Multilevel Demand Modeling Techniques for Analyzing Freight Movements in Stochastic Networks and Uncertain Market Conditions

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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, policy 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 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 and is geared towards attainment of respective objective. Past research is very limited in proposing a unified methodology to address the objective of each player and to assess performance of transportation networks in lieu of 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 at for analyzing impacts of policies at state, county and local level.

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

INTRODUCTION

In recent years, concerns with traffic congestion, energy consumption, and green house gasses are increasingly getting attention in US major metropolitan areas. According to Texas Transportation Institute (TTI), commuters in 439 US urban areas are spending an extra 4.8 billion hours or 34 hours per driver in each year, and wasting 3.9 billion gallons of fuel due to congestion (TTI, 2011). 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 the increase in the accessibility and mobility options and the enhancement the integration and connectivity of the transportation system for freight transportation as well as for passenger travels (FHWA, 1998; Pendyala et al. 2000). SAFETEA allocated funding of over $4.6 million per year over three years to improve research, training, and education specifically for freight transportation planning (FHWA, 2005).

Transportation modeling and forecasting has an important role to address planning and policy issues, ranging from general and long-range planning and project prioritization to modal diversion, policy 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 relatively slow progress in behavioral theory and lack of publicly available data (Ram M. Pendyala, Venky N. Shankar, and Robert G. McCullough, 2000). 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. The objective of each player is different and is geared towards attainment of self-centered goals. The objective of shippers is to reach from origin to destination with minimum travel cost (which consists of travel time, distance, toll). The objective of planners is to design and manage an effective multimodal transportation system without much effort in building new infrastructure. The objective of policy makers is to

In this paper, in order to clearly account for objectives of the three important players, a freight transportation model presented is designed, implemented 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. These freight flows are modeled in stochastic networks with network conditions that vary by time of day and in uncertain market conditions with freight demand vary by player's objective, with a focus on long-distance truck trips in the state-level. 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 [number] 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 and data sources. Then details of analysis results and discussion are presented, and the paper concludes with future research agendas.

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 (Bureau of Transportation Statistics, 2007). Nine percent of the value ($1.08million) and 10 percent of the weight (1.288 billion) were shipped between 50 and 100 miles (USDOT FHWA, 2002). Thus, a development of good statewide freight transportation models is strongly demanded in the assistance for planning and policy making.

Forecasting statewide freight toolkit, a report by National Academy of Sciences suggest that ideally freight planning should be done using Commodity, Origin, Destination, Mode, Route, Time (CODMRT) steps. Because of unavailability of freight data a number of steps make assumption of freight trip generation using ad-hoc variable such as employment. Distribution is done by gravity model using distance and/or time variable. Freight mode choice and time of day distribution are often ignored. In many cases trucks are the only mode considered in the assignment stage (NCHRP, 2006). Freight transportation planning includes facility planning, corridor planning, strategic planning, business logistics planning, and economic development (Southworth, F., Y. J. Lee, C. S. Griffin, and D. Zavattero, 1983). Statewide freight transportation models that incorporate factors that directly influence the demand of commodities (such as macro economic factors and socio-economic demographics) and indirectly affect it through affecting the cost and level-of-service of freight transportation services (such as freight logistics, transportation infrastructure, government policies, and technologies) is quite important in planning (Cambridge Systematics, Inc., 1997; Pendyala et al. 2000).

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 (Kim and Hinkel, 1982) (Pendyala et al.2000). Substantial progress was made in a development of *statewide intermodal* management systems, including freight transportation, because of the provisions of ISTEA, 1991 (Samadi and Maze 1996).

Freight transportation has a number of properties that make it difficult to directly apply passenger demand models (Pendyala, 2000). 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 of person travel. Due to data limitation and modeling difficulty, most freight models focus on truck movements and do not include a mode assignment step (Proussaloglou et al. 2003).

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 (Meyer, 2008). 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.

=The literature review indicates, in order to examine the network performance and freight travel behavior lack of **** and 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.

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

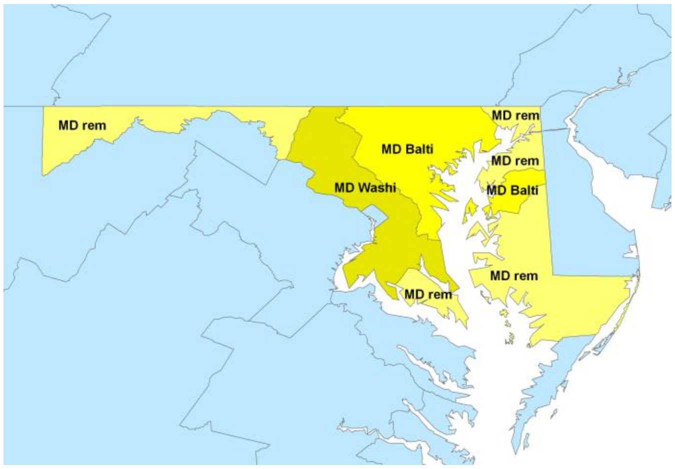
METHODOLOGY

This section is organized into two parts. First, methodology of long distance model is presented. Second, scenarios details of users, planners, and policy makers 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 [14] in the Freight Analysis Framework (FAF). The FAF2 data contain flows between 130 domestic FAF regions and 8 international FAF regions. Efforts are currently underway to update the model to FAF3 data, which has been released recently. Maryland is subdivided into three FAF regions (Figure 1), namely the

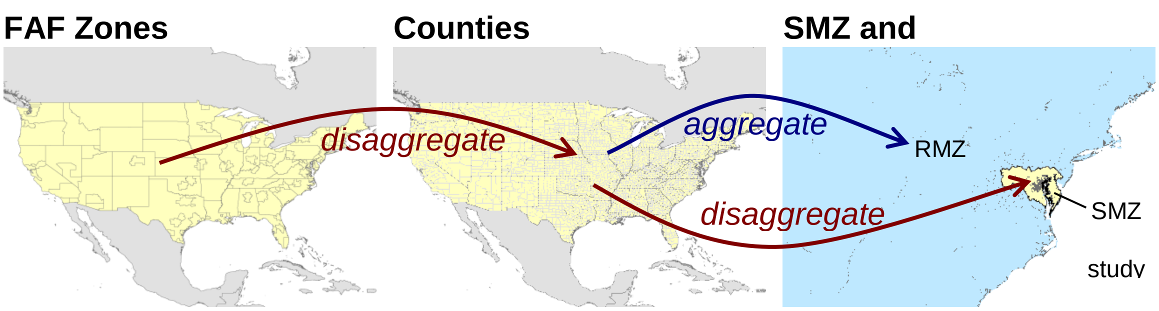
Baltimore region, the surrounding region of Washington DC in Maryland, and the remainder of Maryland.

Figure 1: FAF zones in Maryland



For some other states, such as Maine, Mississippi or Montana, a single FAF region covers the entire state. Flows from and to these large states would appear as if everything was produced and consumed in one location in the state's center (or the polygon centroid)[15] [16]. To achieve a finer spatial resolution, truck trips [17] are disaggregated from flows between FAF zones to flows between counties based on employment distributions. Subsequently, trips are further disaggregated to SMZ within the statewide model areas, and to RMZ outside the statewide model areas.

Figure 2: Disaggregation and aggregation of freight flows



In the first disaggregation step (step 1a in Table 1) from FAF zones to counties total employment is used for most areas. However, Maryland exhibits an exception in the disaggregation from FAF zones to counties (step 1b), using county employment data of 21 industries [7]. These industries have been used to improve the disaggregation of flows into and out of Maryland by ensuring better consistency between employment and commodity flows; for instance, crops are generated in those counties with a higher employment in agriculture or raw metal is sent to counties with higher employment shares in manufacturing. The second disaggregation from counties to SMZ within the statewide model area uses four employment types (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

For step 1a shown in **Table 1** the disaggregation process uses total employment for each U.S. county as a weight to split a flow from one FAF zone to all counties within this FAF zone. A similar 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 FAF zone *a* to FAF zone *b* into flows from county *i* (which is located in FAF zone *a*) to county *j* (which is 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

Total employment in every county is used to disaggregate flows from FAF zones to counties outside of Maryland. The weights are identical for each commodity. Weights for disaggregation 1a of **Table 1** are calculated by:

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

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

To disaggregate flows from FAF zones to counties within Maryland, county employment in 21 categories [7] and make/use coefficients (borrowed from coefficients that were developed for Ohio in a different context) are used. The weights for flows into and out of Maryland are commodity-specific. These weights for disaggregation 1b of **Table 1** are calculated by:

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

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

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*

For disaggregation 2 of **Table 1**, the same equations as in disaggregation 1b are used. The only difference is that 21 employment types with the corresponding make/use (or input/output) coefficients are available for counties in Maryland, while only 4 employment types (Industrial, Retail, Office and Other) and their corresponding make use coefficients are available at the SMZ level (MSTM 2011).

Trips between SMZ and RMZ are assigned to the highway network covering the entire U.S. The higher resolution of 3,241 counties plus 1,607 SMZ instead of 130 FAF regions improves the commodity assignment significantly. These goods' flows are transformed into truck trips through average payload factors. The procedure makes use of the two-layer model design. While there is less detail outside the SMZ area, the distinction of industry-specific employment within the SMZ area helps assigning truck trips to the correct sub-regions.

The disaggregated commodity flows in tons given by FAF2 need to be transformed into truck trips. Depending on the commodity of the good, a different amount of goods fit on a single truck. FAF2 provides average payload factors for four different truck types [17] that were used to calculate number of trucks based on tons of goods by commodity. Average shares of these four different truck sizes in the U.S. where derived from census data (**Table 2**).

Table 2: Share of truck types

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

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

Furthermore, an average empty-truck rate of 20.8 percent of all truck miles traveled (estimated based on U.S. Census Bureau [15]) was assumed. As FAF2 provides tons moved, the empty-truck rate needs to be added to the estimated truck trips.

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

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

Regional Truck Model Data

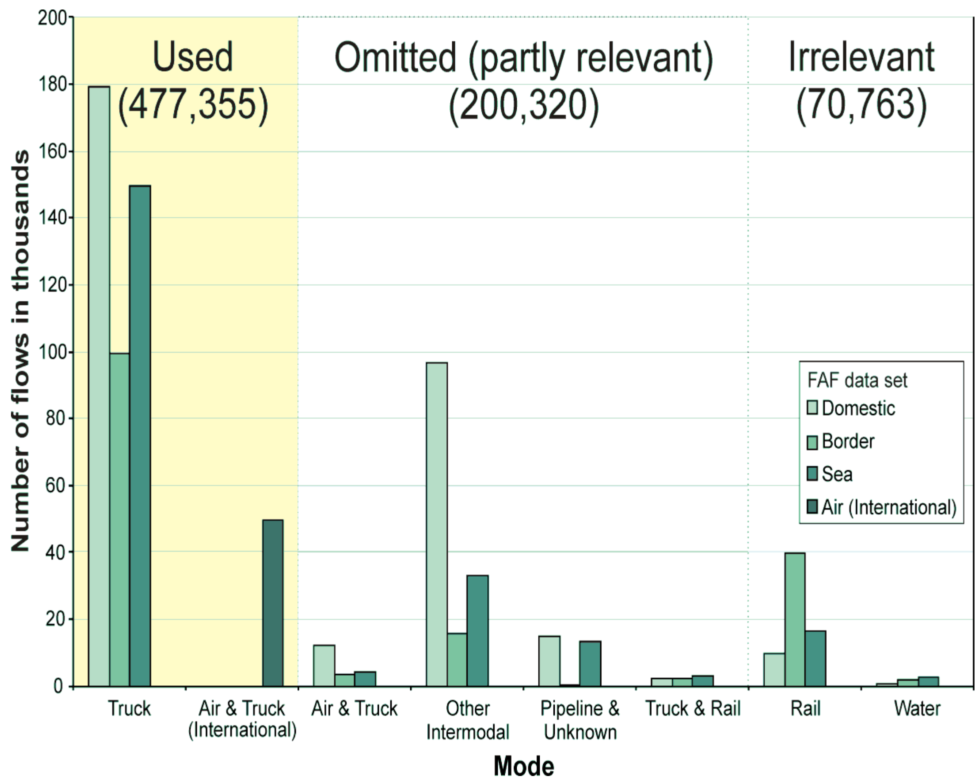
The FAF data is provided in four different data sets.

- **Domestic**: Commodity flows between domestic origins and destinations in short tons.
- **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 at hand, only the mode 'Truck' was used. Figure 3 shows data included and excluded in this analysis. Combinations such as 'Truck & Rail' or 'Air & Truck' were omitted assuming that the longer part of that trip is done by Rail or Air, respectively, and only a small portion is done by truck. As the data does not allow distinguishing which part of the trip has been made by which mode, combined modes were disregarded for this study. 'Air & Truck (International)' was included as these allow extrapolating the portion from the international airport to the domestic destination, and vice versa, done by truck. Of the 200,320 flows that are omitted, only a very small portion of these trips is done by truck. The error is assumed to be fairly small. Border data were considered with 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



A daily capacity of every highway link had to be estimated. In lack of true data, the 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.

STUDY AREA AND INPUT DATA

The travel demand model titled as Maryland Statewide Transportation Model (MSTM), designed as a multi-layer model working at national, regional and local level is used for analyzing the proposed scenarios. The study area covers all of Maryland, Delaware, and Washington D.C.; along with portions of New Jersey, Pennsylvania, Virginia and West Virginia (covers 64 counties in the region).

MSTM consists of 1,607 SMZs and 132 regional modeling zones (RMZs). The 132 RMZs cover the complete US, Canada, and Mexico. Maps of SMZ and RMZ are presented in Figure 4(a) and 4(b) respectively. A four-step travel demand model is developed to forecast passenger travel demand between Origin-destination (OD) pairs by various travel modes and time-of-day periods. In the next section details of the integrated land use transportation model is discussed.

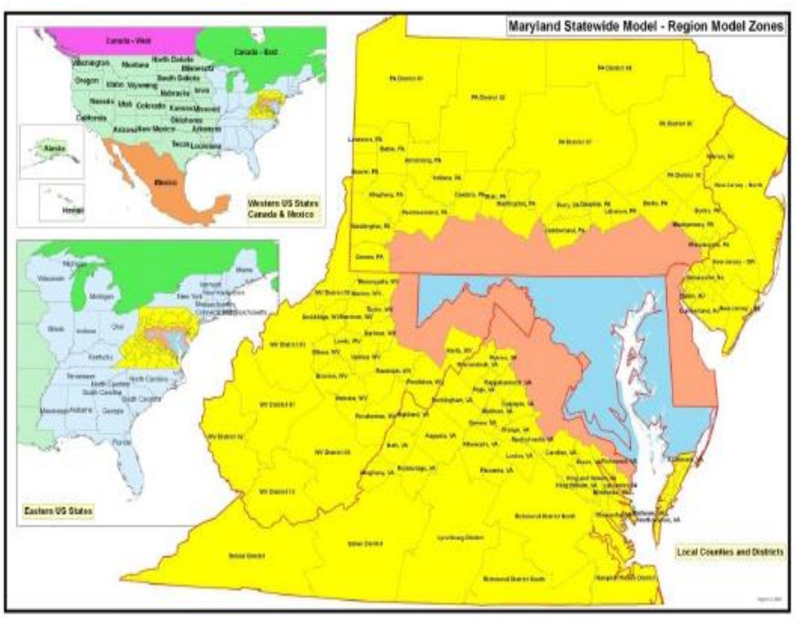


Figure 4(a): Regional Modeling Zones in MSTM

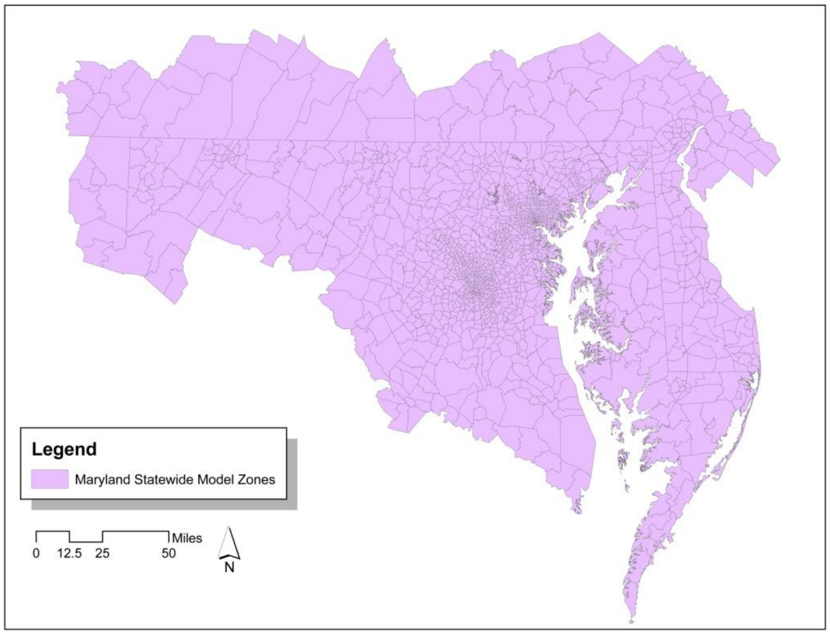


Figure 4(b): Statewide Modeling Zones in MSTM

Integrated land Use Transport Model

The integrated land use transport model is presented in Figure 5. The land use model consists of three stages: (a) an econometric model at the state level, (b) a regional model at the county level, (c) an econometric model at the SMZ level. Please refer to the "Background" section for the details of three stages of the land use model. The transportation model contains the following steps (MSTM, 2009):

- *Trip Generation*[1] is a cross-classified model for production and attraction of person trips by 19 trip purposes (Home Based Work, Home Based Shopping, and Home Based Other trip purposes interactive with 5 travelers' income levels (15 trip purposes); Home Based School, Journey to Work, Journey at Work, and Non Home Based Other).
- *Destination choice*[2] is a logit model for connecting trip production and attraction to OD trip matrices, based on travel times, distances, tolls, and rivers acting as barriers.
- *Mode Choice*[3] is a nested logit model for splitting OD trip matrices into 11 travel modes (3 auto modes, and 8 transit modes). Three auto modes refer to Single Occupant Vehicles (

[1] Trip generation step determines the number of trips produced and attracted to the SMZ.

[2] Trip distribution step determines the origins and destinations of trips between SMZs

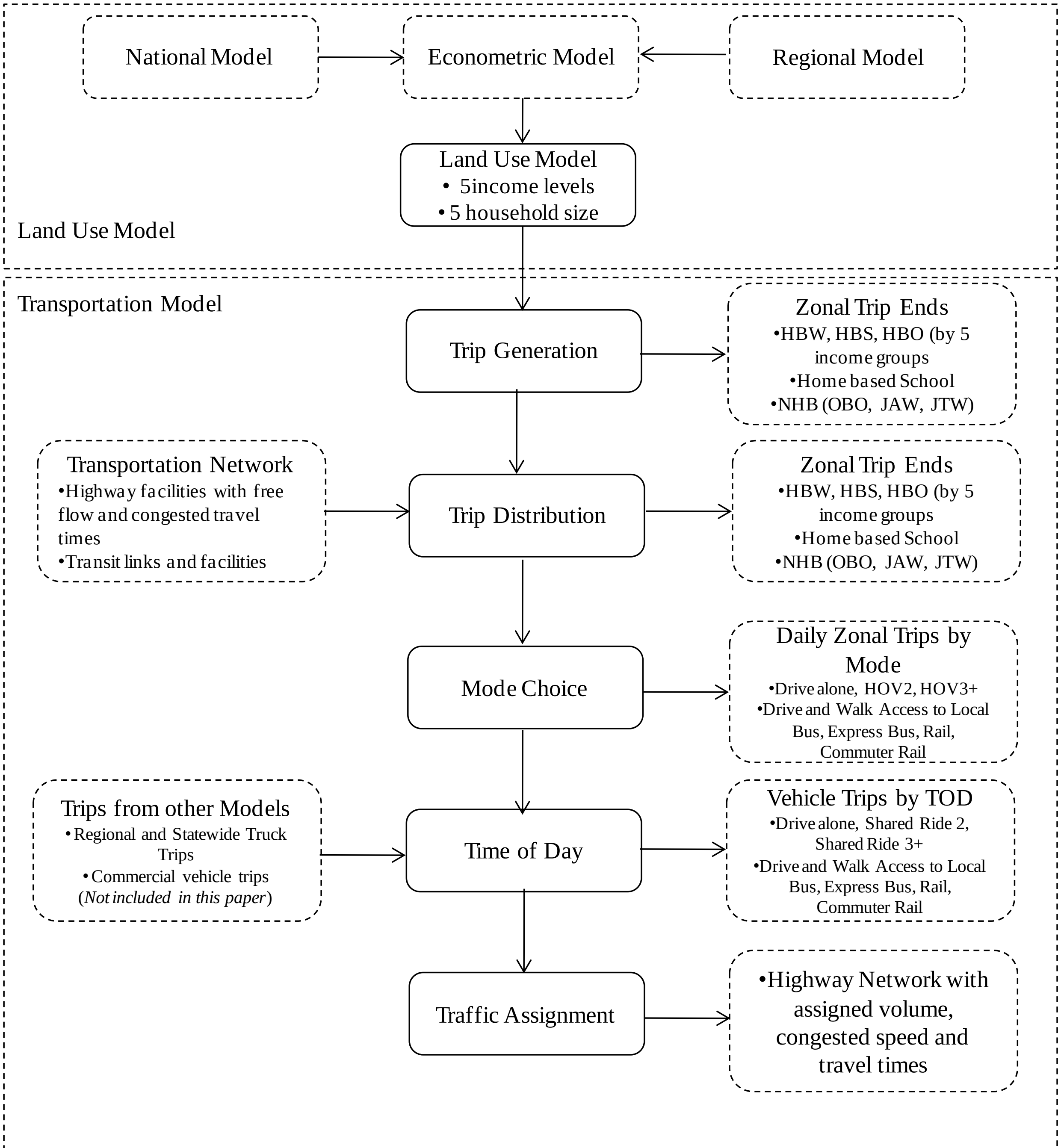


Figure 5: Integrated Land Use Transportation Model

[3] Mode choice computes the proportion of trips between each origin and destination that use a particular transportation mode.

- SOV), High Occupant Vehicles with 2 occupants (HOV-2), and High Occupant Vehicles with three or more occupants (HOV-3+).
- *Time-of-day allocation* is a model for splitting daily travel demand into demand over four daily time periods (i.e. AM peak, PM peak, Midday and Night).
- *Traffic assignment*[4] is based on a user equilibrium method of assigning trips to the links by minimizing the travel time for the users.

Policy Implementation in MSTM

The true value of a mega-regional model becomes apparent when policy scenarios are analyzed. The simulation model allows testing freight infrastructure investments on their likely impact on traffic flows, the economy and the environment, before projects are actually implemented in reality. In addition to the base scenario, which simulates the business-as-usual case, three policy scenarios have been simulated and their likely impact on the transportation system was analyzed. The view point of three stakeholder groups with very different motivations was taken to analyze the broader impact of their specific goals. Table 3 summarizes the scenarios tested with the CBM simulation model.

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

[4] Traffic assignment allocates trips between an origin and destination by a particular mode to a route. Further, a route consists of set of links in the transportation network.

The first stakeholder group is freight shippers. Particularly trucking companies continuously criticize the public administration for not investing sufficiently into road infrastructure, which according to the shippers worsens congestion and costs the economy billions of dollars per year. In this scenario, it is assumed that there were no budget or topological constraints to widen the highway network. The capacity of highways was doubled by adding the same number of lanes to the Interstate Highway system that is in existence in the base scenario. Certainly, this is highly unlikely capacity increase to happen, as government budgets struggle to fulfill mandatory services, and many interstate highways in the CBM region are located in densely population areas without space to widen highways. Leaving 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 a major concern in transportation planning.

The second perspective addresses the planner's standpoint. Frequently, regional and urban planners demand that more goods should be shipped by rail rather than by truck to reduce both congestion and emissions. Within the CBM study area, many rail facilities actually operate at capacity, which suggests that expanding rail capacity is likely to increase shipments by rail. In this scenario, the rail capacity is assumed to be doubled. Given that there appears to be demand for more rail shipments in the CMB region, doubling the rail capacity is assumed to trigger a mode shift from truck to rail. For every FAF zone origin-destination pair, the rail flows are doubled. At the same time, the tons added to the rail network are removed from the truck flows. In some cases, there less truck flows of this particular commodity and origin-destination pair than rail flows. In that case, trucks for this flow were set to 0, assuming that doubling the rail capacity allowed moving all commodity flows of this commodity/origin/destination combination from trucks to rail. Analyzing the impact on congestion on the highway network shall help understanding the likely effects of increasing rail capacity on road travel conditions.

The third scenario took the viewpoint of policy makers. Though policy makers and planners perspectives often overlap, in this case it was assumes that some policy makers were promoting a flagship project that promotes employment and the 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 coming from Asia to access East coast states directly. The ports of Baltimore and the Port of Norfolk are assumed to grow in capacity. Given space limitations at the Port of Baltimore, which is located fairly close to downtown Baltimore, the Port of Baltimore is expected to grow no more than 100 percent, while the Port of Norfolk was assumed to be able to grow by 200 percent. It was not analyzed if there was actually the demand to increase the flows through the Ports of Baltimore and Norfolk, it was simply assumed that additional capacity would be filled up with the widening of the Panama Canal. Existing travel patterns through the port were doubled, i.e. the same commodities and the same origin-destination pairs were used for the additional flows. The employment at the ports was not changed, as increasing automation at ports has tended to reduce employment even under an increasing amount of goods being shipped through the port. The scenario analyzes the impact of increased commodity flow through the port, of which many are shipped by truck to their final destination, on the highway network.

RESULTS AND DISCUSSION

The proposed methodology of freight planning is analyzed using MSTM to realize the objectives of three stakeholders, namely: (1) shippers, (2) planners, and (3) policy makers. The three stakeholders perceive transportation system in different ways. The results in the following section show the impact of policies envisioned by these agencies on the transportation system. The transportation impact results are presented in three categories: (1) at state level, (2) at facility type level, and (3) at corridor level.

State Level Impact

The state level impact is analyzed with measures such as vehicle miles travelled (VMT), vehicle hours of travel (VHT), vehicle hours of delay (VHD), and congested lane miles (CLM). In the following paragraphs impacts of each entity perspective on the aforementioned measure is explained.

Vehicle Miles Travelled

Figure 5 shows the statewide VMT at different times of day. For example, figure 5(a) shows for AM perk period (6:30AM to 9:30AM) statewide VMTs for base case, shipper's perspective, planner's perspective, and policy maker's perspective. VMT from the shipper's perspective is the highest among all. The reason behind higher VMT for shipper's perspective is when capacity of the interstate, expressway, and freeways are increased, the highways become more attractive compared to transit. As a result, traffic volume for highways has increased compared to the base case. The induced demand resulted in increase in VMT for the shipper's perspective can result from mode shift from transit to highways. Note that the ordinate does not intersect with the abscissa at 0. This scale has been chosen to better visualize the differences between the scenarios. The differences between all four scenarios are comparatively small, even though the scenarios implemented fairly dramatic changes in freight infrastructure. However, all scenario aimed at affecting truck flows, an no scenario was aimed at affecting directly the larger share of vehicles on the road: autos. With the exception of the shipper's scenario, which doubled the highway capacity for all vehicles, the scenarios changed freight flows, and autos were only affected indirectly by different levels of congestion.

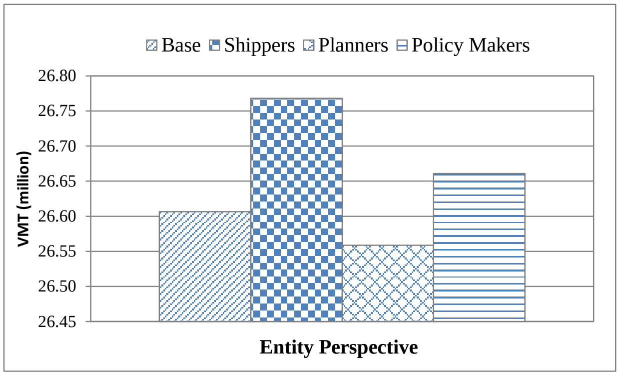


Figure 5 (a): AM Peak Period VMT

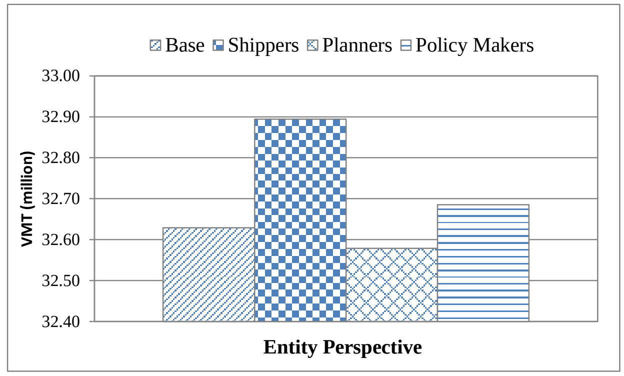


Figure 5 (b): PM Peak Period VMT

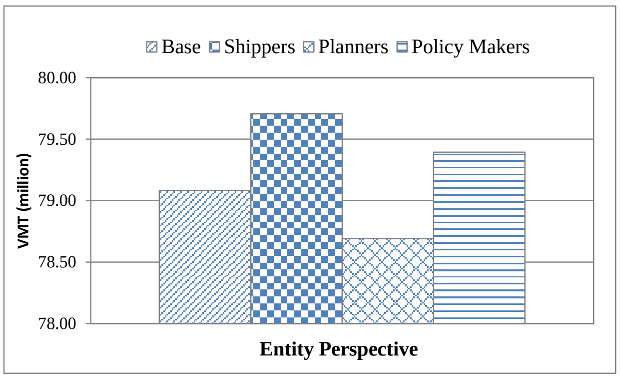


Figure 5 (c): Off-Peak Period VMT

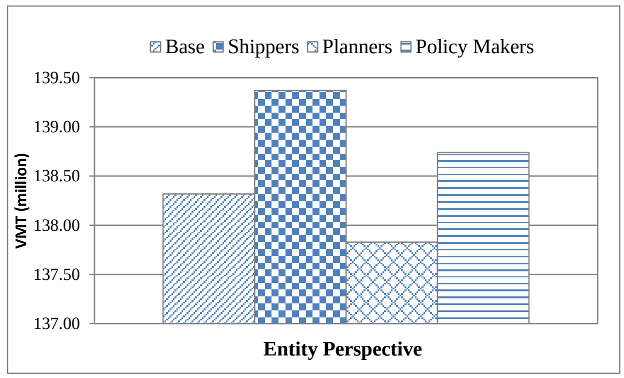


Figure 5 (d): DailyVMT

Figure 5: Statewide VMT by Time-of-day

Figure 5(a) shows that VMT is least from planner's perspective. This is because a larger number of truck trips are diverted to rail to alleviate the congestion from highways. In this scenario a better management of truck traffic is viewed as the planner's perspective is to efficiently design the transportation system without much capital investment. Lastly, when policy maker's scenario is analyzed, the resulted VMT is higher from the base case. This is because; more production and attraction of freight commodities without any capacity expansion of transportation infrastructure. From the policy maker's view point only economic growth is considered without any consideration to the infrastructure management.

Similarly, Figure 5(b), 5(c), and 5(d) represent statewide VMT for PM (3:30PM-6:30PM), off-peak (9:30AM-3:30PM, and 6:30PM to 6:30AM) and daily time periods. The observations are similar to the AM peak period. It is found that irrespective of the time of day, shipper's perspective has highest VMT, planner's perspective has lowest VMT, and policy maker's perspective has VMT between the shipper's and planner's perspectives.

Vehicle Hours of Travel

Figure 6 shows the VHT for various times of day. In Figure 6(a) VHT for base case, perspectives of shippers, planners, and policy makers are shown. Among all cases analyzed VHT for policy makers are the highest. This is because more freight demand is desired by the policy makers to boost the economy without any consideration of improvement to the transportation system. Similarly from shipper's perspective the resulted VHT is the least. This is because with capacity expansion.

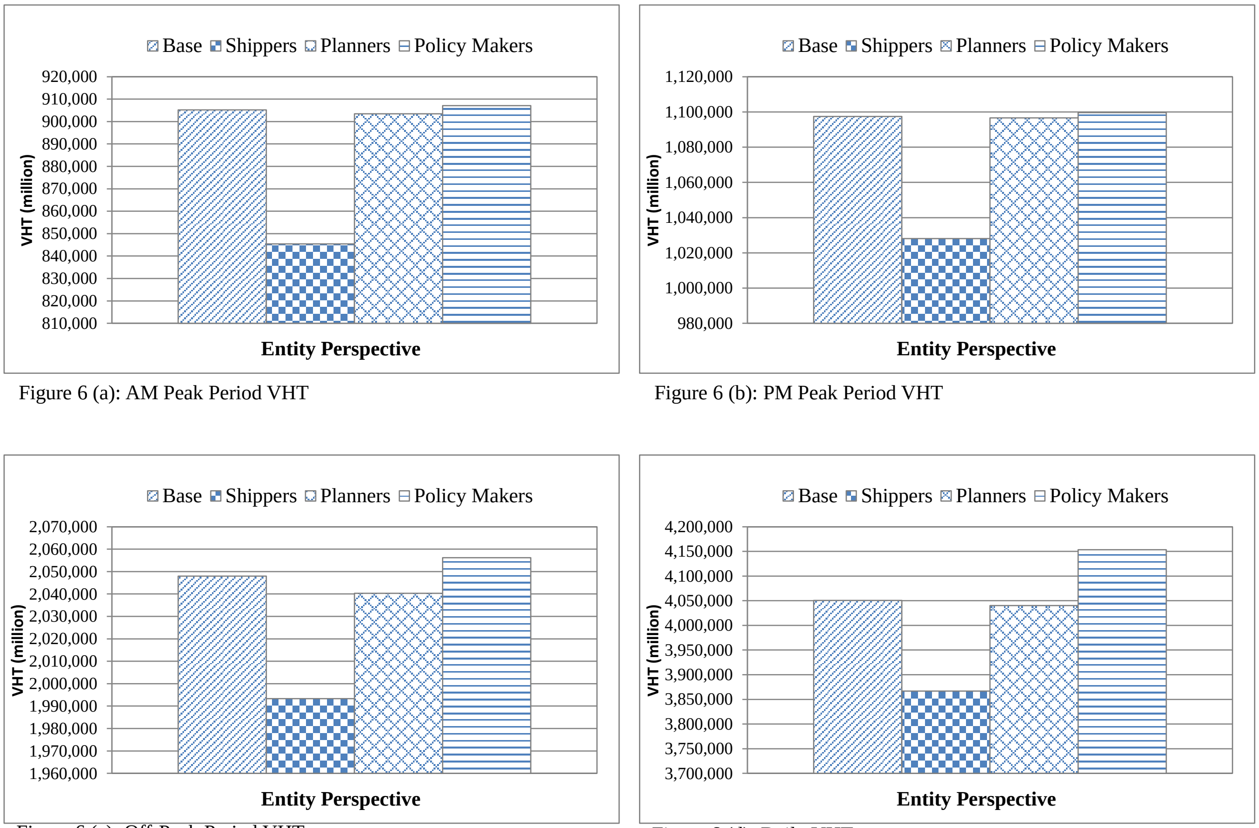


Figure 6 (a): AM Peak Period VHT

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

Congested Lane Miles

Statewide CLMs are shown in Figure 7. CLM represent lane miles with volume to capacity ratio more than 0.8, i.e. level of service (LOS) lower than E. Lesser number of CLM represent better operational conditions. Figures 7(a) through 7(d) represent number of CLM by time of day. For example, Figure 7(a) shows for AM peak period the least number of CLM is from shipper's perspective. The reason for the lower value of CLM is because of the capacity expansion in response to satisfy the shipper's perspective. The highest CLM is observed for the policy maker's perspective, because of increase in demand without any increase in capacity. Better management of traffic is not considered for the policy maker's perspective. The CLM for planner's perspective is in between the shipper's and policy maker's perspective as demand is as per the current conditions and a better management of modal distribution is performed.

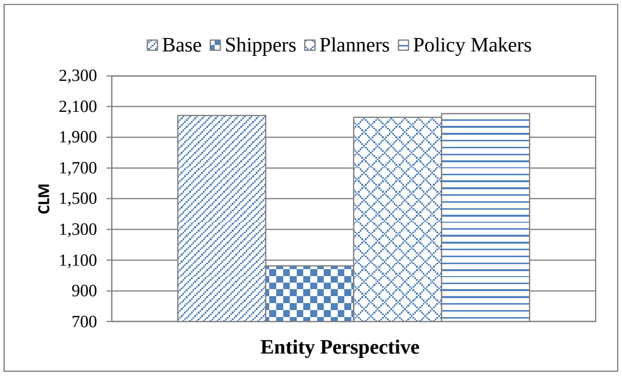


Figure 7 (a): AM Peak Period CLM

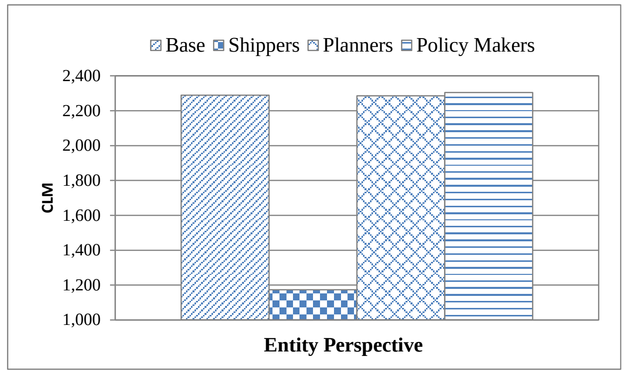


Figure 7 (b): PM Peak Period CLM

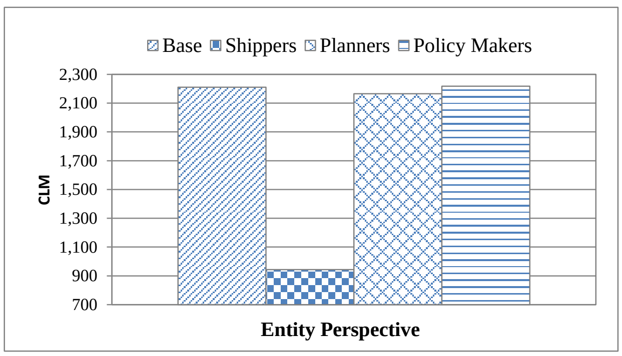


Figure 7 (c): Off-Peak Period CLM

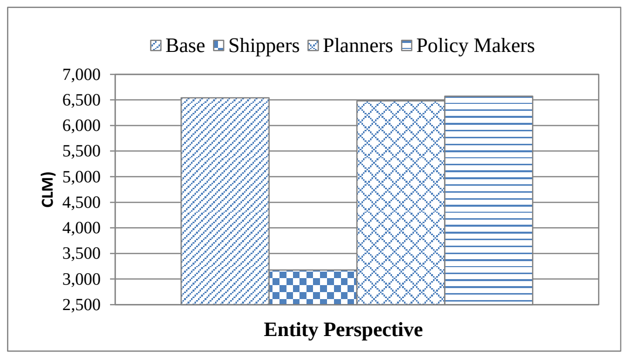


Figure 7 (d): Daily CLM

Figure 7: Statewide CLM by Time-of-day

Facility Type Impact

Facility type represent highway functional class such as freeway, interstates, expressway, major arterial, minor arterial, collector and local streets. The facility type impact should convey network level at much disaggregate level. The facility type impact is analyzed with measures such as VMT, VHT, VHD, and CLM. In the following paragraphs impact of each entity perspective on the aforementioned measure is explained.

Vehicle Miles Travelled

Figure 8 shows the interstate VMT at different times of day. For example, figure 8(a) shows for AM peak period VMTs for base case, shipper's perspective, planner's perspective. As seen in the statewide level results, for interstates as well, the VMT is higher for shipper's perspective.

This is because with capacity expansion interstates become attractive facility to travel, and the increase in traffic volume is the result of shift from the adjacent facilities and from other modes to highway. The least VMT is observed in planner's perspective case as a number of trips are diverted to rail. The decision maker's perspective VMT is higher than the base case because of increased demand to reflect the economic growth without managing the travel demand.

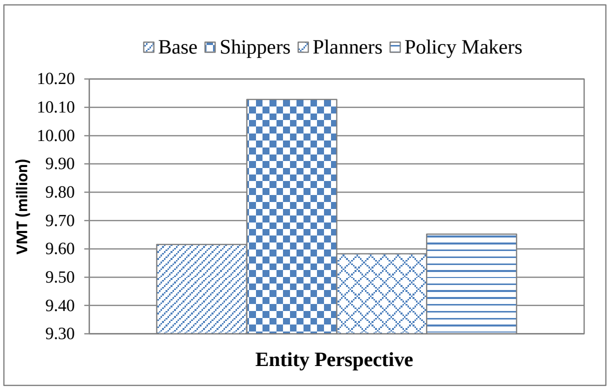


Figure 8(a): AM Peak Period VMT

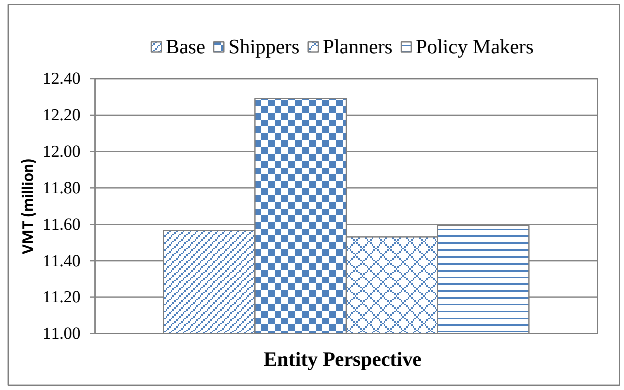


Figure 8(b): PM Peak Period VMT

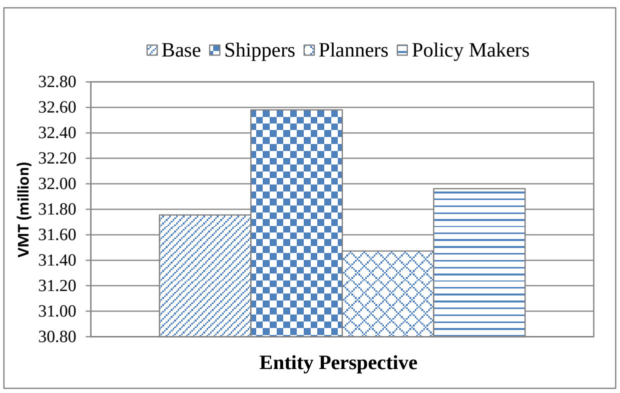


Figure 8(c): Off-Peak Period VMT

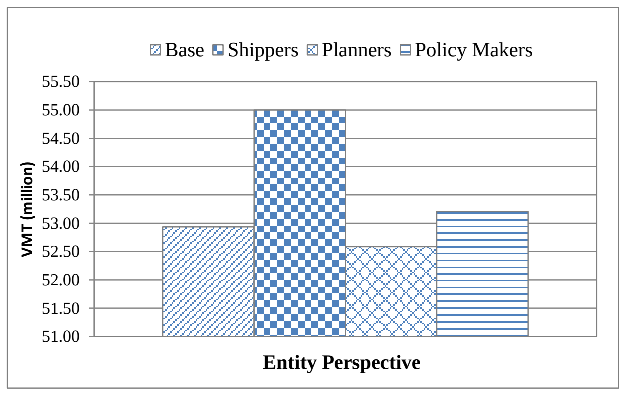


Figure 8 (d): Daily VMT

Figure 8: VMT by for Interstates

Vehicle Hours of Travel

Figure 8 shows the interstate VHT at different times of day. For example, figure 8(a) shows for AM peak, the shipper's perspective case has least VHT. This is because with capacity expansion the travel time on interstates becomes much smaller, resulting in lesser VHT. The highest VHT occurs for policy maker's perspective as the demand is increased with no improvement to the transportation infrastructure. The planner's perspective VHT is in between the shipper's and policy maker's perspective.

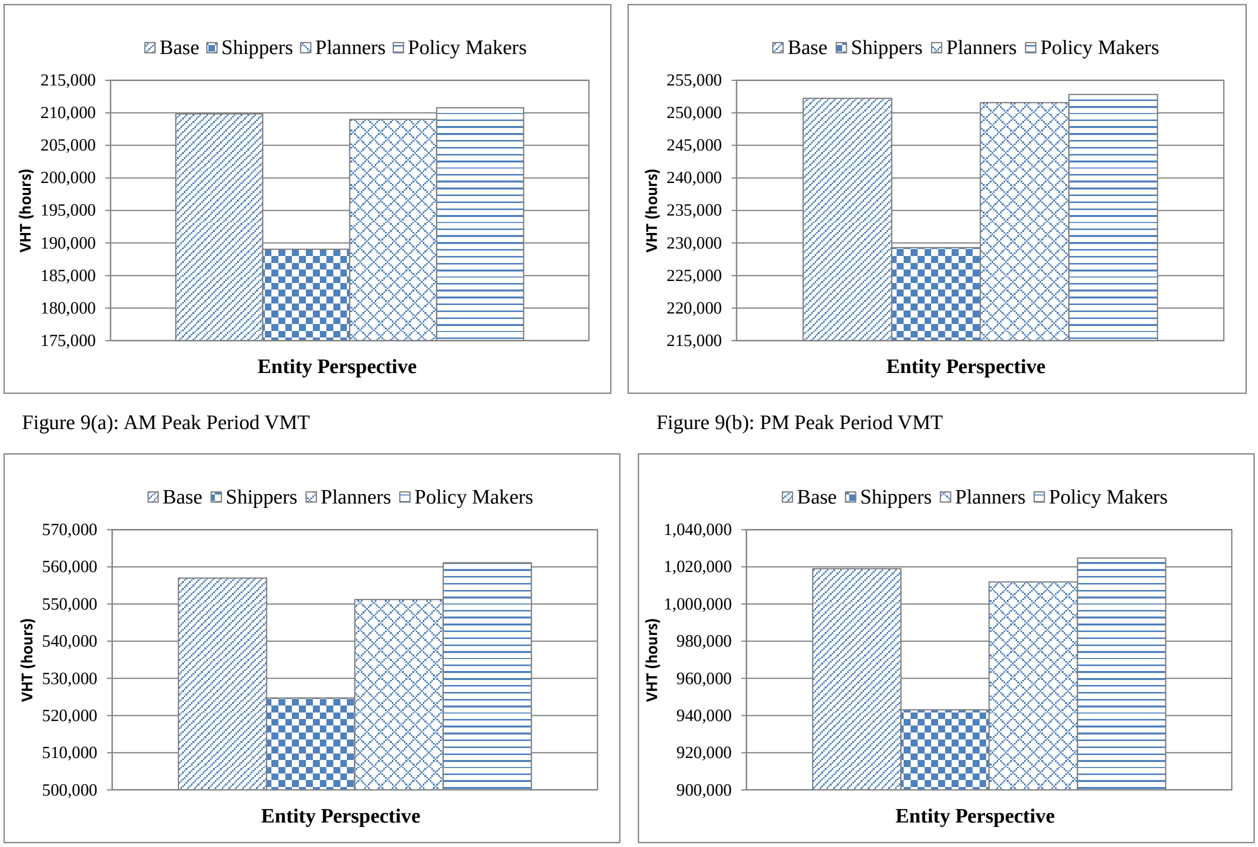


Figure 9(a): AM Peak Period VMT

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

Congested Lane Miles

Interstate CLMs are shown in Figure 10. Figure 10(a) shows that CLM is the least for shipper's perspective. As explained in the earlier sections, this is because of the capacity expansion with using same demand as the base case. Among all scenarios, policy maker's perspective resulted as the highest CLM, followed planner's perspective.

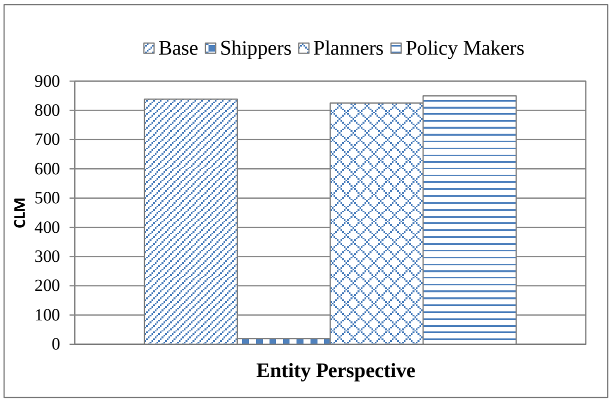


Figure 10(a): AM Peak Period VMT

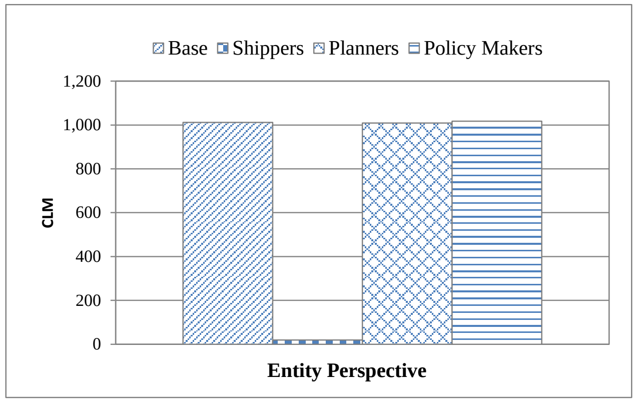


Figure 10(b): PM Peak Period VMT

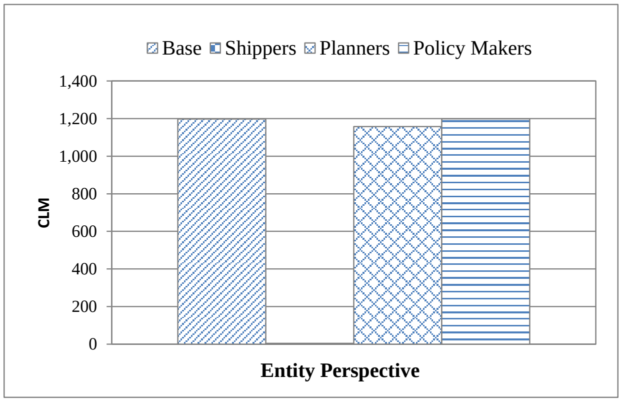


Figure 10(c): Off-Peak Period VMT

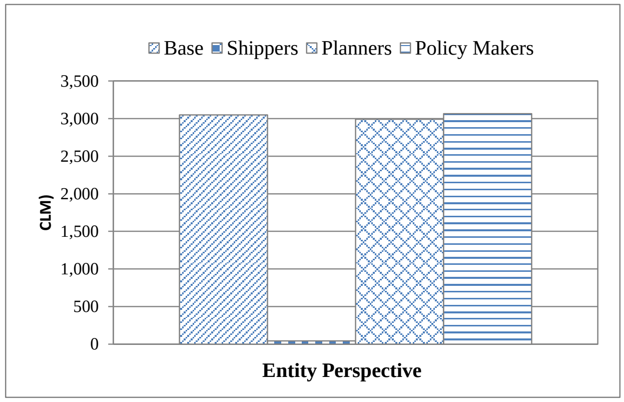


Figure 10(d): Daily VMT

Figure 10: CLM by for Interstates

<u>Link Level Impact</u>

The link level impact represents further disaggregated version of results when compared to the statewide and facility type impact. Results at link level can demonstrate the effect on particular section of roadways. Instead of presenting VMT, VHT, and CLM for the link level, only daily traffic volume (or number of vehicles) is discussed. In addition, to be specific only bridge crossings are considered to demonstrate link level impact. The reason for considering bridge crossing is to demonstrate the impact of each entity perspective results on these critical locations. For brevity five critical bridges are considered for presentation purposes. The impact on these five bridges in both directions is shown in Figure 11. The geographical location of these bridges is shown as an inset in Figure 11. The percentage difference in traffic volume from each entity perspective when compared to the base case is demonstrated for comparison purposes. The results show that from shipper's perspective all the bridges carry higher traffic volume compared to the base case. This is because of the capacity expansion of interstates and freeways, roadways become more attractive. Most of these bridge crossings are interstate highway, and traffic is diverted from local roads on highways after their capacity was increased. In contrast, from planner's perspective traffic volume has declined compared to the base case. This is because of the shift of mode from highway to rail.

Bridge	% Diff		
	Shipper	Planner	PolicyMaker
GovHarryNiceMemorialBridgeNB	16%	-2%	10%
GovHarryNiceMemorialBridgeSB	15%	-1%	14%
WoodrowWilsonMemorialBridge1NB	11%	0%	12%
WoodrowWilsonMemorialBridge1SB	75%	-1%	10%
AmericanLegionMemorialBridgeNB	18%	-4%	10%
AmericanLegionMemorialBridgeSB	22%	-1%	12%
ConovingoRoadHwy1NB	44%	-3%	11%
ConovingoRoadHwy1SB	52%	0%	10%
JohnFKennedyMemorialBridgeNB	8%	-4%	12%
JohnFKennedyMemorialBridgeSB	22%	-2%	10%

Figure 11: Link level results compared to base case

Similarly from policy maker's viewpoint, traffic volumes on these bridge locations are higher than the base case. In this scenario, higher economic growth is designed without making considerable effort in better managing the transportation infrastructure.

Conclusion

This research is envisioned towards design and application of freight transportation modeling techniques to better address planning and policy issues and economic assessment as recognized by principal entities involved in freight planning. Three stakeholders were identified as shippers, planners, and policy makers. While these three entities play important roles in the freight transportation system, their objectives are different. Shipper's objective is to transport various commodities from origin to destination in minimal cost, where the cost can be a function of distance, time, toll, comfort, convenience, and other factors. Planner's objective is to design the transportation infrastructure to better manage the modal shift between highway and rail, so that all modes are used efficiently without any extra capital investment. Policy maker's objective is to bring economic growth to the region to enhance economic stability.

This research attempts to examine the impact on the transportation system when objective of each entity is analyzed. The results are shown at three levels (1) statewide level, (2) facility type level, and (3) link level. In combination of these three levels, a broader picture of the transportation system can be obtained. Further, for each level different measures of effectiveness such as VMT, VHT, and CLM are estimated.

It is observed that when shipper's perspective is analyzed the VMT was highest, VHT, and CLM were lowest. This is because, for shipper's perspective capacity is increased and highways become more attractive than transit for passenger travel; and traffic volume for highways become higher, leading to higher VMT. But with capacity expansion, the time taken for travel is reduced as congested speeds are higher, leading to lower VHT. With capacity expansion, the volume to capacity ratio is now smaller, leading to lower CLMs. From planner's perspective resulted VMT is lowest, because of varieties of commodities are transferred from highway to rail, but resulting VHT and CLM is higher than based on the shipper's perspective. From policy maker's perspective, VMT resulted between the shipper's and planner's perspective, but the VHT and CLM are highest among all. This is because of this scenario laid more emphasize on economic growth without enhancing the transportation infrastructure.

In summary, the trend as opposed to the absolute numbers is important for this research. The research can be viewed upon a toll to obtain macro and micro level results when objectives of three (shipper, planner, and policy maker) principal entities involved in freight transportation systems are analyzed. This tool can be used to enhance state, and local level freight planning needs. This research can be further extended to evaluation at higher disaggregated levels using micro-simulation techniques.

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EXTRA: Hiro's note

Rolf 1: This port scenario turned out to be one of the most challenging things I have implemented in a while.

- The model was not setup to keep track of single flows from one point of entry, so I had to rewrite quite a bit of the code to make this scenario possible.
    - When I ran this scenario for the AMPO conference, I took the shortcut and allowed the model to assign the entire growth through the port to all zones within the county in which the port is located. That was easy to implement, but obviously it was a shortcut that's too simplistic. This time I wanted to get it right, and that turned out to take much more time than I had anticipated. But here it is, please download this zip file: https://ftp.pbworld.com/GetFile.aspx?fn=1691588251.zip.
- I also found a bug in the code that swallowed a small part of the commodity flows. Fixing this slightly increased truck traffic overall. It shouldn't make too much of a difference, but I rerun the rail scenario as well. Now, you have two option:

    (1) If you already analyzed the rail scenario that I sent you yesterday, just keep it as it is. The base scenario from yesterday and the base scenario from today are slightly different, but since both the base scenario from yesterday and the rail scenario from yesterday were run with this small bug, the comparison you did is close enough. To analyze the port scenario, you should compare the base scenario from today and the port scenario from today. Do not compare today's port scenario with yesterday's base scenario, that would be invalid.

    (2) If you did not analyze the rail scenario that I sent you yesterday, please dump the files I sent you yesterday. The download gives you three files (base scenario, rail scenario and port scenario), all without the bug I found today. Using only these newer files should be cleaner.

In the port scenario, I decided to increase flows through the port of Baltimore (both imports and exports) by a factor of 2 and flows through the port of Norfolk by a factor of 3 (assuming that Norfolk has more space for expansion than Baltimore). If you don't like these factors, it's very easy for me to rerun the model and apply whatever factors make more sense to you. Norfolk is actually outside of our SMZ study area, so it would also make sense not to scale Norfolk at all. But that's up to you, let me know if you feel other factors than 2 and 3 tell a better story, and I will rerun the model.

Sabya 2: Thank you for the port scenario. I did run the old base and rail scenario yesterday. But to be consistent (and a bug free model run), I am re-running the base, rail, and port scenarios today. Each model run takes about 3 hours, so I will be done sometime today and start summarizing the results.

3) I ran the rail scenario. In this scenario, I read in the flows by rail, and assumed that those would double. The same amount I subtracted from the truck flows.

I took care that I do not get negative truck flow numbers, they cannot drop below 0. This is relevant for a couple of flows. For example, if there are 100 tons of coal shipped from Ohio to Baltimore, but there are only 10 tons of coal shipped by truck from Ohio to Baltimore, then I set those truck flows to 0.

This scenario led to a reduction of 5.7% in terms of truck trips. This will predominately affect long-distance trips, so I expect the impact on VMT to be higher than that. I don't know at this point how far our study area is affected. I applied this scenario nationwide, and if our study area has a below-average rail share, the impact of this scenario will be less visible in the MSTM area.

Let me know how that works out. You can download the truck files here: https://ftp.pbworld.com/GetFile.aspx?fn=74541217.zip. Note that I added the base scenario and the rail scenario, just to make sure that you can compare apples with apples. It might be, that the base scenario is somewhat different from what you have (even though I don't remember having changed anything for a long time on the long-distance model, so the base scenario could be identical with what you already have).

Sabya 4: Thank you for preparing the data. Quick question. I am wondering how I can use the files in model run. I think the files you prepared goes to the "regionalmodel\input" folder but I thought to check with you before starting the model run.

From Pendlya's article

Pendlaya etc. proposed a framework of as a comprehensive freight transportation planning concept, describing modeling methodology, input variables, and output variables in each step, taking into account availability of network-level and socioeconomic data. It further includes a postfreight assignment process that addresses critical measures-of-effectiveness issues not directly derivable from analytical demand models and help in decision-making processes.

- two extremes of geographic aggregation--firm-level and National Transportation Analysis Region-level.
- the commodity groups identified under "Firm Product" and the activity groups identified under "Industry Activity"

One may use any classification or grouping scheme depending on the type of study. Within trip generation, the value and weight of commodity flows are determined. These flows are then distributed spatially explicitly considering intrastate, interstate, and international movements. The modal choice model explicitly incorporates multiple modes (intermodal) alternatives so as to capture intermodal movements. After trips are assigned to various modes or combinations, they are assigned to a predetermined network based on the O-D pair volumes computed in the distribution and mode choice elements.

measures of effectiveness or performance: delay, queues, pavement conditions, safety, flow and capacity, accessibility, and terminal times.

- Trip generation: aggregate direct demand approaches, simultaneous equations approaches, or disaggregate regression-based techniques.
- Destination choice (trip distribution) and modal split : Discrete choice models.
- Trip distribution: In the absence of adequate data, synthetic origin-destination matrices, traditional gravity models.
- When adequate data are available, network models of logistics for modeling virtually all key elements of freight travel demand, particularly network assignment.
-

Indiana (12). linear regression to estimate productions and attractions and a gravity model to distribute the trips throughout the state.

Florida: a Fratar Growth Factor model that applied various production and consumption-based growth factors to current flows of commodities. modal split models. Was difficult due to data limitation

Aggregated Analysis: When commodity flow volumes are estimated in an aggregated manner within the four-step model framework systems, a basic modal split model where the proportion of total traffic carried by a particular mode is determined; more appropriate to use than a single equation that estimates a single aspect of freight traffic demand. Another approach is the generation of synthetic origin-destination matrices from truck traffic counts—useful in the absence of detailed data (25).

Disaggregate Models: Disaggregated demand models focus on the mode choice step (26–28), and incorporate attributes of modes, firms, and shippers that influence freight decision making. In some disaggregated demand models, firms' decisions on mode choice and production are considered endogenous to each other to integrate production factors, such as shipment size and shipment frequency into a mode choice decision (Pendlya, ***).

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attention must be paid to the potential presence and effects of unobserved heterogeneity that may arise in different ways. For example, one must examine whether the choice process and behavioral structure implied by the model framework is correct. It is conceivable that the choice process and behavioral mechanisms driving freight transport demand vary depending on the type of commodity being shipped, the regulatory environment surrounding the decision process, and other situational constraints.

recognize differences among industries, shippers, carriers, and retailers that may call for separate models to be estimated for various entities. In other words, one must note that the same model may not be universally applicable to all decision makers.