Multi Entity Perspective Freight Demand Modeling Technique: Varying Objectives and Outcomes

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ABSTRACT

The importance of freight transportation modeling and forecasting to better address planning and policy issues, ranging from general and long-range planning and project prioritization to modal diversion and economic assessment, is well recognized by policy makers. Compared to advancement in travel demand modeling for passenger travel, however, current freight demand modeling methods are not yet in the adequate levels to assess increasingly complex and important planning and policy issues. Besides firms generating and consuming commodities, the three most important players in freight demand modeling are (a) the shippers, (b) the planners, and (c) policy (decision) makers. The objective of each player is different as it is geared towards attainment of respective objective. Past research is limited in proposing a unified methodology to address the objective of each player and to assess performance of transportation networks under conditions to achieve such objectives.

In this paper, freight demand modeling is designed to address each objective of three players in a multimodal transportation network. A freight transportation model that combines three geographic scales—national, state, and local—is proposed and developed to capture different characteristics of short- and long-distance freight flows subjected to stochastic networks (when network conditions vary by time of day) and uncertain market conditions (when freight demand vary by objective of the player), with a focus on the state-level modeling in Maryland. Data for the model include freight flows by commodity and by Freight Analysis Framework (FAF) zone, which are further disaggregated to Statewide Modeling Zones in Maryland; a transportation network with detailed link level attributes; user costs in addition to all details needed for auto travel demand model. The model is captured in a multi-class user equilibrium traffic assignment. The results demonstrate the network performance and key information on travel characteristics for each player. The proposed tool can be used for freight travel demand modeling for analyzing impacts of policies at state, county and local levels.

Key Words: freight demand modeling, freight analysis framework, multi-class user equilibrium, traffic assignment

1. INTRODUCTION

In recent years, concerns with traffic congestion, energy consumption, and green house gasses are increasingly garnering attentions in US major metropolitan areas. According to Texas Transportation Institute (TTI), commuters in 439 US urban areas are spending extra 4.8 billion hours or 34 hours per driver in each year, and wasting 3.9 billion gallons of fuel due to congestion *(1)*. In addition, $23 billion of the total delay cost ($101 billion) was the adverse effect of congestion on truck operations, not including any value for the goods being transported by the trucks. Since a high level of traffic is an inevitable by-product of a vibrant economy, it is important to cope with high traffic in an effective way in order to make an urban transportation system work efficiently. In particular, as the Transportation Equity Act for the 21st Century (TEA-21) explicitly recognized, freight transportation is vital to economic growth, calling for an increase in accessibility and mobility options and enhancing integration and connectivity of the transportation system for freight transportation as well as for passenger travels *(2-3)*. Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) allocated funding of over $4.6 million per year over three years to improve research, training, and education specifically for freight transportation planning *(4)*.

Transportation modeling and forecasting has an important role to address in planning and policy issues, ranging from general and long-range planning and project prioritization to modal diversion and economic assessment. Compared to significant advancements in travel demand modeling for passenger travel in the last four decades, however, current freight demand modeling methods are not yet in the adequate levels to assess increasingly complex and important planning issues. Relatively slow progress in freight modeling is due to slow progress in behavioral theory and lack of publicly available data *(3)*. In addition, past research is very limited in proposing a unified methodology of freight demand modeling to assess performance of a transportation network, carefully taking into account objectives of three players—1) the shippers, 2) planners, and 3) policy makers. Each of these three players has a different objective that is geared towards attainment of self-centered goals. First, the objective of shippers is to transport goods from an origin to a destination at the lowest travel cost (which consists of travel time, distance, and toll). The objective of planners is to design and manage an effective multimodal transportation system without much capital investment on new infrastructure. The objective of policy makers is to bring revenue-generating economic activities in the area.

In this paper, in order to clearly account for the objectives of the three important players, a freight transportation model is designed and applied to capture different characteristics of short- and long-distance freight flows in a multimodal transportation network, combining three geographic scales—national, state, and local—with a focus on long-distance truck trips in the state-level. These freight flows are modeled in stochastic networks with network conditions that vary by time of day and also in uncertain market conditions in which freight demand can vary by the player's objective. The proposed model is evaluated in terms of Vehicle Miles Travelled (VMT), Vehicle Hours of Travel (VHT), and Congested Lane Miles (CLM) at different levels of geography such as (1) statewide level, (2) facility type level, and (3) corridor level in real world scenarios in Maryland.

This paper is structured as follows. The next section provides a brief literature review of freight demand modeling with a focus on a state-level modeling, followed by sections to describe research objectives, methodology, and data sources. Then details of analysis results and discussion are presented, and the paper concludes with future research agendas.

2. LITERATURE REVIEW

While freight can take long distance trips, a significant portion of freight trips are made in the state level. The 2007 Commodity Flow Survey reported that 33 percent ($3.9 million) of the value and 54 percent (7.1 billion tons) of the weight of all shipments were transported for distances less than 50 miles *(5)*. Nine percent of the value ($1.08million) and 10 percent of the weight (1.288 billion) were shipped between 50 and 100 miles *(6)*. Thus, a development of robust statewide freight transportation models is strongly demanded in the assistance for planning and policy making.

Freight transportation planning includes facility planning, corridor planning, strategic planning, business logistics planning, and economic development *(7)*. It is very important for the planning purpose to develop statewide freight transportation models that can incorporate the two sets of factors: (1) factors that directly influence the demand of commodities (such as macro economic factors and socio-economic demographics), and (2) those that indirectly affect the demand through changing the cost and level-of-service of freight transportation services (such as freight logistics, transportation infrastructure, government policies, and technologies) *(3,8)*.

Since the 1980s, most freight demand models applied in practice have employed an aggregated analysis based on the traditional four-step person travel demand model, which involves the following three major steps: (1) freight generations and attractions by zone, using trip rates by vehicle type and industry classification, (2) distribution of freight trips or volumes to meet demands at trip destinations, and (3) route assignments of origin-destination trips *(3,9)*. Substantial progress was made in a development of *statewide intermodal* management systems, including freight transportation, because of the provisions of ISTEA, 1991 *(10)*.

Forecasting Statewide Freight Toolkit, a report by National Academy of Sciences, suggests that ideally freight planning should be done using Commodity, Origin, Destination, Mode, Route, and Time (CODMRT) steps. Because some freight data are unavailable, an assumption is made to use ad-hoc variables, such as employment, in a number of steps in freight trip generation. Trip distribution is carried out with a gravity model that uses distance and/or time as a travel impedance variable. Freight mode choice and time of day distribution are often ignored. In the final trip assignment stage, trucks are usually the only mode considered *(11)*.

Due to data limitation and modeling difficulty, most freight models focus on truck movements and do not include a mode assignment step *(12)*.

Freight transportation has a number of properties that make it difficult to directly apply passenger demand models *(3)*. Obviously, very different sets of factors influence each model, including commodities transported and various actors involved in the freight transportation process. Given the different industries that generate truck traffic and different commodities transported, the heterogeneity of freight flows is much larger than person travel. Actors outside the trucking industry significantly influence freight transportation. First, freight trips are derived from the demand of shippers to transport goods from one place to another within a certain time limit. Second, transportation planners manage highway systems for a efficient operation without substantial capital investment due to limited highway infrastructure funding. Third, decision makers' policy decisions to bring in economic activities influence freight demand and movement on the roadway system.

The statewide freight planning study New Jersey Department of Transportation took into account different financial perspectives of the private sector (shippers and freight operators in truck, rail, air, and maritime industries) and the public sector (departments of transportation, metropolitan planning organizations, regional port organizations, and municipal, county, state, and federal governments) *(13)*. Behrends et al. (2008) also identified critical players involved in freight planning and defined their possible roles. But neither of the above studies developed a methodology to include objectives of these actors in a travel demand model and quantify the transportation performance measures *(14)*.

Thus, the literature review indicates, in order to examine the network performance and freight travel behavior, there is substantial room for future progress in terms of: 1) connecting different geographic scales—national, state and local—in one freight transportation model, and 2) incorporating different objectives in freight transportation for three main players—users, planners, and policy makers. It should be noted that some scholars are very critical about the application of the four-step model as the model is developed for passenger travel that is inherently different from freight transportation *(15)*. Meyer (2008) suggests that freight modeling requires more than one type of model—microsimulation, econometrics, hybrids—from multiple disciplines (such as regional economics, industrial engineering, civil engineering, urban geography, and business) to capture different aspects of freight transportation, including logistics, supply chain, and network flow *(15)*.

3. RESEARCH OBJECTIVE

The objective of the paper is to examine the network performance and freight travel behavior at national, state and local levels when different goals are considered from the users, planners, and policy makers. The scopes include:

- Methodology of long distance truck travel demand model
- Scenarios on objectives of users, planners, and policy makers
- Application of the methodology in a real world case study

4. METHODOLOGY

This section is organized into four parts. First, a methodology of long distance model is presented. Second, data used in this study are described. Third, the study area and input data are explained. Fourth, details in scenarios that each group of users, planners, and policy makers pursues their own self-centered objective are discussed.

Long-distance truck trips are generated by commodity flow data given by the Federal Highway Administration of the U.S. Department of Transportation in the Freight Analysis Framework (FAF). The FAF3 data contain flows between 130 domestic FAF regions and 8 international FAF regions. The subject case in this paper is state of Maryland, USA. Maryland is subdivided into three FAF regions (Figure 1): the Baltimore region, the surrounding region of Washington DC in Maryland, and the remainder of Maryland. A single FAF region covers the entire state, including Maine, Mississippi or Montana. Flows from and to these large states appears as if everything were produced and consumed in one location in the state's center (or the polygon centroid).

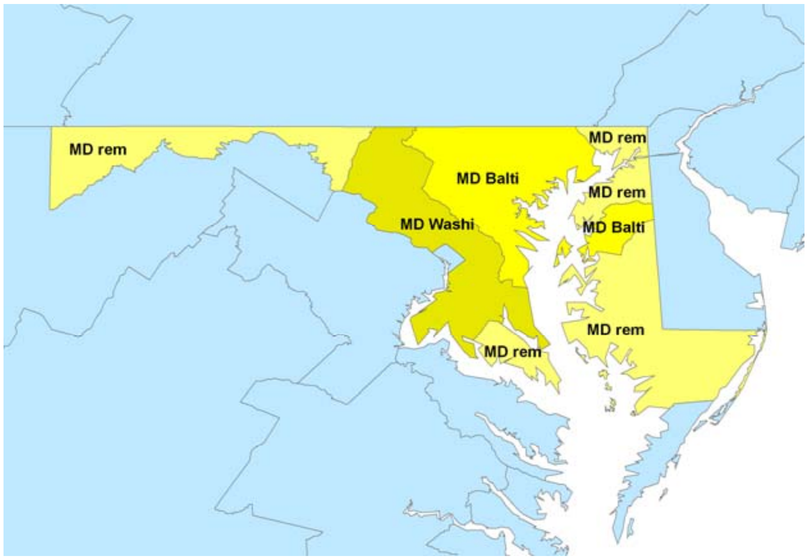

Figure 1: FAF zones in Maryland

To achieve a finer spatial resolution, truck trips are disaggregated from flows between FAF zones to flows between counties based on employment distributions *(16).* Four employment types are considered from Bureau of Economic Analysis: retail, office, industrial, and others. Subsequently, trips are further disaggregated to state modeling zones (SMZ) in the statewide model areas or regional modeling zones (RMZ) outside the statewide model areas (Figure 2).

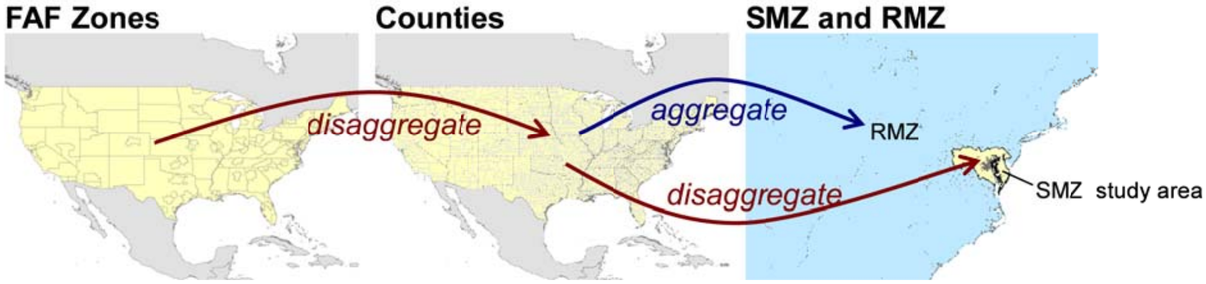

Figure 2: Disaggregation and aggregation of freight flows

Table 1 provides details of these disaggregations in Maryland Statewide Transportation Model (MSTM). In the first step (step 1a), most areas outside Maryland use total employment to disaggregate commodity flows from each FAF zone to all counties within this FAF zone In contrast, Maryland uses county employment data of 21 industries to disaggregate FAF zones to counties (step 1b). The information of these industries ensures good consistency between employment and commodity flows to improve the quality/accuracy in disaggregating flows that enter and depart from Maryland. For example, crops are generated in counties with a higher employment share in agriculture; raw metal is transported to counties with a higher employment share in manufacturing. The second level of disaggregation from counties to SMZ within the statewide model area uses four types of employment (Industrial, Retail, Office and Other) provided by the land use model (step 2).

Table 1: Three types of disaggregation applied in MSTM

Step	From	To	Based on
1a	FAF zones	Counties (outside Maryland)	Total employment
1b	FAF zones	Counties (inside Maryland)	21 employment categories
2	Counties	SMZ	4 employment categories

As in step 1a in Table 1, the disaggregation process uses total county employment shares as weights to split commodity flows from one FAF zone to all counties within this FAF zone. The same methodology is applied for disaggregation within the destination FAF zone; the more employment a county has, the higher the share of commodity flows this county receives, compared to all other counties in this FAF zone. The following equation shows the calculation to disaggregate a flow from the FAF zone to the country level; a flow from FAF zone *a* to FAF zone *b* is converted to multiple flows from county *i* of *k* located in FAF zone *a* to county *j* of *l* located in FAF zone *b*.

$$flow_{county_i,county_j} = flow_{FAF_a,FAF_b} \cdot \frac{weight_{county_i,county_j}}{\sum_{county_k \in FAF_a} \left(\sum_{county_l \in FAF_b} weight_{county_k,county_l} \right)}$$

where $county_i$ is located in FAF_a

$county_j$ is located in FAF_b

$county_k$ are all counties located in FAF_a

$county_l$ are all counties located in FAF_b

The weights are identical for each commodity, and are calculated by the following equation:

$$weight_{county_i,county_j} = empl_i \cdot empl_j$$

where $empl_i$ is total employment in county *i*

In step 1b in Table 1, county employment in 21 categories and coefficients that are adapted from the Ohio's model are used to disaggregate flows from FAF zones to counties within Maryland *(17)*. There are two kinds of coefficients[1]; while the "make" coefficient represents the level of production of goods related to each commodity, the "use" coefficient represents the level of consumption. Different from step 1a, the weights for flows into and out of Maryland in step 1b are commodity-specific. These weights are calculated by the following equation:

$$weight_{county_i,county_j,com_c} = \sum_{ind_m} \left(empl_{county_i,ind_m} \cdot mc_{ind_m,com_c} \right) \cdot \sum_{ind_m} \left(empl_{county_j,ind_m} \cdot uc_{ind_m,com_c} \right)$$

where $empl_{county_i,ind_m}$ is the employment in county *i* in sector *m*

[1] Make and use coefficients that reveal the mix of goods required to produce $1 of output or consumption, respectively, can be derived from the IO flows. These coefficients are typically used in lieu of the actual flows, as they scale to any level of production and consumption. Hewings (1985) and de la Barra (1989) both provide an excellent description of their typical derivation *(18-19)*.

mc_{ind_m, com_c} is the "*make*" coefficient describing how many goods of commodity *c* are produced by industry m

uc_{ind_m, com_c} is the "*use*" coefficient describing how many goods of commodity *c* are consumed by industry *m*

In step 2 in Table 1, the same equations as in disaggregation 1b are used. The only difference is that 21 employment types with the corresponding "*make/use*" coefficients are available and used for counties in Maryland, while only four employment types (Industrial, Retail, Office and Other) and corresponding "*make/use*" coefficients are available at the SMZ level *(17)*.

In the next stage, commodity flow trips distributed between SMZs and RMZs are assigned to the highway network of the entire U.S. This model with 3,241 counties and 1,607 SMZ achieves the higher resolution of commodity assignment, compared to less detail modeled outside the SMZ only with 130 FAF regions.

In the procedure of converting these disaggregated goods flows to truck trips, the second layer of this two-layer model design improves the accuracy in assigning truck trips to sub-regions based on the distinction of industry-specific employment within the SMZ area. These goods' flows are converted into truck trips, using goods' flows in the weight unit of *tons and* average payload factors for four different truck types *(16)*. Depending on the commodity of the good, a different amount of goods fit on a single truck. The breakdown of trucks/trailers in four different sizes in the U.S. is obtained from census data (Table 2).

Table 2: The Breakdown of Trucks and Trailers by Size

Single Unit Trucks	Semi Trailer	Double Trailers	Triples
30.7 %	15.5 %	26.9 %	26.9 %

Source: U.S. Department of Commerce 2004: 43

In addition, an average empty-truck rate of 20.8 percent of all truck miles traveled (estimated based on U.S. Census Bureau (2008)) is assumed and added to the estimated truck trips that are based on FAF2 goods' flows in weight, using the following equation *(20)*.

$$trk(all)_{i,j} = \frac{trk(loaded)_{i,j}}{(1-etr)}$$

with $trk(all)_{i,j}$ Trucks from zone *i* to zone *j* including empty trucks

$trk(loaded)_{i,j}$	Loaded trucks from zone *i* to zone *j* based on FAF2 data
etr	Empty truck rate

The route assignment stage of modeling requires a daily capacity of every highway link. Due to a lack of comprehensive information, the road capacity was estimated based on the highway class and the number of lanes. While Interstate highways (both Urban Interstate and Rural Interstate) are assumed to have a capacity of 2,400 vehicles per hour per lane (vphpl), all other highways are assumed to have a capacity of 1,700 vehicles per hour per lane. The daily capacity is assumed to be ten times higher than the hourly capacity, as most transportation demand arises during daylight hours. To transform Annual Average Daily Traffic (AADT) into Annual Average Weekday Traffic (AAWDT) a factor of 265 working days was assumed.

4.1 Regional Truck Model Data

This study uses the FAF data that is provided in four different data sets.

- **Domestic**: Commodity flows between domestic origins and destinations in short tons[2].
- **Border**: Commodity flows by land from Canada and Mexico via ports of entry on the U.S. border to domestic destinations and from the U.S. via ports of exit on the U.S. border to Canada and Mexico in short tons.
- **Sea**: Commodity flows by water from overseas origins via ports of entry to domestic destinations and from domestic origins via ports of exit to overseas destinations in short tons.
- **Air**: Commodity flows by air from abroad origins via airports of entry to domestic destinations and from domestic origins via airports of exit to abroad destinations in short tons.

The FAF data contains different modes and mode combinations. For the purpose of this study, only the mode 'Truck' was used. Figure 3 shows the numbers of data included in the analysis as well as data excluded from the analysis. Tips made in a combined mode, such as 'Truck & Rail' or 'Air & Truck', were disregarded from the study, as the data do not allow us to identify which mode was dominant. 'Air & Truck (International)' was included as these trips allow extrapolating the portion of trip from the international airport to the domestic destination (and vice versa) made by truck. As only a very small portion (1.5 percent) of trips in the omitted 200,320 flows was made by truck, the error is assumed to be fairly small. Border data considers

[2] 1 short ton = 907.18474 kilograms; a United States unit of weight equivalent to 2000 pounds.

the portion from the border crossing to the domestic destination or from the domestic origin to the border crossing. Likewise, sea and air freight was included as a trip from or to the domestic port or airport.

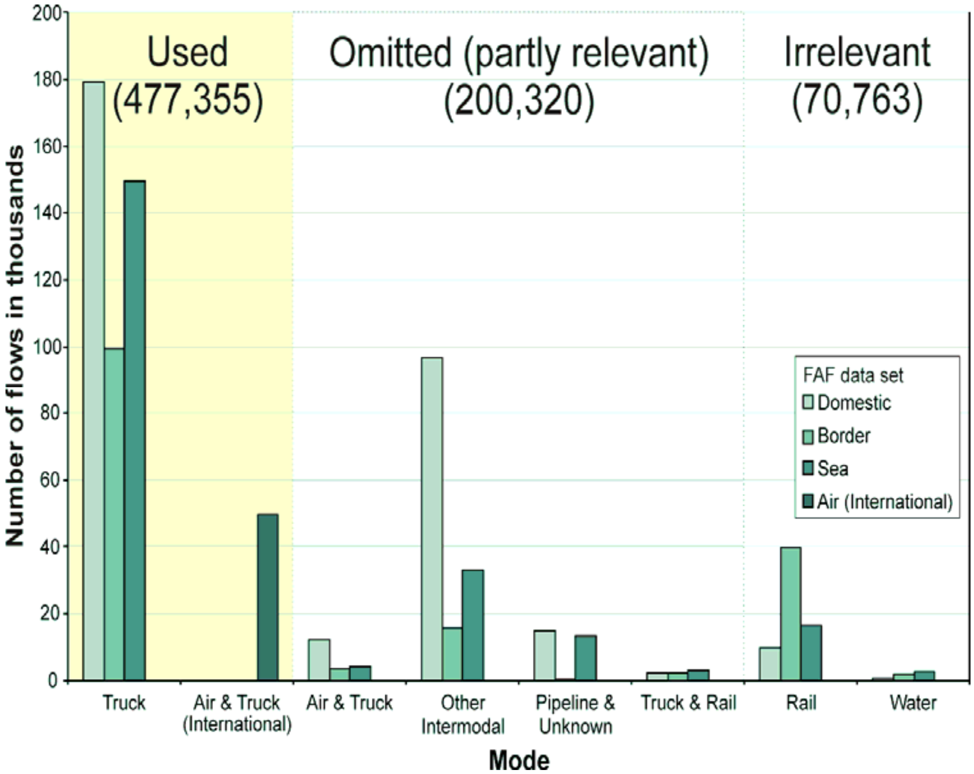

Figure 3: Freight Mode and flows

5. STUDY AREA AND POLICY IMPLEMENTATION

Maryland Statewide Transportation Model (MSTM), which is designed as a multi-layer model working at national, regional and local level, is used for analyzing the impacts of different scenarios on the highway traffic in different scales. The study area covers all areas of Maryland, Delaware, and Washington D.C. and 64 counties in parts of Pennsylvania, Virginia and West Virginia. MSTM consists of 1,607 SMZs and 132 RMZs. The 132 RMZs cover the entire US, Canada, and Mexico. Figure 4(a) and 4(b) show maps of SMZs and RMZs respectively.

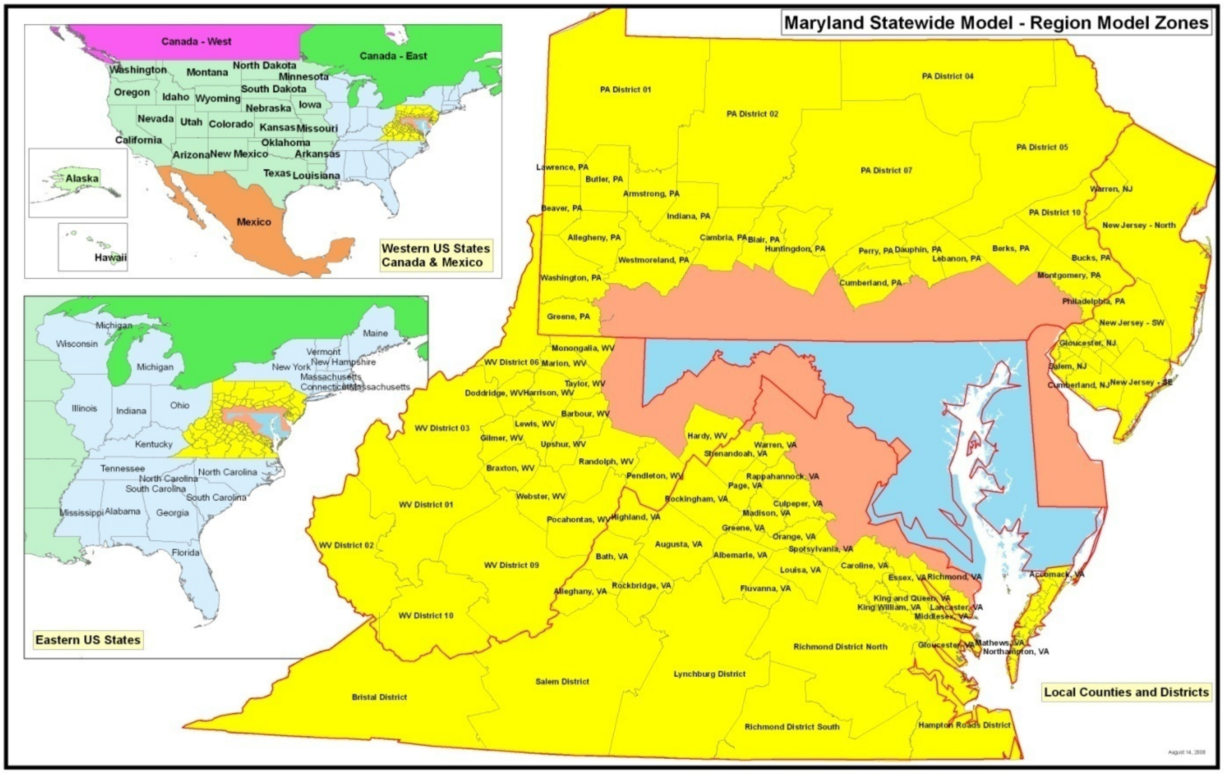

Figure 4(a): Regional Modeling Zones in MSTM

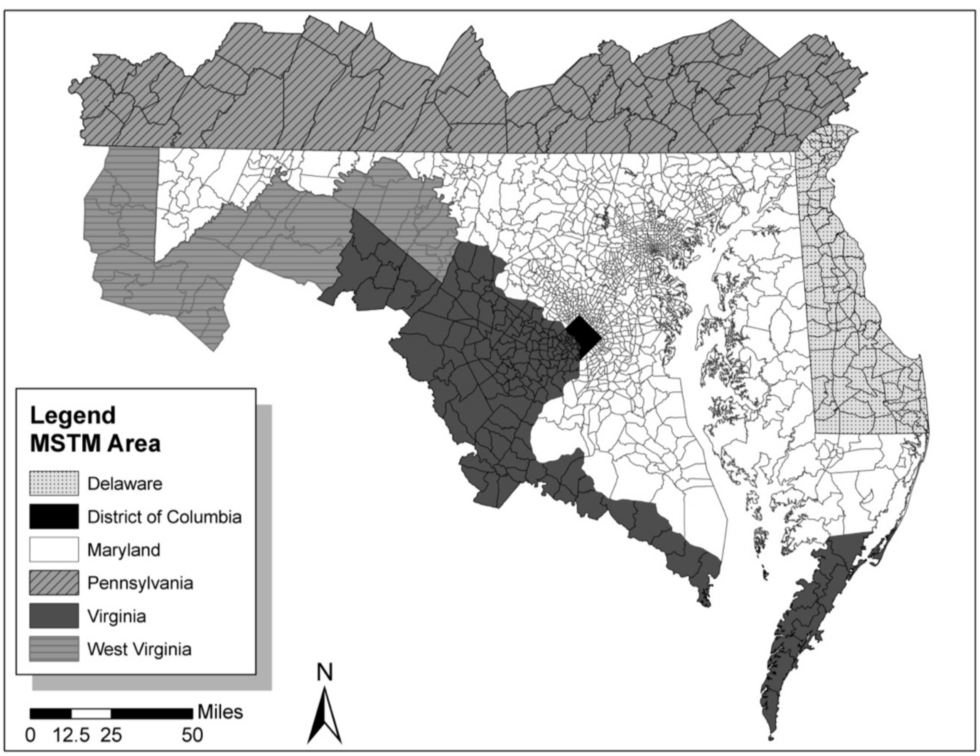

Figure 4(b): Statewide Modeling Zones in MSTM

The true value of a comprehensive statewide model becomes apparent when policy scenarios are analyzed. For example, the model makes it possible to examine the impacts of freight infrastructure investments on traffic flows, the economy and the environment, prior to the actual implementation of proposed projects. Table 3 shows, in addition to the base scenario that analyzes the business-as-usual case, three policy scenarios are simulated to examine their likely impact on the transportation system. The scenarios are based on the perspectives of three stakeholder groups with different motivations, and aim at affecting truck flows, not affecting directly the larger share of vehicles on the road—and passenger vehicles. Table 3 summarizes the policy scenarios tested with the MSTM.

Table 3: Policy Scenarios

Stakeholder's perspective	Objective	In MSTM
Shipper's	Congestion-free travel	Capacity of access controlled facilities is doubled
Planner's	Relief congestion and reduce emissions	A better transfer of commodities from highway to rail is obtained.
Policy Maker's	Economic Growth	Economic growth of Port of Baltimore is enhanced

The first stakeholder group is freight shippers. Trucking companies often criticize a lack of road infrastructure investment by the public administration, claiming that traffic congestion is exacerbated to result in the economic loss to the order of billions of dollars per year *(13)*. In this scenario, the capacity of interstate highways is doubled in terms of the number of lanes from the base scenario, with an assumption that there are no budgetary and engineering constraints to widen the highway network. Certainly, this is not a realistic capacity increase to happen, as many governments struggle to provide even adequate road maintenance services and as many interstate highways in the MSTM region are located in densely populated areas with little space left to widen highways. Setting such practical issues aside, this scenario has been chosen to explore the validity of shipping companies' claim that the bottlenecks on the highway network should be addressed.

The second scenario reflects the planners' perspective. Regional and urban planners think that congestion and vehicle emissions are reduced more effectively by shifting freight transportation from trucks to rail *(21)*. Since many rail facilities operate at capacity within the MSTM study area *(17)*, it is likely that expanding rail capacity will increase shipments by rail. Thus, the scenario based on the planners' perspective assumes doubling the rail capacity. Specifically, for every FAF zone origin-destination pair, the rail flows are doubled, and the tons added to the rail network are removed from the truck flows. An analysis based on this scenario improves an understanding of the likely effects of increasing rail freight capacity on road traffic conditions on the highway network.

The third scenario represents the viewpoint of policy makers, assuming that some policy makers promotes a flagship project that would increase regional employment and stimulate a regional economy. The expansion of east coast ports has been discussed in the media, particularly because the widening of the Panama Canal will allow larger ships from Asia to access East coast states directly. Thus, in this scenario, the Port of Baltimore and the Port of Norfolk are assumed to grow in capacity. Specifically, the Port of Baltimore is assumed to expand by no more than 100 percent, because it is located fairly close to downtown Baltimore and does not have much space left to expand. On the other hand, the Port of Norfolk is assumed to grow by 200 percent. It should be noted that it is simply assumed that additional capacity would be filled up without an analysis of whether or not such demand to increase the flows through the Ports of Baltimore and Norfolk actually exists. Existing freight flows through the port are doubled; the same commodities and the same origin-destination pairs are used for the additional flows. The scenario does not include any change in employment at the ports, as increasing automation of technologies at ports has tended to reduce employment even under an increasing amount of goods shipped through ports *(22)*. The scenario based on policy makers' perspective analyzes the impact of increased commodity flows, which go through the two ports and are transported by truck to final destinations in the MSTM region, on the highway network.

6. RESULTS AND DISCUSSION

The proposed methodology of freight planning is analyzed by MSTM, which incorporates the objectives of the three different stakeholder groups—shippers, planners, and policy makers. In this section, the analysis results presents the impacts of the different policies envisioned by these stakeholder groups on the transportation system in the following three geographic/physical levels: (1) at state level, (2) at facility type level, and (3) at corridor level.

6.1 State Level Impact

The state level impact is analyzed with measures such as VMT, VHT, and CLM. The following paragraphs describe the impacts of each stakeholder group perspective on these measures.

6.1.1 Vehicle Miles Travelled

Figure 5 shows the statewide total VMT at different times of day. (Note that the Y-axes in the graphs show different scales, not starting from zero at the bottom. This scale has been chosen to better visualize the differences between the scenarios.) For example, Figure 5(a) shows statewide VMT for AM perk period (6:30AM to 9:30AM) for the base case and under the three different scenarios.

The differences between all four scenarios are relatively small, even though the scenario assumed a fairly dramatic change in the transportation infrastructure. Figure 5 shows that VMT under the shippers' perspective scenario is the highest among all, because the increase in the highway system makes highways, expressways, and freeways more attractive than in the base case, resulting in the higher traffic volume for these roadways. In other words, a mode shift from transit to highways is induced by the highway capacity increase to result in an increase in VMT under this scenario.

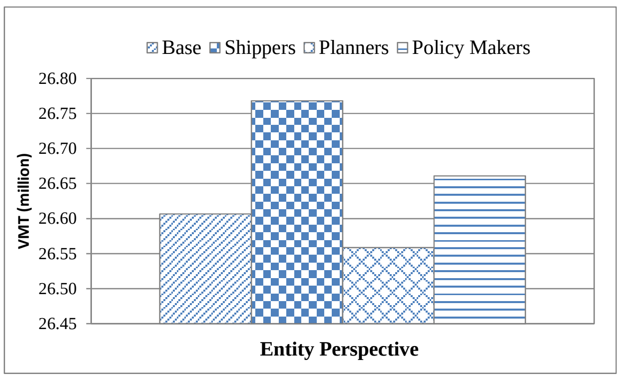

Figure 5 (a): AM Peak Period VMT

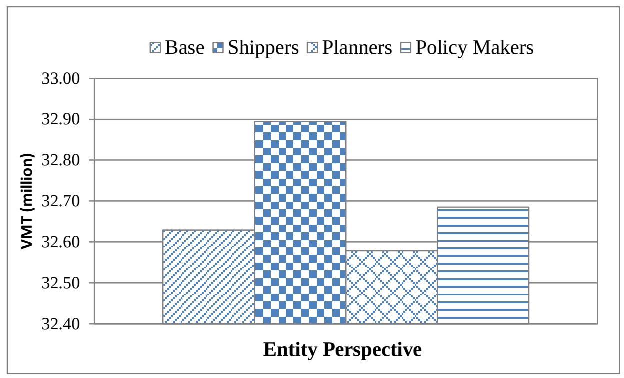

Figure 5 (b): PM Peak Period VMT

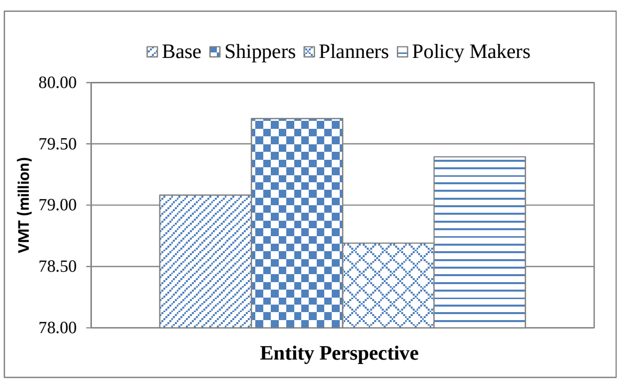

Figure 5 (c): Off-Peak Period VMT

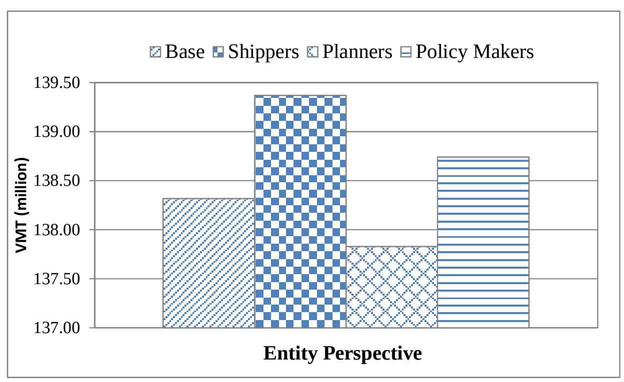

Figure 5 (d): DailyVMT

Figure 5: Statewide VMT by Time-of-day

Figure 5(a) shows the lowest VMT under the planners' perspective scenario. This is because the larger number of truck trips are diverted to rail to alleviate congestion from highways. In this scenario, a mode shift from trucks to rail could reduce highway vehicle traffic from the base case, showing a potentially preferable management of truck traffic without large capital investment in the highway system because of recent attentions toward intermodalism, sustainable transportation, and less dependence on oil. Lastly, the policy makers' scenario resulted in the higher VMT than the base case, because the levels of production and attraction of freight commodities increase while no capacity of transportation infrastructure is added.

Similarly, Figure 5(b), 5(c), and 5(d) present the statewide total VMTs for PM (3:30PM-6:30PM), off-peak (9:30AM-3:30PM, and 6:30PM to 6:30AM), and daily time periods respectively. The observations are similar to the AM peak period. In short, irrespective of the time of day, the shippers' perspective scenario has the highest VMT, and the planners' perspective scenario has the lowest VMT.

6.1.2 Vehicle Hours of Travel

Figure 6 shows the VHT for various times of day for the base case and the scenarios of three different stakeholders. Among all cases analyzed, the policy makers' perspective scenario results in the highest VHT, because the freight demand generated in the additional good movements at the ports increases freight traffic that is not accommodated well by the highway infrastructure system without additional capacity, causes more congestion, and results in the overall longer travel time. In contrast, the capacity expansion under the shippers' perspective scenario results in the least VHT as expected.

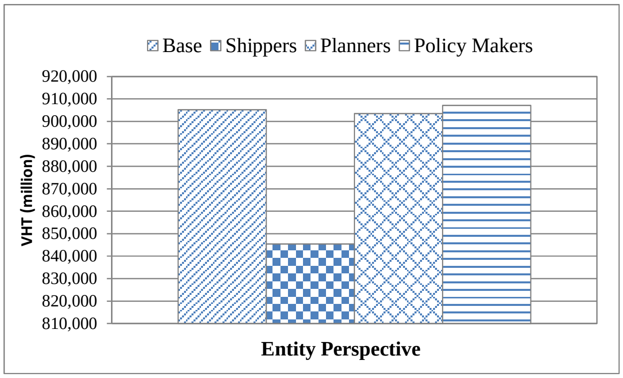

Figure 6 (a): AM Peak Period VHT

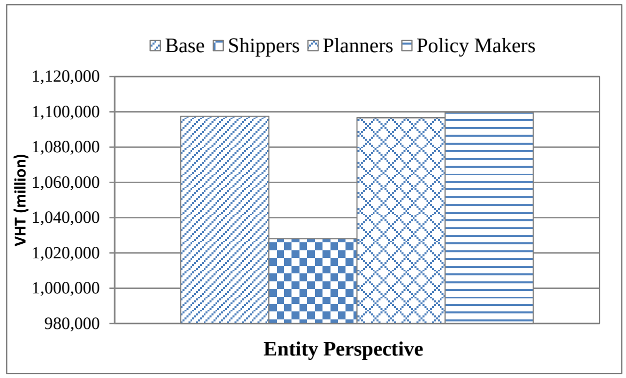

Figure 6 (b): PM Peak Period VHT

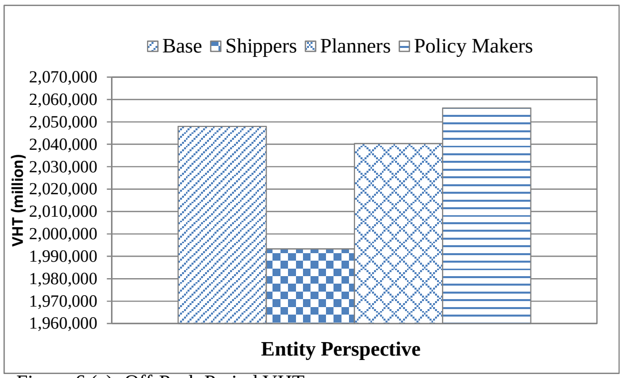

Figure 6 (c): Off-Peak Period VHT

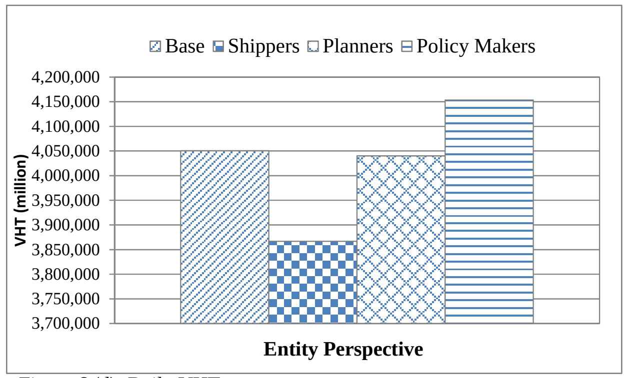

Figure 6 (d): Daily VHT

Figure 6: Statewide VHT by Time-of-day

6.1.3 Congested Lane Miles

Figure 7 shows the total statewide CLM by time of day. CLM represents lane miles with volume to capacity ratio more than 0.8 (i.e. level of service lower than E). The lower number of CLM represents a better operational condition. Figure 7(a) shows the lowest number of CLM in the AM peak period under the shippers' perspective scenario, because of the highway capacity expansion desired by the shippers. The highest CLM is observed under the policy makers' perspective scenario, because of an increase in freight travel demand with no increase in the highway capacity. The CLM under the planners' perspective scenario shows the CLM level in between the two other scenarios as the total freight travel demand remains the same as in the base case and it is managed by a better modal distribution.

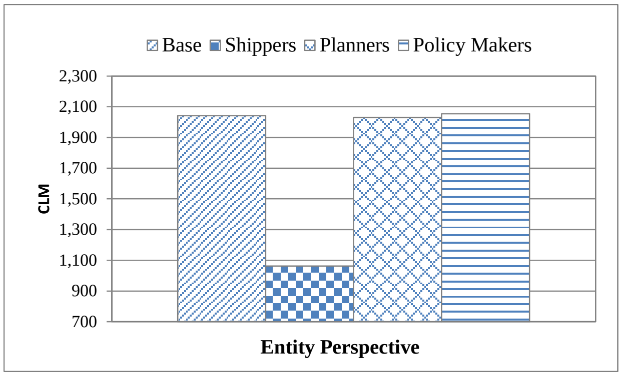

Figure 7 (a): AM Peak Period CLM

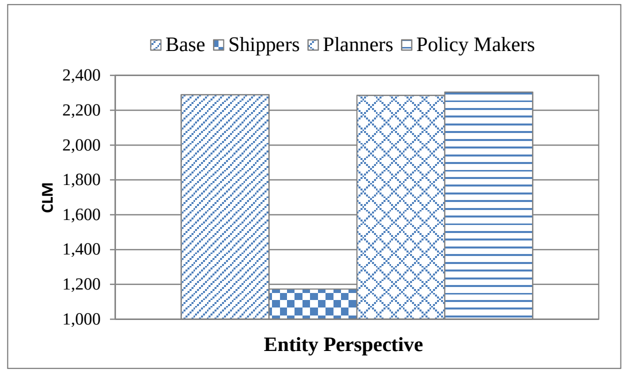

Figure 7 (b): PM Peak Period CLM

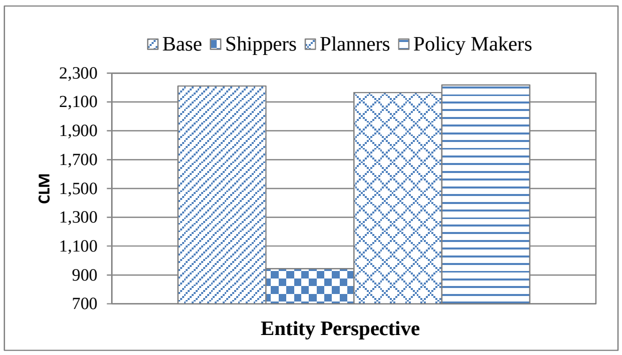

Figure 7 (c): Off-Peak Period CLM

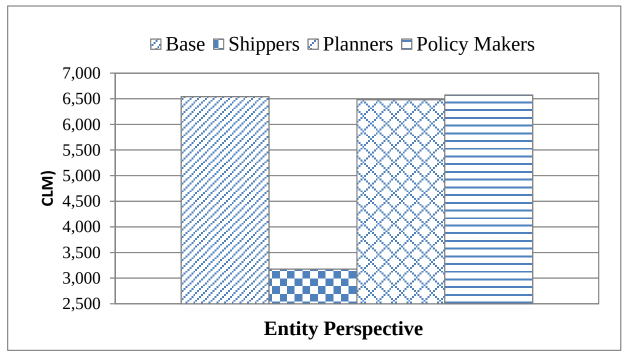

Figure 7 (d): Daily CLM

Figure 7: Statewide CLM by Time-of-day

6.2 Facility Type Impact

Facility types represent highway functional classes such as freeway, interstates, expressway, major arterial, minor arterial, collector and local streets. The facility-type impact is examined at a more disaggregate level than the state level, and is analyzed with measures such as VMT, VHT, VHD, and CLM. The following paragraphs describe the impact of each entity perspective on these measures.

6.2.1 Vehicle Miles Travelled

Figure 8 shows the interstate VMT at different times of day. For example, Figure 8(a) shows the VMTs in the AM peak period for the base case and under the three different scenarios. As seen in the statewide level results, the VMT is the highest under the shippers' perspective scenario also for only interstate highways, because the capacity expansion of interstate highways makes this facility advantageous in terms of travel time, and attracts trips from the adjacent facilities and from other modes to highways, resulting in the higher traffic volume. The least VMT is observed under the planners’ perspective case as part of freight trips are diverted to rail. The decision makers’ perspective scenario shows slightly higher VMT than the base case because of increased demand to reflect economic growth without managing travel demand.

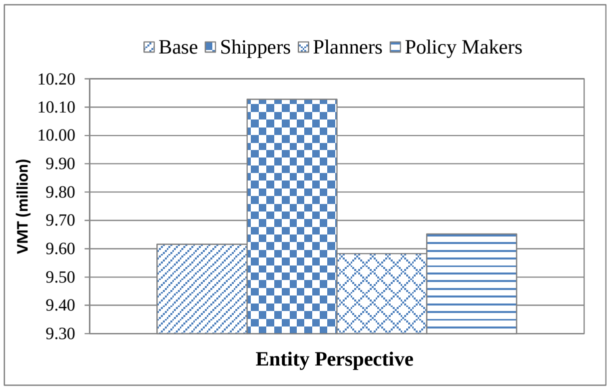

Figure 8(a): AM Peak Period VMT

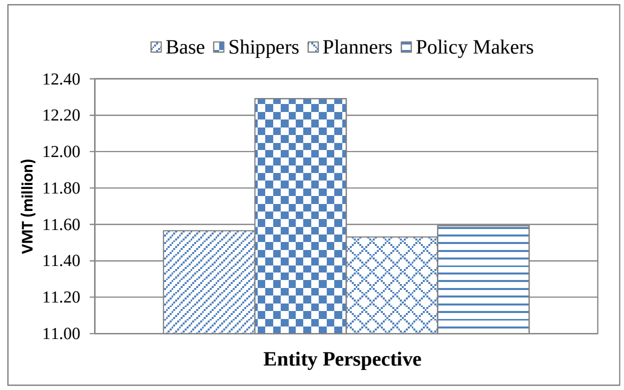

Figure 8(b): PM Peak Period VMT

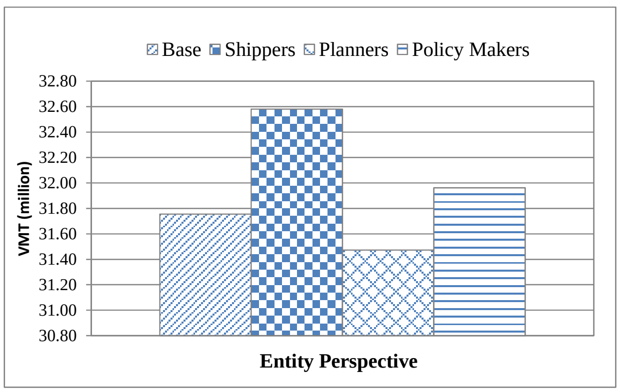

Figure 8(c): Off-Peak Period VMT

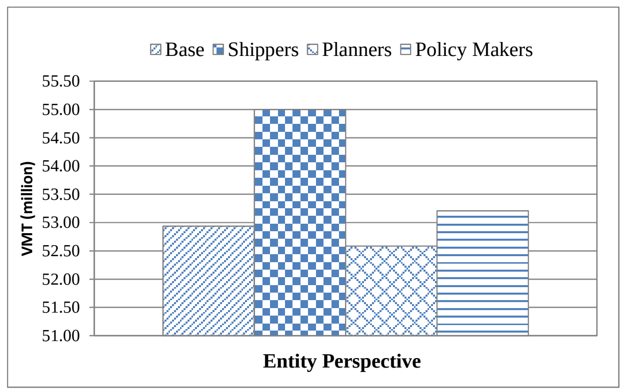

Figure 8 (d): Daily VMT

Figure 8: VMT by for Interstates

6.2.2 Vehicle Hours of Travel

Figure 9 shows the VHT on the interstate highways at different times of day for the base case and the scenarios of three different stakeholders. For example, Figure 9(a) shows the shippers’ perspective case has the least VHT in the AM peak period, because the highway capacity expansion under this scenario lowers the travel time on interstates, resulting in overall less VHT. The highest VHT occurs under policy makers’ perspective. Under planners’ perspective scenario, VHT is in between the other two cases.

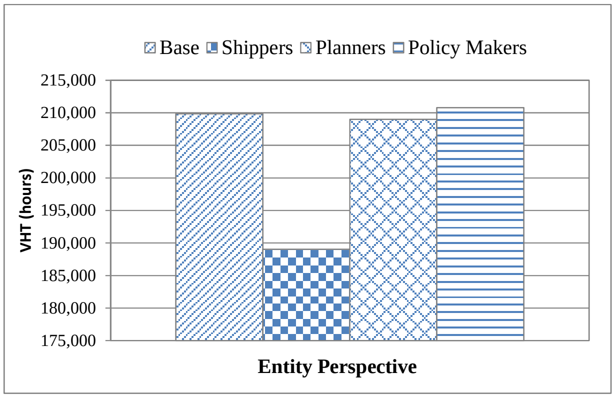

Figure 9(a): AM Peak Period VMT

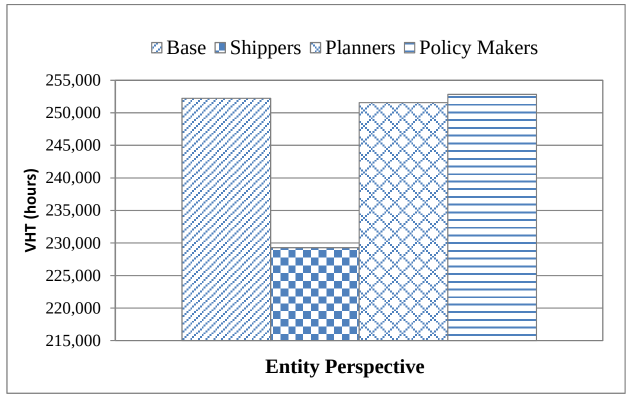

Figure 9(b): PM Peak Period VMT

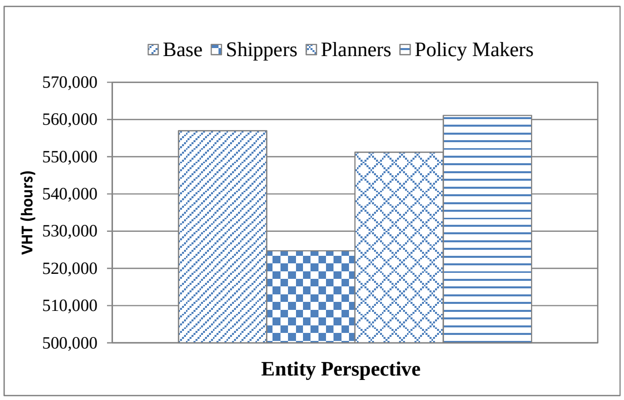

Figure 9(c): Off-Peak Period VMT

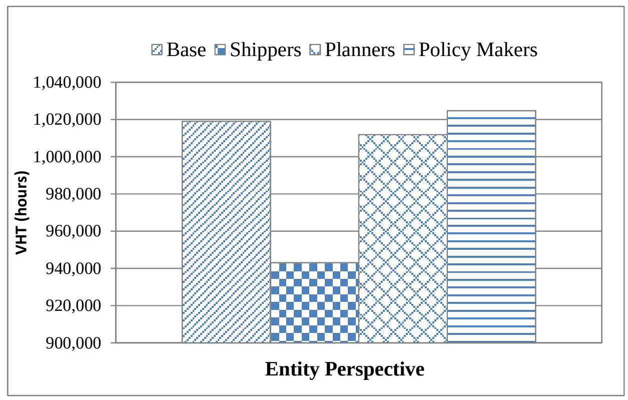

Figure 9(d): Daily VMT

Figure 9: VHT by for Interstates

6.2.3 Congested Lane Miles

Figure 10 shows CLMs on the interstate highways. Figure 10 (a) shows similar results to the statewide total CLMs; CLM is the least under the shippers' perspective scenario. This is again result of the capacity expansion with the maintained demand level as in the base case. Among all scenarios, the policy makers' perspective scenario resulted in the highest CLM, followed by one of the planners' perspective.

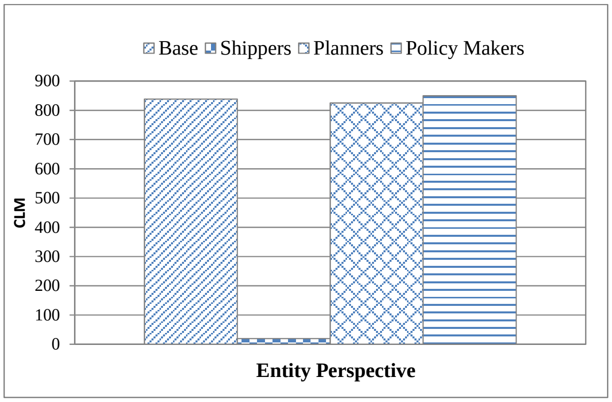

Figure 10(a): AM Peak Period VMT

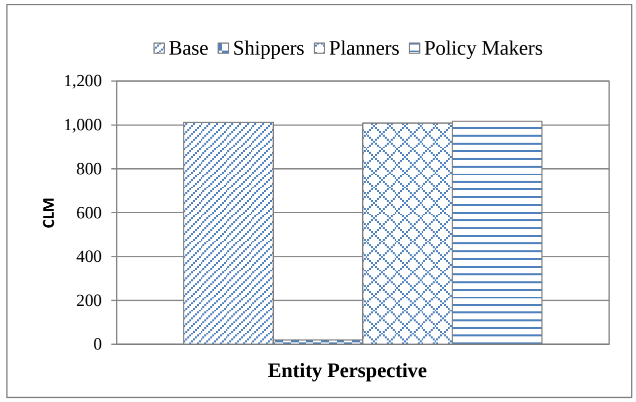

Figure 10(b): PM Peak Period VMT

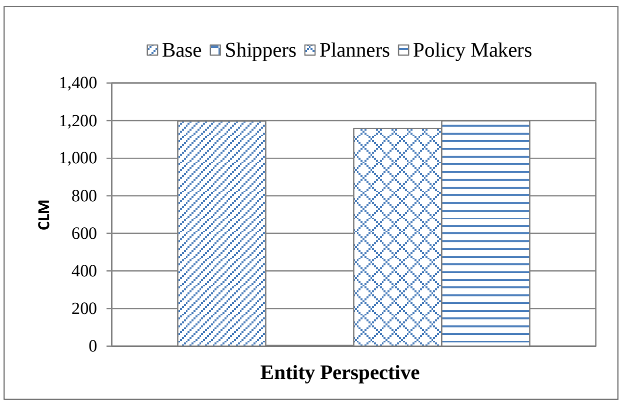

Figure 10(c): Off-Peak Period VMT

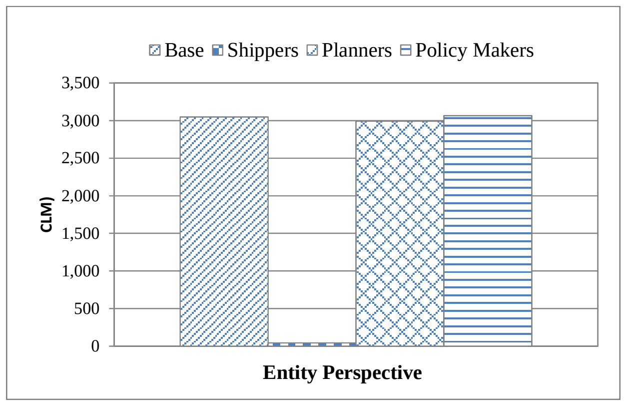

Figure 10(d): Daily VMT

Figure 10: CLM by for Interstates

6.3 Corridor (Link) Level Impact

The corridor level impact represents results in the most disaggregated level among the three geographic/physical levels. Results at corridor level demonstrate the effects caused on a particular section of roadways. Different from the previous sections, this section discussed only daily traffic volume at the corridor level. Specifically, only five bridge crossings are used here to demonstrate the corridor level impact as they are often considered as critical locations in the transportation system. Figure 11 shows the impacts on these five bridges in both directions, as well as the geographical locations of these bridges. The impact is measured in terms of percentage difference in traffic volume under a different scenario, compared to the base case. The results show that all bridges carry substantially higher traffic volume, compared to the base case, from the shippers' perspective scenario, in which the capacity expansion of interstates and freeways make roadways become more attractive. Most of these bridge crossings are on an interstate highway, and traffic is converged from local roads on to highways after capacity is increased. In contrast, under planners' perspective, traffic volume declines from the base case, because of the mode shift from highway to rail.

Bridge	% Diff		
	Shipper	Planner	PolicyMaker
Gov. Harry Nice Memorial Bridge (North Bound)	16%	-2%	10%
Gov. Harry Nice Memorial Bridge (South Bound)	15%	-1%	14%
Woodrow Wilson Memorial Bridge (North Bound)	11%	0%	12%
Woodrow Wilson Memorial Bridge (South Bound)	75%	-1%	10%
American Legion Memorial Bridge (North Bound)	18%	-4%	10%
American Legion Memorial Bridge (South Bound)	22%	-1%	12%
Conovingo Road Hwy (North Bound)	44%	-3%	11%
Conovingo Road Hwy (South Bound)	52%	0%	10%
John F Kennedy Memorial Bridge (North Bound)	8%	-4%	12%
John F Kennedy Memorial Bridge (South Bound)	22%	-2%	10%

Figure 11: Link level results compared to base case

Also under the policy makers' scenario, traffic volumes at these bridge locations are higher than the base case, reflecting higher economic growth expected from an increased goods' flow through the ports without better management of the transportation infrastructure.

7. CONCLUSION

This study envisioned design and application of freight transportation modeling techniques to quantitatively assess the impacts on the highway traffic of three distinct perspectives that could significantly influence decisions in freight transportation planning and policy. Stakeholders of these three perspectives were shippers, planners, and policy makers whose primary objectives are different from each other. Shippers' objective is to transport various commodities from origin to destination within a minimal cost, which includes travel distance, time, toll, comfort, convenience, and other factors. Planners' objective is to design and manage the transportation system by the modal shift from trucks to rail, addressing concerns with auto-dependency and related environmental problems. Policy makers' objective is to bring an economic growth to the region. The analysis results were presented at three geographic/physical levels (1) statewide level, (2) facility type level, and (3) link level to gain a broader picture of the transportation system. Performance measures—VMT, VHT, and CLM—are used to numerically show how the transportation system will be affected by each of these three objectives.

In summary, the relative comparison of performance measures under different policy scenarios is important in assisting policy decision making. This paper has three main contributions to research and practice. First, we developed a methodology to clearly incorporate freight trips in the travel demand model that takes into account all of state, regional, and local levels (with an emphasis on the state level). Second, the objectives of key players are identified and incorporated in the scenario analysis in freight planning to demonstrate the capability of the developed statewide travel demand model. Third, the use of FAF data in truck travel behavior is another substantial improvement in this study, as FAF allows the model to preserve commodity flows in both national and regional levels for the whole North America, and also in the local TAZ level with finer disaggregation of trips. This proposed three layer methodology works well to develop the statewide freight model.

This paper has two main contributions to research. First, the proposed methodology and statewide freight model addressed a significant shortcoming in conventional MPO and statewide travel demand models that do not incorporate freight trip generation and distribution in details, but consider only external centroid connectors to represent long distance freight trips. Second, the proposed methodology simultaneously takes into account passenger cars and trucks in the model, thereby estimate the effects of both categories of vehicles on congestion in concert in the traffic assignment stage. In addition, this proposed model provides more accurate estimates of traffic volume and congestion at the link level for different policy scenarios, and allows policy makers and planners to identify congested roadway segments for future improvements.

The research presented in this paper can be extended in future in the following ways. First, the model should be improved to properly examine policies that induce changes in freight mode choice, which are not adequately represented by a fixed demand in the FAF data. Second, with data on entities' preference of freight shipping mode, the proposed methodology can be further improved for modeling freight mode choice, which has been a challenging task as a choice by shipping entities depends on a variety of factors, including type, weight, and value of commodity, and urgency of shipment.

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