A STATEWIDE FREIGHT FLOW MODEL FOR ALABAMA

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ABSTRACT

Transportation infrastructure is an integral piece of the economic growth puzzle. The proper alignment of needed infrastructure with economic opportunity enhances the return on investment from that infrastructure investment. Decision tools to assist in this alignment activity are not readily available. The development of a transportation model that accurately shows the current state of Alabama's infrastructure and allows for predictive analysis of the impact that relocating or developing industries have on economic regions was developed during this research. A survey was conducted to determine freight volume and movement for a select group of industries. Data from published government sources were also used. Regression analysis was performed to study the relationships between industry size and type and the volume of freight that moves using different modes of transportation. The model was developed using TRANPLAN and can be used to determine the expected effect of a new business on the local transportation infrastructure.

INTRODUCTION

Modeling transportation infrastructure needs generated by increases in freight transportation has been performed with limited success in this country. Complicating the issue is the fact that the increases in transportation often result from economic growth occurring many, sometime hundreds, of miles away. An important component to understanding the economic growth and infrastructure needs puzzle are Intermodal Statewide Freight Transportation Models. The Transportation Equity Act for the 21st Century (TEA-21) supported the development of statewide models through identified transportation planning factors, specifically stated "to enhance the integration and connectivity of the transportation system, across and between modes throughout the State, for people and freight" (1). This support has continued in Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) (2).

The primary reason the forecasting of freight movements has been ineffective is that the current state-of-the-practice is focused on examining historical growth, then forecasting the historical growth trends into the future, essentially utilizing the notion that previous growth is a good predictor of future growth. Unfortunately, this method of freight forecasting is limited by the fact that freight growth does not typically follow historical trends and growth in freight requirements is generated by large, independent events that require a multitude of factors to come together in a symbiotic fashion.

Increases in freight requirements occur when a new facility is opened or there is significant improvement in business activity. A roadway or rail-line that has been experiencing limited freight movement could see an abrupt increase in transportation usage after the construction of a manufacturing plant or timber processing facility. When a specific set of external factors such as economic activity, an increase in productivity and industry cluster development occurs in combinations that create a growth pattern, transportation infrastructure demand can outpace supply quickly. It is the combination of discrete freight generating events and external factors that limit the effectiveness of trend line analysis for freight forecasting.

In an effort to improve freight forecasting methodologies, this research attempted to utilize an urban transportation planning model as a tool to model multi-modal statewide freight transportation. These models, used in almost every metropolitan area in the country, take input levels of transportation demand (in the form of trips produced from one area and trips attracted to another area) and transportation supply (in the form of roadways available to accommodate the trips) and predict future traffic volumes on city streets. The outputs of these models are used to identify current deficiencies in the transportation system and, with forecasted population and employment data, identify future transportation system deficiencies in a specified horizon year. Advantages of this model over trend line forecasting include the fact that the model inputs can be adjusted for discrete events such as sudden changes in employment and/or changes in the transportation network.

This paper examines the development of a statewide transportation model utilizing travel demand modeling methodologies. There is a brief literature review of other recently developed statewide models and a presentation of the two-tiered methodology for the Alabama model. A case study is presented that demonstrates the model. Conclusions and recommendations about the ability of the model to support multi-modal infrastructure decisions are discussed.

The model inputs were developed following the traditional travel demand modeling methodology. First, a network was developed to represent the facilities where the future level of transportation demand was of interest due to potential volumes. For our model, both a highway network and rail network were developed although in this paper only the highway network is discussed. Second, relationships between common economic and population factors were developed from a freight transportation survey of industry clusters which was conducted as part of the research effort. The relationships studied focused on the demand for transportation expected as a function of the employment of the company and the unique relationships between the individual industries reviewed during the survey. After defining the relationships a projected demand for transportation services was generated with knowledge of the industry employment for a county and the overall county population. When applying the software for performing a run of the urban transportation planning model the supply side input networks and demand side transportation requirements were combined to determine the traffic volume, or freight flow, expected on an individual roadway or rail line facility in the network.

LITERATURE REVIEW

To fulfill the requirement for statewide transportation modeling supported in legislation several states have developed unique modeling approaches. The following literature review contains a brief overview of some of the statewide models recently completed.

The Virginia Department of Transportation developed a model focused on predicting the future flow of freight and improving the freight flow pattern in the state of Virginia. This was accomplished by developing a GIS database containing infrastructure data for freight transportation and county demographics. Commodity flow data was obtained on a county basis and a statistical relationship was established between the production of freight and the attraction of freight (3). A Fratar Growth model was used to distribute the freight from origins to destinations. Researchers plan to use a modified growth factor model to predict trips and develop ton-to-vehicle conversion factors for future trip distribution.

In another recent study in Mississippi, a prototype simulation model of freight movements was developed (4). This model used the Commodity Flow Data, Cargo Density Database (5) and Vehicle Inventory Used Survey data (6) as freight inputs. Simulations were performed in TransCAD to model the transportation system performance using the traditional four-step transportation planning process. Additionally the model contains simulation and animation software to display freight flow movements, change of modes at the terminals, and evaluate the importance of different modes and routes (4).

A model developed by researchers at the Center for Transportation Research and Education at Iowa State University for the Iowa Department of Transportation uses a layered approach, referred to as the 'Onion Model' for freight flow projections (7). Basic model assumptions are that intercity freight transportation doesn't lead to congestion because the loading of traffic is not simultaneous. The demand for truck transportation is assumed to not be the same for different economic regions, i.e. the truck traffic interacts independently. The meat packing industry was selected as the layer to demonstrate the model assuming that freight origins are proportional to the number of persons employed in a region (7). The model adopted the four step planning process, but the trip generation step was skipped as the model was interested in predicting future trips. A nationwide freight flow database, organized by the Business Economic Areas, was purchased for use in the model.

BUILDING THE MODEL

The modeling aspect of this project began with a task initially described as a Forecasting Model for Alabama. In order to eventually produce a forecasting model for Alabama, the project was divided into phases. The first phase was to develop an accurate understanding of the current reality of freight transportation in the state using a modeling approach based upon the traditional four-step urban transportation planning process. This required preparation of a highway infrastructure network model. The Alabama specific network used counties as traffic zones. The roadways were attributed with distance, capacity using Alabama Department of Transportation recommended values, and speed.

The purpose of this model is to accurately represent the current state of Alabama's infrastructure and allow for predictive analysis of the impact that relocating or developing industries would have on the state's freight transportation network. The model was built using TRANPLAN software, which can be employed to determine the expected effect of industry growth on the local transportation infrastructure. The data for the model was developed from published government sources and a freight transportation survey. Regression analysis was performed to study the relationships between industry size and type and the resulting freight flow. As freight flow was a primary focal point for this work, a statistical analysis was performed on the relationship between freight flow and the industries located in Alabama to determine the overall county freight movement. The specific tasks performed were: data collection, definition of a relationship between industry and freight flow, network development, and assignment of traffic. Traffic was assigned to the Alabama specific network using the socio-economic data for the counties in Alabama and an equilibrium assignment algorithm. The trips were determined using the relationships developed for freight flow from the industry cluster survey information and personal travel characteristics. The model utilizes input data described in Table 1.

TABLE 1 Model Data Sources

Alabama Dept. of Transportation • Traffic flow on interstates and highways • Railroad maps with company rail line designation	**Federal Highway Administration** • Traffic flow on interstates and highways • Historical traffic growth
Private Industry Sources • CSX Intermodal • Norfolk Southern Intermodal • BNSF Intermodal • Moffit and Nichols – Choctaw Point Report	**Survey of Alabama Manufacturers** • Freight by mode • Freight projections (5 & 10 yr) • Employment • Origin and destination
Dept. of Geography University of Alabama • Maps of Alabama	**American Association of Railroads** • Freight carried on Alabama railways
Bureau of Transportation Statistics • Air Freight data by airport • Commodity flow survey	**Army Corp of Engineers** • River-borne commerce for Alabama • Freight by port

The network was developed using GIS data for Interstates facilities, United States Highways and Alabama State Highways within the CUBE/VIPER environment. There were two separate networks developed: one focusing on the national highway infrastructure and one focusing on Alabama specific roadways. The national level network identified individual states as traffic zones, while the Alabama specific network used counties as traffic zones. The roadways were attributed with distance, capacity (using Alabama Department of Transportation recommended values), and speed. The networks are shown in Figures 1 and 2. The national model was developed to predict flows passing into and out of Alabama as well as through Alabama. A model was developed that used the states as the natural zones for the production and attraction of freight. To add realism to the model and to reduce bias for the selection of single roadways, states in close proximity to Alabama that have multiple highways connections were sub-divided into smaller zones, with the freight movements distributed to the new sub-state zones based on population. An example of this division can be found in Mississippi, where the state has been divided into three sub-state zones to account for freight movements from south Mississippi entering Alabama on Interstate 10, central Mississippi entering Alabama on Interstate 20/59, and northern Mississippi entering Alabama on U.S. Highway 72. Then, the statewide model, additional entries and exits for Alabama were added to account for local freight movements.

FIGURE 1 U.S. Highway Infrastructure

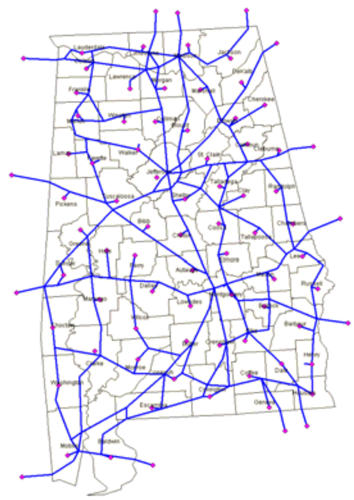


FIGURE 2 Alabama Highway Model Network

The traffic was assigned to the national network using freight flow information from the Commodity Flow Survey and an all-or-nothing assignment algorithm. Traffic was assigned to the Alabama specific network using the socio-economic data for the counties in Alabama and equilibrium assignment algorithm. The trips were determined using the relationships developed for freight flow from the survey information and personal travel characteristics adapted from the Virginia statewide model (2), as a personal travel survey was not conducted as a component of this project.

MODEL OUTPUT

The model was used to predict future traffic levels and congestion in five years. These predicted traffic levels were then compared to a projected traffic volume based upon the historical growth rate of traffic in Alabama over the last 15 years. The current highway model has several important constraints and limitations. Freight flow in the current demand model, is based on averages and traffic flows are assigned at a fixed rate so variation in demand that is evident in everyday activity is not considered. The model uses employment as the main characteristic of freight generation. Unfortunately, this methodology does not incorporate the impact of productivity improvements, however, it is considered an advantage to trend line forecasting. The current model does not incorporate endogenous changes in mode choice.

As volume to capacity ratio is a standard measure used to quantify congestion, our comparison of the forecasted traffic using the demand model and the predicted traffic using trend line analysis will be based on this measure. According to ALDOT specifications, a volume to capacity ratio of 0.75 or greater in a rural area and 0.90 in an urban area indicates a deficient condition (congestion) on that segment of highway. The difference in deficiency condition ratios between urban and rural areas is based on driver expectation of congestion. In an urban area travelers expect higher volumes and will tolerate slightly more congested roadways.

Figure 3 is an output chart from the model that indicates current and forecasted traffic volumes compared to true capacity and ALDOT congestion guidelines for Interstate 65. Note that there are areas where current volumes exceed the available ALDOT facility capacity guidelines. Using the forecasted volume created by including specific cluster growth knowledge, the area at or over capacity greatly expands in five years.

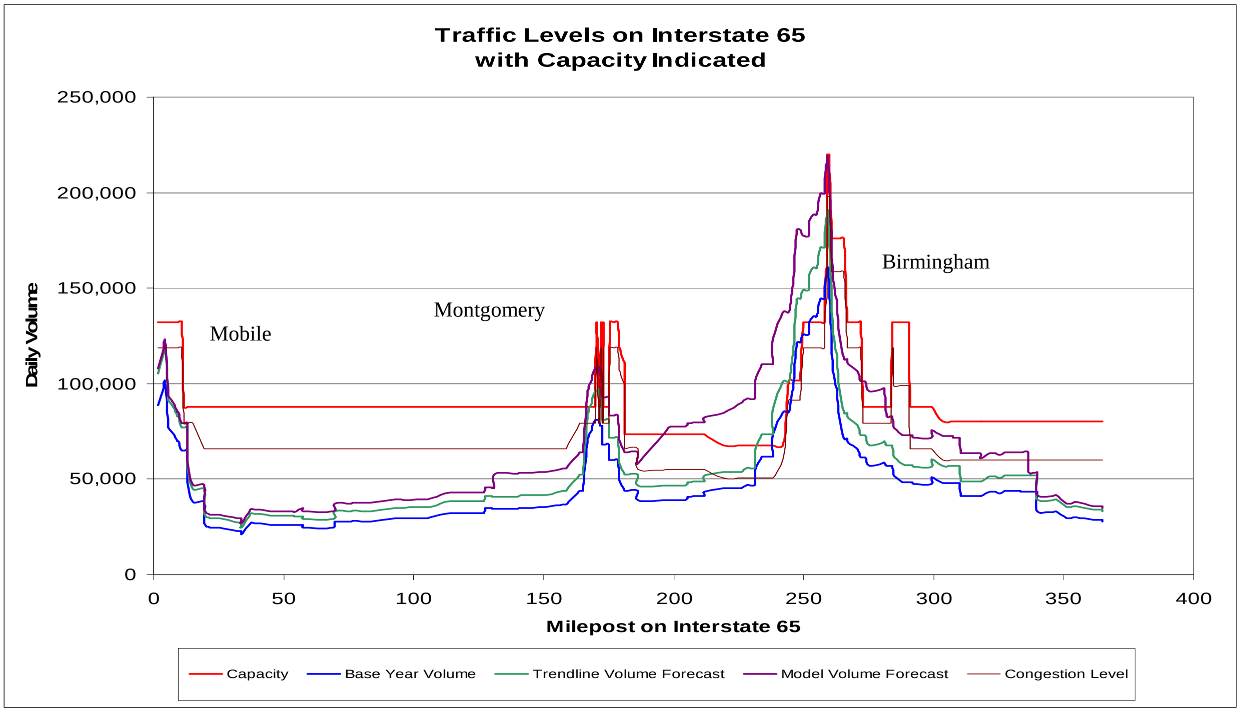
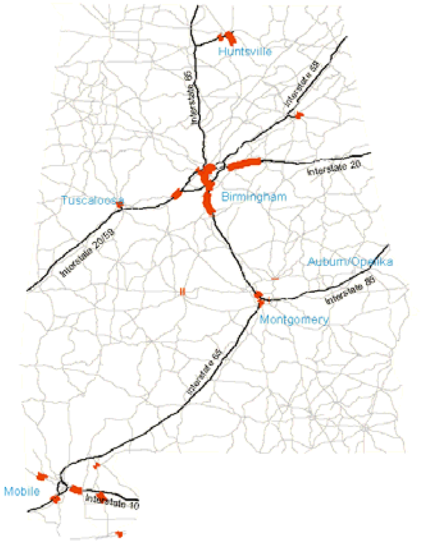


FIGURE 3 Interstate 65 Capacity Concerns

The major advantage to this modeling methodology was the ability to develop future scenarios that were reflective of discrete events where the demand for transportation services would change. For example, the development of a new manufacturing plant in a specific county could be input to the model as a change in employment, which would be reflected as a change in demand for transportation services on that county. The model would then be able to predict the future transportation requirements and allow the user to identify deficiencies in the infrastructure that might need to be addressed to ensure the growth scenario identified is brought to fruition. An example of this is a demonstration utilizing the highway network and the specific growth anticipated in the automotive and aerospace industries in Figures 4 through 6, with Figure 6 showing the impact of employment increases expected in the automotive and aerospace industries in Alabama in the next five years. Figure 4 shows the base year levels of congestion on the highway network and highlights the 455 miles of roadway considered congested by the ALDOT guidelines.

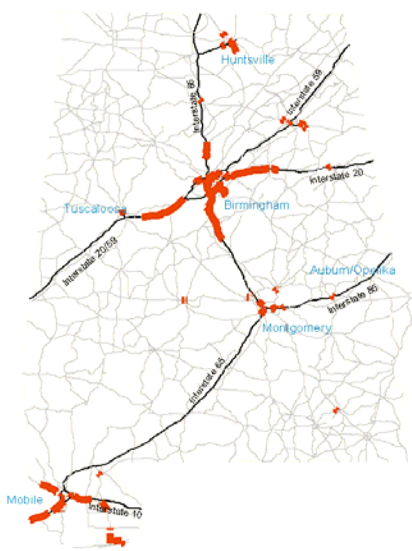


455 Lane Miles of Congested Facility

Shaded areas indicate a roadway in which volume exceeds ALDOT capacity guidelines.

FIGURE 4 Congested Locations Base Year (Alabama DOT Volumes)

Assuming historical growth rates Figure 5 shows anticipated congestion in five years resulting in 1035 lane miles of congested roadway, a 128% increase from the base year.

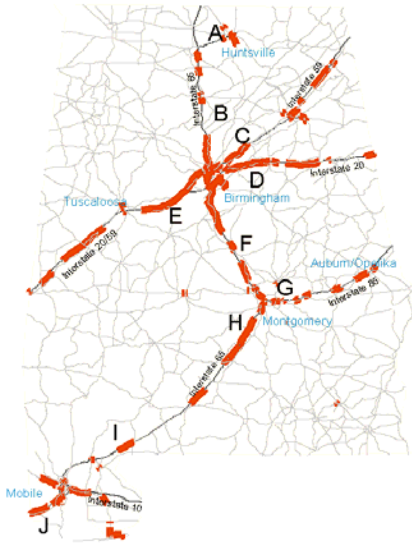


1035 Lane Miles of Congested Facility

Shaded areas indicate a roadway in which volume exceeds ALDOT capacity guidelines.

FIGURE 5 Congested Locations in Five Years (Alabama DOT Volumes)

Figure 6 presents the much greater congestion in five year arising from the projected increase of automobile and aerospace industry cluster growth over the next several years. In Figure 6 the roadway congestion is projected to be 1760 lane miles. This forecast predicts a growth in congested roadways of 287% over the base year. Table 2 indicates location-specific roadway traffic volumes from the historical trend line forecast and demand model forecast highlighting differences in the percent increase from base year traffic, the locations of the segments are shown in Figure 6. The inclusion of specific cluster knowledge in traffic forecasting identified 70% more congested roadway than the historical trend forecasting method (Table 3).



1760 Lane Miles of Congested Facility

Shaded areas indicate a roadway in which volume exceeds ALDOT capacity guidelines.

FIGURE 6. Congestion Location in Five Years with Automotive and Aerospace Cluster Information Included

Table 2. Increases in Traffic volumes with Automotive and Aerospace Cluster Information Included

Map Location (Figure 6)	Base AADT	Future AADT Historical Trend Forecast	% Increase from Base Using Trend Line Forecast	Future AADT Forecast with Specific Cluster Growth	% Increase from Base Using Industry Cluster Analysis
A	57,121	67,842	18.8%	78,577	37.6%
B	48,901	58,080	18.8%	73,494	50.3%
C	29,680	35,251	18.8%	52,885	78.2%
D	61,773	73,367	18.8%	79,853	29.3%
E	53,117	63,087	18.8%	71,112	33.9%
F	43,591	51,773	18.8%	82,589	89.5%
G	84,332	100,148	18.8%	137,207	62.7%
H	34,427	40,942	18.9%	52,735	53.2%
I	26,082	30,978	18.8%	33,165	27.2%
J	53,729	63,814	18.8%	65,314	21.6%

TABLE 3 Summary of Congested Highway Miles

Model Methodology	Miles of Congested Highway
Actual Volume of Traffic	455
Historical Trend Analysis Forecast	1035
Industry Cluster Knowledge of Growth Projections	1760

The construction of the traffic demand model brought forth several observations. First, forecasting traffic based on historical rates and growth is going to leave the state unprepared to deal with infrastructure demands shown in Figures 5 and 6. In these two depictions of model output, historical growth was applied to Figure 5 and knowledge based on specific industry characteristics and growth was applied to Figure 6. If traditional methods were used to plan, as shown in Figure 5, a severe lack of capacity would develop with little or no warning from the forecasting tools. It is quite apparent that a traffic plan established for a 128% increase in congested roadway would be inadequate for an actual increase of 287%.

An additional issue with forecasting tools comes from the source of data used to prepare the forecast. Traditional freight forecasting models utilize employment and SIC or NACIS codes to calculate freight generated. This method of forecasting does not take into consideration the productivity improvements implemented by a company to increase the competitiveness of the organization. Productivity improvement can result in an increase in production with the same number of employees or the same production with fewer employees. In either instance the traditional forecasting methods will understate the freight requirements. This leads to the realization that employment and industry codes are not adequate predictors of freight need generation in a region.

Another finding from the modeling effort was that the lead time to add capacity to Alabama's transportation infrastructure is often longer than the time period by which the infrastructure will be at, and over, capacity. There needs to be substantial effort made to investigate alternatives to building capacity.

CONCLUSIONS

One of the primary uses for the transportation model is to predict changes in the transportation network that would result from industries either relocating to Alabama or developing within the state. The main factors affecting the network are assumed to be the volume of incoming and outgoing freight, the mode or modes of transportation utilized, and the origin or destination of the freight. Data from the industries surveyed can be used to forecast these parameters for future developing industries. These predictive relationships will be of particular interest to local communities seeking to attract new industries. In addition to the traditional analysis on the local economy, a detailed transportation analysis can be done to determine the effect of various types of industries on the local, existing infrastructure. Communities could then target those industries that would create economic growth and have the least amount of negative impact on the local transportation infrastructure.

The ability to forecast and model freight transportation is important to understanding the relationship between infrastructure and economic activity. The data collected and model presented here is an important first step to assisting decisions makers in addressing the needs of businesses and understanding how transportation infrastructure decisions can improve or discourage the business environment. Future efforts must include examining the business data to determine how transportation infrastructure decisions affect travel mode. The existing forecasting tool only examines the effect of the freight moving to and from a specific business. It does not incorporate the "trickle down" effect a new industry would have on the local economy. Extensions of this model would need to incorporate a multiplier to include the increase of transportation related to the growth of the local economy stemming from the new industry. Additionally, other predictors of freight generation and attraction such as Per Capita Income and Value of Items Shipped should be investigated as a way to include economic activity and productivity in the model.

The application of the urban transportation planning model provided a tool to improve the ability to forecast freight transportation needs in the state. The model proved superior to the trend line analysis because of the ability to account for plant openings and discrete changes in the industrial landscape of the state. However, the model was limited in its ability to incorporate the entire universe of economic and social changes that influence freight transportation. The future improvements to the model need to focus on obtaining a better understanding of the relationships between productivity and freight transportation needs, and ultimately, understanding the universe of external factors that cause industry growth and development.

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