	Old Model	Count	New Model	Old Model
Freeway	6.8	7.1	2.4	3.1	2.9	11.4
Arterials	3.9	4.0	1.2	2.6	2.5	8.2
Collectors	4.7	5.1	0.9	3.0	3.0	7.5
All Roads	5.8	6.0	2.0	2.9	2.7	10.6

Table 4 compares the adaptable assignment method for developing a truck model to the traditional survey based approach using the BMC model. The adaptable assignment method cost far less and took much less time than the traditional survey based approach. The first primary work activity involved with adaptable assignment is in obtaining and organizing reliable count data. BMC staff spent several months organizing classified count data, checking for consistency, and linking it to the model network. The second primary work activity was selecting truck special generator TAZs. BMC staff worked with Freight committees and officials over a period of several months and made several site visits to develop a final list of truck TAZ locations. The primary work activity involved with the traditional approach is in designing, conducting, and analyzing truck survey results. A truck survey is a major undertaking because of the difficulty in obtaining reliable survey data from trucking firms.

The primary data obstacles with the adaptable assignment approach are twofold. First, is the issue of maintaining consistency in count data. In the BMC application, there were many inconsistencies between local and state of Maryland count data that could not be resolved and resulted in local counts being discarded. A second issue was the lack of observed average trip length data to compare to model results. The adaptable assignment approach generally results in average trip length being shortened. The average trip length in both the new heavy and medium truck models was less than it had been in the old truck models, but in the absence of observed survey data, there was no way to verify whether or not this was correct. With the traditional survey based approach, the key data obstacle is in obtaining adequate truck survey results. The BMC in conjunction with the Metropolitan Washington Council of Governments conducted an Internal and External Truck Survey in 1995-1996. The survey was unsuccessful because of an extremely low response rate from trucking firms due to privacy concerns. As a result, there was inadequate data from which to calibrate a model. The second problem with the traditional approach is the lack of data at external stations. It is generally cost prohibitive to survey every external station in a modeling region. The BMC model has 42 external stations, but the cost of surveying them all is prohibitive. As a result, only a subset of the most major roadways can be surveyed which results in no data being available for the remaining locations.

Table 4: Adaptable Assignment versus Traditional Survey Based Approach

Criteria	Adaptable Assignment	Traditional Survey Based Approach
Cost	\$42,500	\$500,000-\$1,000,000 Est. \$325,000 in 1995-1996
Time	1 year	2-3 year Est.
Primary Work Activity	Obtaining/Organizing reliable count data Selecting truck special generators	Truck Survey
Data Obstacles	Maintaining consistency in Local/State count data No average truck trip length to compare model results to	Obtaining adequate truck survey results for model development Inadequate survey data at External Stations

In conclusion, the adaptable assignment approach was much faster, cheaper, and better than the traditional survey based approach. The adaptable assignment approach also showed significant improvement over the old model in accuracy and logic. The project also underscored the importance of including both technical and policy staff and committees in the model development process. The expertise and input that both sides offered was critical to the success of the project.

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