Transportation Infrastructure In Alabama

Finding & Filling the Holes

DRAFT REPORT

Dr. Gregory A. Harris, P.E.,
The University of Alabama in Huntsville
The Office for Freight, Logistics & Transportation
This research was sponsored by the
U.S. Department of Transportation, Federal Transit Administration
Project No. AL-26-7262-02
October 14, 2009

Table of Contents

Table of Figures

Executive Summary

Table of Tables

Section 2

Section 3

EXECUTIVE SUMMARY

This research builds upon the previous work on the development of tools to bridge the gaps in the analysis and understanding of the relationships between economic growth and transportation infrastructure in Alabama. This work continues the forward-look thinking that has brought positive reactions within the state and around the country from transportation professionals and legislators. The research at the University of Alabama in Huntsville (UAHuntsville) focuses on four research initiatives concentrating on the development of the data and tools that can be used at the state and MPO transportation planner level. The four research initiatives are:

- Freight planning and forecasting methodology
- Transportation system modeling and simulation
- The interrelationships between transportation infrastructure, population and economic activity
- Productivity enhancements in transportation, logistics and supply chains

The Office for Freight, Logistics & Transportation (OFLT) at UAHuntsville has developed an excellent working relationship with the Alabama Department of Transportation (ALDOT) and is viewed as the transportation and freight planning and modeling resource for the state. The Alabama Development Office (ADO) and Alabama Department of Economic and Community Affairs (ADECA), agencies of the state government, view the research performed by the OFLT at UAHuntsville as vital to the continued economic growth in Alabama.

In the 1990s the need to integrate freight into the policy, planning and programming activities of State Departments of Transportation (DOTs) and Metropolitan Planning Organizations (MPOs) became very apparent as global manufacturing, outsourcing, and off shoring became more prominent in the world and U.S. economy. Business and community leaders, as well as public sector officials recognized that the effective and efficient movement of freight is a key factor to a region's economic competitiveness. By almost any measurement, freight traffic is growing faster than passenger travel. Freight, by its nature, crosses modal boundaries; therefore any analysis method that does not consider multiple modes of transportation will not adequately understand the complex relationships in the system. However, by better understanding freight needs and issues, it is possible to design and conduct an economical and efficient freight planning process that can be integrated with conventional transportation planning.

More than 15 billion tons of freight valued at over $9 trillion traveled on US transportation infrastructure in 1998. By 2020, freight will have grown by nearly 70 percent according to the Federal Highway Administration. This level of activity and growth demands the attention of transportation system planners to provide data for making informed decisions.

The availability and accuracy of freight data is the key to making informed decisions on infrastructure investment and policy issues that affect the effectiveness and efficiency of the freight transportation system. Available and accurate freight data is critical to the evaluation of options to mitigate congestion, improve economic competitiveness, facilitate the effective use of land planning, optimization of modal activity, improve safety and security, reduce fuel consumption, and enhance air quality. Although data by itself does not ensure good decision-making, it is impossible to make informed decisions without valid data.

In response to the need for a methodology and tool to investigate freight from a multi-modal and comprehensive perspective, researchers at UAHuntsville developed and implemented the Integrated Freight Planning Framework (IFPF), shown in Figure 1. This methodology produces a direct freight forecast based upon industry sector economic activity. An industry sector based forecast offers an improvement to a forecast based upon a percentage of overall traffic flow which is typically used by transportation planners throughout the U.S. The IFPF establishes a direct relationship between the major industry sectors in a region and the freight traffic generated as a result of industrial sector activity, formalizing the methodologies utilized in developing the forecasts used to operate the Alabama Transportation Infrastructure Model (ATIM) developed in previous research. Value of Products Shipped, Household Income, Employment, and Population are used as indicators of sector economic activity in the relationships for forecasted freight traffic.

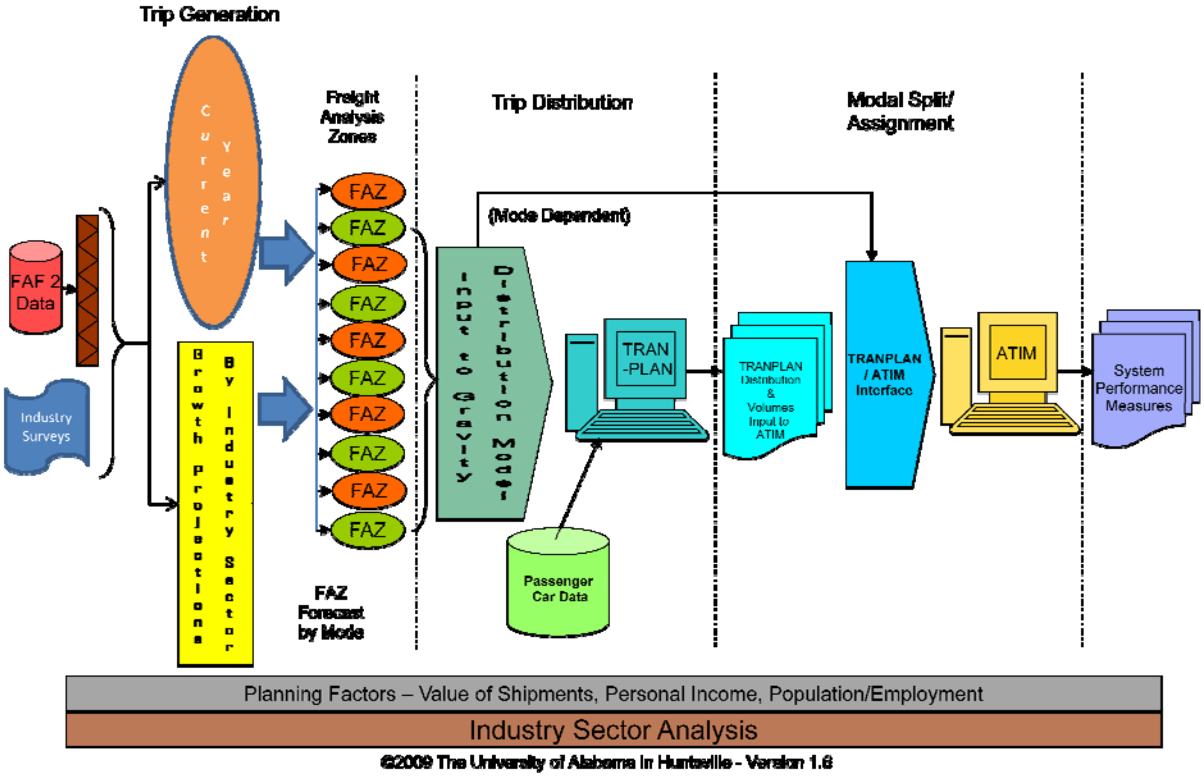


Figure 1 - The Integrated Freight Planning Framework

The IFPF methodology is a forward looking approach to freight planning. As such, the foundation of the framework is the use of industry sector analysis to establish the basic need for transportation infrastructure access. If the underlying principles of freight demand generation can be discovered and understood, the ability to predict accurately infrastructure requirements to support freight movement is improved. Once the freight generation principles of an industry sector are known, it is theoretically possible to apply those relationships anywhere the industry sector exists to estimate the demand for freight system requirements. The ultimate goal of this research is to provide tools and information that can be used by state and MPO level transportation planners and decision makers. These tools should improve the results of analysis and reasonable decisions on program and infrastructure necessary to improve the overall function and performance of the transportation system for passenger, transit and freight users.

Alabama is standing on the threshold of significant economic opportunity and the need for transportation infrastructure to carry the economy forward is greater now than ever. Therefore, it is imperative that the nature of economic growth and transportation needs are better understood. Subsequently, the development and application of more accurate forecasting models will help ensure the optimal allocation of scarce infrastructure improvement resources.

Findings

- The Integrated Freight Planning Framework (IFPF), developed by the UAHuntsville Office for Freight, Logistics & Transportation, continues to be a valid approach to integrating freight transportation needs into a comprehensive transportation planning process.
- The Freight Analysis Framework 2 (FAF2) database contains valuable and useful information which can enhance state and local level transportation infrastructure planning. Relevant data can be extracted and manipulated through the use of a structured process like the Integrated Freight Planning Framework. Supplemental information acquired from various sources, including primary research, can be integrated into datasets. Development of transportation networks at the appropriate level (local, state, or nation) coupled with reasonable planning assumptions, produces useful insight for transportation system planning.
- A modular framework method to model development is an efficient and effective approach to modeling transportation systems. All four modes of transportation (road, rail, air, and water) can be accommodated through the use of a submodel based programming architecture. A modular model can readily be replicated for transportation networks, intermodal centers, and ports in other regions or states of the U.S.
- Process improvement potential exists in many areas of our transportation system. Planning and forecasting models that attempt to represent transportation systems must be able to accommodate productivity improvements in one or many activities to produce better forecasts of demand and supply. Training programs specific to freight transportation activities can be developed and will help organizations sustain process improvement benefits beyond the first year of implementation.
- Transportation networks such as the interstate highways should be considered part of an overall system for moving people and freight in the U.S. and around the globe. For example, use of the new I-22 interstate link being built between Birmingham, Alabama and Memphis, Tennessee may have significant (and negative) impacts on major parts of the Southeastern U.S. interstate system spanning more than (as the name implies) one state. Just as processes in an efficient organization should not be run in "stove pipe" isolation, transportation networks should not simply attempt to maximize local benefits but should at least be aware of their effects on the overall transportation system.
- System level research capabilities will continue to be a valuable resource for transportation planning at the national level and also for the state and local levels. The "holes", real or perceived, in the data resources can be "filled-in" using innovative and systematic integration processes.

1. INTRODUCTION

According to the Center for Business and Economic Research at the University of Alabama in Tuscaloosa, Alabama lost 96,100 nonagricultural jobs since May 2008. A total of 208,917 out of work Alabamians pushed the unemployment rate to 9.8% in the third quarter of 2009. The projection is for Alabama's economy to continue to weaken albeit at a slower rate in the coming year. In this economic environment, Alabama is not unlike any other state in the U.S.

With the slowing economy, there is even more pressure to effectively and efficiently utilize the scarce funds and resources available for maintenance and improvement of the transportation infrastructure. Without tools to understand the totality of demand on the transportation system, decision makers are left to rely on historical behaviors and less than optimum data to determine how and where transportation resource will be utilized.

The focus of the research at the Office for Freight, Logistics & Transportation at the University of Alabama in Huntsville has been to develop and implement tools to aid and assist the decision makers within the transportation community in the allocation of these resources to promote the best possible outcome for the people the transportation system is here to serve.

The use of national freight data at the local level is challenging due to the high level of aggregation and because freight data is proprietary. Many national freight databases aggregate information to the individual states or major communities. Most methods of utilizing freight data depend on applying proxy factors to allocate the freight to the system. The planning factors used in freight system analysis must be capable of describing the freight generation and attraction characteristics of the region. The use of employment as a planning factor has come under scrutiny mainly due to the inability of the factor to estimate accurately the effect of productivity improvements made by a company to increase production without increasing employment.

This research has shown that local economic data from many different sources can successfully be used to allocate freight volume into smaller zones from the future freight traffic volumes provided by highly aggregated national databases. The output of this effort is used as input to the modeling of freight, and the integration of that freight into existing transportation planning and modeling activities at the state and local level. This has been accomplished in Alabama at the statewide and metropolitan planning organization level, resulting in validated transportation models that integrate freight into the planning activity. The methodology developed here can easily be replicated by other states and metropolitan planning organizations.

2. The Integrated Freight Planning Framework (IFPF)

This research was initiated to uncover the relationships between transportation infrastructure and economic growth and sustainability. It became evident rather quickly that the data for freight analysis and the tools needed to include freight in the conversation, were not available to the researcher or the transportation planner. The UAHuntsville OFLT research team determined that there was a need for the establishment of methods to discover the data required and develop the tools to integrate freight into the transportation planning process.

This identified need led to the development of the Integrated Freight Planning Framework (IFPF) by the UAHuntsville OFLT research team shown in Figure 2-1. The IFPF uses existing public national and local freight data, along with a variety of other planning tools, to develop statewide and local Metropolitan Planning Organization (MPO) level origin/destination freight flow patterns, freight specific traffic models and discrete-event simulations of freight activities.

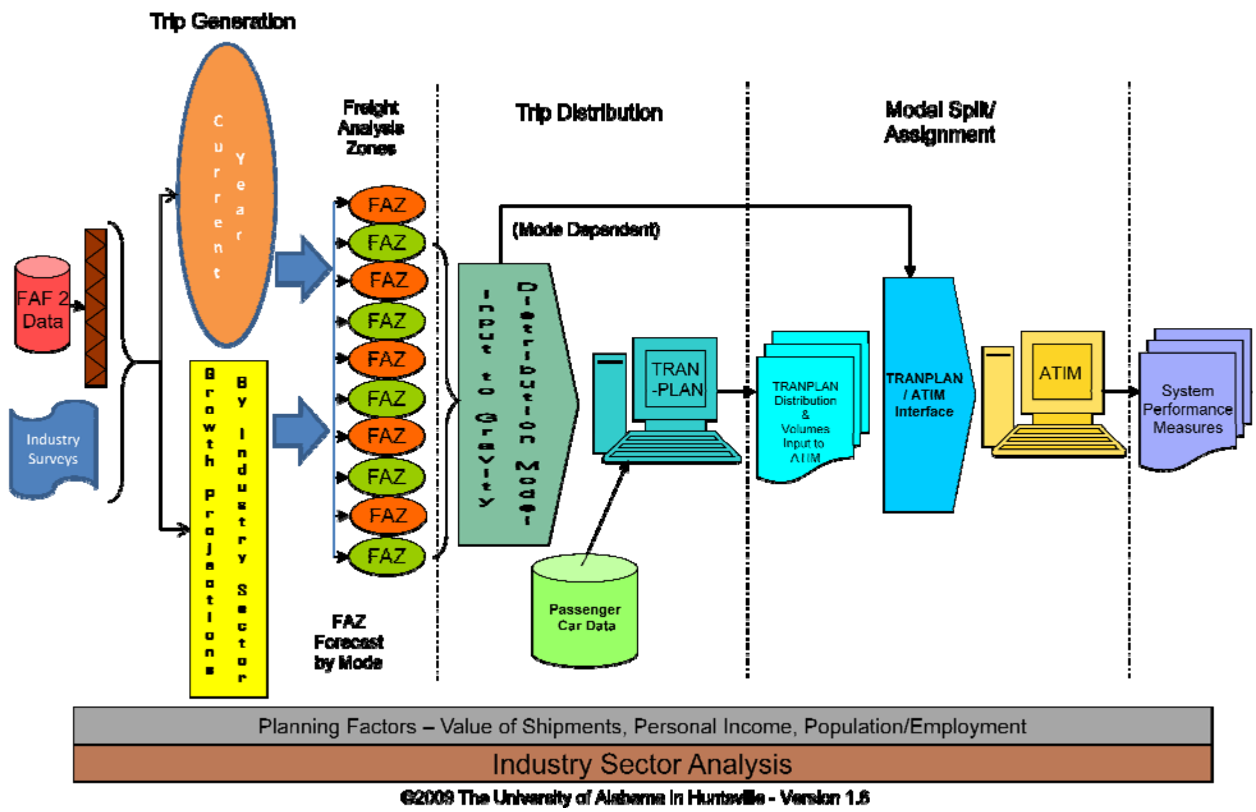


Figure 2-1 The Integrated Freight Planning Framework

The IFPF is a forward looking methodology for freight planning. As such, the foundation of the framework is the use of industry sector analysis to establish and understand the basic need for transportation infrastructure access by a particular industry. The hypothesis here is that if the underlying principles of freight demand generation can be discovered, the ability to predict accurately infrastructure requirements is improved. Once the freight generation principles of an industry sector are discovered, it is theoretically possible to apply those principles anywhere the industry sector exists to estimate the demand for freight system requirements.

Freight transportation is vital to the growth and economic development of a region or state. The ability to model appropriately the impact of freight on the existing transportation infrastructure is paramount to successfully identifying deficiencies in the existing infrastructure. Identification of such deficiencies allows for better allocation of transportation infrastructure improvement funds to ensure congestion does not limit economic growth.

Traditional transportation planning activities often ignore freight transportation in the modeling process or add them as an afterthought to the model. Freight planning applications (if included in the process at all) often rely on projections that cannot account for major changes in the workforce or economy of the area. Therefore, an approach to freight modeling that considers economic activity and can be incorporated into the transportation planning process is needed to better allocate resources to transportation infrastructure. The IFPF builds upon the traditional four-step transportation planning process by creating this forward looking approach to trip generation issues. The main purpose behind this research is to provide data and tools for use by transportation planners and decision makers that previously did not exist.

The IFPF methodology utilizes a combination of multiple data sources and analysis tools bundled together to generate validated data and models for use in transportation planning. The IFPF can be applied at multiple planning levels; regional, state, sub-state and MPO. The factors used to estimate the generation and attraction of freight in the system are Value of Shipments, Personal (or Household) Income, Employment and Population.

Value of Shipments

If freight is included at all, traditional transportation forecasting methods typically rely on employment as the primary factor for freight in developing future needs. The time is past when industries in the United States could compete solely on the basis of labor cost. Developing countries will continually be able to under bid U.S. industries on labor costs. Today, industry in the United States competes on productivity. Using employment as a freight planning factor does not take into account the productivity improvements by which U.S. companies compete in the world marketplace. If employment is used as the sole factor in freight planning, any increase in production due to plant productivity improvement initiatives will be ignored. Thus the freight forecast will not include the increased amounts of freight generated by the growth in output per employment. Even worse, if the same amount of production were achieved with fewer employees due to technology or productivity improvements, traditional freight planning methods would actually forecast a decrease in the demand for freight requirements. Value of Shipments, or sometimes termed Value of Sales, (VoS) is proposed to alleviate the issues mentioned above. As productivity improvements increase the output of a plant, the VoS factor captures this information. With knowledge of the relationships between value and vehicle loads acquired on a particular industry, the freight system requirements can be calculated from the VoS. Seasonal or structural fluctuations in employment do not affect the VoS calculation; therefore (constant dollar) VoS provides a more consistent factor to use in the generation of freight from industries within the region.

Personal (Household) Income

Personal Income (PI) is a proxy for the attraction of freight to a region. The disposable income of an area increases as PI increases. As the disposable income of a region increases, the ability of the population to spend creates more demand for products. The increased consumption increases the demand for freight to the area as the desired consumer goods are made available. As PI decreases in a region, the population perceives a loss of disposable income and spending tends to slow. This reduces demand for products in the region thus decreasing the amount of freight destined for the region.

Population/Employment

Population is a traditional factor in transportation planning. The population of a region is a proxy for the volume of vehicles in the region, from which the number of trips and distances can be derived. Employment has traditionally been used as a proxy factor for freight. It is generally assumed that as employment increases the freight increases and as employment decreases the freight in the region decreases. However, these two factors alone do not provide an adequate predictor of freight activity, but combined with VoS and PI they potentially improve the accuracy of the planning factors.

To support the IFPF methodology, researchers at UAHuntsville developed a program to analyze the Freight Analysis Framework Version 2.2 database and determine the freight volume, by commodity and mode, which passes through Alabama on its way to the final destination. This tool can be used to determine the pass-through freight for anywhere in the US. The information is then used as input to a gravity distribution model which outputs information into a discrete event simulation. The simulation allows multiple investigations of the freight activity as it is integrated into the transportation network. In the next section the four specific components of the IFPF are discussed.

2.1 Trip Generation - Development of Freight Data and Analysis Methodologies and Tools

The IFPF methodology takes freight flow data at the national level and structures it in a format usable for various sub-levels of freight planning purposes. This methodology adds a valuable tool to the overall transportation planning toolbox. This part of the research at UAHuntsville OFLT focuses on data collection, manipulation and analysis to provide input to the transportation planning process. Freight planning factors were investigated and utilized to provide more accurate input to the state and Metropolitan Planning Organization (MPO) transportation planners. Emphasis was placed on data gathering methodologies utilizing public databases, industry surveys, data disaggregation and clustering approaches and preparing the data for input to the transportation planning process.

2.1.1 Developing a Freight Database to Allocate Freight Traffic to Sub-State Traffic Zones

The foundation of any reasonable methodology for the understanding of freight activity in an area is the availability of accurate and verifiable data. Freight planning in the United States has traditionally been performed by applying backward-looking data analysis and forward-projecting trend line forecasting. Trend analysis has been shown to be insufficient as a method of data development and analysis in today's economic environment. At best, trend line forecasting assumes that the past will be replicated in the future.

It is difficult to incorporate freight information into transportation models and plans because freight data is often proprietary and the release of that data is considered to be detrimental to the company's competitive position. In the United States, many national freight databases aggregate information to the individual states, or major communities in the states. An example is the Freight Analysis Framework, Version 2 Database (FAF2), developed and distributed by the Federal Highway Administration (FHWA). The U.S. is divided into 131 separate traffic zones in the FAF2 Commodity Origin-Destination (O-D) Database. Seventeen of these regions are the major freight entry points into the country [1] and the remaining 114 are either a Metropolitan Statistical Areas (MSA) or Consolidated Statistical Areas (CSA), or the remainder of the state that lie outside of these MSAs and CSAs. This high level of aggregation in the publicly available national databases is not conducive to analyzing the effect of freight on the transportation infrastructure at the state or local level. As a result, the data has limited use for state or local transportation planning activities.

In the FAF2 database, the state of Alabama is divided into two zones – the Birmingham CSA and the remainder of the state. This geographical division does not provide enough detail to forecast future freight movements within the state. A way had to be found to allocate to sub-state freight analysis zones (FAZs) the incoming and outgoing traffic assigned to Alabama in the FAF2 Commodity O-D Database [2].

Estimation of freight demand has most often relied upon driver surveys, which can be expensive, or some other method of piecing together fragments of information from multiple sources [3]. This lack of data is explained, in part, by the level of complexity in the freight system itself with multiple individual players that must interact and the costs associated with gathering the data which for-profit companies deem proprietary [4]. The need to estimate freight demand and its relationship to the freight transportation supply are critical in any effort to model the overall system. In 2000, Pendyala, et al., compiled a synthesis of approaches for freight system analysis investigating the factors that affect freight demand [5].

The ability to plan and forecast freight demand is limited by the lack of available data at the level of detail that is meaningful to the transportation planner. Disaggregation of the data to a more detailed level is required to apply the freight flow data to the sub-state planning level under consideration. The fundamental problem is how to disaggregate the data to a usable level, without reducing the quality of the data to a point where its use would introduce excessive error [2].

In most instances the disaggregation of freight data from national levels for use in local areas has been based on the factor “employment” by prorating the employment in the local area to the total employment in the study region. Using employment as a planning factor has come under scrutiny due to the inability of this approach to accurately capture increased production when there is no increase in employment.

The IFPF has been developed as an alternative for freight analysis by utilizing the underlying principles of freight demand generation of a particular industry sector to predict freight demand on a transportation system. Almost all methods of utilizing freight data depend on applying proxy factors to allocate the freight on the system [6]. Planning factors used in freight system analysis must be capable of describing the freight generation and attraction characteristics of the region.

2.1.1.1 Developing a Sub-State Database for Alabama

Two criteria were used to choose the geographical basis of the sub-state database; (1) the availability of local socioeconomic information and (2) the number of resulting sub-state Freight Analysis Zones (FAZs). Most routinely published socioeconomic data is based on counties, of which Alabama contains 67. Thus, arranging this information by county is relatively easy and still provides a much more detailed picture of intrastate freight traffic movement than using just the two traffic zones provided by the FAF2 O-D matrices.

2.1.1.2 Development of Freight Analysis Zones

The research team continued the development of the methodology presented in the 2008 report "Transportation Infrastructure in Alabama- Bridging the Data & Information Gap" and was applied to the state of Alabama. The basic approach was also applied to the analysis and formulation of Freight Analysis Zones (FAZs) using data from a Metropolitan Planning Organization (MPO), specifically the MPO for Mobile Alabama. This section will review the basic methodology used in both instances. Phase 1 is a summary of the approach used to develop statewide FAZs as presented in the 2008 report.

Phase 1: Development of State Level Freight Analysis Zones:
In the first phase of the project, a cluster analysis based approach was used to develop preliminary Freight Analysis Zones (FAZs). A guiding principle in the development of FAZs is that the zones should be homogeneous within the cluster but diverse from the surrounding clusters. Since the purpose of this initiative was to develop a methodology that transportation planners can use to enhance their freight planning, it is important that the final clusters promote the movement of traffic between clusters to provide the level of transactional data needed for planning purposes. The basic methodology used economic data (employment, total value of shipments, personal income) and geographic data (longitude, latitude, and distance from interstate) to develop county clusters. The interstates that cut across the state provide natural boundaries for application of the clustering procedures using economic and geographic data for the counties within the interstate sectors. The cluster solution within the final four (4) interstate sectors was based on the economic variables, proximity data, and each county's distance from the interstate. It resulted in a total of 27 clusters, shown in Figure 2-2. The research team felt that this solution showed the most promise because the clusters were in close proximity within the natural boundaries provided by the interstates traversing Alabama.

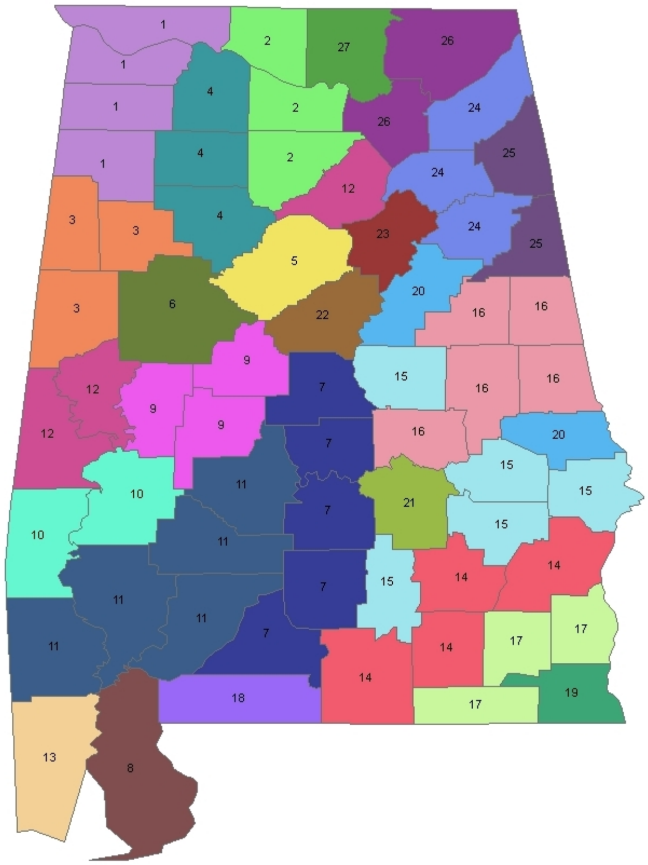


Figure 2-2 Cluster Solution within Modified Interstate Sectors based on Economic Variables, Longitude, Latitude, and Distance from Interstate.

After completion of the cluster analysis, the final 27 clusters were evaluated based on the type of industry and growth in each of the clusters. This step was performed in order to validate the defined clusters, and to refine and validate the total solution.

The next step was to evaluate the differences between using FAZs versus all the counties in a state via a case study developed using the State of Alabama Freight Model. This was accomplished by creating a Freight Distribution and Assignment Model the TRANPLAN/CUBE® environment for two different data sets: 1) the 67 counties created by a direct disaggregation of the FAF2 data using the various county proportions and 2) the 27 Freight Analysis Zones created as outlined above. The Freight Distribution and Assignment Models were used to develop a truck trip exchange and determine the trucks forecasted to each section of roadway in the state.

To compare the performance of the two approaches (i.e., 67 counties versus 27 FAZs), a series of Alabama Department of Transportation (ALDOT) truck counts were added to the attributes for the network roadway segments. Two scatter plots were developed to view the variations between the model assignment and the truck counts with both models assigned and the location of roadways where the daily truck volume exceeds 1,000 identified. Figures 2-3 and 2-4 show the scatter plots for the two models.

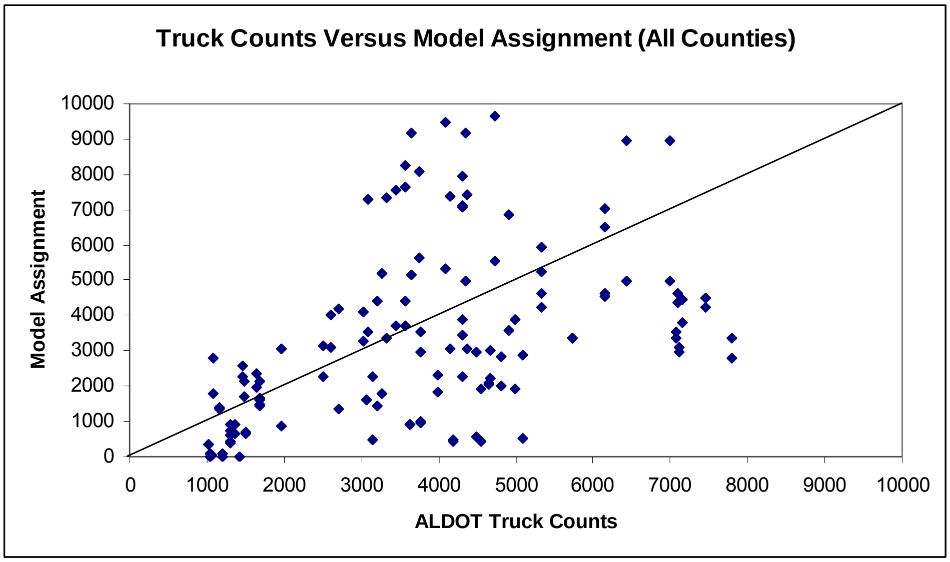


Figure 2-3 Scatter Plot for the 67 County Model

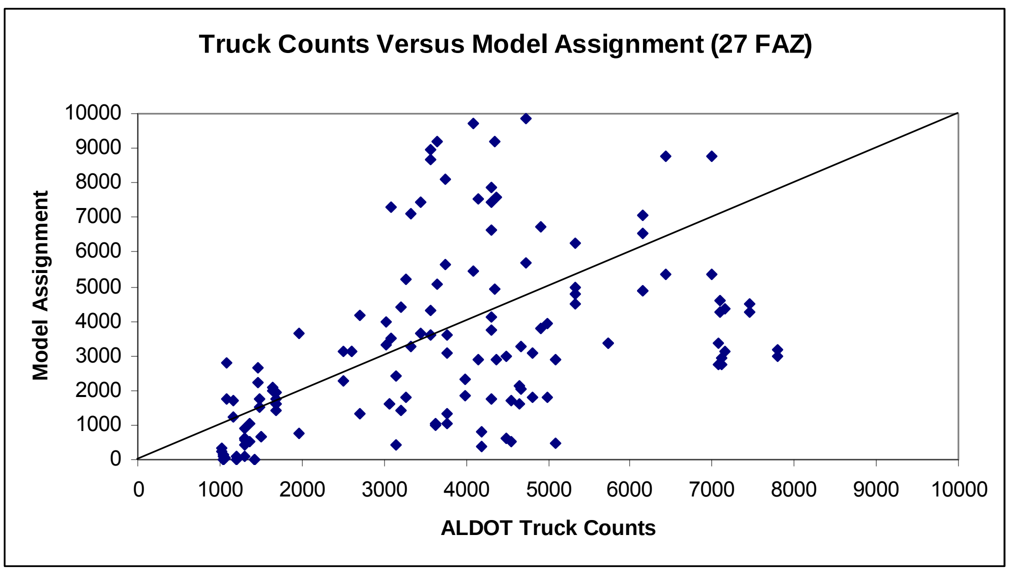


Figure 2-4 Scatter Plot for the 27 FAZ Model.

To measure the difference between the model assignments using the two input levels (all 67 counties or the 27 FAZs), the Nash Sutcliffe's (NS) coefficient was employed [7]. The Nash-Sutcliffe value can range from $-\infty$ to 1. An efficiency of 1 (E=1) corresponds to a perfect match of forecasted counts to the ground counts. An efficiency of 0 (*E*=0) indicates that the forecasted values are as accurate as the mean of the ground counts, whereas an efficiency less than zero ($-\infty < E < 0$) occurs when the forecasted mean is less than the ground values. The greater the NS-value is the better the forecast. It can be calculated using the formula:

$$\text{NS-Coefficient} = 1 - \frac{\sum_{1}^{n}(ModeledCounts - GroundCounts)^2}{\sum_{1}^{n}(GroundCounts - MeanGoundCounts)^2}$$

The Nash Sutcliffe's statistic is considered the best measure of deviation between two data sets and used in many similar instances. Applying the Nash-Sutcliffe test for the two input files results in a NS-coefficient of 0.689 for the model that uses all 67 counties and a NS-coefficient of 0.679 for the model with 27 FAZs, indicating that there is no statistical difference in the assignments obtained using the 67 county model and the 27 FAZ model. This result supports the hypothesis that FAZs can be used to limit the data collection needs for freight planning without a reducing the quality of the assignment output.

Phase 2: Development of MPO Level Freight Analysis Zones:
This phase of the project involved applying the methodology developed in Phase 1 to data from an MPO. Economic, demographic and employment related data from Mobile County, Alabama was provided as input to the clustering algorithm which developed zones with maximum similarity of entities within a zone and maximum dissimilarity of entities between two separate zones. Iterative reduction in the number of parameters considered for input and inclusion of additional parameters that were found to be of higher relevance for zone formation was carried out for higher quality of distinction and definition of freight zones within the existing district zones/locations. The formation of clusters within the existing district zones was considered of primary importance, thus allowing only entities from a given district zone to group together. Then, the freight zones obtained after iterative application of clustering techniques are compared with the existing zones used by the Department of Transportation for the Mobile County which are based on geographical proximities. And finally, the freight zones were evaluated for consistency based on type of industry.

To determine the number of statistically significant clusters and the optimum number of clusters, a best cut and tree-validation were performed using ClustanGraphics™. A best cut method involves application of a series of t-tests to fusion values at every possible level in the tree structure. Tree validation method compares the tree generated as a result of hierarchical clustering with a family of trees obtained due to random permutation of the data or proximity matrix. Thus, tree structures having maximum departures from randomness were determined and an optimum number of clusters, where such departures occur was computed [8]. Once clusters were formed, for data reduction and consideration of new attributes it is necessary to determine which attributes are statistically significant. Graphical or visual tools such as interval plots, individual value plots and scatter plots can be used to obtain visual evidence supporting the findings from the statistical test.

Finally, the existing Traffic Analysis Zones (TAZs) currently being used by the Department of Transportation were treated as clusters and the total increase in the errors sum of squares was computed and compared with the error sum of squares in the structure obtained by iterative application of cluster analysis techniques. This comparison provided an objective basis for identification of the final clusters/zones for use in the analysis of Freight movement.

The data for FAZs of Mobile County contained 40 attributes which provide demographic, geographic, economic and employment related data for 317 areas. Each area is a part of one of the 5 district zones. Preliminary analysis found that 8 of the 40 attributes provide all the necessary information and basis for determination of clusters:

- Number of households
- Median values of all household incomes
- Total number of employed people
- Number of people employed in the retail sector
- Number of people employed in the service sector
- Number of people employed in other sectors
- Latitude
- Longitude

Furthermore, 5 of the 317 zones had no economic, employment or demographic data. Thus, the input dataset for first phase of cluster analysis contained 312 areas and 8 non-parametric attributes, with 5 district zones.

The data for 52 zones falling under the first district zone served as input to cluster analysis software package ClustanGraphics™ and a best cut and tree validation procedure was performed with squared Euclidean distance as the metric and Ward's hierarchical clustering algorithm as the execution routine. The bootstrap validation without replacement for 1000 trials indicated that the best number of clusters for the dataset containing 52 zones was 7. This is illustrated in Figure 2-5 shown below – each of the colored groupings is the recommended freight analysis zone for this initial cluster analysis.

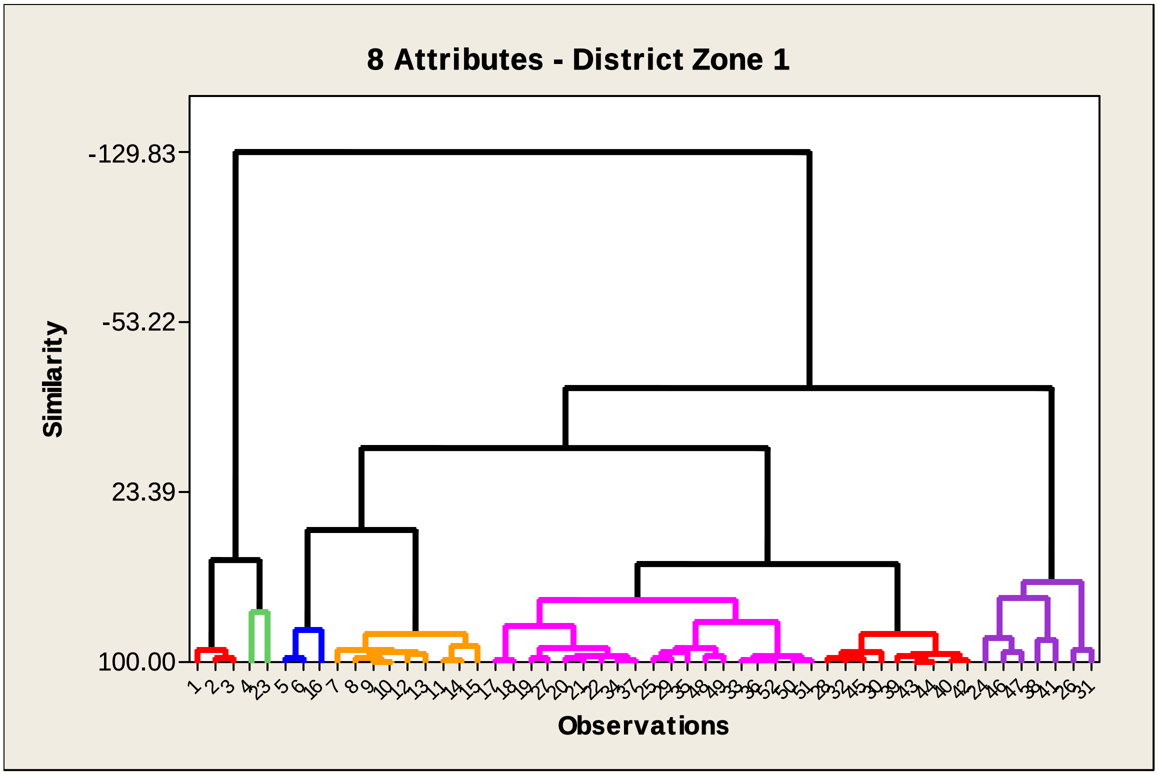


Figure 2-5 Recommended Freight Analysis Zones

Performing a similar sequence of operations for the remaining four district zones, it is noticed that the overall data matrix results in a structure comprising of 30 clusters with restrictions on district zones. Table 2-1 presents the number of clusters and the sequence of allocations for all five district zones.

Table 2-1 Initial Result for Clusters for District Zones

District Zone	Number of zones	Number of Clusters	Sequence Allotment
1	52	7	1-7
2	82	6	8-13
3	102	8	14-21
4	45	4	22-25
5	31	5	26-30

Based on the results of the Kruskal-Wallis test for non-parametric data and additional demographic insight, it is found that the number of households, median household income, total number of employed people, latitude and, longitude are influential in cluster formation. Preliminary principal component analysis reveal that five attributes are sufficient to explain about 90% of the total variability underlying overall data matrix. Also, considering the statistical significance and loading impacts, either one of median household income or total number of households could be included to further reduce the data matrix without loss of generalization. Two models are used to quantify the effectiveness of each option; one using median household income and the other using total number of households.

The reduced data matrix consists of five attributes instead of eight, namely: median household income, zip code, number of employed people, latitude and longitude. This set of attributes resulted in a total of 27 clusters, as shown in Table 2-2.

Table 2-2 Result for Clusters for District Zones with 5 Attributes

District Zone	Number of zones	Number of Clusters	Sequence Allotment
1	52	4	1-4
2	82	9	5-13
3	102	9	14-22
4	45	2	23-24
5	31	3	25-27

Likewise, the second model which also included five variables with the number of households replacing the median household income resulted in a 30 cluster solution as shown in Table 2-3.

Table 2-3 Result for Clusters for District Zones with Number of Households

District Zone	Number of zones	Number of Clusters	Sequence Allotment
1	52	5	1-5
2	82	10	6-15
3	102	10	16-25
4	45	2	26-27
5	31	3	28-30

After allocating the required sequences, an objective comparison was made to compare the various solutions. This is shown in Table 2-4. It is clear that two five variable models have the lowest Error Sum of Squares and were ultimately the candidates for use in establishing the FAZs for Mobile County.

Table 2-4 Comparison of Results

Model	Cumulative Error Sum of Squares (ESS)	Number of Clusters
Median Household Income based (Ward's method)	267.26	27
Number of Households	287.06	30

based (Ward's method)		
District based (median household income)	474.82	30
District based (number of households based)	517.48	30

Identifying and Organizing TAZ Islands
The next step in the process was to select the zone allocation method and then validate that allocation based on industry and growth data. The statistical clustering analysis of the primary industry clusters in each traffic analysis zone (TAZ) produced a patchwork grouping of TAZs. TAZs within a geographic region of the MPO planning area with similar concentrations of industries were grouped. TAZs of similar industry composition were identified on the MPO map by a unique color. This method of review allowed for easy identification of non-contiguous TAZs. There were several TAZs that were "islands" in that they were surrounded by one or more dissimilar Freight Analysis Zones (FAZs) that were otherwise homogenous groupings of TAZs. These TAZ islands were examined to determine if and how they might be combined with adjacent FAZs to arrive at a manageable number of geographically homogenous FAZs that could readily be translated to and from the TAZs used by the MPO planners.

Step One: Examine Industry Types
The company data for each island TAZ was analyzed to determine the industry sectors with the highest concentration of companies. The rationale of using only the company type characteristic in the data set was that similar companies should generate and receive similar types of freight. The three-digit NAICS code for each company with at least 25 employees in the TAZ was examined and used to segment the companies into industry groups. The review produced multiple industry groups of various sizes within the TAZ. The industry groups for the TAZ were ranked in order of largest to smallest based on the number of companies with at least 25 employees. The same process was used for the two or more adjacent TAZs with which the island might be related.

Step Two: Compare Industry Concentrations
The primary (largest) industry group(s) in the island TAZ was compared to the primary industry groups in the adjacent TAZs to determine which, if either, adjacent TAZ was most similar. Similarity was based on significant presence of industry types grouped by the three-digit NAICS codes.

Step Three: Group Similar TAZs
The island TAZ was grouped with the most similar adjacent FAZ if the primary industry group(s) of the island TAZ had a significant presence in the FAZ. If there was little or no industry type correlation with the adjacent TAZs, the island TAZ was not combined with another FAZ group.

The results of this process reduced the number of FAZs in the Mobile MPO region from 38 to 27 clusters of TAZs (FAZs). The resulting map is shown in Figure 2-6.

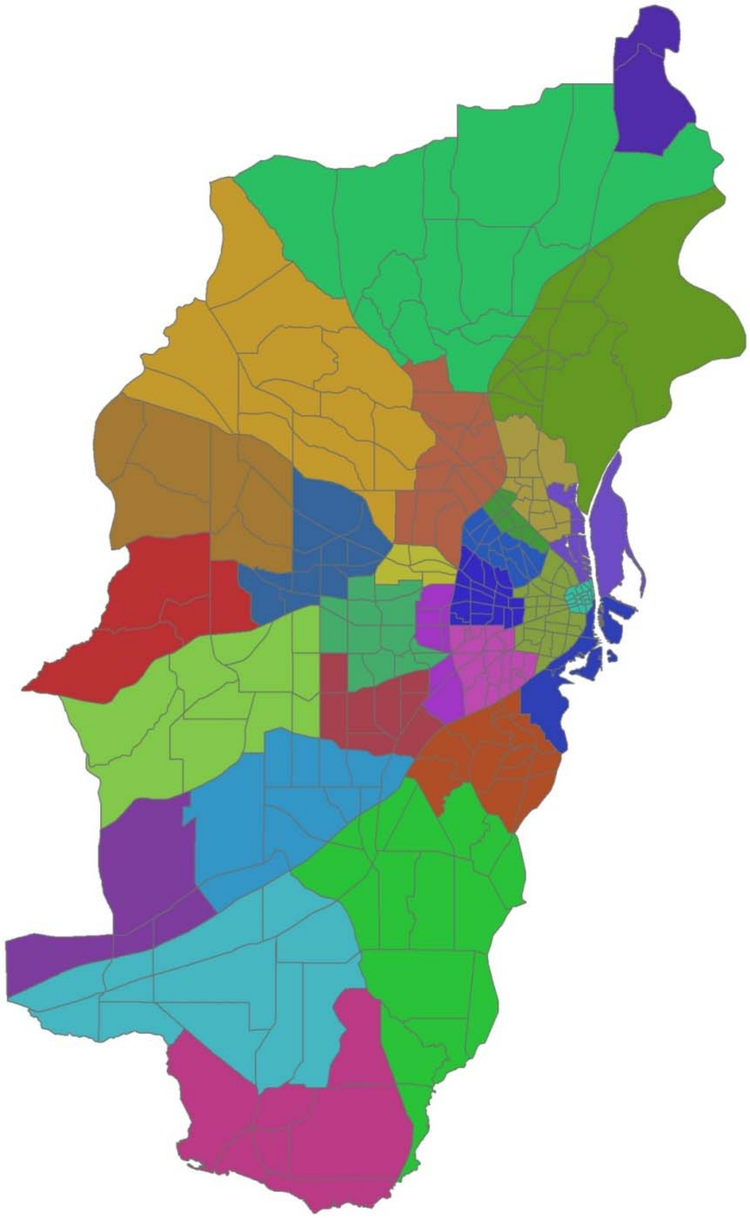


Figure 2-6 Final FAZs in the Mobile MPO

These homogenous FAZs could then be identified in the freight traffic allocation model as specific origins/destinations. Links between FAZs could then be identified and used to route the freight traffic in, out, and across TAZs. The MPO Planners could continue to use their Traffic Analysis Zone map for their models since the TAZ designations were retained in the Freight Analysis Zone designations.

2.1.1.3 The Combination of Economic and Freight Data

The Standard Classification of Transported Goods (SCTG) is used to categorize freight in the FAF2 Commodity O-D Database [9]. Most economic data is classified by the North American Industrial Classification System (NAICS). It is necessary to meld these two systems together as closely as possible in order to provide the transportation planner with enough detail to allocate traffic by industrial sector. The matchup of SCTGs and NAICS classifications are provided in Table 2-5. Fourteen of the 43 SCTG codes have counterparts under the NAICS classification at the three digit level. The 14 are highlighted in bold in Table 2-5. In other cases, either the SCTG or the three digit NAICS classifications offer more detail. For example, the three digit food processing classification under NAICS encompasses four separate SCTG categories. The textile and apparel SCTG category includes three different NAICS codes. Despite the loss of detail these mismatches create, the combined categories still allow for substantial industrial detail in the sub-state database and consequently a more reliable freight allocation among the sub-state FAZ's. Two of the SCTG categories – mixed freight; and waste and scrap – have no NAICS counterparts and must be estimated separately using other sources such as company surveys. Figure 2-6 presents the different data sets utilized in this research, the manner of use and the interactions of the data to produce input for use by transportation planners as input for their particular models and planning activities.

2.1.1.4 Determining a County's Economic Base

The economic base for each county must be defined in order to gauge properly the amount of future freight traffic that will be entering and leaving. For freight modeling purposes, the economic base can be defined as all goods producing industries within a county. For Alabama counties, the economic base includes major manufacturing industries, agriculture, logging, and mining (Figure 2-7). Each of these industries can potentially generate both incoming and outgoing freight traffic. Retailing, wholesaling and warehousing activity (Figure 2-7) can also create inbound traffic for sales to households and businesses within a county or outbound traffic for sales to households and businesses located elsewhere.

TABLE 2-5 SCTG Code Matchup With NAICS Codes

SCTG Code	Name	NAICS Code	Name
1	**Animals**	**112**	**Animals**
2	**Grains**	**111**	**Grains**
3	Other		

4 5 6 7	Animal Feed Meat, Seafood Bakery Goods Other	311	Food Processing Food Processing Food Processing Food Processing
8 9	Alcohol Tobacco	312	Alcohol, Tobacco Alcohol, Tobacco
10 11 12 13 14 **15**	Stone Sand Gravel Non-metallic Minerals Metallic Ores **Coal**	212	Stone, Clay, Gravel Stone, Clay, Gravel Stone, Clay, Gravel Stone, Clay, Gravel Stone, Clay, Gravel **Coal**
16	**Crude Oil**	**211**	**Petroleum**
17 18 19	Gasoline Fuel Oils Other	324	Refineries Refineries Refineries
20 21 22 23	Basic Chemicals Pharmaceuticals Fertilizers Other	325	Chemicals Chemicals Chemicals Chemicals
24	Plastics	326	Plastics
25	**Logs**	**113**	**Logs**
26	**Wood Products**	**321**	**Wood Products**
27 28	Pulp, Newsprint Paper	322	Paper Paper
29	**Printed Products**	**323**	**Printed Products**
30	Textiles & Apparel	313 314 315	Textile Mills Textile Products Apparel
31	**Nonmetallic Mineral Products**	**327**	**Nonmetallic Mineral Products**
32	**Primary Metals**	**331**	**Primary Metals**
33	**Fabricated Metals**	**332**	**Fabricated Metals**
34	**Machinery**	**333**	**Machinery**
35	Electronics & Electrical Equipment	334 335	Electronics Electrical Equipment
36	Motor Vehicles	336	Transportation Equip
37	Transportation Equip	336	Transportation Equip
38	**Instruments**	**339**	**Instruments**
39	**Furniture**	**337**	**Furniture**
40	**Misc. Manufacturing**	**339**	**Misc. Manufacturing**
41	Waste & Scrap		
42	Unknown		
43	Mixed Freight		

2.1.1.5 Determining the Base Year

FAF2 O-D matrices use 2002 as the base year for the sub-state economic database. The year 2002 is also when the US Census Bureau surveyed industries for its series of state economic censuses including the *Census of Manufacturing*, *the Census of Agriculture,* and the *Census of Mining* (Figure 2-7). The base year will change after the 2007 O-D matrices are released.

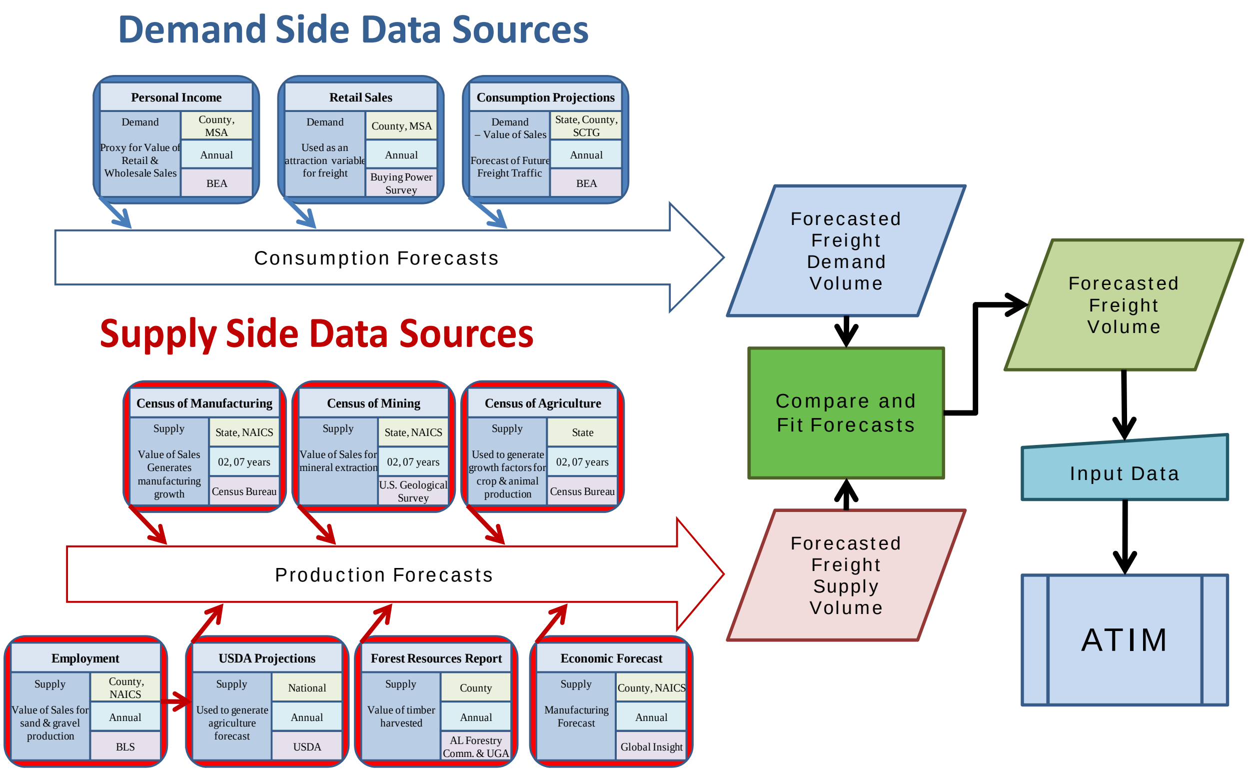


Figure 2-7 Data Sets and Interactions

2.1.1.6 Determining Variables to Use to Allocate Freight Traffic to Sub-State FAZ's

Employment growth has typically been used to generate a freight traffic forecast in a particular area. However, employment growth has been shown to be a poor predictor of freight traffic increases because it doesn't take into account productivity improvements in goods producing industries [10]. The Value of Sales (or Shipments) has been shown to be a better predictor of freight generation activity. Thus, the Alabama sub-state economic database includes the value of sales from goods producing industries (Figure 2-7). Using value of sales instead of employment factors in future productivity improvements and consequently should provide a better forecast of future freight traffic.

Personal income was chosen to proxy the value of retail and wholesale sales to households and businesses in a sub-state region (Figure 2-7). The growth of personal income is highly correlated with the growth of household consumption expenditures and consequently should give a more accurate forecast than either population or employment growth.

2.1.1.7 Estimating the Value of Sales and Personal Income

The value of sales data for manufacturing are published in the *Census of Manufacturing* (Figure 2-7) for each state, metropolitan area, and county that contains manufacturing enterprises [11]. If there are only a few manufacturers, the value of sales data will be suppressed to protect the privacy of the firms. In Alabama the value of sales data was suppressed in 19 of 67 counties – nearly all of them small rural counties with a single dominant company. An estimate must be prepared in these cases. Generally the Census Bureau will provide a range of employment for the plant(s) in these counties. Taking the mid-point in the employment range and multiplying it by the average value of sales per employee for the industry as a whole within the state will give a reasonable proxy for the actual value of sales in these counties. The value of sales in each county, including the ones for which estimates had to be made, can then be summed and compared to the actual total value of sales for the state. If the published total is larger or smaller than the total containing the estimates, the estimates can be increased or reduced until the total equals the published state total.

The *Census of Agriculture* (Figure 2-7) provides detailed value of sales data for each type of crop or animal sold from a particular county [12]. The US Geological Survey (USGS) periodically publishes a state geological survey which includes the value of sales for the mineral industry [13]. The most recent USGS survey for Alabama was done in 2003. Production and sales data are provided by geological area rather than by county in this publication so it must be supplemented by information from the *Census of Mining* (Figure 2-6) to allocate the value of mineral extraction to each county in the state [14].

Smaller sand and gravel operations are located in almost every Alabama county. They can be found using *County Business Patterns* (Figure 2-7) where the publication lists total employment by county in this sector [15]. Allocating sand and gravel sales by employment provides an estimate of the contribution of the sand and gravel industry to total sales in each county.

The physical amount of logs harvested in each county is released in an annual report (Figure 2-7) from the Alabama Forestry Commission [16]. The data are provided by type of log and by volume in board feet. The value of these logs was determined by translating board feet into tons and using 2002 pricing data for the South published by the Daniel B. Warnell School of Forestry Resources, University of Georgia [17].

Personal income (Figure 2-7) by county is released annually by the Bureau of Economic Analysis (BEA), US Department of Commerce. It is a part of BEA's Regional Economic Accounts database [18].

2.1.1.8 Projecting Value of Sales and Personal Income

Various sources can be used to project the value of sales and personal income from the base year to the end year (Figure 2-7). The Alabama sub-state economic database includes industry and county specific projections to the year 2035. They are derived from a series of 30 year national production index projections prepared quarterly by Global Insight [19]. These projections cover all NAICS codes except animals and crops. National projections of crop and animal sales are provided by the US Department of Agriculture (Figure 2-7) and can be found on their website [20]. Since the projections are published for just a ten year period, they have to be extended another 20 years to make them comparable to the other projections in the database. A simple ordinary least squares (OLS) regression equation for each crop and animal type was used for this purpose.

A projection of personal income growth to the year 2035 was prepared for each Alabama County using an OLS regression equation and annual personal income data for that County over the time period 1975 through 2005. A few Alabama counties have recently experienced very rapid personal income growth which skewed the results of the regression analysis in an upward direction. In these cases, projected income growth in the out years was reduced by forcing the growth rate to converge with the US projected rate.

The methods described above provide a unique 30 year projection of value of sales and personal income for each county in Alabama. The projection is based on each county's mix of commodity-producing industries and historical personal income growth. The techniques allow for a county's share of future freight traffic to change significantly over the 30 year period based on its economic growth rate compared to the other counties in the state.

Table 2-6 displays the projected change in the freight allocation for each Alabama County between 2005 and 2035. It is based on weighting the value of sales and personal income equally and is expressed as a percentage of total projected freight traffic. Counties highlighted in bold in the table are projected to increase significantly their share of freight traffic between 2005 and 2035. The largest such increase is for Madison County where the share grows from 8.4% to 12.6%. Madison County's share grows so fast because of its mix of rapidly expanding high tech industries along with continuing strong growth in personal income. Other counties projected to increase their shares of freight traffic over the 30 year period include Baldwin, Elmore, Limestone, Morgan, Shelby, and Tuscaloosa.

TABLE 2-6 Change in the Allocation of Freight Traffic: 2005-2035

County	2005 Allocation	2035 Allocation
Autauga	0.7%	0.8%
Baldwin	**2.8%**	**3.8%**
Barbour	0.7%	0.6%
Bibb	0.2%	0.2%
Blount	0.6%	0.7%
Bullock	0.2%	0.2%
Butler	0.3%	0.2%
Calhoun	2.6%	2.4%
Chambers	0.8%	0.3%
Cherokee	0.4%	0.3%
Chilton	0.6%	0.5%
Choctaw	0.7%	0.5%
Clarke	0.6%	0.4%
Clay	0.3%	0.3%
Cleburne	0.3%	0.1%
Coffee	0.9%	1.0%
Colbert	1.4%	1.1%
Conecuh	0.2%	0.2%
Coosa	0.2%	0.1%
Covington	0.7%	0.7%
Crenshaw	0.3%	0.2%
Cullman	1.4%	1.4%
Dale	0.5%	0.4%
Dallas	1.1%	0.8%
De Kalb	1.7%	1.2%
Elmore	**1.0%**	**1.4%**
Escambia	0.8%	0.5%
Etowah	1.8%	1.5%
Fayette	0.3%	0.1%
Franklin	1.0%	0.9%
Geneva	0.3%	0.3%
Greene	0.1%	0.1%
Hale	0.3%	0.3%
Henry	0.5%	0.2%
Houston	2.0%	2.3%
Jackson	1.5%	1.2%
Jefferson	14.6%	12.6%
Lamar	0.4%	0.3%
Lauderdale	1.3%	1.1%
Lawrence	0.9%	0.7%

County	2005 Allocation	2035 Allocation
Lee	2.3%	2.5%
Limestone	**1.8%**	**2.2%**
Lowndes	0.4%	0.5%
Macon	0.2%	0.1%
Madison	**8.4%**	**12.6%**
Marengo	0.6%	0.4%
Marion	0.7%	0.6%
Marshall	2.4%	2.5%
Mobile*	8.3%	7.5%
Monroe	1.0%	0.7%
Montgomery	4.7%	4.8%
Morgan	**4.2%**	**4.7%**
Perry	0.2%	0.1%
Pickens	0.3%	0.2%
Pike	0.6%	0.5%
Randolph	0.3%	0.2%
Russell	0.6%	0.4%
Shelby	**3.4%**	**4.8%**
St Clair	1.2%	1.6%
Sumter	0.1%	0.1%
Talladega	1.8%	1.6%
Tallapoosa	0.8%	0.4%
Tuscaloosa	**6.3%**	**6.9%**
Walker	0.9%	0.7%
Washington	0.6%	0.8%
Wilcox	0.3%	0.2%
Winston	0.7%	0.5%

* The projected share for Mobile County does not include freight from the Port of Mobile

2.1.1.9 Economic Database Update Schedule

The sub-state economic database requires updating so that the most current information can be used to allocate freight traffic. The state's economic circumstances can change because of national, international, and local events and these changes can have long term consequences for freight movement patterns. Most of the data required by the economic database is publicly available and published by federal or state agencies. Some are published quarterly, annually, or with a lag of five years. The update schedule for the Alabama sub-state economic database is provided in Table 2-7.

TABLE 2-7 Database Update Schedule

Data Items	Frequency	Next Update	Source
County Baseline Data			
Manufacturing	5 years	2009	US Census of Manufacturing
Agriculture	5 years	2009	US Census of Agriculture
Logging	5 years	2009	Alabama Forestry Commission

Mining	5 years	2009	US Census of Mining
			US Geological Survey
			County Business Patterns
Growth Projections			
Manufacturing	1 year	2010	Global Insight
Agriculture	1 year	2010	US Dept. of Agriculture
			Economic Research Service
Mining	1 year	2010	US Geological Survey
			US Dept. of Energy
			Energy Information Agency
County Personal Income			
	1 year	2010	US Dept. of Commerce
			Bureau of Economic Analysis

2.1.1.10 Future Additions to the Economic Database

The current economic database was developed based upon the variables value of sales and personal income to predict future sub-state freight traffic distribution. Other variables may provide a better fit to actual freight traffic counts on Alabama's major highways. To test which set of variables gives the best fit, new data will be added in the future to the economic database. Some possible additions include:

- Employment in heavy industry
- Population by age
- The value of wholesale and retail sales
- Electricity usage
- The tonnage of agricultural products including logs
- The tonnage of extracted mineral products
- Median household income
- State gas tax revenue
- Truck licenses

This work shows that local economic data from many different sources can successfully be used to allocate freight volume into smaller FAZs from the future freight traffic volumes provided by highly aggregated national databases such as FAF2. The output of this effort is used as input to the modeling of freight, and the integration of that freight into existing transportation planning and modeling activities at the state and local level. The methodology described here can easily be replicated by other states and metropolitan planning organizations. Additional research will aim at finding the set of economic variables that best predicts present freight movements into and out of these FAZs and consequently will most likely improve the accuracy of future freight movement predictions.

2.1.2. Collecting and Integrating Local Freight Information

The use of local freight data in transportation planning is essential to ensure accuracy in the travel demand modeling process. However, unlike passenger transportation, where extensive research work has been performed in the collection and use of household travel data, limited research has been performed to collect and use local freight travel data. This research was undertaken to develop a structure and methodology to collect and summarize local freight data in an urban area to be used in the transportation planning process within a Metropolitan Planning Organization.

Traditional transportation planning activities in urban areas, performed by staff at Metropolitan Planning Organizations (MPOs), usually focus on forecasting passenger travel to alleviate congestion in peak periods. This approach is warranted because peak period travel congestion levels are generally severe and travelers experiencing this congestion are often vocal members of the community.

The forecasting of passenger travel is heavily reliant on the collection of data related to passenger travel, and there have been numerous studies addressing the collection of passenger travel information [21, 22, 23, 24]. It would follow that the forecast of freight transportation would rely heavily on accurately collecting local freight data. Freight data generation studies are usually developed and disseminated at the national level and not specific to the urban area [25, 26]. However, there are limited guides and literature available on developing a local freight collection system tailored to the freight model to the local level. This is not surprising due to the fact that freight is explicitly modeled in the process and freight data is considered proprietary.

This situation begs the question, “What can industry input provide when developing a long-term freight plan?” The answer is plenty, because after all, it is the conduct of business that creates freight through the attempt of suppliers to meet the demands of customers. Each company has a view of their industry’s sector freight transportation system. Gaining insight from these companies alerts planners to pattern shifts, network realignments, or simply current industry trends. Maybe the greatest benefit from obtaining input from local industry is the building of relationships with business leaders.

The UAHuntsville OFLT research team designed and implemented a system for collecting, storing and analyzing local freight data within an MPO area and the application of that freight data to transportation planning. The research team designed and developed a questionnaire used to collect freight data and the database used to store and access collected freight data. The system developed is a viable tool for freight data management and can support transportation planning activities. An overview of the survey development process steps is provided in Appendice A.

The tool was developed to be generic, in so much that the final product can be used in any location, however, there are aspects of the tool that are specific to Mobile, AL, where the tool was implemented. Additionally, all of the summary data shown has been collected from businesses within the Mobile Metropolitan Planning Organization.

2.1.2.1 Collecting Data

The keys to building beneficial relationships and obtaining useful information from local industry representatives, or any other stakeholder in transportation planning, are to ask relevant questions, don't waste time, don't build unrealistic expectations, and follow-up when necessary. The creation of a structured approach should keep the process organized but not limit the opportunity for listening. A data form, if used effectively, can keep the discussion focused on the relevant topics while allowing the interviewer to capture unanticipated gems of insight. After the visit, a routine processing of the input will ensure insight is not lost and may identify where follow-on questions are needed.

The form entitled *Freight Transportation Survey, Industry Interview Form* contains 16 discussion/data topics (see Figure 2-8 below – complete form – Appendice B). It is presented in a format conducive to a personal interview. To build a relationship, it is important to have person to person interaction. Trust can seldom be developed through online conversions and email exchanges. Several questions have multiple parts which help complete the insight on the topic of the question. There is ample whitespace to use in capturing clarifications, estimating quantities, and calculating conversions for entering the information into the database after the visit.

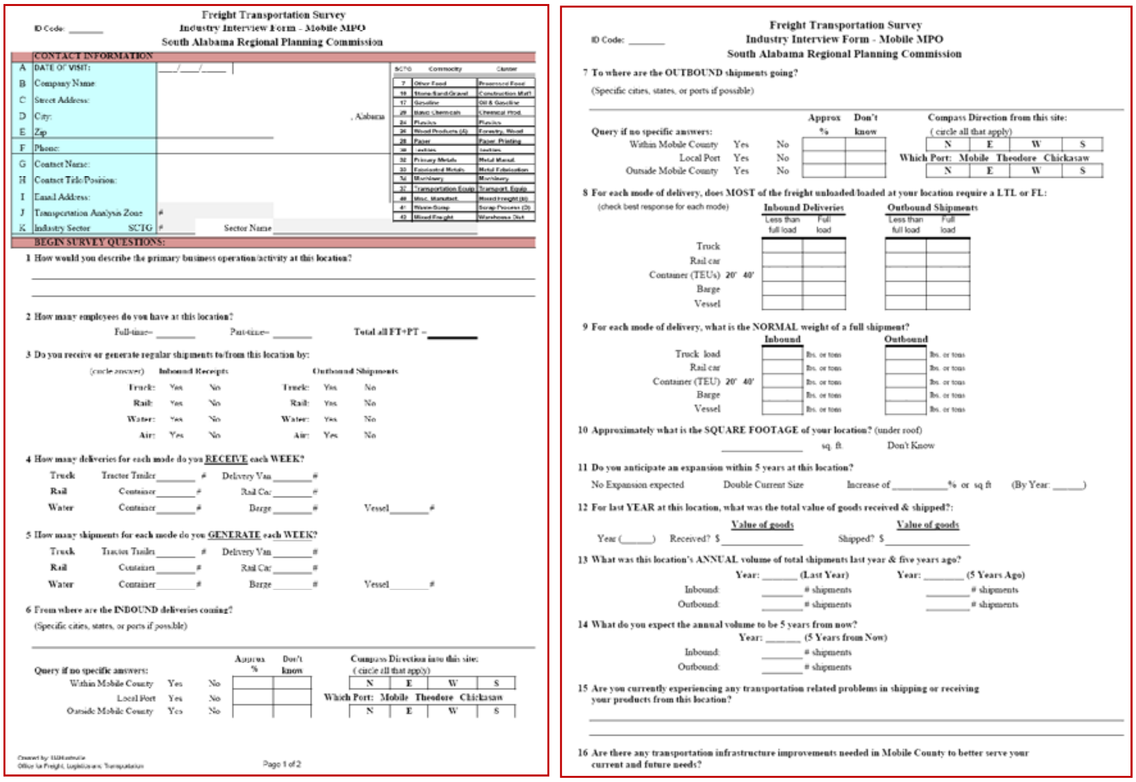


Figure 2-8 Questionnaire Form

The interview form itself contains several key pieces of information. The company name, address, contact name of the person interviewed, transportation analysis zone, and industry sector (a 2-digit number and category assigned by a representative of the data collecting organization). The interview questions are designed to target specific pieces of data that are needed for modeling purposes.

Q1. Business Description: Use <u>keywords</u> to capture the primary business activity(ies). This will be used to assign each company to <u>only one</u> industry sector. If the company has multiple lines of business, note the area where most of the freight is generated or received.

Q2. Number of Employees: Ask for the current <u>number</u> of full-time and part-time employees at this location. There is no need to convert part-time employees to full-time equivalents. Make sure to ask about the number of people working at the location. If the company has multiple locations within the county, you may consolidate all employees or treat each location as a separate company. Just make sure that the answers to the other questions are consistently treated. Add the number of full-time employees plus the number of part-time employees to get a total employee count to enter into the database.

Q3. Shipments by mode: Capture how the company receives and ships most of its goods. Circle yes or no based on whether they receive (Inbound) or generate (Outbound) shipments for each mode.

Q4. Deliveries received by mode WEEKLY: This is an average number of deliveries received weekly. The interviewee is probably more familiar with a weekly average than another measure like monthly or annually. Take their response as they know it and convert to weekly after the interview if necessary.

Q5. Shipments generated by mode WEEKLY: This is an average number of shipments generated weekly. The interviewee is probably more familiar with a weekly average than another measure like monthly or annually. Capture their response in the terms with which they are most familiar and convert to weekly after the interview if necessary.

Q6. Origins of inbound deliveries: Capture the major points of origin from where their shipments come directly to their location. Cities, states, regions, or countries are acceptable responses. In other words if the company gets products from California but the last leg of the trip is from Dallas, state as California through Dallas. The most important concern is the direction from where goods come to their location. Try to obtain enough information to allow the three origins (Within County, Local Port, Outside County) to be weighted as percentages of their total receipts. The percentages must total 100% for the information to be used in the database calculations. Circle the compass direction for Within City and Outside of City for the direction from which shipments come to their location. If a port is used note which port, e.g. Mobile, Theodore, or Chickasaw by circling the port name.

Q7. Destinations for outbound shipments: Capture the major destinations for where the shipments that the company generates are headed. Cities, states, regions, or countries are acceptable responses. In other words, if the company ships products to California but the first leg of the trip is to Memphis, state as California through Memphis. The most important concern is the outbound direction of goods leaving their location. Try to obtain enough information to allow the three destinations (Within County, Local Port, Outside County) to be weighted as percentages of their total shipments. The percentages must total 100% for the information to be used in the database calculations. Circle the compass direction for Within Mobile and Outside of Mobile for the direction for where the shipments are headed from their location. If a port is used note which port, e.g. Mobile, Theodore, or Chickasaw by circling the port name.

Q8. Size of Shipment: Check for each mode they use inbound to their location and outbound from their location whether MOST of the shipments are Less than Full Load or Full Load. For containers, circle whether they normally use 20 foot or 40 foot containers.

Q9. Weight of Shipment: Note the NORMAL weight of a full shipment (not including the vehicle weight) into or out of their location for all modes they use. To receive shipments by rail, they must have a rail spur at their location. For Barge or Vessel, they must have a water port at their location. Otherwise, the shipments will probably arrive by truck. Containers are assumed to arrive by truck but are shown separately on the reports. Circle whether the weight is tons or pounds. The data MUST be entered into the database in pounds. For data entry, convert the number of tons to pounds by multiplying tons by 2,000.

Q10. Size of Facility: Note the size in square feet of their facility under roof. Outdoor yards are not to be included in the square footage total. You may note the outdoor area used on the form in the margin for your paper file.

Q11. Expansion Plans: Note whether or not the company is anticipating an expansion sometime in the next 5 years. Write the anticipated year of the expansion and the amount of the increase. If the interviewee gives you a percentage, note it and then convert to square footage using the answer in Question 10. Only square feet are to be entered into the database.

Q12. Value of Goods Last Year: Note the total value in dollars of the goods received and/or shipped for the most recent year for which they have data. If they do not know or won't share either, ask for annual sales amount and place in the Shipped $ blank. Any insight that you can gain will help but it is not mandatory to answer the question.

Q13. Annual Volume of Shipments- Actual: Note the year and the total ANNUAL number of shipments inbound (received) and outbound (generated) for the most recent year for which they have data. Also, note the year and total ANNUAL number of shipments inbound and outbound for 5 years ago. If the company has been in business less than 5 years or if they only have information for less than 5 years ago, capture the information and make sure the year of the information is noted. The inbound and outbound shipments for last year should be approximately 52 times the answers to questions 4 and 5, respectively.

Q14. Annual Volume of Shipments – Forecasted: Note the year and the ANNUAL total number of shipments the company expects five years into the future. If they make projections for less than 5 years, e.g., 3 years, capture the information and ensure that the forecasted year is noted.

Q15. Problems at the Location: Make note of any company location or site specific issues mentioned. Get enough information to clarify the issue. But, DO NOT IMPLY or leave the interviewee with the impression that their problem(s) will be fixed. Only communicate that their responses will be passed on to the Metropolitan Planning Organization and used for improving transportation infrastructure over the next 30 years.

Q16. Problems in Mobile: Make note of any route or significant problems in the area which are mentioned. Get enough information to clarify the issue. But, DO NOT IMPLY or leave the interviewee with the impression that their problem(s) will be fixed. Only communicate that their responses will be passed on to the Metropolitan Planning Organization and used for improving transportation infrastructure over the next 30 years.

2.1.2.2 Data Entry

The information obtained through company visits was entered into a Freight Survey Database. Microsoft Access 2007 was used to store the database information. The input screens are arranged similar to the Interview Form described above. The database opens to a MENU screen with options to (see Figure 2-9):

- Open the Survey Form
- Go to a Company in the database
- Open Report – Avg Freight Weights by Mode
- Open Report – Directions
- Open Report – Shipments per Employee
- Open Report – Shipments per Square Foot
- Next (which opens the second menu)

Figure 2-9 Data Entry Screen

The second menu contains (see Figure 2-10):

- List Companies Surveyed in the Last 6 Months
- List of Problems & Improvements by Business Activity
- List of Problems & Improvements by Company
- List of Problems & Improvements by Survey Date
- List of Problems & Improvements by TAZ
- Back

Users simply click on the square button to the left of the option title to select it.

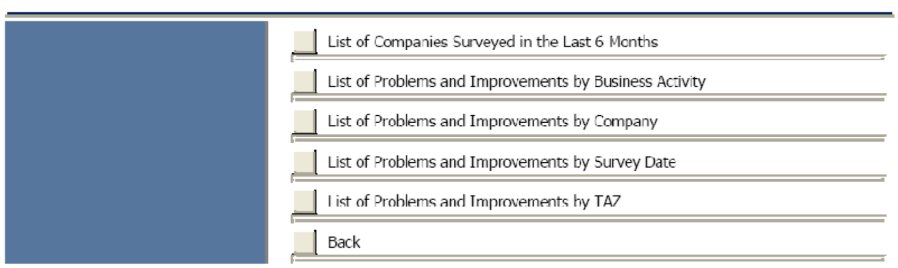


Figure 2-10 Second Data Entry Screen

Before entering survey data into the database it is important to ensure that the data is expressed in the appropriate units of measure and time. The insight gained from the company visits will most likely be shared in the units which are most commonly tracked by the company such as the number of monthly shipments instead of weekly or annual shipments.

2.1.2.3 Database Output

Data in the database only becomes useful information for transportation planning when it is processed appropriately and can be extracted in a useable form such as a report. Persons familiar with writing Microsoft Access reports may create custom reports to extract any or all information in the database. However, the company visit information that is used in the freight transportation models is contained on the reports shown on the MENU screen. The prepared reports are:

- Average Freight Weight by Mode
- Travel Directions
- Shipments Per Employee
- Shipments Per Square Foot
- List of Companies Surveyed in the Last 6 Months
- List of Problems and Improvements by Business Activity
- List of Problems and Improvements by Company
- List of Problems and Improvements by Survey Date
- List of Problems and Improvements by TAZ

The Average Freight Weight by Mode is used to calculate the average full-load shipment weights in pounds by mode: truck, railcar, container, barge, and vessel. These averages are calculated from all entries that receive or ship full loads. Only companies that provide an answer to the weight and full load questions are used in the calculations. The date on which the report is run is shown at the bottom (see Figure 2-11).

UAHuntsville - Office for Frieght, Logistics, and Transportation Annual Report by Industry- Mobile MPO Average Weight by Mode in Pounds		
	Inbound (in Pounds)	Outbound (in Pounds)
Truck	44,370.37	41,625.00
Rail Car	158,428.57	177,833.33
Container	32,666.67	44,000.00
Barge	3,000,000.00	6,100,000.00
Vessel	74,040,000.00	

Wednesday, February 04, 2009

Figure 2-11 Output Weights By Mode

The report for travel direction is used to calculate the percentages of freight coming To Mobile (incoming) and leaving From Mobile (outgoing). These proportion calculations are made for:

- The local area (Within County, Ports, Outside County)
- The compass directions (North, East, West, South)
- The transportation mode (Truck, Rail, Water, Air)

Also shown are database sums for the Total Deliveries Received Annually, Total Deliveries Generated Annually, the Number of Records in the Database, the Number of Different Companies in the database, and Number of Survey Forms Used for the Reports.

The first section of the report shows the percentage of freight shipments destined for surveyed companies located in the County which originate in the County (31.12%), originate at the Port (1.63%), and originate from outside of the study area (67.25%). Also shown is the percentage of shipments generated by surveyed companies in the study area and are destined for a location within the County (26.82%), destined for a local Port (1.26%), and going to a destination outside of the County (71.92%). See Figure 2-12.

UAHuntsville - Office for Frieght, Logistics, and Transportation Report of the industry- Mobile MPO		
Freight To/From Mobile	**To Mobile**	**From Mobile**
Within Mobile County	31.12%	26.82%
Ports in Mobile	1.63%	1.26%
Outside of Mobile County	67.25%	71.92%
Total	100.00%	100.00%

Figure 2-12 Internal/External Distribution

The second section of the report shows the percentage of freight shipments destined for surveyed companies in Mobile County from origins by compass direction. The last column shows the percentage of outbound freight shipments originating at surveyed companies located in Mobile by compass direction (See Figure 2-13).

Freight To/From Mobile	To Mobile	From Mobile
North	38.50%	44.19%
East	31.32%	12.63%
West	23.47%	38.71%
South	6.71%	4.47%
Total	100.00%	100.00%

Figure 2-13 Directional Distribution

The third section of the report shows the percentage of companies receiving freight shipments in the County by freight mode. The right column shows the percentage of companies with freight shipments leaving surveyed companies in the County Note that these calculations are for the last leg of inbound receipts and the first leg of outbound shipments. For example, no companies load an airplane at their location in this example. Their air freight is moved by truck to the air cargo terminal so the shipment is included in the Truck mode. See Figure 2-14.

	Inbound Receipts	Outbound Shipments
Truck	97.06%	91.18%
Rail	22.06%	10.29%
Water	13.24%	16.18%
Air	2.94%	0.00%

Figure 2-14 Shipment Usage

The final section of the report totals several fields in the database as indicators of the amount of data being used and as a check for the number of records in the database. The Total Deliveries Received Annually sums the number of the shipments received for all companies in the database. The Total Deliveries Generated Annually sums the number of shipments generated by all of the companies in the database. The Number of Records in the Database counts the number of records in the database. The Number of Different Companies in the Database counts unique company surveyed. The Number of Forms Used counts the number of surveys used to produce the reports which is determined by the use of the Use for Reports box in the top section of the survey screen.

The Shipments by Employee and by Industry reports break out the number of shipments per employee for 15 industry sectors using the **Standard Classification of Transported Goods** (SCTGs) for both inbound shipments and outbound shipments. The total number of employees from all companies in the database is shown in the most right column. For example, the companies classified in the Construction Materials Sector (SCTG 10) receive an average of 146.9 shipments annually per employee. These companies generate an average of 267.43 shipments annually per employee. All of the companies categorized as Construction Materials have a total of 297 employees. Note that these averages will change based on the companies surveyed and should become more reflective of each industry sector as more companies are interviewed in each sector. The industry sectors are determined by the specific makeup of the industries in the study area. See Figure 2-15.

UAHuntsville - Office for Frieght, Logistics, and Transportation Annual Shipments by Employee and by Industry Report - Mobile MPO	Inbound	Outbound	# Employees
Food Shipments	11.29	26.80	456.00
Construction Mat	146.90	184.71	297.00
Petroleum	104.93	267.43	14.00
Chemicals	7.93	15.95	777.00
Plastics	71.50	201.50	40.00
Wood Products	46.50	44.27	350.00
Paper	53.09	65.53	715.00
Textiles	27.25	13.78	166.00
Primary Metals	52.08	62.50	634.00
Fabricated Metals	20.06	20.06	140.00
Machinery	41.30	25.85	141.00
Transportation	1.71	59.74	880.00
Misc Manufacturing	45.58	58.83	624.00
Waste And Scrap	275.10	11.41	155.00
Mixed Freight	47.58	91.71	553.00

Wednesday, February 04, 2009

Figure 2-15 Shipments by Employee

The report of Shipments per Square Foot by Industry Sector breaks out the number of shipments per 1,000 square feet of covered buildings for 15 industry sectors (SCTGs) for both inbound shipments and outbound shipments. The total square footage (in 1,000s) for covered buildings of all companies in the database is shown in the most right column (See Figure 2-16).

UAHuntsville - Office for Frieght, Logistics, and Transportation Annual Shipments per Square Feet and by Industry Report- Mobile MPO	Inbound / sq ft	Outbound / sq ft	1000 per Sq Feet
Food Shipments	11.09	26.34	464.00
Construction Mat	113.45	165.45	55.00
Petroleum	1.13	2.88	1,300.00
Chemicals	19.25	23.75	208.00
Plastics	6.16	217.84	37.00
Wood Products	79.56	71.76	100.00
Paper	42.18	52.06	900.00
Textiles	26.00	19.76	50.00
Primary Metals	1.12	56.73	55.00
Fabricated Metals	10.70	10.70	262.40
Machinery	25.43	15.92	229.00
Transportation	7.01	244.52	215.00
Misc Manufacturing	42.36	45.15	428.46
Waste And Scrap	104.00	62.40	15.00
Mixed Freight	19.02	19.61	1,087.00

Wednesday, February 04, 2009

Figure 2-16 Shipments per Square Feet

The other reports are basic information for the local agencies surveyed and contain more descriptive data.

- The report of the Companies Surveyed in the Last 6 Months contains a listing of company name, survey date, and business activity (industry sector).
- The report of Problems and Improvements by Business Activity shows the company name, transportation related problems, and the transportation infrastructure improvement comments by each company surveyed. The list is categorized by industry sector (SCTG). This report is also useful in showing the companies in each industry sector.

- The report of Problems and Improvements by Company shows the company name, survey date, transportation related problems, and the transportation infrastructure improvement comments for each company surveyed. The list is shown in alphabetical order by company name. This report is also useful in showing all of the companies surveyed.
- The report of Problems and Improvements by Survey Date shows the survey date, company name, transportation related problems, and the transportation infrastructure improvement comments for each company surveyed by date of survey. The list is shown in date order. This report is also useful in showing all of the companies surveyed on a particular date or range of dates.
- The report of Problems and Improvements by Traffic Analysis Zone (TAZ) shows the survey date, company name, transportation related problems, and the transportation infrastructure improvement comments for each company surveyed by the TAZ for the company's location. The list is shown in TAZ numeric order. Entries without a TAZ assigned will be shown at the top of the report.

All the reports are directed at providing information on the local freight activity in the area and supplying needed information and data to the transportation professional.

2.1.2.4 Data Collection Process & Schedule

Data is collected by surveying companies on a continual basis through a regular process of choosing a company, making an appointment, confirming the appointment, visiting the company, completing the survey form, and sending a note of thanks to the person interviewed.

When choosing a company to interview the goal is to identify a geographic dispersion of companies. Lists of companies are generally obtained from trade associations, local chambers of commerce, business license departments, etc. The overall objective in selecting companies to interview is to get a reasonable representation of each of the industry sectors in the survey database.

Companies with a large and/or growing number of shipments are specifically targeted for revisits within 12-18 months. Companies with few shipments may be visited every 2-3 years. Companies which provide very little data may not be worth re-visiting.

2.1.2.5 Tracking Supplemental Data

The purpose of obtaining input from industry is to improve the understanding of a particular industry sector or geographic region. Although company data is extremely valuable, it will usually be incomplete. Supplementing the information gathered from companies through sources such as the newspaper, trade association announcements, economic development announcements, etc. can add much to the intelligence available to forecast freight into the future. A company that plans to double its size in the next year may need to be visited or revisited within the next year to update or expand the database. Monitoring news sources for this type of information daily or weekly will greatly improve the knowledge available when forecasting/projection assumptions are made.

Likewise, maintaining a collaborative relationship with organizations that have access to current useful information can be very helpful for both parties. For example, an economic development organization can share the recent project announcements and may benefit by knowing more about the long-term transportation plan for the area.

The presented questionnaire used to collect freight data and the database used to store and access collected freight data were designed specifically for the Mobile Metropolitan Planning Organization, but can be used in any local area. The result of this effort in Mobile has been the integration of freight transportation requirements into the region transportation plan. The information gathered through this process, along with information on commodity flows from around the country, allowed the MPO to produce an intelligent estimate of freight movement within the study area and resulted in a validated transportation model.

Improvements to the traditional transportation planning activities performed in urban areas through the inclusion of freight activities has the potential to more accurately identify congestion and its cause. The database management tool allows specific freight information to be incorporated into the travel demand model process and can essentially be used to give freight a voice in the future infrastructure decision making process.

2.2 Trip Distribution – Integration of Freight and Transit System Loads

Traffic Analysis Zones (TAZs) are a key component to transportation planning at all levels. Freight is not as applicable at the TAZ level. Therefore, the concept of Freight Analysis Zones (FAZs) needs to be developed to allow for the integration of the freight component into state and MPO transportation plans. This research focuses on developing appropriate planning levels for freight and how they relate to traditional TAZs.

Once the planning level is determined, it is important to integrate and distribute the load on the transportation network. A second focus of this subtask is the development of integration methods and techniques of freight, transit and passenger travel loads.

2.1.1 Modeling Freight in a Medium-Size Community With Federal Databases and Local Knowledge

In most urban areas, freight volumes are not explicitly considered within the transportation planning process. This section describes the methodologies developed to overcome two limitations, the proprietary aspect and the external nature of the data, through the use of a publically available, highly aggregated freight flow database within a travel demand model. The researchers developed solutions to issues associated with the use of highly aggregated data in a travel model, and applied a multi-tiered mechanism to incorporate freight from a highly aggregated source into a travel model through a case-study of Mobile, AL.

2.2.1.1 Background

Transportation modeling activities focus on the development of travel demand models as a tool to support infrastructure investment decisions within an urbanized area. Typically, these models focus on passenger transportation, often peak hour levels of travel, to determine the existing and future roadway congestion to test roadway alternatives. The commonly used process is to develop the amount of travel or number of trips (trip generation), origin/destination pairs for the trips (trip distribution), mode for the trip, if alternate modes are available which is not the case in smaller urban areas, (mode choice), and finally the route for the trip (traffic assignment) [27]. A considerable amount of research has been performed into this process, as well as optimization within each step, and although there is more work to be done, this area of transportation modeling is relatively well understood.

Unfortunately, developing a travel demand model that only includes passenger car trips is omitting a significant number of vehicles on the roadways. The missing trips consist of heavy vehicles, or freight trips, which have the potential to account for 20-25 percent of the trips on major roadway facilities, especially in industrial/ manufacturing sections of town (data verified using Alabama Department of Transportation Traffic data [28]). Additionally, this traffic consumes a significant amount of the roadway capacity. These trips are growing rapidly as freight movements are increasingly being transported by truck.

The need for the integration of freight traffic into the transportation modeling effort is evident by the recent publication of "NCHRP 570 Guidebook for Freight Policy, Planning, and Programming in Small- and Medium-Sized Metropolitan Areas" [29] and ongoing research being performed by the National Cooperative Freight Research Program (NCFRP) [30]. However, even with a greater focus on the importance of freight transportation in the modeling environment, it is still difficult for transportation professionals to obtain accurate data for use in the models. This problem exists because freight data is proprietary, and as such, companies are reluctant to release this information. Often freight activities resulting in pass through traffic, occur outside the study area, such that transportation professionals have no direct mechanism to collect freight trip information [29].

The application of freight within a travel demand model is not a new concept. There have been several attempts to collect and incorporate freight flow information into a community's travel model. NCHRP 570 contains a brief examination of 15 case studies performed in small and medium sized communities [29]. However, these model options often act as a stop-gap, or place-holder, for freight within the travel demand model and these applications are difficult to validate to actual travel patterns.

In this research the team utilized the Federal Highway Administration's Freight Analysis Framework Database, Version 2.2 (FAF2) for application within an urban area. The FAF2 is a flow database that contains 114 internal zones and 17 ports of entry for the United States [31]. The geographic location for the zones is presented in Figure 2-17. The flow information is given for 43 specific commodities, for 7 transport modes, in either kilotons transported annually or value of shipment transported annually [31].

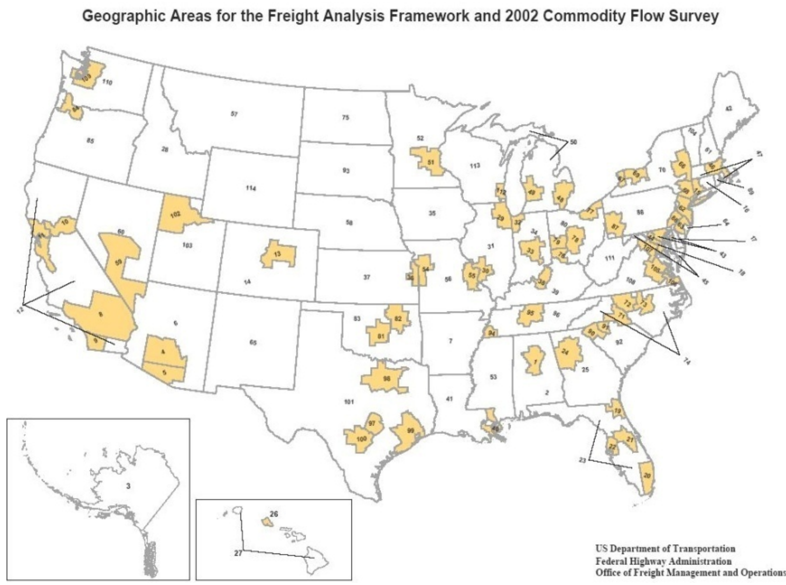


Figure 2-17 FAF2 Geographic Areas

Often, using the freight flow information contained in FAF2 is questionable because of limitations associated with the data due to the scale for the zones and the lack of empty vehicles being included in the database. There have been studies performed to disaggregate the FAF2 data to smaller geographic regions [6, 32, 33]. Additionally, the empty vehicles can be accounted through the conversion of kilotons to vehicles by selecting the appropriate weight per vehicle that will take into account the portion of empty vehicles [34]. With these adaptations included, it was theorized that the aggregated data can be used to support freight transportation in a travel demand model.

2.2.1.2 Methodology and Case Study

The methodology is presented through the case study used to test the application of the federal freight flow database for travel modeling. The case study location selected was Mobile, AL. The case study community has an area population of approximately 350,000, an international port for bulk and container freight, and is positioned at the intersection of Interstate 10 and Interstate 65 – two important freight corridors within the nation (see Figure 2-18).

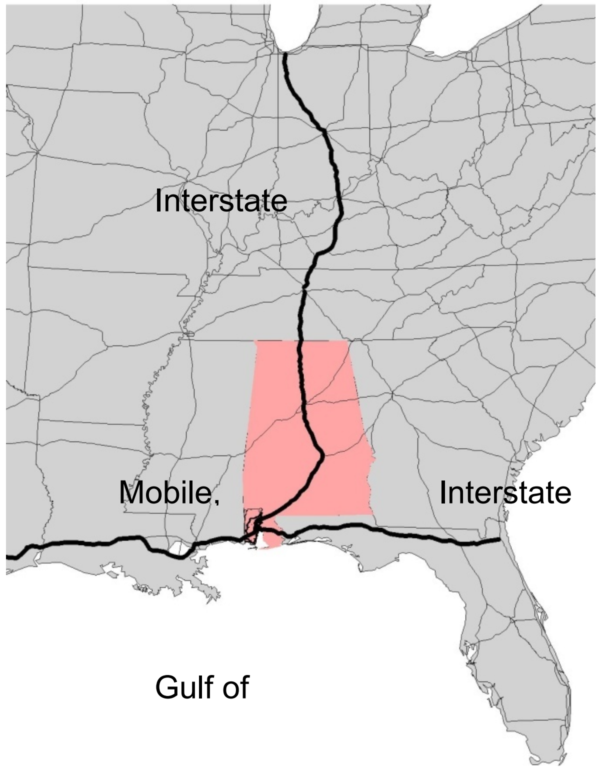


Figure 2-18 Mobile, AL in relation to the United States

The existing travel demand model for the Mobile area is run in TRANPLAN and models trucks implicitly. The trucks passing through the area are accounted for through the use of the traffic count at the study boundary. The external-external trips are preloaded in the model and these trips are constrained to selected roadways in the networks. The internal truck trips are assumed to be a portion of the non-home-based trips in the study area. These trips are distributed through a gravity model and assigned to the network using an equilibrium assignment.

2.2.1.3 Truck Trip Purposes

Initial examination of the Mobile, AL area and the aggregation levels and geography of the FAF2 database identified nine possible freight movements in the area. The freight movements identified are:

1. External-External Trips (through trips)
2. Port to the US (non Alabama)
3. Alabama to the US (non Mobile)
4. Port to Alabama (non Mobile)
5. Mobile, AL and the rest of Alabama (non Birmingham, Alabama area)
6. Mobile, AL to Birmingham, Alabama area

7. Port to Mobile, AL
8. Mobile, AL to the US (non Alabama)
9. Internal to Mobile

The reason the Birmingham, Alabama area freight trips need to be considered separately is that they are contained in a different FAF2 zone, see Figure 2-17. The following is a brief description of the multi-tiered modeling methodology used to convert the FAF2 data into a format for entry into an urban travel demand model.

External – External Trips

The external-external trips, or through trips, are the trips that impact Mobile, AL simply because of its geographic location. These trips have no relationship with Mobile with the exception that Mobile happens to be located along the roadway used to get from that particular freight load's origin to its destination. For study purposes, these external-external trips travel entirely across the state of Alabama. For trips that are external to Mobile that either have an origin or destination in Alabama, a separate trip purpose has been established.

These trips were modeled using the FAF2 database and a national level roadway network developed in TRANPLAN (see Figure 2-19). The network was developed to include the interstate system links and a few US Highways in close proximity to Mobile, the case study city. The decision to use the interstates in the national network is logical because most trips traveling between states are assumed to take the major interstates while the trips close to the case study city might choose to use some additional local roadways. Additionally, trips between locations that do not impact the case study area are not of great importance.

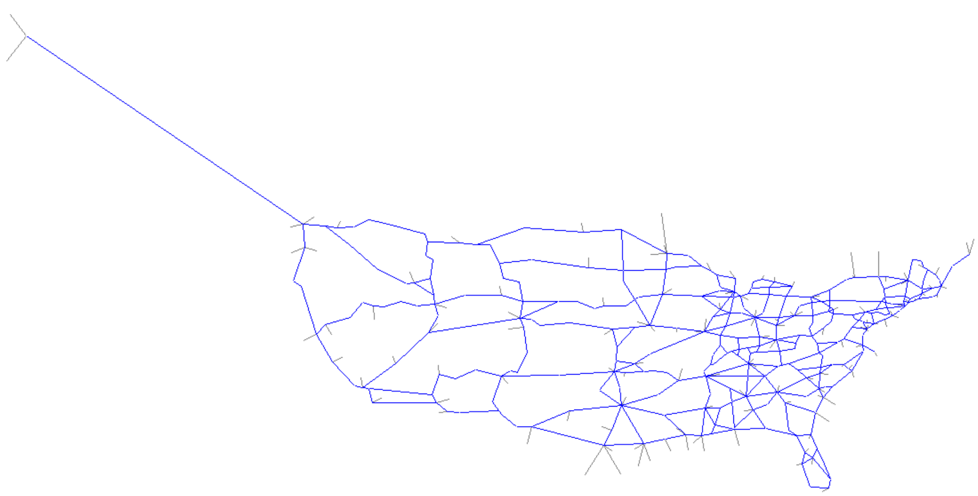


Figure 2-19 National Network

The truck trip table assigned to the network is obtained from the FAF2 database, using the actual origins and destinations entered in the database and converted into truck volumes from the original truck weights. Empty trucks are included in the process by manipulation of the study truck weight as described earlier. The trips are determined by adding five trip types from the FAF2 Database (Domestic Trips, Border Crossing into the US, Boarder Crossing out of the US, and Port trips into the US, and Port trips out of the US). A Matrix Manipulate function in TRANPLAN is used to aggregate the data into one table for assignment. A Matrix Update function in TRANPLAN is used to remove any Alabama trip, those in zones 1 or 2, as well as the zone 123 (the Port of Mobile). During the assignment step, the use of select link loading allows for the identification of specific trips traveling through Mobile. The trip volumes were then manually renumbered to match the external stations used in Mobile.

Port – US (non-Alabama)
The truck trips from the Port of Mobile to anywhere in the US, non Alabama, were developed in a similar fashion to the external-external trips. Since these are trips with a destination outside of Alabama, and will more than likely utilize the interstate network, the same national level network was used and the same database that combined the five trip types from the FAF2. The difference is that only the Alabama zones (1 & 2) were set to zero to remove any trips to and from Alabama in the analysis. The assignment step again used selected link loading options for only the centroid connector that served as the port. The trip volumes were then manually renumbered to match the external stations used in Mobile.

US – AL (non-Mobile)
The truck trips between Alabama and the nation not directly relevant to Mobile use the same national level network but require some manipulation of the FAF2 data. The contribution of Mobile to the FAF2 zone containing Mobile must be removed prior to assignment to the network to avoid double counting trips (these trips will be included in a later trip purpose). The disaggregation of the FAF2 data to the counties is performed using county level population, personal income and value of shipment [33]. Once the contribution of Mobile County was determined, this value was removed from FAF2 zone 2 which contains Mobile County. An option was also included that removes the Port of Mobile as that truck traffic is handled separately. The assignment therefore only included truck trips between Alabama and the nation.

Port – AL (non-Mobile)
The truck trips between the Port of Mobile and locations in Alabama, non Mobile, were determined using a statewide level network and disaggregation of the two FAF2 zones for Alabama to the county level and the port data from FAF2. The statewide network was developed to contain all Interstate facilities, US Highways and some Alabama Highways within the state. Again, these roadways were selected as they represented

the main routes trucks would travel through the state, assuming long distance truck trips would avoid using county roadways, see Figure 2-20.

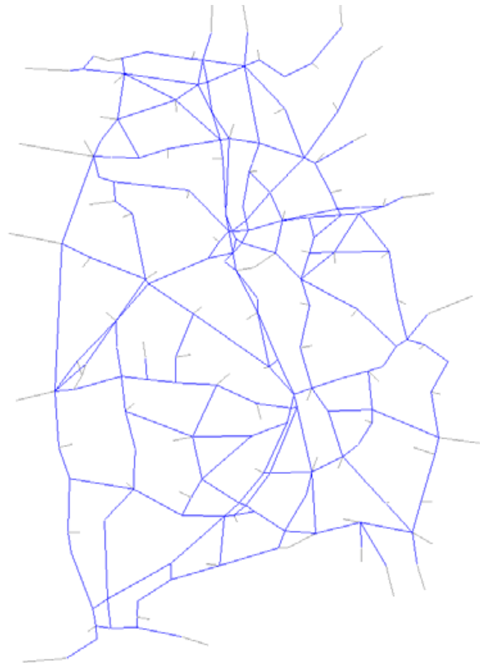


Figure 2-20 Statewide Network

These truck trips were determined with a disaggregation of the FAF2 data for zones 1 and 2 using the county population, personal income and value of shipment allocation factors [10]. The disaggregation was performed in Microsoft Excel and only the trips to and from the Port of Mobile was distributed to the 67 counties in Alabama. It is important to note that trips were distributed to Mobile County; these trips will be used as the basis for the Port to Mobile trip purpose.

The assignment to the statewide network provided the number of truck trips on US Highway 43, US Highway 45, Interstate 65, and Interstate 10, the four main roadways leading out of Mobile. The trip volumes were then manually renumbered to match the external stations used in Mobile.

Mobile – AL (non Internal-Internal)

The truck trips between Mobile and Alabama (non Birmingham area) were determined using the statewide network and the portion of trips from the FAF2 zone 1 and 2 disaggregation to the county level for the 67 counties in Alabama. For example, truck trip between Mobile County and Montgomery County would be included in this trip purpose. The portions of trips that either originated or terminated in Mobile and went to any of the other counties in zone 2 were included. Note that zone 1 trips were not used at this time, as zone 1 represented the Birmingham area and these were treated as a separate trip purpose. The FAF2 database was disaggregated using the same county factors as before. The origin/destination table was then assigned to the statewide network and the truck volumes were manually renumbered to match the external stations used in Mobile.

However, in this trip purpose, since the truck trips were specifically associated with Mobile, it was necessary to develop a mechanism to further disaggregate the trips into the urban area of Mobile. The disaggregation of trips within Mobile was performed using Freight Analysis Zones (FAZs) within Mobile. The concept behind the development of the FAZ is that there are so many traffic analysis zones (TAZs) within the urbanized area, the disaggregation to that level would become extremely fine, and there would be several zones with fractions of trips. The FAZ allowed for an aggregation of TAZs with similar household, employment and income characteristics to be grouped into a larger region. Statistical tests and an analysis of freight characteristics associated with each FAZ were used to determine the appropriate grouping levels and over 300 internal TAZs were converted into 28 FAZs [2]. The final disaggregation of trips into FAZs was performed using the number of manufacturing employees that were considered working in freight related industries. Originally, the total employment was used for disaggregation to the FAZs, however, this led to an over-estimation of truck trips because of retail and manufacturing locations where the manufacturing consisted of software and pharmaceuticals. Once the FAZs were determined, the assignment of trips was made to the local area network, see Figure 2-21.

Figure 2-21 Mobile, AL Network

Mobile - Birmingham
The truck trips determined using the FAF2 database and the disaggregation for trips from Mobile County to Zone 1 (Birmingham area) and trips from Zone 1 to Mobile County were used for this purpose. The process of disaggregating the trips within the study area to FAZs using freight related manufacturing employment was employed. The external station for the trips were all set as Interstate 65, the most logical way to travel from Mobile County to the Birmingham area, eliminating the need to run the statewide model.

Port – Mobile
The truck trips between the Port of Mobile and locations within Mobile were developed during the step where the port trips were disaggregated to the 67 counties of Alabama. The disaggregation of the trips within Mobile follows the formulation developed previously and uses the number of freight related manufacturing employees per FAZ as the weighting factor. These trips are assigned directly to and from the port location to the FAZs using the Mobile area network.

Mobile – US (non-AL)
The truck trips specific to Mobile that exchange to the rest of the country that were removed from the data during the US-AL (non Mobile) step were added to the study at this point. They are assigned to the specific freight analysis zone within Mobile based on the number of manufacturing employees working in industries that generate significant volumes of freight. The directional distribution of the freight trips was determined through an industry survey of shipping activities. These trips were directly assigned to the Mobile urban area network.

Internal to Mobile
The truck trips that are generated between FAZs result from the disaggregation of FAF2 data to the county level for Zone 2 specifically for Mobile County. This volume represents internal to Mobile trucks. To account for the possibility of smaller trucks inside the community, the weight per truck was modified. The FAZ distribution was done as before, using freight manufacturing employees, and the assignment was specific to the Mobile area network. It is important to note, that since these trips were internal, a gravity distribution model was used to allocate the trip exchange and the Non Home Based friction factors were used for distribution.

2.2.1.4 Input to the Model

The aggregation of the nine trip purposes described form a single truck origin/destination matrix for Mobile. To incorporate this new matrix into the model, a few changes to the modeling structure were required. First, the external station traffic count volumes were reduced to remove trucks and the non-home-based trips were reduced to reflect the removal of trucks, both were done to avoid double counting. Second, the model structure was altered such that the truck matrix was assigned through a preload to the network as a separate mode which was constrained to selected roadways in the network. The selected roadways in the networks for truck traffic were carefully identified examining locations that contained limited turning radii and existing traffic calming devices.

2.2.1.5 Model Results

The nine separate trip purposes presented in the case study were aggregated to create a total truck origin/destination matrix for the community. This truck matrix was assigned to the Mobile area network and validated to truck counts collected in the study area. The calibration of the model led to two important changes from the methodology mentioned previously. For the trips from the Port of Mobile to Alabama and the US, it was determined that there were shippers responsible for taking the trucks solely onto and off the port property. Investigation by the research team and MPO personnel determined that these shippers were not located on the main road and were not taking the obvious path the trucks would take if the trucks were to travel directly from the Port to their destination. Therefore, a change was made in the trip table to reflect a stop-over point for these trips.

The second change related to the Mobile – US trip, which were distributed using an industry survey to identify directionality. Based on the limited data collected in the industry survey at the time of the study, the directionality was adjusted to reflect the actual traffic conditions. This decision was made because it was not certain which route was used to leave town for long-haul trips into and out of the study area. For example, a trip listed as heading north, might instead head west out of Mobile to continue on a north-south interstate in Mississippi.

Validation of the truck model was performed using a comparison of the assigned trucks and the trucks counts collected in the study area. The validation plot of the data is shown in Figure 2-22 and the R-square coefficient for the data is 0.767.

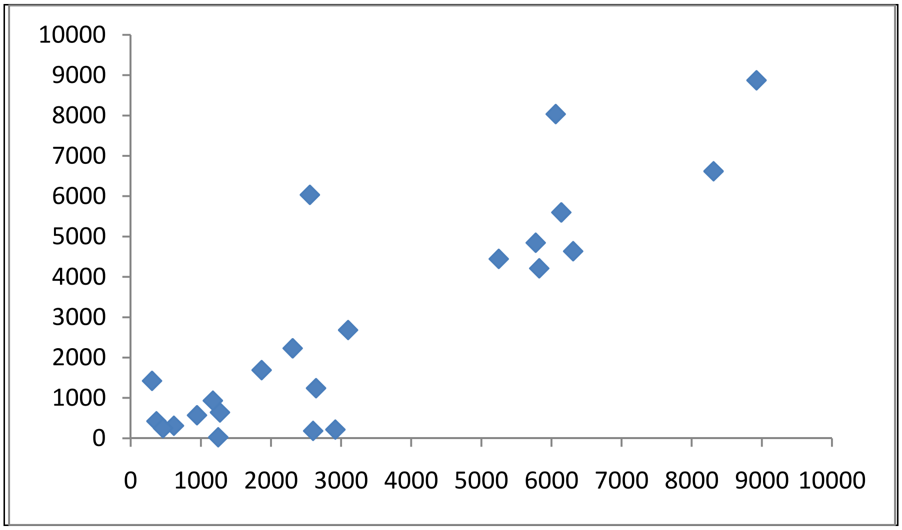


Figure 2-22 Validation of the Trucks in the Model

The validation of the model demonstrates that, with proper calibration, the aggregated freight data can be used as a sufficient transportation planning tool. While some will point to the results and conclude that the output does not provide perfectly accurate model results, the results demonstrated in this paper present a method that is preferable over the alternative, ignoring freight in the modeling process.

Finally, as a transportation planning tool, the model results justify the application of the FAF2 2035 forecast as a tool for developing future truck forecasts. These future forecasts can be used to model future scenarios and examine freight impacts.

2.3 Modal Split and Assignment – State and Local Simulations

The Alabama Transportation Infrastructure Model Version 1(ATIMv1) developed in 2005, was a discrete simulation model capable of analyzing traffic flow for roads, railroads, and waterways for each hour of a twenty-four hour day. For the roadway portion, the automobile and truck traffic are calculated independently and then combined to simulate overall traffic flow. ATIMv1 applied stochastic modeling through the incorporation of random variation, which is naturally inherent in transportation systems, as well as modeling the complex interactions of how freight moves over the transportation network and through intermodal connector points.

ATIMv1 could estimate the impact of changes in the infrastructure network or in utilization of the infrastructure network components and determine how the changes will affect the performance of the overall transportation system. Moreover, ATIMv1 effectively communicated the expected performance of the system, allowing for comparing various investment alternatives through visualization and animated presentations.

ATIMv1was developed using ProModel™, a discrete event simulation software application. While ProModel™ has many capabilities, it also has some structural limitations. These limitations do not allow the flexibility necessary to incorporate additional communication and performance features.

To overcome the limitations of the existing ProModel™ platform on which ATIMv1 operates, it was determined that the modeling platform must be transferred to a micro-simulation that uses an open-source programming language. Some alternatives that hold promise for developing these types of model include JAVA, using the Discrete Event Simulation Module, or direct coding in a stand-alone programming language, such as VisualBasic or C++. This would allow ATIMv2 to overcome many of the limitations the tools are currently experiencing including the incorporation of infrastructure alternatives, improved graphics capabilities, the ability to model incidents, queues and recovery time to fully understand the traffic flow. This research was focused on the development of Version 2 of the ATIM model in a more flexible and expandable software.

2.3.1 Implementation

The implementation environment for ATIMv2 is the Java in the Eclipse Integrated Development Environment. We chose Java for several reasons: high platform portability, well-established reputation in discrete event simulation, well-documented graphical user interface (GUI) tools, and the research team's previous experience with implementing an agent-based simulation in Java.

GUI interactions come through the Standard Widget Toolkit (SWT), which has some advantages and some disadvantages vs. other GUI packages such as Swing. SWT is based on a more operating system native interface, and is therefore generally thought to generate better performance, although Swing is perhaps more portable.

The execution speed of the model is currently quite acceptable. With thousands of vehicles on the network, one hour of simulation time passes in several seconds of clock time on a middle-of-the-line laptop. As the research moves to larger numbers of vehicles, it may be necessary to move to a more powerful machine, and consider some opportunities in coding for more efficient operation.

2.3.2 Agent-based Traffic Simulation

The simulation development team has created a highly flexible and extensible agent-based model of freight traffic on Alabama road, rail and river networks. Agent-based modeling [35] works under the premise that entities in the model are somewhat "intelligent" and have a high level of autonomy. Each agent makes its own decisions as to how it will behave according to a set of internal characteristics and external stimuli. Internal characteristics may include knowledge-base, goals and pre-dispositions; external stimuli may include environmental conditions or "observation" of particular emergent events. Traditional examples of agents are entities like enemy soldiers inside computer games, but recently agents have been used much more broadly, even as system maintenance monitors in large simulation projects. Agent-based modeling has been used very successfully for research purposes in a host of different modeled scenarios, including excitable crowd vignettes, urban mass casualty events, and terrorist attacks on airports. In the UAHuntsville OFLT case, the agent is the driver of a vehicle; each vehicle has a unique driver agent.

Behaviors of the Agents

Agents generally have a set of behaviors which they can choose from based on the various external stimuli and internal characteristics discussed above. For ATIMv2 purposes, the only behaviors of interest are described by speed and position of a vehicle, and the only current stimuli are the speed limit, and the positions and speeds of nearby vehicles. The internal characteristics are all identical in the current state model. Namely, the driver simply maintains the highest speed possible that does not violate the posted speed limit, and does not position the vehicle too close to the vehicle in front of his. This is explained in more detail later in this section.

Representation of the Modal Networks

The environment in this model is the road, rail and barge networks of Alabama. The road network includes all interstates, most federal highways, and several state routes. The rail network includes major CSX, BNSF and Norfolk Southern rail lines, in addition to local short lines. The barge network consists of four major rivers in the state. For the purpose of modeling, the networks are divided into individual links which connect intersections or points of interest, called nodes. These have much the same logical meaning as links and nodes in directed graphs used in discrete mathematics [36].

Each of the three modal networks is input at runtime to the model as an XML file. Note that because the networks are input at runtime, there is complete flexibility of the model with respect to network. If one wishes to add a new road, it is simply a matter of changing the input file. The simulation developers have developed an interactive network editor that makes this process even easier. Table 2-8 provides a typical entry for a link in the XML input file. Figure 2-23 illustrates the road networks in the model.

Table 2-8 XML representation of a link in the road network.

```
<link>
<route>AL 27</route>
<orig>31</orig>
<dest>1167</dest>
<grp>0</grp>
<dist>6.8800</dist>
<speed1>50.0</speed1>
<speed2>99999.0</speed2>
<dir>1</dir>
<cap>1000</cap>
<vol>0</vol>
<lanes>2</lanes>
<render>
<x>2420.752</x><y>1175.5735</y>
<x>2422.4565</x><y>1186.94</y>
<x>2417.342</x><y>1193.1915</y>
<x>2405.975</x><y>1200.58</y>
<x>2401.9965</x><y>1210.81</y>
<x>2403.1335</x><y>1219.335</y>
<x>2398.0185</x><y>1232.4065</y>
<x>2398.5865</x><y>1252.2985</y>
<x>2400.86</x><y>1257.9815</y>
<x>2401.428</x><y>1288.6715</y>
<x>2408.2485</x><y>1302.3115</y>
<x>2414</x><y>1310</y>
</render>
</link>
```

Route Planning

Graphs form a significant field of study in discrete mathematics, which is fortunate for this research. The problem of route-planning on a road system can be very closely related to the problem of seeking the lowest cost path through a graph. This problem has been largely solved by the A* algorithm, due to Hart, Nilsson and Raphael [37]. This algorithm is regarded as "best first" as opposed to "depth first" or "breadth first" in that in generates the optimal path on its first pass through the network, rather than first searching the network and then identifying the best path. By "best," the authors mean least cost, and leave it to the implementer to decide what cost is. For this research, time was chosen as the "cost." The best path is the one that takes the least time.

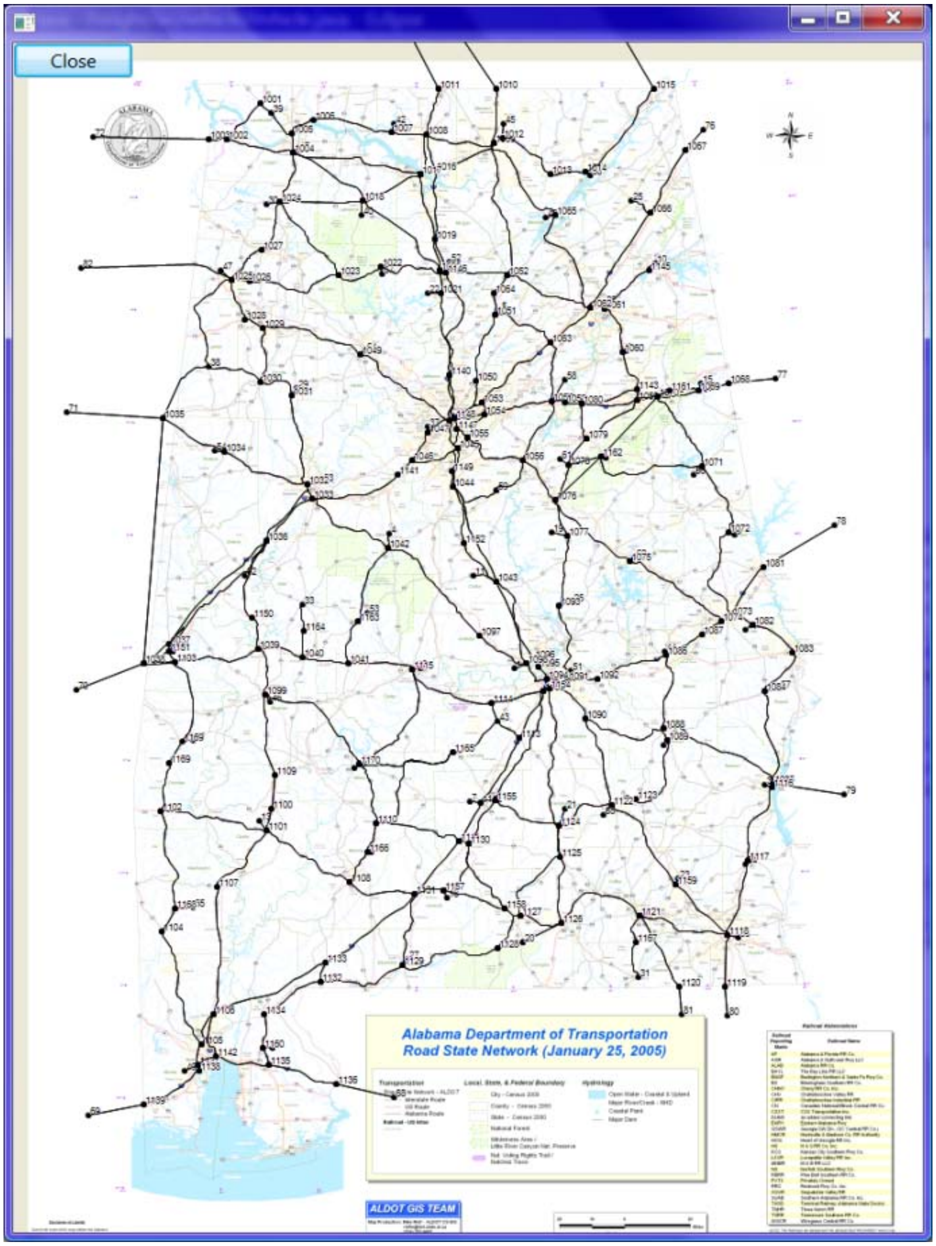


Figure 2-23 The Roadway Network

Each vehicle (driver) possesses its own route, and is free to change its route as conditions arise. However, the model does not currently allow any of the agents with sufficient knowledge of conditions to change their routes during the trip. Savvy commuters or truckers on CB radios would likely have such capability, and so the code is written to allow for route changes as an important future capability.

The performance of the system has been greatly enhanced by creating a route manager that stores routes between particular origins and destinations for future use. When a vehicle requests a route from the route manager, the manager first checks to see if such a route has already been created, and if so, simply returns that route without having to carry out the time consuming A* process.

Network Traffic Loading

Aside from the network itself, the principal inheritance by the ATIMv2 Agent-based model from previous ATIM work is the traffic loads placed on the network. These outputs are converted into an XML file for input to the Java code using a simple Perl script (an example is shown in Table). Typically, we have a total traffic count over a 24-hour period for a given origin node and destination node. The loading package reads in all the loads, and initiates the statistical sequence which will create each vehicle at the appropriate time according to the load rates.

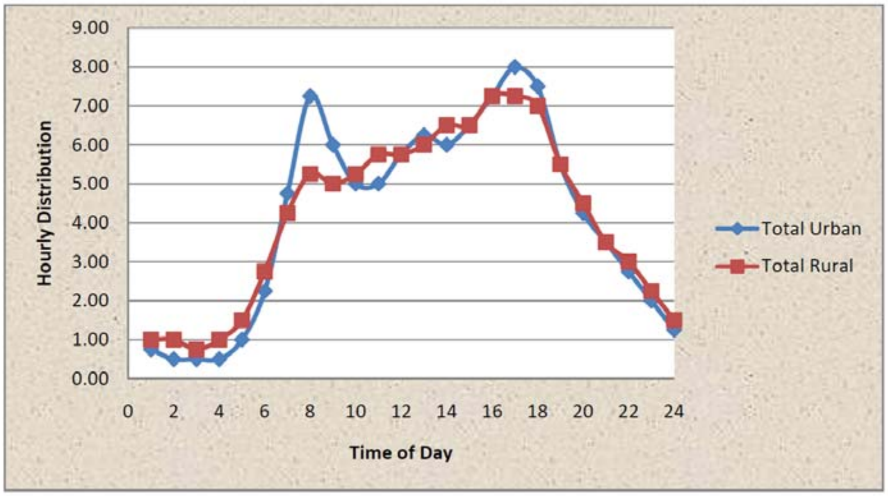
The load given in Table 2-9 shows a distribution (XML tag `<dist>`) called "cardist." This distribution refers to the rate, as a function of time of day, at which cars will be produced by the loader. Choices for currently implemented loaders are "uniform" which simply loads at a uniform rate, "half-day split," which loads at a higher rate for some 12-hour period and a lower rate for the other 12-hour period, and "car distribution," "cardist" for short. The car distribution is a mathematical distribution, seen in black in Figure 4 bottom, based upon the 2008 report [38]. The mathematic representation is two Gaussian (normal curve) functions centered around 8 AM and 4:45 PM, added to a base rate. Between the two Gaussian peaks is a simple slope that attaches the two curves below peak (green). However, to create a smooth transition from the Gaussian curves to the sloped portion, cubic transition functions that ensure continuity through the first derivative (continuous in value and slope) were computed and used in the transition regions. The mathematical function is intended to be something of a compromise between the urban and rural distributions seen in Figure 4 top.

Table 2-9 Example of XML encoding of network loading

```
<load>
<name>.</name>
<vclass>freight</vclass>
<vsubclass></vsubclass>
<nodeA>1</nodeA>
<nodeB>3</nodeB>
<dist>cardist</dist>
<number>4</number>
<gentype>uniform</gentype>
</load>
```

Rail and barge traffic is loaded according to the half-day split model such that traffic between 8AM and 8PM is twice as heavy as that between 8PM and 8AM. We base this purely upon informal conversations with various rail managers around the state. More detailed exploration of these loading distributions will be an important component of the future work on the model.

Finally, the loader must generate times at the appropriate rate, given by the distributions discussed above. This is achieved by integrating the rate function from the current time, *t*, forward by some Δt until the integral hits the desired value, *q*.



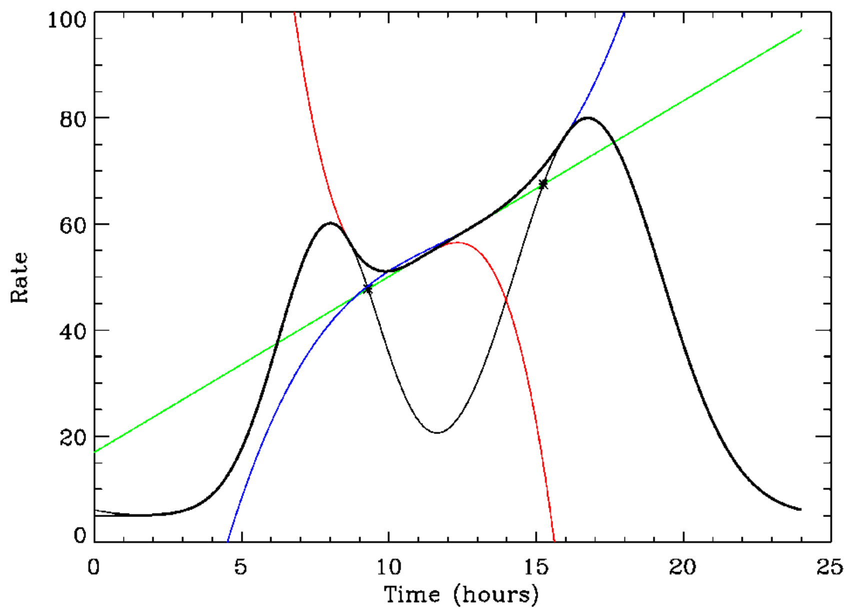


Figure 2-24 Traffic flow rates of roadway vehicles, observed (top), and modeled (bottom, heavy black)

The next vehicle is produced at time $t + \Delta t$. In the case of a uniform generator, q is always 1. In the case of a random generator, q is exponentially distributed between zero and infinity, but with a mean of one. In practice, the uniform and half-day split functions are integrated analytically, while the "cardist" distribution's integral is computed off-line and tabulated over 241 values running from 0 to 24 hours (inclusive); then simple linear interpolation is used to find the correct Δt for the given q value.

2.3.3. Event-Driven Execution

Discrete event simulation generally runs in either of two modes: time-stepped or event-driven. In time-stepped mode, all the entities in the simulation are updated at fixed time-steps. In event-driven mode, the entities are only updated when their states change. The former has the advantage in that it is significantly simpler to code; the latter has a few significant advantages: 1) Greater precision—actions occur at "exactly" (to machine precision) the correct time, not at a fixed time-step, 2) Better performance—since actions only occur exactly when necessary, all of the repetitive updating of all entities at each time-step is largely avoided. The penalty for these advantages is substantially more difficult coding, and, in our case, multi-threaded architecture. It was decided that the benefits were ultimately worth the coding difficulties. Some of the details of the event-based system are discussed below.

State
Each vehicle has a "state" which is necessarily a complete representation of all information about the vehicle relevant to the simulation. In our case, state is simply {link, lane, position, speed, and epoch}. These five variables provide a complete description of the car's situation on the network. The first four are sufficiently descriptive that no further explanation is probably necessary, but the fifth (epoch) must be present to define when the position of the car was defined. Other vehicles will determine this vehicle's position at a particular time, t, according to $x(t) = x_0 + v(t - t_0)$, where x_0 is the position in the state, v is the speed in the state, and t_0 is the epoch.

Because the state is a complete description of the vehicle's situation, any change to the situation is a change to the state. This is somewhat reminiscent of the "finite state machine" [39]. However, the states here are not finite since the position, speed and epoch variables are all continuous values.

Events
In an event-driven discrete event simulation, all action is dictated by events. Generally events reside in an event queue, which is a time-sorted list of all the events. The simulation runs by pulling the first event off the queue, and executing according to that event's parameters, spawning any necessary new events, adding those to the queue, then removing the original event from the queue. While there is a good deal of research

into how exactly such event queues should be stored and accessed, we have used a simple sorted list type arrangement which sorts by time on the way in, using a normal binary search algorithm. This allows addition, access, and removal to and from the queue to occur in $O(\log N)$ time.

The set of event types must be sufficient to encompass all types of actions, interactions and reactions used to evolve the system. Table gives a list of the event types in the simulation. The function of each of these events is described in the following sections.

Initiation events

The vehicle is initiated into the simulation by a VehicleCreate event. VehicleCreate events are spawned by the traffic loader described in the previous section. At the outset of the entire run, the loader is called for each traffic load to get the first VehicleCreate event associated with each load. After the vehicle is created, the loader is called upon to create the next VehicleCreate event associated with the load and the current event is removed from the queue. The route manager is then asked to create a route for this vehicle based on the origin and destination nodes set forth in the load.

Table 2-10 Vehicle event types

Initiation	Navigation	Interactions
VehicleCreate	EnterFirstLink LinkChange RouteComplete	StateChange CheckCarAhead

Navigation events

The vehicle, once created, must enter the network successfully. Namely, it must enter the first link of its route. As soon as a vehicle is successfully created from VehicleCreate event, the main execution thread generates an EnterFirstLink event at the same model time as the VehicleCreate event. The reason these two are separated is that the vehicle might not successfully enter the first link, in which case it will have to wait and try again later.

When an EnterFirstLink event is encountered in the model, the model commands the vehicle to try to enter the first link. The vehicle then checks to see if there is room on the first link and which lane is most desirable for entry (this is explained in more detail in the Interaction Events section just below). If there simply is not room available, an exception is thrown with information on when, barring other changes, the model should try again.

Upon successful link entry, the vehicle issues a LinkChange event for itself at a time when it will finish transiting the current link. When the LinkChange event appears at the front of the queue, the vehicle will attempt to enter the next link in its route, according to the same basic rules used to enter the first link. At this point, the next LinkChange event is created. These LinkChange events move the car through the network until the end of the route is encountered. In that case, a RouteComplete event rather than a LinkChange event is created. When the RouteComplete event is at the front of the event queue, the model removes the vehicle from the simulation run.

Interaction events
If there were no other vehicles in the network, the navigation events would be sufficient to carry out all of the movements in the model. However, there are other vehicles and that fact is central to our modeling effort. Therefore, interaction events are introduced which accommodate multiple vehicles.

First, there is the StateChange event. This event allows a car to recognize that it must change state at some future time. Generally, this would be either speeding up or slowing down, based on the situation. A typical example would be slowing down until there is enough space between one vehicle and the vehicle ahead then resuming normal speed. StateChange events are generated during assignment of state to be described shortly.

Whenever a vehicle's state changes, it must notify the vehicles behind it. It does so by notifying the link it is on of its' state change. The link then notifies the appropriate vehicles of the change via a CheckCarAhead event.

Situation Evaluation and State Assignment
The decisions made by the vehicles (drivers) are modeled by the situation evaluation and state assignment components of the model. Remember that, given a lane, the state of each vehicle in the lane is simply position and speed. That means for the driver to evaluate his situation, he need only consider the position and speed of the vehicles directly ahead or behind in nearby lanes. This purview is limited to adjacent lanes only, meaning a vehicle may only change one lane at a time (currently the network only has a maximum of two lanes in each direction).

Two parameters of the model, minimum time gap, and minimum space gap, are introduced. The space gap is the current distance between two vehicles. The time gap is the time it would take for the rear vehicle to reach the current position of the forward vehicle at its current speed. The minimum of each of these values are parameters set forth in XML input files according to vehicle type (car, truck, train, or barge).

The next question is how to evaluate each lane in order for the driver to decide which lane is the best to use. First, the driver must determine if there is space to enter each of the two adjacent lanes based on the cars behind him—namely are the time and space gaps larger than their minimum parameter values? If there is sufficient space to move safely into a particular lane, the time gap to the vehicle ahead in that lane is computed.

If there is no car ahead in that lane, a very large time gap is reported. The safe lane with the greatest time gap to the car ahead is selected as the lane of choice.

The driver also slightly prefers to remain in the same lane, in that, if the time gap and space gap are greater than a “maximum” time and space gap, and the vehicle ahead is moving at a speed at least as great as his desired speed, he chooses to stay in the same lane. The maximum values are set at five times the minimum values.

Once the best lane has been decided upon, the new state must be assigned. The new state is based upon the state of the vehicle ahead. Consider the following cases:

1. No vehicle ahead:
   - set speed to desired speed (usually the speed limit on the link)
2. Time gap > min time gap; space gap > min space gap; speed ahead = desired speed:
   - set speed to desired speed
3. Time gap > min time gap; space gap > min space gap; speed ahead < desired speed:
   - adjust speed to average of desired speed and speed of vehicle ahead; create a ChangeStateEvent to adjust speed to speed of vehicle ahead when gaps are exactly met at the speed of the vehicle ahead
4. Time gap < min time gap:
   - adjust speed to half of vehicle ahead’s speed; create a ChangeStateEvent to adjust to speed of vehicle ahead when gaps are exactly met at that speed
5. Space gap < min space gap
   - error is reported; program terminates

Note the high importance on the vehicle ahead and behind of the current car. Because the number of vehicles can be fairly high on a given link, we chose to use a sorted queue to store the vehicles in each lane (sort by position). This means that finding the vehicle ahead of the current vehicle is simply a matter of looking one ahead or behind in the sorted list. As it turns out, maintaining all these sorted queues for each lane (and the very large sorted queue for the vehicle events) was one of the main difficulties in the coding process. The flip side was that the relative pickiness of such queues has served as a quite sensitive debugging tool.

The fairly basic logic for vehicle behaviors described above produces most of the desired functionality. There is room for particular improvements or at least considerations, such as allowing for acceleration as part of the state. This may generate somewhat more realistic driver behaviors at the micro scale, though their effect at the macro scale are not obviously substantial.

2.3.4 Multi-Threaded Model-Viewer-Controller Architecture

The migration in FY09 to an event-based architecture required one other major architecture modification to achieve functionality. In a time-stepped simulation, all vehicles are updated at each time-step. Therefore, the display system can simply render the state of the vehicles at the end of each time-step in perfect synchrony with the model as it steps through time. However, with an event-based system, the model does not update the state of each vehicle at regular time-steps, but it is still desirable to display the state of the vehicles are regular time-steps lest there results a very confusing display. In short, it is required for the model to display at even time-steps even though that is not the way the model runs. The model-viewer-controller (MVC) architecture [40] addresses precisely this problem.

In the MVC paradigm, the viewer and controller run basically together providing outputs to the user and allowing various inputs from the user to be gathered by the controller. The model runs nearly independently from the other two interrupted only occasionally for update requests or run specification changes introduced by the controller. Today's multi-threaded architectures greatly facilitate this coding under this paradigm since the model can simply be given its own thread.

In the case of ATIMv2, the main execution thread executes the control and viewer while the model is run simultaneously in its own independent thread. This is particularly important when using an interactive graphical user interface (GUI) because the GUI has various "listeners" that do nothing but listen for mouse-clicks or keyboard interactions. These listeners can greatly compromise performance if run in the same thread as the model.

While moving the model to a different thread makes sense both from the logical standpoint and the performance standpoint, a new problem arose. The viewer may (and in fact will usually) try to display the vehicles in the midst of an ongoing event process, while some vehicles are being modified. Because the model is running in a completely different thread with its own execution timing, there is no possible way of guaranteeing synchrony between model entities and the display of those entities across threads. The answer is to create, when requested by the controller, a "deep" display copy of all vehicles at the end of the event process call. This copy of all the vehicles is passed back to the viewer through the controller. Because the copy was made by the model, logical synchrony is guaranteed. A "deep" copy means that entirely new versions of all vehicles are created, with careful attention to creating new instances of all class variables, rather than merely copying the references. This is a key point since the variables at those references are being updated by the event processor as it continues to run after making the copies. Only by generating these deep copies can synchrony be guaranteed.

The only other question is when to make these copies. Here the viewer requests a copy from the controller when it is time to refresh the display. The controller sets a flag that the model checks at the end of an event process. If the flag is set, it makes a deep copy and returns it to the controller and unsets the flag. The viewer then displays that copy and waits for the next time at which a view is desired and then resets the flag. It has been determined that it is necessary to build in a delay (of order a millisecond) during the copy process just to ensure that the threads do not out-race each other during the actual copy.

2.3.5 User Interface and Interactive Tools

Over the course of the model development during FY09, it was recognized that there is a need for several interactive tools to augment the model itself for some improvements in look and feel.

Look and Feel Improvements

During FY09, the model has been demonstrated to several possible research partners, transition partners and future funding sources, including the Mississippi Department of Transportation, the University of South Alabama, and the Mayor of Huntsville, Alabama. One recurring feedback theme was the desire for a “zoom” feature which would allow users to see a particular area of the map up close as the model ran. This feature has now been included in not only the main run window (Figure 2-25), but also other windows, such as the route interface, and network editor.

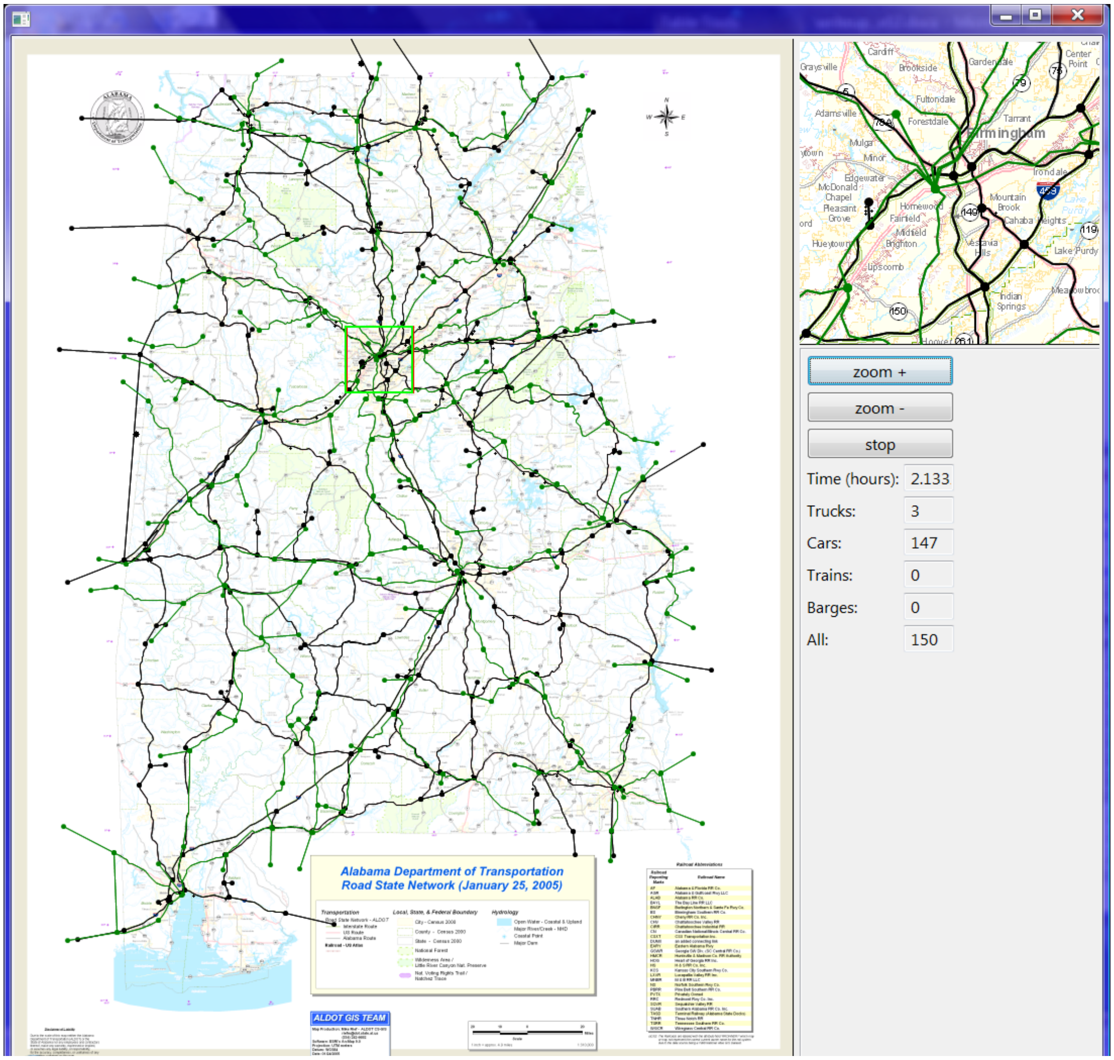


Figure 2-25 Zoom feature (at upper right)

Network Editor

The first network developed was the highway network, which was imported from previous ATIM work. However for purposes of display, the ATIMv2 required more detailed GIS information on the physical paths of roads than previously existed. For purposes of a rapid prototype, IDL (Interactive Data Language) was used with much hand-tuning to input the GIS data. When it came time to develop the rail network, it was quickly recognized that an integrated graphical network editor was a necessary component of our model. Therefore, the team developed a highly interactive point-and-click driven tool to create and modify the transportation networks (**Error! Reference source not found.**).

2.3.6 Development of the Rail Network

In building the railroad network in the ATIMv2 the initial thought was the rail network would be like the highway network. The rail network was created using the railroad maps and information from the Alabama Rail Plan and Alabama Rail Directory. There are currently twenty shortline railroads in Alabama with approximately 1077 miles of track. Alabama also has one regional railroad with approximately 344 miles of track serving southwest Alabama. The four class I railroads servicing Alabama have approximately 2670 miles of track. (AAR) All shortline, regional, and class I railroads in Alabama are included in the ATIMv2 rail network.

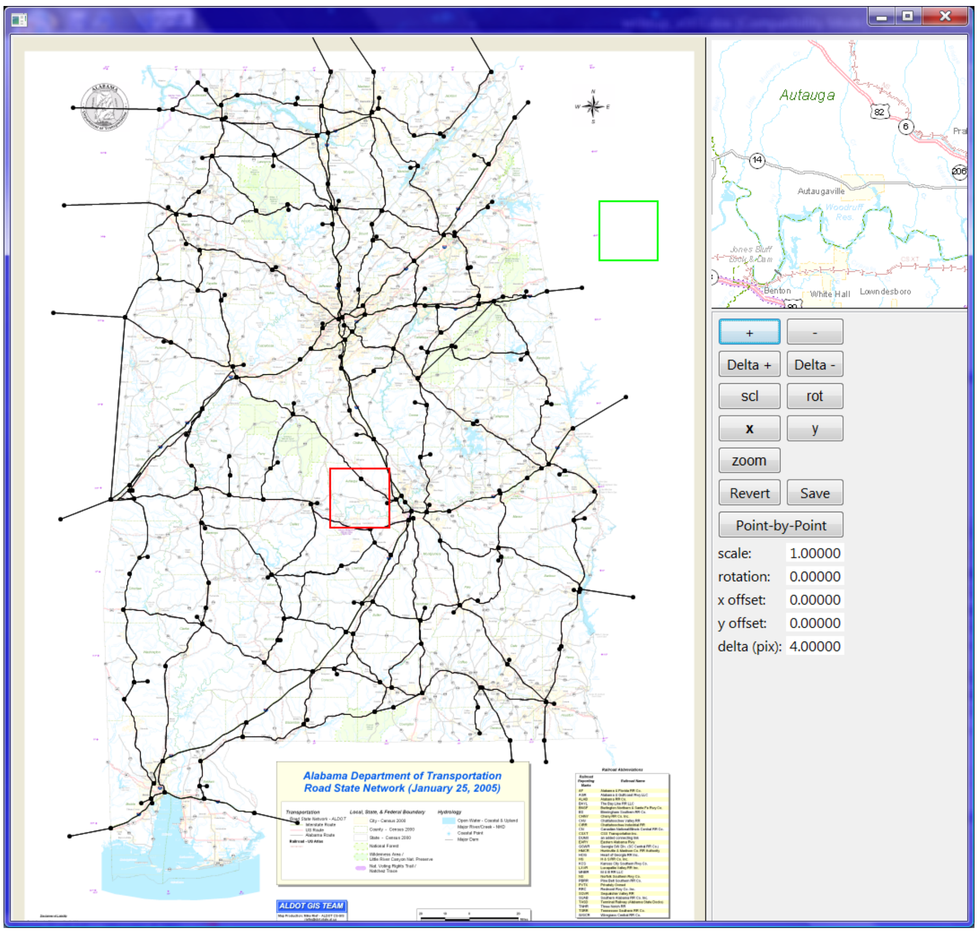


Figure 2-26 Network Editor: Gross Geometry Interface

The rail network (Figure 2-27) was created similar to the highway network using county center links to the mainline links representing shortline, regional, or class I railroads. These county center links serve as the origin/destination points for freight allocation. Every county in Alabama, with the exception of Bullock County, has access to a shortline or class I and therefore has a county center link. Some counties have more than one county center link if there is more than one railroad present in the county. This is significant if railroads are present on either side of the county.

After developing the rail network in ATIMv2, several issues arose that led our research team to realize that rail traffic is unlike highway traffic and therefore cannot be modeled in the same way. First, rail traffic is restricted by ownership of the rail lines. A railroad company may only travel on their own line and deliver freight from origins to destinations where their line is present unless they have trackage rights on another Railroad's line. Second, rail traffic is planned ahead. Individual train engineers do not behave like drivers on highways in terms of planning their routes or changing them as necessary. While drivers can choose another route to avoid a stop in highway traffic, railroads are confined to a single lane of track and must wait if a train is stopped ahead of them on the line, except in an area where the rail line has double track.

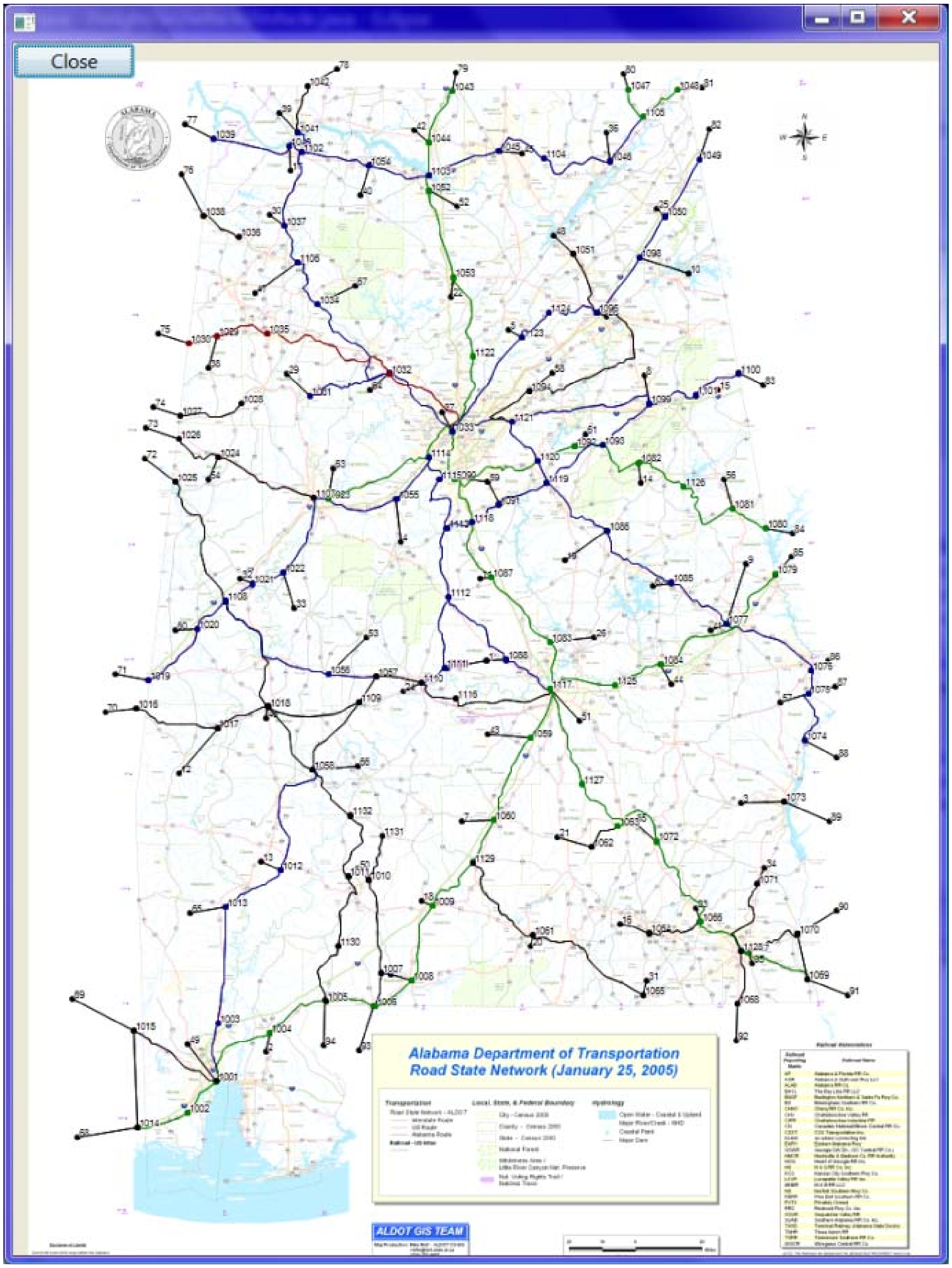


Figure 2-27 Alabama Rail Network

The rail network in ATIMv2 is populated using freight volumes from the FAF2 database and the 2008 Alabama Rail Plan [41]. The FAF2 database provides the amount of tonnage moved by rail that originates and terminates in Alabama. Data is provided in annual kilotons by commodity and includes the origin zone and the destination zone. All freight originating and terminating in Zone 1 and 2 is represented in the model. Assumptions were made for which rail line a freight shipment would enter or leave the state based on its location relative to Alabama and the railroads present in the origin or destination zones. For example, freight originating in Nashville, Tennessee, or Zone 95 would most likely enter Alabama, in either Zone 1 or Zone 2, by the CSX line running south because there are no other railroads with this direct connection to the state.

Once the freight volumes were determined for each link between zones, the number of trains per week on each line was determined by dividing the annual tons by 85 resulting in the number of 85 ton carloads per year. This number was then divided by 52 weeks per year to achieve the number of carloads per week on each rail line. Finally, most trains have 100 railcars with a percentage of railcars being empty. Given this information, it is assumed trains typically run at 80% capacity, or 80 full railcars. The number of carloads was divided by 80 to determine the number of weekly trains running with an assumed 80 full railcars.
Example calculations:

20,000,000 annual tons ÷ 85 ton carloads = 235,294.11 carloads per year

235,294.11 carloads per year ÷ 52 weeks per year = 4,524.88 carloads per week

4,524 carloads per week ÷ 80 rail cars per train = 56.56 trains per week

The 2008 Alabama Rail Plan was used to determine the amount of pass through freight which neither originates nor terminates in Alabama but uses the rail lines within the state to reach its final destination. The rail plan provided the number of tons which passed through with known origination and destination pairs (O/D). Table 2-11 presents the pairs. As with the FAF2 data, assumptions were made about which rail line in Alabama would most efficiently connect the O/D pairs. Once this was determined the number of trains per week for each line was calculated using the same method detailed above.

Table 2-11 Principal Overhead Traffic Flows through Alabama, 2006 (all commodities)

	Flow Origin	Flow Destination
1	LA, TX	FL, GA, SC, NC, VA
2	OH, IN, MI, IL, WI, MO, IA, MN	LA, TX, MS, TN, GA, FL
3	KY, TN	GA, FL
4	CA, OR, WA	FL, GA, SC, NC, VA

2.3.7 FY 09 Development Accomplished

Portions of the work described above were carried out prior to FY09. These include the route planning algorithm, and a very basic version of the graphical display. Additionally, networks and O/D pair information from ATIMv1 were incorporated.

Items developed in FY09 include:

- Event-driven execution, including vehicle and vehicle event queues
- Model Viewer Controller architecture
- Multi-lane roadways
- Rail network
- Barge network
- Advanced mathematical traffic loading representations
- Advanced user interface features
- Network editor

2.4 Analysis – System Performance Measures

The final component of the IFPF is the development of capability to measure the performance of the transportation system. The IFPF is proposed as a tool to use for continuously improving the transportation system's ability to efficiently, effectively, and safely move people and freight. Improvement cannot take place if a measurement system is not in place to quantify the performance.

Performance data has been collected for many years on the highway systems across the U.S. for multiple purposes. The data collected is point specific in nature and does not provide the managers and planners of the transportation systems with a measurement of how the system as a whole is performing. Metrics that accurately portray the performance of the system as a whole are a missing tool needed for transportation system planners and managers to optimize the performance of the entire system.

An optimal set of metrics for use in evaluating the performance of multimodal transportation systems is needed to direct the application of resources to address problems in the transportation system in a manner that best serves the users. The multimodal transportation system includes the roadway network used by passenger cars, mass transit systems, freight vehicles, the railway network used for passenger and freight movement, and the navigable inland waterways.

Access to an efficient transportation system is a key element to the promotion of economic growth and development within a region. It is essential that the performance measures used by Alabama be chosen with that goal in mind. It is also important to choose metrics appropriate to the needs of the intended audience: the state government, the state legislature, DOT management and staff, other agencies, elected officials, and the public at large. An optimal set of performance metrics will provide the ability to determine the impact of improvements to the transportation system performance over time, and compare the results to short-term and long-term goals and objectives. This component of the research focuses on the development and evaluation of transportation system performance measures at the state and MPO level.

The next sections summarize and expands upon the research in the 2008 UAHuntsville report "Establishing Performance Measures for Alabama's Transportation System" funded by the Alabama Department of Transportation Research Project 930-698 [38].

2.4.1 Establishing Performance Measures for Alabama's Transportation System

This research set out to answer the following questions:

- How can we improve the performance of Alabama's transportation system to enhance service to individuals and businesses in the state?
- What is the return on investment to Alabama from improvements to the transportation system?
- Are investments in the transportation system being made as effectively and efficiently as possible?

The approach was to determine if there is an optimum set of performance measures that would provide the answers. It is believed that along with answering these questions, performance metrics would provide any transportation department with the capability to track system performance over time in relation to short-term and long-term goals and objectives.

At the November 2000 conference, "*Performance Measures to Improve Transportation Systems and Agency Operations*," Pickrell and Neumann listed six fundamental reasons for adopting performance measures [42]:

- Accountability
- Efficiency
- Effectiveness
- Communications
- Clarity
- Improvement

Improvement is simply not feasible without a measurement system in place. Performance measurement is, in general, successful when meaningful measures are selected, the proper data needed for the measurement is obtained, and the measurement is incorporated into an overall planning process that guides decision making based on the measurements.

The result of this research was a suggested set of performance measures that a transportation department can begin to use to quantify the performance of the transportation system:

- Safety
- Need vs. Wants
- Economic Development

- System Preservation
- Percent of System Congested
- Travel Cost
- Vehicle Occupancy
- Traffic count
  - Vehicles
- Passengers
  - Freight
- VMT
- Travel Time
- Speed
- Density
- Recurring Delay
- Duration of
- Congestion
- Travel Time
- Reliability
- Number of incidents
  - Weather-related traffic incidents
  - Rail grade crossings
- Duration of delay caused by incidents
- Response time to incidents
- Commercial vehicle safety violations
- Security for highway and transit
- Weather-related route closures
- Evacuation times
- Toll
  - revenue
  - delay from toll collection
  - delay from incidents
- Operating budgets
- Maintenance funds
- Construction costs
- Schedule Compliance
- Budget Compliance
- Compliance w/ FHWA Regulations & SAFETEA-LU
- Annual Reports to FHWA, legislature
- Effectiveness of Project Based on Reduction of Crashes, Fatalities
- Public Opinion/Approval

In the execution of this research, current transportation system metrics were researched for the purpose of developing a set a performance measures appropriate for establishing the current level of performance for Alabama's multimodal transportation system and the effectiveness and efficiency by which it is able to supply reasonable user access to jobs, goods, and services (both public and commercial).

2.4.2 Performance Measure Review

Performance measures have been applied to state transportation systems since the 1950s, but they became more widely used after the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991 and finally became required by the Government Performance and Results Act (GPRA) of 1993. However, as stated by Pratt and Lomax in their article "Performance Measures for Multimodal Transportation Systems" [43]:

> "Change is coming … performance measures are being put to broader uses. The goals and objectives with which they are being paired have been augmented or changed. A measure designed to gauge the achievement of vehicular flow is not necessarily going to be a good measure for assessing the satisfaction of reasonable access to jobs, goods, and services with the least social cost."

Legislation in the early 1990s led to the development and execution of performance measures and performance-based management that have been at the core of national and state transportation policy. Performance measures and management strategies have long been utilized by the private sector [44] and are being incorporated within the public sector to provide a means to assess the success or failure of projects and initiatives [45]. Performance measures are important because they allow the stakeholders in the transportation system to get more value from the dollars spent, taking special significance when considering the diverse nature of potential transportation stakeholders that have interest in the system performing well (commuters, state and local governments, trucking companies and associated customers, emergency response personnel, law enforcement, and environmental groups to name a few) [46].

As public transportation agencies have moved forward with performance measures, the primary focus has been on passenger car-related performance but recently other areas, such as freight movement, have become more important [53]. Performance measures allow for agencies to manage to plans that have been selected due to their ability to achieve high-level performance in areas that the users/owners of the transportation system have deemed important [46].

In order to effectively determine which performance measures were appropriate for Alabama's transportation infrastructure, it was necessary to examine the existing research and literature on performance measures. Several other state DOTs have well-established performance measurement systems from which best practices can be learned. NCHRP has also sponsored several research projects to determine how performance measurement can and should be applied to the roadway system.

2.4.3 NCHRP Documents Address Transportation Performance Measures

In researching performance measures, the team consulted *NCHRP Report 446: A Guidebook for Performance-Based Transportation Planning* and *NCHRP Synthesis 311: Performance Measures of Operational Effectiveness for Highway Segments and Systems*. These comprehensive documents provide a wealth of information regarding the development of performance-based measurement programs and provide needed insight into the state of the practice and recommendations for the future. Though some overlap exists between these documents, *NCHRP Report 446* provides broad guidelines for instituting performance measures into existing planning programs while *NCHRP Synthesis 311* provides more tangible detail regarding the selection and usefulness of specific measures for highway applications.

NCHRP Report 446 describes an eight-step development procedure for setting up a process to incorporate performance measures into system planning:

Step 1: Getting Started
Step 2: Select Application
Step 3: Develop a Working Group
Step 4: Develop Goals and Objectives
Step 5: Develop Performance Measures
Step 6: Identify Data Needs
Step 7: Identify Analytical Tools
Step 8: Report Results

NCHRP Report 446 also lists and describes the procedures needed to acquire performance data. Various types of survey methods (e.g., workplace, transit on-board, truck, and parking) are detailed as well as traffic data collection procedures, customer satisfaction polling, and national databases compiled by the Federal Highway Administration, such as the Highway Performance Monitoring System (HPMS).

Table 2-12 (replicated from NCHRP Report 446) details the public sector needs for performance-based planning. Among the freight data needs that are currently deficient among many State DOTs and MPOs are the number of trucks and type of commodity delayed by traffic congestion, time of day information regarding truck traffic within intermodal facilities, accident data regarding type of trucks and associated industry costs, and the value of freight flowing into and out of metropolitan areas.

Table 2-12 Public-Sector Freight Data Needs for Performance-based Planning

Function	Data Needs	Support for Performance-Based Planning
Congestion Management	Truck-hours of travel	Understand impact of congestion on goods movement
	Average truck speed	
	Added truck-hours due to congestion	
	Truck transport cost	
	Added cost due to congestion	Understand contribution of trucks to urban congestion and air quality problems
	Transport time reliability	
	Types of trucks and commodities caught in congestion	
	Energy consumption for trucks	
	Emissions rates for trucks	
Intermodal Access	Volumes of truck entering or exiting an intermodal facility	Identify land-side access improvement needs
	Variability in demand for, and supply of access to, intermodal facilities	
	Congestion-related delays on access road to the facility	
	Queuing counts related to the capacity of the facility	
	Accident rates on access roads	
	Travel time contours around the facility	
	Number of people living or working within *x* miles of facility	
Truck route designation and maintenance	Truck traffic volumes	Identify high-volume truck routes and corridors
	Origin-destination patterns	Assess pavement damage and replacement needs
	Truck size and weight data	
Safety mitigation	Accident rates	Identify safety hazards and develop mitigation strategies
	Rail-grade crossings	
	Low-clearance bridges	
	Steep grades	
Economic development	Truck volumes	Assess economic benefits and costs of freight transportation investment projects
	Commodity movements	
	Origin-destination patterns	
	Shipping costs	

NCHRP Synthesis 311 was published in 2003 and seeks to summarize the current knowledge and practice of the use of performance measures for the monitoring and operational management of highways. The document has a narrower scope than *NCHRP Report 446* with most of the content focusing on the key factors for selecting performance measures and which measures have been successfully implemented in practice. *NCHRP Synthesis 311* presents a literature review of the seminal works on highway performance measures, summarizes the results of a nationwide survey, and lists highlights of federal, state, and local agency practices.

The literature review from *NCHRP Synthesis 311* contains many valuable insights about the selection of performance measures. In separate studies, Pratt and Lomax (1996) and Turner et al (1996) recommended similar key principles and guidelines for instituting performance measures, including matching performance measures with objectives, using common denominators to facilitate comparisons between multimodal systems, remembering the intended audience, and emphasizing the importance of quantification over subjective judgment.

Additionally, Lomax et al (1997) in *NCHRP 398: Quantifying Urban Congestion* developed specific performance measures to gauge congestion that include:

- Travel rate in minutes per mile
- Delay rate in minutes per mile
- Total delay in person-hours
- Corridor mobility index (speed of person movement divided by a normalizing value)
- Accessibility, percent of destinations within *x* minutes
- Congested travel in person-miles, sum of congested lengths multiplied by number of persons

Additionally, the literature review indicated that more recent research on highway performance has emphasized a reliance on reliability measurement – namely, the accepted variability between expected travel time and the actual travel time that users of the system experience on a daily basis. Survey data and other research indicate that travel time reliability consistently ranks as one of the most important expectations from system users.

NCHRP Synthesis 311 outlines several research efforts to quantify travel time reliability, including the *Florida Reliability Manual* (2000) and the Texas Transportation Institute's *Urban Mobility Report*. The *Florida Reliability Manual* proposes to classify travel reliability by considering the median travel time across a corridor during a specific period of interest plus an additional amount of time estimated as a percent of the median travel time (such as 15%) that a traveler would find acceptable. Preference surveys are recommended to determine the acceptable additional time depending on the route and community.

Additionally, the *Urban Mobility Report* uses a reliability "buffer index" that is defined as the difference in the average travel rate and the 95th percentile travel rate divided by the average travel rate times 100%. This index is meant to illustrate the extra time that a traveler must budget when traveling during peak periods of the day. In any case, reliability measures are a very important component to any highway performance measurement system.

As mentioned, *NCHRP Synthesis 311* conducted a survey of state transportation agencies and MPOs to determine the state of the practice. The survey covered many aspects of performance measurement, including the agencies' history regarding performance measures, their intended audience, the data collection procedures, how the information is reported, and what measures are used for highway operations.

Among the most notable findings --- the most important type of performance measures collected were those that described *quantity* and *quality* of service. Quantity measures of volume, vehicle-miles traveled, and truck-miles traveled were important to agencies with stated goals of maximizing the movement of people/goods that can use the system. In addition, these basic measures allow for the derivation of important environmental measures such as fuel consumption and noise and air quality impacts. Measures that describe the quality of travel were also identified by agencies as having a high importance. These measures include highway volume to capacity ratios, delay, speed, travel time, and highway segment level of service. Additionally, several agencies reported measures that relate more to agency output than system-related outcomes. These output measures include performance-based budgeting, percent of railroads with active crossing protection, and the number of signals retimed per year. These measures are less important to the users of the system, but can be very important to agencies in prioritizing goals and allocating funding.

In addition to the survey, *NCHRP Synthesis 311* includes information about specific performance measurement programs instituted by the Federal Highway Administration and several states and cities. For example, the California DOT has a well-established system that seeks to establish performance measures that are outcome-based, multimodal, easy to understand, reliant on existing data, and are able to both monitor and forecast. Table 2-13 depicts the performance measures used by the California DOT.

Table 2-13 California DOT's Performance Measures/Indicators

Desired Outcome	Definition	Candidate Measure/Indicator
Mobility/accessibility	Reaching a desired destination with relative ease within a reasonable time, at a reasonable cost with reasonable choices	Travel time
		Delay
		Access to desired location
		Access to system
Reliability	Providing reasonable and dependable LOS by mode	Variability of travel time
Cost-effectiveness	Maximizing the current and future benefits from public and private transportation investments	Benefit/cost ratio

Sustainability	Preserving the transportation system while meeting the needs of the present without compromising the ability of future generations to meet their own needs	Outcome benefit per unit cost
Environmental quality	Helping to maintain and enhance the quality of the natural, physical, and human environment	Household transportation costs
Safety and security	Minimizing the risk of death, injury, or property loss	Accident and crime rates
Equity	Distributing benefits and burdens fairly	Benefits per income group
Customer satisfaction	Providing transportation choices that are safe, convenient, affordable, comfortable, and meet customers' needs	Customer survey
Economic well-being	Contributing to California's economic growth	Final demand (value of transportation to the economy)

Other states of interest that were profiled in the report include Florida and Minnesota. Florida has developed very detailed standards for measuring mobility built around assessing the quantity of travel, quality of travel, accessibility, and system utilization. Minnesota's performance measurement was unique to the research in that it specified freight and intermodal performance among its many measures. The freight performance measures identified include shipper point-to-point travel time, travel time to major regional, national, and global markets (by air, rail, water and truck), shipment cost per mile, and crash rate per mile traveled by freight mode.

Finally, *NCHRP Synthesis 311* provides a summary table (Table 2-14) that adapts evaluation criteria from various studies to assess the strengths and weaknesses of highway performance measures. The study then used these evaluation criteria to assess the relative value of the nearly 70 performance measures considered in this research. The assessment indicated that the following measures received favorable scores according to the criteria:

- Quantity of travel (user perspective): person-miles traveled, truck-miles traveled, vehicle-miles traveled, persons moved, trucks moved, vehicles moved.
- Quality of travel (user perspective): average speed weighted by person-miles traveled, average door-to-door travel time, travel time predictability, travel time reliability, average delay, and level of service.
- Utilization of the system (agency perspective): percent of system heavily congested, density, percentage of travel heavily congested, volume to capacity ratio, queuing, percent of miles operating in desired speed range, vehicle occupancy, duration of congestion.
- Safety: incident rate by severity or type.
- Incidents: incident induced delay and evacuation clearance time.

- Outputs (agency performance): incident response time by type, toll revenue, bridge condition, pavement condition, percent of ITS equipment operational.

Table 2-14 NCHRP Synthesis 311 Evaluation Criteria

NCHRP Synthesis 311	
General Criteria	**Specific Criteria**
Clarity and simplicity	The measure is simple to present, analyze, and interpret
	The measure is unambiguous
	The measure's units are well defined and quantifiable
	The measure has professional credibility
Descriptive and predictive ability	Technical and nontechnical audiences understand the measure
	The measure describes existing conditions
	The measure can be used to identify problems
	The measure can be used to predict change and forecast condition
Analysis capability	The measure reflects changes in traffic flow conditions only
	The measure can be calculated easily
	The measure can be calculated with existing field data
	There are techniques available to estimate the measure
	The results are easy to analyze
Accuracy and precision	The measure achieves consistent results
	The accuracy level of the estimation techniques is acceptable
	The measure is sensitive to significant changes in assumptions
	The precision of the measure is consistent with planning applications
	The precision of the measure is consistent with an operation analysis
Flexibility	The measure applies to multiple modes
	The measure is meaningful at varying scales and settings

Rail Performance Measures

Rail performance measures were gathered from two major railroad organizations, the Association of American Railroads (AAR) and the Federal Railroad Administration (FRA). The Association of American Railroads tracks freight performance such as the types of railcars used by a particular class I railroad or the number of terminal dwell hours. The AAR publishes these types of performance measures for each of the major class I railroads weekly on their performance measurement website (www.railroadpm.org). The FRA tracks safety performance measures such as equipment-caused train accidents and grade crossing incidents. A complete list of the performance measures currently tracked by each organization can be found in Appendix A.

The research team also looked at the NCHRP Report 446 which includes a broad range of performance measures for the railroad industry and is compiled from various research reports documenting state and local practices. NCHRP 446 lists dozens of potential rail measures across several categories, including system preservation (e.g., measures of track condition) and operational efficiency (e.g., rail revenue versus operating expenses). The complete list of rail performance measures can be found in Appendix A.

Waterway Performance Measures

Waterway performance measures were compiled from the US Department of Maritime Administration (MARAD) and the US Army Corps of Engineers (USACE) – Mobile District as well as the NCHRP Report 446. MARAD measures waterway and port performance such as the number of foreign and domestic container imports and exports. Many of their performance measures can be found in the US Water Transportation Statistical Snapshot which highlights major changes occurring in the water transportation industry. While the MARAD data focuses primarily on port trade, the USACE performance measures are more concerned with inland waterways, dams, and locks. The USACE collects measures of mobility (e.g., delay at locks/dams), system preservation (e.g., dams needing structural upgrades), safety (e.g., collisions/maritime injuries), and economic development (e.g., cargo volume). The NCHRP Report 446 includes several areas of waterway performance measurement not covered by the MARAD or USACE, including customs/administrative processing time, number of miles needing dredging, and percent of on-time performance. It is important to note that while the NCHRP document details a large number of measures, many states do not track waterway performance.

A complete list of the performance measures from each source can be found in Appendix A.

Air Performance Measures

Air performance measures were gathered from the Federal Aviation Administration (FAA), The Huntsville International Airport, NCHRP Report 446, and *"Aviation System Performance Measures"* by Geoffrey D. Gosling. The FAA tracks performance measures such as departures, arrivals, and seating capacity for each airport. Huntsville International Airport collects many of the same performance measures as the FAA as well as additional passenger, cargo, and military metrics. The NCHRP Report 446 lists a broad range of performance measures for air transportation many of which are found in the Gosling paper. These two documents contain comprehensive lists and include measures of mobility, accessibility, reliability, economic development, sustainability, safety, and environmental conservation. The Gosling paper differentiates the performance measures specific to commercial airports and general aviation airports, which have differing operating characteristics.

A complete list of the performance measures from each source can be found in Appendix A.

Intermodal Performance Measures

Intermodal performance measures were gathered directly from the Huntsville Intermodal Center as well as the NCHRP Report 446. The Huntsville Intermodal Center collects basic information for performance measurement including the number of inbound and outbound train loads and truck gate activity. The NCHRP Report 446 includes a wide variety of intermodal related performance measures such as the transfer time between modes, number of accidents per intermodal transfer, and dwell time.

A complete list of the performance measures from each source can be found in Appendix A.

2.4.4 Current Alabama Performance Measures

Based on the performance measures documented in the literature review, the research team developed a list of 29 performance metrics commonly used in highway systems which also had parallel implementation in alternate transportation modes. The state of ALDOT's current use of performance metrics was then documented through the use of a survey instrument based on this subset of performance measures (see Appendix C for survey). The survey questions were organized into seven categories: Operations, Level of Service, System Measures, Safety, Environmental, Toll, and Financial.

The ALDOT Planning, Construction, Maintenance, Bridge, Design, and Aeronautics Bureaus were surveyed and the responses were confirmed during a follow-up meeting with the Project Advisory Committee. The survey results and follow up meeting indicated that performance measures used by ALDOT are primarily collected and used on a project-based schedule and not systematically collected and archived for analysis.

Traffic count, construction costs, and number of safety incidents were reported as the primary measures by bureaus outside of Planning but none of those departments actually collected metrics. Planning, however, collected metrics in all seven categories and provided the data that was needed to the other bureaus as necessary. The performance measures reported in the survey responses are as follows:

- Traffic Count
- Construction Costs
- Number of Safety Incidents
- Vehicle Miles Traveled
- Travel Time
- Speed
- Density (passenger cars per hour per lane)
- Level of Service
- Travel Time Reliability

- Percent of System Congested
- Travel Costs
- Vehicle Occupancy
- Weather-related Traffic Incidents
- Rail Grade Crossing Incidents
- Duration of Delay Caused by Incidents
- Response Time to Incidents
- Commercial Vehicle Safety Violations
- Security for Highway and Transit
- Weather Related Road Closures
- Response Time to Weather-Related Closures
- Evacuation Times
- Toll Revenue
- Operating Budgets
- Maintenance Funds

The Maintenance Bureau is an exception to this general finding. During the time of this research project, Maintenance was using an automated computer system called the "Maintenance Management System" (MMS). This system collected and made available information on labor, equipment, and materials cost and usage. During a telephone interview with a representative from the Maintenance Bureau, it was indicated that an update to MMS was imminent after which the system was hoped to include information pertaining to Quality Assessment/Assurance and Condition Assessments of Assets to trigger maintenance activities.

2.4.5 Selection of Performance Measures

The research team then performed a gap analysis to determine the difference between the measures that ALDOT currently tracks and the measures the research team determined were most appropriate to evaluate system performance.

Because of the reasonably comprehensiveness of NCHRP Report 311, the UAHuntsville OFLT team chose to use it as the basis for their study of performance measures useful to the Alabama Department of Transportation (ALDOT). The NCHRP 311 survey listed 26 performance measures that were utilized in this study. These measures, shown in Table 2-15, were chosen because they were of the greatest relevance to ALDOT.

Table 2-15 NCHRP 311 Performance Measures

Performance Measure	Definition
Traffic count	annual average daily traffic, peak-hour traffic, or peak-period traffic
Vehicle-miles traveled	volume times length
Travel time	distance divided by speed

Speed	distance divided by travel time
Density	passenger cars per hour per lane
Recurring delay	travel time increases from congestion but does not consider incidents
Level of service/Highway Capacity Manual	qualitative assessment of highway point, segment, or system using “A” (best) to “F” (worst) based on measures of effectiveness
Duration of congestion	period of congestion
Travel time reliability	several definitions are used that include (1) variability of travel times, (2) percent of travelers who arrive at their destination within an acceptable time, and (3) range of travel times
Percent of travel congested	Percent of vehicle-miles or person-miles-traveled
Percent of system congested	percent of miles congested (usually defined based on Level of Service)
Travel costs	Value of drivers time during a trip and any expenses incurred during the trip (vehicle ownership and operating expenses, tolls, or tariffs)
Vehicle occupancy	Persons per vehicle
Number of incidents	Traffic interruption caused by a crash or other unscheduled event
Weather-related traffic incidents	Traffic interruptions caused by inclement weather
Rail grade crossing incidents	Traffic crashes that occur at highway-rail grade crossings
Duration of delay caused by incidents	Increase in travel time caused by incidents
Response times to incidents	Period required for an incident to be identified and verified and for an appropriate action to alleviate the interruption to traffic to arrive at the scene
Commercial vehicle safety violations	Number of violations issued by law enforcement based on vehicle weight, size, or safety
Security for highway and transit	Number of violations issued by law enforcement for acts of violence against travelers
Weather-related road closures	Traffic interruption caused by inclement weather
Response time to weather-related closures	Period required for an incident to be identified and verified and for an appropriate action to alleviate the interruption to traffic to arrive at the scene
Evacuation times	Reaction time and travel time for evacuees to leave an area at risk
Toll revenue	Dollars generated from tolls
Delay from toll collection	Increase in travel time caused by toll collection
Delay from incidents	Increase in travel time caused by incidents

One final measure that was included in the list of suggested metrics is public opinion/approval. Although it is not directly tied to determining the system performance level, public opinion is of vital importance to ALDOT’s ability to maintain and increase the funding levels and support necessary to effectively perform their stated mission.

2.4.6 Gap Analysis

The research team performed a gap analysis comparing the metrics necessary to measure desired system performance and the metrics currently being collected and used. Based on the preliminary feedback from PAC members, the research team was able to make some general assessments about the state of performance measurement at ALDOT as shown in Figure 2-28:

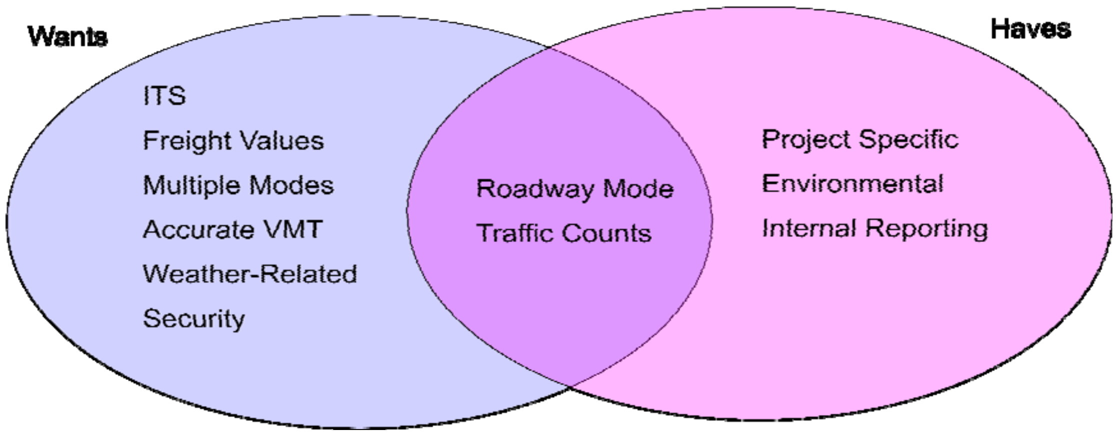


Figure 2-28. ALDOT Current State of Performance Measures

The gap analysis that was performed looked at two questions: first, was the metric under consideration currently collected and/or analyzed by ALDOT and second, what method was used to collect and/or analyze the data.

2.4.7 Illustration of Metrics Use

The final step in this research was to illustrate the use of metrics in the transportation system by employing the Alabama Transportation Infrastructure Model (ATIMv1) to simulate freight and transportation network activity.

2.4.7.1 Application of Performance Measurement in Transportation Modeling

The research team used the Statewide Transportation model, developed by UAHuntsville, to illustrate the use of the metrics and show the impact of systemic changes on the transportation system. In order to demonstrate how performance measures can be used in conjunction with traffic simulation to better predict the effect of growth and increased demand for the transportation infrastructure system, the research team exercised the Alabama Transportation Infrastructure Model (ATIMv1) and observed the impact on the performance measures included in the model output.

The application of the two-pronged modeling approach to evaluate the performance of the transportation system included the base understanding of congestion in the roadway network and forecast of congestion for 2015 – using the Freight Analysis Framework Database Version 2 (FAF2). The base data is derived from 2002 (the base year in FAF2) and was modeled in TRANPLAN as well as in ATIMv1. With a volume to capacity ratio of 0.9 to indicate congestion, the centerline miles of congestion in Alabama for the base year were calculated by the models and are shown in Table 2-16.

Table 2-16 ATIM/TRANPLAN 2002 Centerline Miles of Congestion

2002 Centerline Miles of Congestion	TRANPLAN Model	ATIM Model
Interstate	25	28
US Highways	33	46

The numbers are slightly different due to the method used to assign the trips to the roadway network. The TRANPLAN model allows for path selection to avoid congestion while the ATIMv1 model relies on fixed paths. From the TRANPLAN model, there were 130 lane-miles of congested interstate and 104 lane-miles of congested US Highway.

The anticipated centerline congestion in the system using the FAF2 freight projection data for 2015 and growing passenger cars at the accepted ALDOT rate is shown in Table 2-17.

Table 2-17 ATIM/TRANPLAN 2015 Centerline Miles of Congestion

2015 Centerline Miles of Congestion	TRANPLAN Model	ATIM Model
Interstate	343	305
US Highways	128	138

Figure 2-29 indicates the location for the congestion identified for 2015.

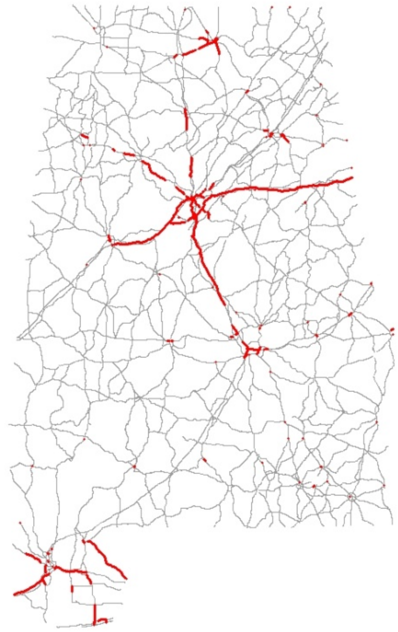


Figure 2-29 2015 Centerline Miles of Congestion

It is important that the congestion levels and locations indicated in these tables and via the image are the result ONLY if there are no additional roadway construction efforts performed by ALDOT. Obviously, this is not likely to happen as ALDOT is constantly working to improve roadways through added capacity.

An additional capability of the models to understand roadway congestion is the anticipated travel speed for the selected facilities. Using the ATIM model and examining the output, in 2015 there will be several segments of Interstate 65 and Interstate 20 where the travel time will increase to more than 25 percent above the anticipated travel time when traveling at the posted speed limit. These increases happen if there are no improvements to the present roadway network, which is known to be unlikely.

The ability to model the roadway network is an important performance measurement tool. Understanding the current state of congestion and anticipated state of congestion will allow for improved decisions regarding the investment of scarce ALDOT resources. Having updates to the model run frequently, adjusted to contain the actual capacity of the facilities, will help ALDOT personnel determine if the mileage of congestion and travel times are being addressed in an appropriate fashion. Additionally, monitoring of the system will allow ALDOT representatives to justify requests for funds for roadway infrastructure improvements and answer traveler queries as to how they are utilizing public funds.

2.4.7.2 Pilot Implementation of Performance Measurement System

The next step in this research is to work with ALDOT to choose a Bureau or department to begin pilot implementation of a performance measurement system. During the survey process, several departments indicated a desire to pursue more precise performance measurement but did not have the in-house experience or funding to do so.

Once chosen, historical data can be used to "go back in time" and determine what the performance measure was signaling, then compare that signal to the actual events. In this way, the relationship of the performance measure to the outcome can be understood and utilized.

It is important to note that although Performance Measurement would provide more insight into system behavior and the key pressure points in the system, it does not guarantee that it will influence those behaviors into favorable patterns. For example, ALDOT might have the ability to re-engineer a sharp curve into a less dangerous turn but they cannot force drivers to not drive under the influence or passengers to always wear their seat belts.

2.5 References

Review of Performance Measures Used
Missouri Department of Transportation "Tracker: Measures of Departmental Performance" July 2008
Missouri DOT Tracker:
http://www.modot.mo.gov/about/documents/Tracker_PDF_July08/TrackerJuly08.pdf

Paula J. Hammond, P.E., Washington State Department of Transportation. "Measures, Markers, and Mileposts: The Gray Notebook for Quarter Ending March 31, 2008" Edition 29, published May 20, 2008
Washington DOT Gray Notebook: http://www.wsdot.wa.gov/NR/rdonlyres/BFF201B6-F6BD-406E-BEB7- 71F0C4E7D92A/0/GrayNotebookMar08.pdf

Roadway Performance Measures
"Alabama Statewide Transportation Plan Update." Alabama Department of Transportation, June 2008.

Railroad Performance Measures
"Railroad Performance Measures." Association of American Railroads, http://www.railroadpm.org

Air Performance Measures
"Aviation System Performance Measures." http://aspm.faa.gov/aspm/entryASPM.asp

Section 2 References

[1] Federal Highway Administration, *Freight Analysis Framework (FAF), Version 2.2 User Guide*, Nov. 20, 2006, pp. 4-11.

[2] Harris, G.A., P. Farrington, M. Anderson, N. Schoening, J. Swain, and N. Sharma. Developing Freight Analysis Zones at a State Level: A Cluster Analysis Approach. In *Proceedings of the Transportation Research Board Annual Meeting, TRB 88th Annual Meeting Compendium of Papers DVD*. Washington, D.C., January 11-15, 2009.

[3] Al-Deek , H.M. Which Method Is Better for Developing Freight Planning Models at Seaports— Neural Networks or Multiple Regression? *Transportation Research Record: Journal of the Transportation Research Board 1763, Paper No. 01-256.* Transportation Research Board of the National Academies, Washington, D.C., 2001.

[4] Holguín-Veras, J., E. Thorson and K. Ozbay. Preliminary Results of Experimental Economics Application to Urban Goods Modeling Research. *Transportation Research Record: Journal of the Transportation Research Board No. 1873.* Transportation Research Board of the National Academies, Washington, D.C., 2004.

[5] Pendyala, R. M., V. N. Shankar, and R. G. McCullough. Freight Travel Demand Modeling: Synthesis of Approaches and Development of a Framework. *Transportation Research Record 1725, Paper No. 00-0200.* Transportation Research Board of the National Academies, Washington, D.C., 2000.

[6] Opie, K., J. Rowinski and L. N. Spasovic. Commodity Specific Disaggregation of the 2002 FAF2 Data to the County Level for New Jersey. In *Proceedings of the Transportation Research Board Annual Meeting, TRB 88th Annual Meeting Compendium of Papers DVD*. Washington, D.C., January 11-15, 2009.

[7] Nash, J. E. and J.V. Sutcliffe. River flow forecasting through conceptual models. Part I: A discussion of principles. *Journal of Hydrology*. 10, 282-290, 1970.

[8] Wishart, D., ClustanGraphics (Version fourth edition). Edinburgh: Clustan Limited. 2006.

[9] Federal Highway Administration, *Freight Analysis Framework (FAF), Version 2.2 User Guide*, Nov. 20, 2006, pp. 11-14.

[10] Anderson, M., G. Harris, S. Jeereddy, S. Gholston, J. Swain and N. Schoening. Using a Federal Database and New Factors for Disaggregation of Freight to a Local Level. *Proceedings of the 10th International Conference on Application of Advanced Technologies in Transportation*, Athens, Greece, May 2008.

[11] US Census Bureau, 2002 Census of Manufacturing: Alabama County Data.

[12] National Agricultural Statistics Service, USDA, *2002 Census of Agriculture: Alabama County Data*, pp. 265-275.

[13] US Geological Survey, *Geological Survey of Alabama*, 2003, pp. 3.1-3.5.

[14] US Census Bureau*, 2002 Census of Mining: Alabama.*

[15] US Census Bureau, *2004 County Business Patterns: Geographic Area Series: State, County and Metropolitan Area Series: 2004 and 2003*, December, 2006.

[16] Alabama Forestry Commission, *Forest Resources Report, 2003*, pp.2-3.

[17] Warnell School of Forest Resources, University of Georgia, Timber Mart – South, "South-wide Average Stumpage Prices Press Release," October, 2002.

[18] Bureau of Economic Analysis, Regional Economic Accounts: Local Area Personal Income: Alabama, March, 2009.

[19] IHS Global Insight, *The US Economy: The 30 Year Focus*, Third Quarter, 2008, pp. 178-185.

[20] Economic Research Service, US Dept. of Agriculture, "USDA Long Term Projections," February, 2009, pp. 32, 50-51.

[21] TRB Special Report 288, Metropolitan Travel Forecasting: Current Practice and Future Direction. 2007.

[22] TRB Synthesis 236, Methods for Household Travel Surveys, 1996.

[23] Dickey, J. *Metropolitan Transportation Planning.* Second Edition. Hemisphere Publishing Corporation, Bristol, PA. 1983

[24] J.de D. Ortuzar and L. G. Willumsen. *Modeling Transport.* Second Edition. John Wiley and Sons, New York, NY. 1994.

[25] TRB Synthesis 298, Truck Trip Generation Data, 2001.

[26] Cambridge Systematics, Inc. Quick Response Freight Manual II. Federal Highway Administration. Publication No. FHWA-HOP-08-010. 2007.

[27] Dickey, J., *Metropolitan Transportation Planning.* Second Edition. Hemisphere Publishing Corporation, Bristol, PA, 1983.

[28] ALDOT. Alabama Traffic Data. http://aldotgis.dot.state.al.us/atd/default.aspx. Accessed June 30, 2009.

[29] NCHRP 570. Guidebook for Freight Policy, Planning, and Programming in Small- and Medium-Sized Metropolitan Areas. 2007.

[30] TRB. National Cooperative Freight Research Program. http://www.trb.org/crp/ncfrp/ncfrp.asp. Accessed June 30, 2009.

[31] Federal Highway Administration, *Freight Analysis Framework (FAF), Version 2.2 User Guide*, Nov. 20, 2006.

[32] Krishnan Viswanathan, K. Daniel Beagan, V. Mysore, and N. Srinivasan. *Disaggregating FAF^2 Data for Florida: Methodology and Results*, Submitted to the 2008 Transportation Research Board Annual Meeting, 2008.

[33] Rowinski, J., K. Opie, and L. N. Spasovic. *Development of a Method to Disaggregate the 2002 FAF2 Data down to the County Level for New Jersey*, Proceedings of the 87th Annual Meeting of the Transportation Research Board, 2008.

[34] Federal Highway Administration, *Development of Truck Payload Equivalent Factor (TPEF), Final Report*, 2007.

[35] Axelrod, Robert, 1997, *The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration*, Princeton: Princeton University Press, ISBN 978-0-691-01567-5.

[36] Johnsonbaugh, R., 1986, *Discrete Mathematics*, Macmillan, New York, p. 118.

[37] Hart, P. E.; Nilsson, N. J.; Raphael, B., 1968, "A Formal Basis for the Heuristic Determination of Minimum Cost Paths". *IEEE Transactions on Systems Science and Cybernetics SSC4* (2): pp. 100–107.

[38] Harris, G. et al., Transportation Infrastructure in Alabama – Bridging the Data & Information Gap, a Report to the U.S. Department of Transportation – Federal Transit Administration, Project Number AL-26-7262-01, November 20, 2008.

[39] Wagner, F., 2006, *Modeling Software with Finite State Machines: A Practical Approach*, Auerbach Publications, 2006, ISBN 0-8493-8086-3.

[40] Reenskaug, Trygve M. H. 1979, XEROX PARC 1978-79, http://heim.ifi.uio.no/~trygver/themes/mvc/mvc-index.html.

[41] Alabama Rail Plan 2008, Alabama Department of Transportation, prepared by Burk-Kleinpeter, Inc., December 2008.

[42] Pickrell, S., & L, Neumann, "Use of performance measures in transportation decision making," *Conference Proceedings 26: Performance Measures to Improve Transportation Systems and Agency Operations*. Washington, DC: National Academies Press, 2001.

[43] Pratt, R. H. and T.J. Lomax, "Performance Measures for Multimodal Transportation Systems," *Transportation Research Record Volume 1518*, Transportation Research Board, National Research Council, Washington, D.C., 1996, pp. 85-93.

[44] Johns, R., et al., "Impact of Performance Measures on Internal and External Relationships," *Conference Proceedings 36: Performance Measures to Improve Transportation Systems*. Washington, DC: National Academies Press, 2005.

[45] Poister, Theodore. "Performance Measurement in Transportation: State of the Practice," *Conference Proceedings 36: Performance Measures to Improve Transportation Systems*. Washington, DC: National Academies Press, 2005.

[46] Meyer, Michael. "Measuring System Performance: Key to Establishing Operations as a Core Agency Mission," *Transportation Research Record,*

Volume 1817, Transportation Research Board, National Research Council, Washington, D.C., 2002, pp 155-162.

[47] Pickrell, S., & L, Neumann, “Use of performance measures in transportation decision making,” *Conference Proceedings 26: Performance Measures to Improve Transportation Systems and Agency Operations*. Washington, DC: National Academies Press, 2001.

[48] Hendren, P, L. Neumann, S. Pickrell, “Linking Performance-Based Program Development and Delivery,” *Conference Proceedings 36: Performance Measures to Improve Transportation Systems*. Washington, DC: National Academies Press, 2005.

[49] Shaw, Terrel. *NCHRP Synthesis 311 – Performance Measures of Operational Effectiveness for Highway Segments and Systems.* Washington, D.C.: Transportation Research Board, 2003.

[50] Tarnoff, Philip. “Customer-Focused Performance Measures.” *ITE Journal*. May 2005.

[51] PBS&J Consultants. *Transportation System Performance Measures – Final Report*. Tennessee Department of Transportation, December 2005.

[52] *Measuring Performance Among State DOTs.* American Association of State Highway and Transportation Officials, March 2006.

[53] Schofield, M. & R, Harrison. “Developing Appropriate Freight Performance Measures for Emerging Users.” Southwest Region University Transportation Center, University of Texas at Austin. 2007.

3. Evaluation of Alternative Transportation Modes for Improving Transportation and Freight Flow

Freight and passenger traffic are both users of the same transportation networks. If analyzed and optimized individually, the overall system will more than likely be sub-optimized. Therefore, it is important to consider the effects of transportation infrastructure decisions and the decisions made by users on the performance of the entire system.

Several research initiatives within the OFLT have been aimed at utilizing simulation tools to provide decision analysis support for freight operations, particularly port operations. The following section provides a look at the methodology for rapidly creating simulation tools for use in decision analysis.

3.1 Development of a Modular Approach for Rapidly Developing Simulation Models for Analyzing and Evaluating Port Operations

Discrete event simulation is a powerful computer tool to analyze and evaluate systems and processes. Some companies will not launch a major expansion, change a process, or make a capital expenditure until a detailed analysis is completed using simulation. Many users consider simulation as inexpensive insurance against costly mistakes especially when large capital expenditures are being considered [1].

Even with all the benefits of simulation, there are difficulties that constrain the successful development and implementation of simulation models. This is especially true in obtaining management support because of preconceived ideas about the time and cost overruns on past simulation projects. The time to create, validate and verify a simulation project seems to be the most significant barrier to overcome. In many instances the data needed for a successful simulation do not exist. The data are generally not readily available in a form that can be easily used. Even then, the available data are not credible, incomplete, or inaccurate. Furthermore, in many instances there is not sufficient time to collect the data because of urgency from management for answers.

This research was undertaken to addresses these critical issues, especially the time factor, to develop, verify, and validate simulation models and the data collection efforts. Simulation models of port and terminal operations have become very valuable as decision support tools. It is critical to understand the impact of change prior to expending resources. To accomplish this, the research team established a modular approach for rapidly developing simulation models that can analyze and evaluate port planning and operations, changes in operations and capital expansions.

3.1.1 Modeling Modular Framework

Figure 3-1 is a visual representation of the framework of the modular approach for developing simulation models of ports. The framework consists of a number of submodels that run independent of each other. Each submodel has its own data input and entities with specific attributes. For example, the data input can include arrival and service times, storage capacities, and available resources.

In the modular approach, data are shared between the submodels by global variables. The content of global variables can be altered within any submodel with the new values immediately shared and used by any other submodel. These global variables not only pass data between the submodels but can also be used in logic statements to control the movement and routing of entities, branching logic, and updating entity attributes.

To assist in verification and validation (V&V), the modular approach includes a set of output blocks, or labels, that display current values from the global variables during the running of the simulation. These values are generally overlaid on top of the simulation model so the user can observe the movement of entities as well as any bottlenecks.

A simplified and rapid approach to data collection is to ask the appropriate questions through interviews with personnel directly involved with the application. This is not only effective, but also a time saving approach to obtaining data. In these instances, the triangular distribution is often used as a subjective description of a population when there are only limited sample data and especially where actual data are scarce and the cost of collection high.

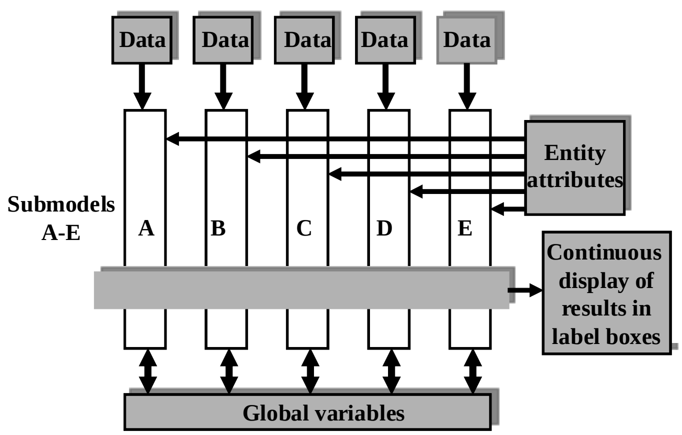


Figure 3-1 Overview of Modular Approach

For example, if the smallest value, the largest value and the most likely value are known for a process, then the outcome can be approximated by the triangular distribution. Most personnel engaged in a process can readily give estimates for the minimum, maximum and most likely values which correspond to the three parameters of the triangular distribution (See Figure 3-2).

It is reasonable to assume that service times follow triangular distributions. It is rather easy to ask knowledgeable personnel the most frequent time or mode (parameter c), the smallest time (parameter a) and the largest time (parameter b) to obtain the needed parameters for the triangular distribution in Figure 3-2. The triangular distribution (probability density function) is a continuous distribution with a mode of c and:

$$\text{Mean} = (a + b + c)/3$$

$$\text{Variance} = (a^2 + b^2 + c^2 - ab - ac - bc)/18$$

The triangular distribution closely resembles the normal distribution if (c - a) = (b - c). However, most data are skewed and more accurately represented by the log normal distribution. The triangular distribution in Figure 3-2 resembles the log normal since (c - a) > (b - c). It should be noted that log normal distributions could have relatively long tails, which may or may not be desirable in the simulation.

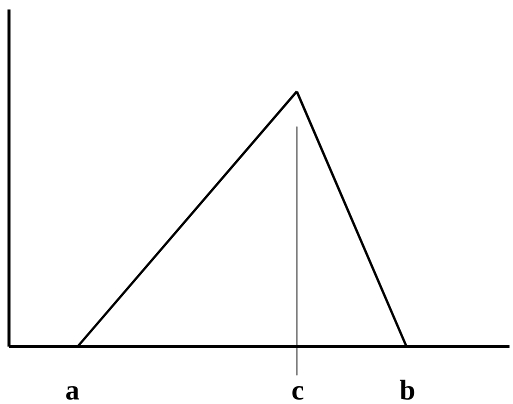


Figure 3-2 Triangular Probability Density Function

3.1.2 Modeling System

ProcessModel [2] was the simulation program selected to implement the modular modeling approach. ProcessModel is a commercially available discrete event simulation package. The building blocks in ProcessModel were ideal for constructing the submodels in the framework of the modular approach. ProcessModel has four building blocks: entities, activities, resources and stores.

Entities are items (such as ships, trains and trucks) or people being processed. Activities are tasks performed on activities (such as unloading a ship or truck). Resources are agents used to perform activities and move entities (such as inspectors). Stores are stock spaces where entities wait for further processing.

Within each block type and for each routing option (connecting line) ProcessModel has the capability of adding very complex logic. Global variables and entity attributes can be easily defined within ProcessModel. ProcessModel also has a label block function that can be used to continually display the current content of selected global variables during the simulation. The label block function is an effective tool during model verification and validation.

The primary steps in constructing a ProcessModel following the modular approach are:

1. Define and name as many of the global variables, entity attributes, resources, and output blocks as possible.
2. Construct each submodel, debug and verify, and validate separately. The use of constants for all data input greatly reduces the debugging time as well as model verification. Before starting another, submodel development the arrival of entities is turned off.
3. Add back entity arrivals into the submodels once all the submodels have been constructed.
4. Combine all submodels into one model and re-verify and re-validate with distribution data.

3.1.3 Applications of the Modular Approach

The following opportunity for application of this methodology has been implemented using the modular approach:

- Model 1 - Operations of a coal handling terminal
- Model 2 - Impact of continuous improvements on a coal terminal
- Model 3 - Expansion of a container terminal
- Model 4 - Impact of increased security inspections on a container terminal
- Model 5 - Operations of an intermodal center

Each of these applications is discussed in the following sections. An overview of each application is given followed by the use of the modular approach in constructing the simulation model and a summary of the significant results of the simulation.

3.1.3.1 Model 1 – Operation of a Coal Handling Terminal

The McDuffie Coal Terminal at the Alabama State Docks in Mobile, Alabama was established in 1976 as an export facility. The McDuffie Terminal consists of 556 acres and is the largest coal terminal on the gulf coast and the second largest in the U.S. In 1998, the facility began importing low sulfur coal for use at power generation plants. Total tonnage through the terminal for FY05 was 15.5 million tons. Total ground capacity is 2.3 million tons. Annual throughput capacity is 20 million tons. A major customer would like to see the throughput increased to 30 million tons annually. The modular approach was used to determine if the current resources could handle this increase in coal throughput.

Model
Figure 3-3 is the model of the McDuffie Coal Terminal [3]. Low sulfur coal arrives on ships and leaves on barges and trains. High sulfur coal arrives on barges and trains and leaves on ships. This series of activities are not unlike many other coal handling facilities [4] and thus this approach has potential applicability to many situations. Developing submodels with commonality of purpose allows for quick response to utilize simulation as a decision analysis tool.

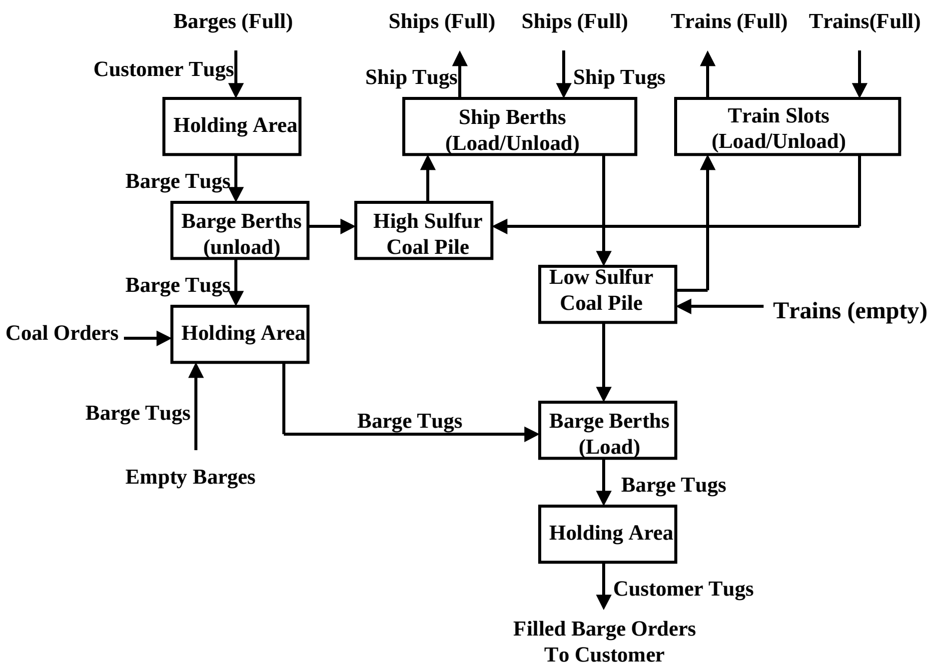


Figure 3-3 Coal Terminal Model

Translating this model using the modular approach resulted in the following submodels:

- A - Ships unloading low sulfur coal and loading high sulfur coal
- B - Barges unloading high sulfur coal loading low sulfur coal
- C - Trains unloading high sulfur coal and loading low sulfur coal

The entities in the model are ships, barges, trains, empty barges and empty trains. The entity "scoop" was defined as the amount of coal that is moved at a time. A ProcessModel scoop entity was created that is displayed and moved on the screen during coal unloading and loading. The development of the "scoop" was critical to the functionality of the model and key to accurately simulating the activities in the coal terminal. The resources are ship berths, barge berths, train slots, ship cranes, coal car flippers, tugs and four types of conveyors.

Simulation Results

The simulation results indicated that the coal terminal can unload 21million tons and load 19 million tons annually. Because of the nearly 100% utilization of several of the resources, it appears that the goal of 30 million tons annually may not be possible without an equipment upgrade.

3.1.3.2 Model 2 - Impact of Continuous Improvements on Coal Terminal Operations

The systems and equipment at the McDuffie Terminal at the Alabama State Docks have evolved over the years resulting in inefficiencies in the operations and processes. The condition of equipment and processes, along with customer requirements for increased coal volume led management to find opportunities to improve operational efficiency, system productivity and coal throughput. The management team at the port became aware of the principles of lean manufacturing and continuous improvement through a series of meetings and educational programs and agreed to try the approach at the McDuffie Terminal [5].

The main focus of a continuous improvement culture is to identify and eliminate inefficiencies, termed waste, in a process and create value in the eyes of the customer [6, 7]. The wastes can be categorized into overproduction, inventory, defects, motion, transportation, waiting, over processing, and underutilizing people [8, 9]. Many of the operations at the McDuffie Terminal would not typically be considered value added. Examples of these non-value added activities are equipment setup and breakdown, unevenness in scheduling, handling and movement of coal throughout the terminal, and coal storage. Ideally, coal would arrive at the coal terminal and be immediately dispensed to another transportation mode for delivery to the customer, much like cross docking at a truck terminal. However, economic conditions within the coal industry make the storage of strategic inventory at McDuffie Coal Terminal a desirable market smoothing mechanism.

Eight kaizen process improvement events [6, 7, 8, 9] were conducted at the coal terminal between 2005-2006 with the goal of improving operations efficiency and increasing productivity, throughput and velocity. The results of the kaizens identified barge loading/unloading and ship unloading as primary areas for improvement.

Model

The modular approach was used to evaluate the impact of the continuous improvement events on the operations of the McDuffie Terminal [3]. Interestingly, the ProcessModel was almost identical to Model 1 described in the previous section. The only modifications were to the logic in several of the ProcessModel activity blocks and some of the data input [10].

Simulation Results

The Alabama State Docks implemented most of the recommendations from the eight kaizens at minimum costs and with very little capital expenditures. For example, several of the recommendations were to develop standard operating procedures, list of maintenance activities, shift change procedures, daily maintenance checklists, and critical spare parts lists. These recommendations resulted in a reduction in the unloading and loading of barges and an increase in the throughput tonnage per day. The simulation model not only verified that the kaizen recommendations were achievable but also provided additional insight in the operations of the terminal, gave credibility to the kaizen events, and comforted management during the implementation of the recommendations. As a result of the kaizen events, the port realized a significant increase in throughput capacity and a corresponding reduction in operating costs.

3.1.3.3 Model 3 – Expansion of a Container Terminal

The Alabama State Docks is currently enhancing container and intermodal operations in Mobile, Alabama through the addition of a new container terminal. The shipping terminal will include 92 acres with 2,000 feet of berthing space dredged to a depth of 45 feet for two berths. A grade-separated roadway will connect the container terminal with an intermodal terminal and value added warehousing and distribution area.

The new container terminal will initially be capable of handling 250,000 to 300,000 Twenty-foot Equivalent Units (TEU's) annually. The Alabama State Docks was interested in validating the design capacities of the container terminal. Of special interest were the utilization of the berths, cranes, and stackers and the maximum container throughput of the terminal. The modular approach was used to validate capacity and resource utilizations.

Model

Figure 3-4 depicts the model of the container terminal at the Alabama State Docks [11]. Containers arriving on ships depart on trains and trucks. Containers arriving on trains and trucks depart on ships. Translating the model into the modular approach resulted in the following submodels:

- A - Ships unloading and loading of containers
- B - Trains unloading and loading of containers
- C - Trucks unloading and loading of containers
- D - Movement of containers from ship dock to container yard
- E - Movement of containers from container yard to ship dock
- F - Movement of containers from train pavement to container yard

- G - Movement of containers from container yard to train pavement

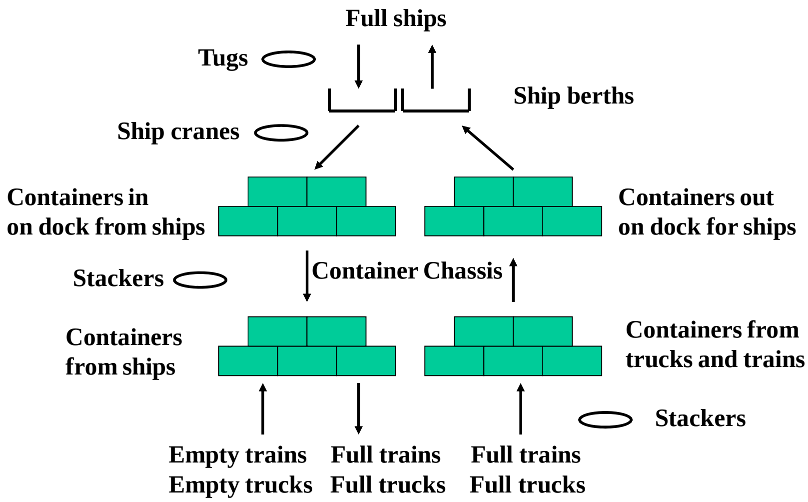


Figure 3-4 Container Terminal Model

Entities are ships, trains, trucks, empty trains, empty trucks, and trucks with empty containers. A ProcessModel container entity was developed that is displayed and moved on the screen during any container movement such as unloading and loading. There are also four Move_Order entities that trigger the movement of containers between ships, trains and trucks, and the container yard. The resources are: ship berths, train slots, truck slots, tugs, ship cranes, stackers, and chassis.

Figure 3-5 contains the simplified ProcessModels for submodels A, D, and E. In submodel A, containers are unloaded and placed on the dock. The global variable Containers_on_dock_unloaded is incremented by one as each container is unloaded. After all the containers have been unloaded, other containers are loaded back onto the ship. Containers are loaded as long as global variable Containers_on_dock_load is greater or equal to one. After a container has been loaded the global variable Containers_on_dock_load is decremented by one.

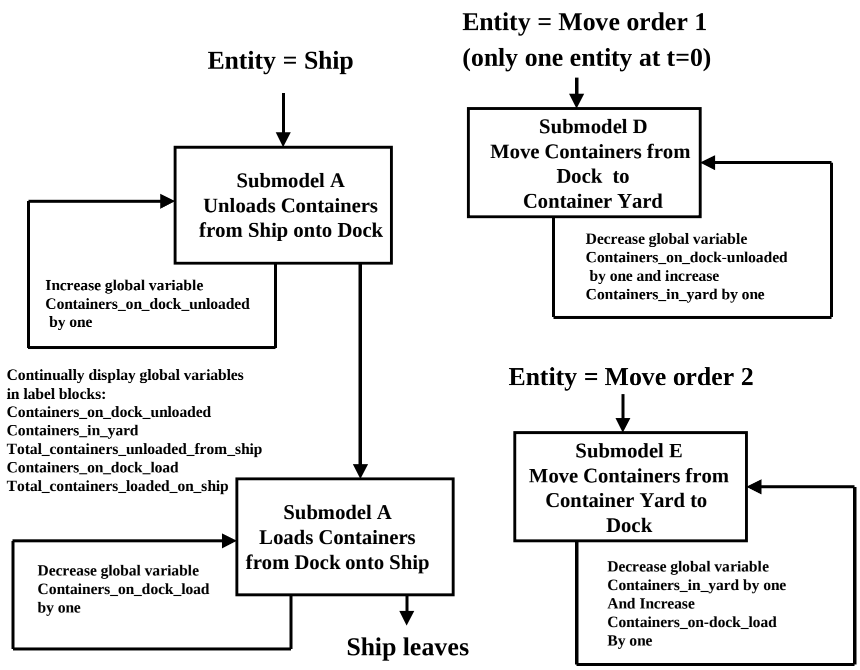


Figure 3-5 Simplified ProcessModel for Submodels A, D and E

Submodel D continually checks to see if global variable Containers_on_dock is greater or equal to one. If so, a container is moved from the dock to the container yard. The global variable Containers_on_dock_unloaded is then decremented by one and the variable Containers_in_yard incremented by one.

Submodel E continually checks to see if global variable Containers_in_yard is greater or equal to one. If so, a container is moved from the container yard to the dock. The global variable Containers_in_yard is decremented by one and the variable Containers_on_dock_load is incremented by one.

Table 3-1 presents the design of the experiment. The objective was to determine the container capacity of the terminal. Therefore, the logical variable was the time between arrivals of the entities. Since the capacity for a truck was only one container, the time between arrivals for full and empty trucks was kept constant at two hours. All other data remained the same as the baseline.

Table 3-1 Experimental Design

Time between arrivals			
	Ships	**Full trains**	Empty trains
Run1	3 days	3 days	3 days
Run2	3 days	2 days	2 days
Run3	3 days	1 day	1 day
Run4	3 days	12 hours	12 hours
Run5	2 days	3 days	3 days
Run6	2 days	2 days	2 days
Run7	2 days	1 day	1 day
Run8	2 days	12 hours	12 hours
Run9	1 day	3 days	3 days
Run10	1 day	2 days	2 days
Run11	1 day	1 day	1 day
Run12	1 day	12 hours	12 hours
Run13	1 day	6 hours	6 hours

Simulation Results

A goal of 325,000 containers annually is feasible with the proposed design parameters. Run12 exceeded the goal and Run7 came close to the goal. To achieve this design goal, the time between arrivals of ships must drop from three days for Run1 to one day and the time between arrivals of trains must drop from three days for Run1 to twelve hours.

For Run12, ships averaged thirty-three hours in the terminal, trains averaged nine hours and trucks twenty-four minutes. Again, these times were well within the desired turnaround times. Value added times were twenty-two hours for ships, five hours for trains, and thirteen minutes for trucks. The differences in the times in the terminal and the value added times are the times waiting for containers, resources or activities.

Overall, utilization of resources is low. The model indicated a large buildup of containers in the terminal at the end of the simulation. For Run12 this buildup was 53,712 containers annually. It appears that this buildup will continue to increase as the simulation continues to run. This issue needs to be addressed with several additional runs of the model. For example, the container buildup from ships could be reduced with an increase of empty train arrivals. The container buildup from trains may point to an over arrival of container trains. One approach may be to increase the time between arrivals of container trains while at the same time increasing the arrival of empty trains.

3.1.3.4 Model 4 – Impact of Increased Security Inspections on a Container Terminal

Increased security is having a significant impact on the operations of ports resulting in longer times that ships, trains, and trucks are at container terminals. Ports are wrestling with various inspection procedures and installing equipment to minimize the container inspection times.

The purpose of this model was to determine the impact of various container inspection protocols on the operation of a container terminal at the Alabama State Docks in Mobile, Alabama. The three inspection protocols are A) no inspection, B) container sampling with unloading and inspection coupled, and C) inspection after unloading or decoupling inspection from unloading [12].

Model

The modular approach was used to evaluate the impact of each inspection protocol on container throughput [12]. Interestingly, the ProcessModel was almost identical to Model 3 described in the previous section. The only modifications were the logic in several ProcessModel activity blocks and some of the data input. Table 3-2 presents the experimental design. Protocol A is the Baseline Run1 with no container inspection. An inspection rate of 100% is used in Run2, 80% in Run3 and 60% in Run4. In Protocol C (Run5), the inspection is decoupled from container unloading and all containers are inspected independently of unloading from the ship.

Table 3-2 Experimental Design

Run	Description
Run1	Protocol A - no container inspection (Baseline Run)
Run2	Protocol B - 100% inspection of incoming containers
Run3	Protocol B - 80% inspection of incoming containers
Run4	Protocol B - 60% inspection of incoming containers
Run5	Protocol C – Container inspection independent of unloading

Simulation Result

The simulation results indicated that any sampling plan using Protocol B had an impact on entity throughput. However, decoupling the inspection from unloading in Protocol C did not impact entity throughput. In fact, entity throughput for Protocol C was similar to no container inspection for Protocol A. Any inspection plan for containers that includes inspection as a part of the unloading operation, such as that described in ProtocolB, increased the times for entities at the terminal. For example, 100% inspection of all incoming containers increased the time a ship was at the terminal by 260%, a train by 477% and a truck by 96%. A 60% sampling plan of incoming containers increased the time a ship was at the terminal by 38%, a train by 44% and a truck by 20%

Decoupling the container inspection from the unloading of the container minimized the impact of the inspection. The inspection protocol C for Run5 resulted in entity times identical to the Baseline Run with no inspection. The time a ship was at the terminal was 2,007 minutes for Run5 as compared to 2,013 minutes for the Baseline Run. The time a train was at the terminal was 695 minutes as compared to 684 for the Baseline Run. The time a truck was at the terminal was 33 minutes as compared to 26 minutes for Baseline Run. It can be assumed that the decoupled inspection process might require similar resources to the in-process inspections described in Protocol B.

3.1.3.5 Model 5 - Operations of an Intermodal Center

The International Intermodal Center is located at the Huntsville International Airport between Huntsville and Decatur, Alabama on Interstate 565 approximately 10 miles from Interstate 65 which is designated as a Freight Significant Corridor by the Federal Highway Administration. The Intermodal Center is served by CSX Railroad and operates its own Class 3 Rail Service to move container car pulls to and from the main line [13].

The Intermodal Center had an interest in analyzing its operations and evaluating various operational alternatives before finalizing the design of any planned expansion. The two primary questions to be answered by the simulation model were: 1) can container throughput satisfy anticipated demand, and 2) are resources sufficient to support anticipated growth in demand?

Model

Figure 3-6 is the model of the intermodal terminal center at the Huntsville International Center [13]. Containers arriving on airplanes depart on trucks. Containers arriving on trains depart on airplanes and trucks. Containers arriving on trucks depart on airplanes and trains. Translating this model into the modular approach resulted in the following submodels:

- A - Planes unloading and loading of containers
- B - Trains unloading and loading of containers
- C - Trucks unloading and loading of containers
- D - Movement of containers from plane dock to container yard
- E - Movement of containers from container yard to plane dock
- F - Movement of containers from train dock to container yard
- G - Movement of containers from container yard to train dock

Entities are planes, trains, trucks, empty trucks, empty trains, and trucks with empty containers. There are also four move order entities. The resources are plane terminals, train slots, truck slots, gantry cranes, plane forklifts, stackers, and chassis.

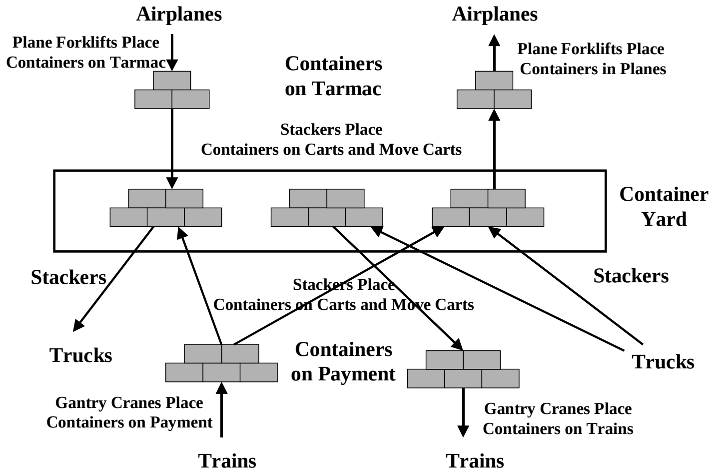


Figure 3-6 Intermodal Center Model

The experimental design is given in Table 3-3. The current intermodal center operations are defined in Baseline Run1. Each following simulation run was based upon the output from the previous run. Resources were reduced for each successive simulation run and defined as Runs2-10. Each run with fewer resources (by continuing the reduction in the number of plane and train terminals, truck slots, plane and train lifts, stackers and carts) was evaluated against the Baseline Run1. The number of plane, train, and truck entity arrivals was increased from Run10 to Run11. Runs 12-15 evaluated Run11 with fewer resources by continuing the decrease in the number of plane and train terminals, truck slots, plane and train lifts, stackers and chassis.

Table 3-3 Experimental Design

Run	Description
Baseline Run1	Current intermodal center operations
Runs 2-10	Multiple runs reducing the number of resources from Baseline Run1based upon the output of the previous run
Run11	Increased number of entity arrivals in Run10
Runs 12-15	Multiple runs reducing the number of resources in Run11

Simulation Results

The reduction in truck slots from twenty for the Baseline Run1 to 12 for Run10 indicates that only twelve trucks need to be inside the intermodal center at a time. This results in considerably less space required and possibly fewer personnel. The container throughput can be increased substantially without any deterioration in entity times at the terminal. For Run15, the container throughput reached 47,040 lifts annually up from 36,720 for Run11. Consequently, entity times at the intermodal center remained relatively constant. For example, the average plane entity time was 93 minutes for Run11 and 111 minutes for Run15. The average train entity time was 312 minutes for Run11 and 312 minutes for Run15. The average truck entity time 29 minutes for Run11 and 32 minutes for Run15.

Resource utilizations after reducing the number of resources were still relatively low. However when the resources such as stackers was reduced below eight, the average entity times increased significantly because of higher waiting times for either a resource or a container. Future research may be warranted in using overall equipment effectiveness instead of equipment utilization as a measure.

Run16, which was not of the experimental design, indicated that considerably more container traffic is possible with the existing resources from the Baseline Run1. Run16 indicated that these resources can process 68,118 lifts annually. This is a 51% increase over the projected 2007 container traffic of 45,000 lifts.

3.1.4 Summary of Results

Table 3-4 presents a comparison of the five models developed by using the modular modeling approach developed by UAHuntsville OFLT researchers. The first model developed was the coal model, followed by the container model and finally the intermodal model. The impact of a number of continuous improvement events was also added to the coal model which helped validate the impact of continuous improvement activities by port personnel (Model 2). The impact of increased security inspection of containers was added to the container model allowing stakeholders to better understand the effects of supporting different inspection protocols (Model 4).

The model development times were 48 hours for the coal model, 32 hours for the container model, 16 hours for the intermodal model, 16 hours for Model 3, and 16 hours for Model 4. The intermodal model (Model 5) was the most complex model, especially in terms of the logic. However, this model required the least development time, demonstrating a learning effect and the use of previously defined models.

Table 3-4 Comparison of Various Models

	Coal Model 1	Container Model 3	Intermodal Model 5	Coal Model 2 – Continuous Improvements	Container Model 4 – Security Inspections
Submodels	3	7	7	3	7
Entities	5	7	9	5	7
Blocks	43	50	55	49	55
Attributes and Global Variables	10	23	28	10	23
Logic Statements	110	99	178	120	109
Development Time (hours)	48	32	16	16	16
V&V Time (hours)	16	12	12	8	8
Data Collection Time	12	8	8	4	4

The following observations were made regarding the use of simulation as an inexpensive tool providing answers to questions at the Alabama State Docks and the Huntsville International Intermodal Center.

• The modular approach provides an excellent template in the development of port and terminal simulation models. This framework greatly reduced model development time, debugging, and verification & validation. Each submodel can be debugged and verified separately thus reducing development time. The submodels for the five applications were very similar. Consequently, the ProcessModels for the submodels were similar with the exception of the branching logic.

• The time to develop the models varied between 16 and 48 hours and is considerably less than traditional model developments. Likewise, the verification & validation was between 8 and 16 hours. More importantly, data collection was between 4 and 12 hours with the use of the triangular distribution -- the primary reason for these low data collection times.

• The use of the global variables was also similar for all five applications. As a result, the use of the ProcessModel Label Blocks function was similar.

• Modifications to a model were simplified because of the modular framework. Changes made to a submodel could be easily debugged without having to worry about the other submodels.

• Data collection was done by interviewing the personnel at the Alabama State Docks and the Huntsville Intermodal Center. It is rather easy to ask knowledgeable personnel about the most frequent values, the smallest values, and the largest values to obtain the parameters for the triangular distributions.

In conclusion, the modular approach has been demonstrated as an effective tool for rapidly developing simulation models. It can analyze and evaluate existing port planning and operations, changes in operations, and capital expansions.

3.2 Evaluation of Commuter Rail Service Application Between Birmingham, AL and Montgomery, AL.

I-65 from Birmingham to Montgomery is one of the most congested facilities in Alabama. This subtask will focus on the analysis of a potential commuter rail application between the two Metropolitan Planning Organizations (MPOs). Additional analysis will evaluate the potential improvements to the flow of freight and passenger traffic as a result of the new travel option. To begin to answer the question posed, the first modeling attempt was to evaluate the impact of increased traffic by using discrete event simulation, and conversely, determine the impact of removing traffic via commuter rail or some other answer.

3.2.1 Project Description

Interstate I-65 in Alabama connects the four major cities in the state: Mobile, Montgomery, Birmingham, and Huntsville. Traffic volumes on I-65 through Alabama have increased 30-50% in the last ten years. This growth in traffic on I-65 between Montgomery and Birmingham was the reason for selecting this corridor.

The study corridor begins near the Alabama River Bridge north of downtown Montgomery (mile marker 172) and extends north to mile marker 238 near Pelham and the southern Birmingham suburbs. The corridor contains three lanes in each direction from mile marker 172 to mile marker 182 and two lanes in each direction for the remainder. The study corridor contains 12 exits and is mostly rural.

Traffic volumes in Figure 3-7 were obtained from the Alabama Department Transportation (ALDOT). The ALDOT data included daily traffic volumes for each freeway segment between exit ramps along I-65, peak hour truck percentages, and k and d-factors for the conversion of daily volumes to peak hour volumes. Estimates were made for exiting/entering traffic based on crossing street volumes and traffic balancing needs. Only the northbound PM peak direction was modeled.

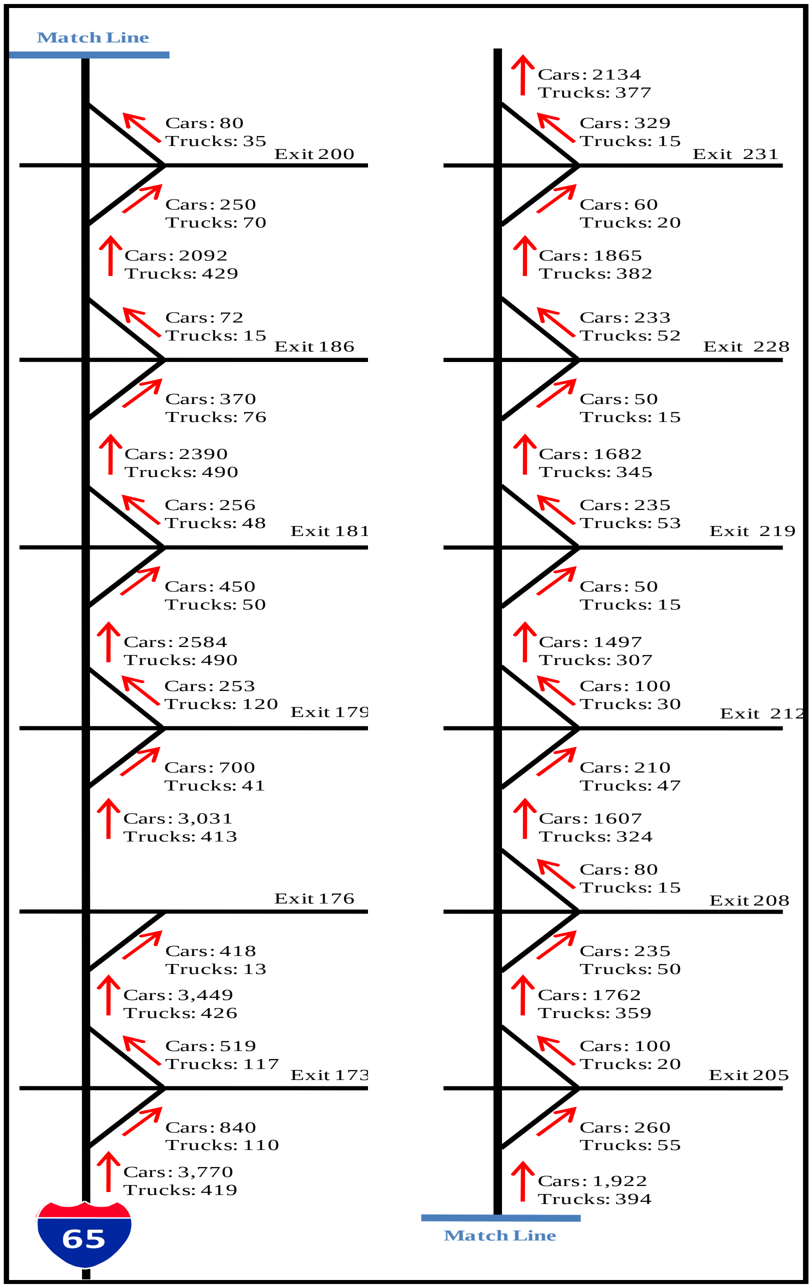


Figure 3-7 Traffic Volumes for Selected Roadway

Figure 3-8 gives a conceptual framework for the ProcessModel. Passenger car and truck entities enter the system at the first roadway segment. Each segment represents a roadway capacity based upon the segment length (2 to 14 miles) and the number of lanes (2 to 3 lanes in one direction). The model was constructed such that a truck equals 2.5 passenger cars, which is consistent with the *Highway Capacity Manual* for rolling terrain [14].

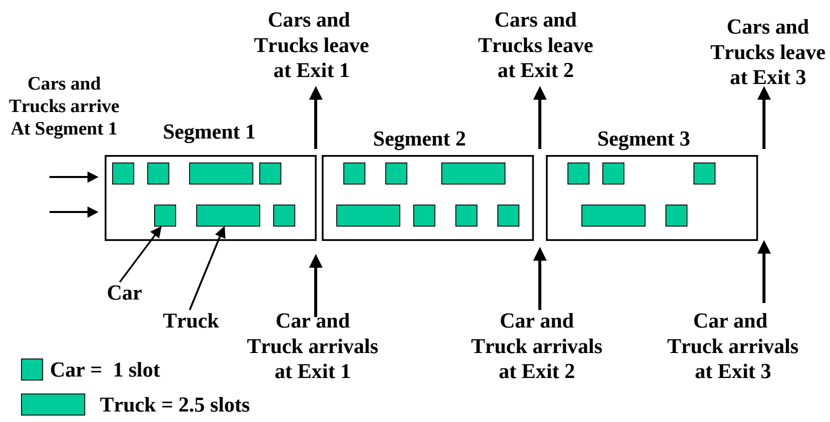


Figure 3-8 Conceptual Model Framework

The ProcessModel entities are cars (one slot) and trucks (2.5 slots). The ProcessModel has the following global variables:

- Traffic I = Current traffic volume (slots) in use at segment I (12 variables)
- Capacity I = Capacity (slots) for segment I (12 variables)

The volume to capacity ratio, or congestion, for each segment is defined as:

Volume (or traffic i) / Capacity I

The ProcessModel has the following attributes for each entity:

- Vehicle = Car or truck
- S I = Speed (mph) for each vehicle in segment i
- T I = Time (min) for each vehicle to travel segment i

Figure 3-9 is the ProcessModel for one of the road segments. This submodel is replicated for each of the twelve road segments. Therefore, model development time and verification and validation time were greatly reduced.

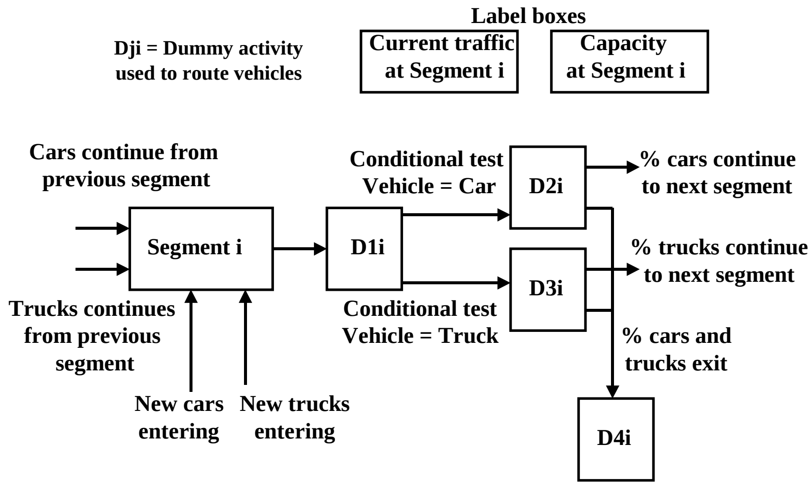


Figure 3-9 ProcessModel Submodel for a Road Segment

The ProcessModel logic embedded within each segment activity or submodel is given in Figure 3-10. The logic for a car entity is similar to the logic for a truck entity with the exception of the 2.5 slots for a truck. The vehicle entity waits until the global variable Traffic1 slots is less than the global variable Capacity1 –1 slots. If so, Traffic1 is increased by one and the attribute speed S1 is computed based on congestion. If there is no congestion, then S1 = 70 mph. If congestion =1, then S1 = 50 mph. Next, the attribute time T1 to travel the segment is computed. The entity then travels through the segment following the triangular distribution T(a,b,c) where a is the minimum time T1*0.90, c is the maximum time T1*1.05 and b is the most likely time T1. Once the travel time has been spent, the global variable Traffic1 slots is decreased by one and the entity moves to the next activity segment.

Each road segment has a maximum number of slots. A car requires 117 feet and defined as one slot. A truck occupies 2.5 slots. There is a maximum of 45 slots per lane per mile. The total number of slots in a segment is:

[Number of lanes] x [segment length (miles)] x [45 slots/mile/lane]

Each ProcessModel activity block has a queue element where an entity remains until the activity is available. Each activity block has a capacity element that allows for more than one entity to occupy the activity. In the traffic model, this capacity element is the maximum number of vehicles for each road element. Since the truck entity is equivalent to 2.5 car entities, an approximation is made to determine ProcessModel activity block capacity. For example if the traffic in a segment is initially estimated by ALDOT at 100 cars and 20 trucks then 100/120 = 83% are cars and 20/120 = 17% are trucks. If the segment has the capacity of 200 slots then the above traffic will take 200 slots x 83% = 166 slots for cars and 200 slots x 17% = 34 slots for trucks. Since there are 2.5 slots/truck, 34/2.5 = 14 trucks. Therefore, the ProcessModel capacity for this activity is 166+14 = 180 entities or vehicles. Once all the capacity is in use, entities will remain in the queue element and therefore the queue statistics can be collected within ProcessModel.

```
IF Vehicle=Car THEN
BEGIN
WAIT UNTIL Traffic1<=Capacity1-1
INC Traffic1,1
S1=70mph – (20mph * Traffic1/Capacity1)
T1 (min) =L1 miles /S1 mph  *60 min/hour
        TIME(T(T1*0.90,T1,T1*1.05)min)
DEC Traffic1,1
END
ELSE
BEGIN
WAIT UNTIL Traffic1<=Capacity1-2.5
INC Traffic1,2.5
S1=70mph – (20mph * Traffic1/Capacity1)
T1 (min) =L1 miles /S1 mph  *60 min/hour
TIME(T(T1*0.90,T1,T1*1.05)min)
DEC Traffic1,2.5
END
```

Figure 3-10 ProcessModel logic embedded within each segment activity

3.2.2 Model Verification and Validation

Model verification can be defined as determining if the model is correctly represented in the simulation code. Verification in ProcessModel was accomplished by eliminating all variation in the model and only using constants for all arrival times and service times. The times through the system could then be readily compared with the input data.

Model validation is the determination of whether the model is an accurate representation of the real world system. ProcessModel has a Label block that displays data generated by the global variables during the simulation [15]. By slowing the simulation down, it is possible to observe these values as the entities move through the simulation. A group of transportation experts observed the model operation and the peak hour volume moved through the system as designated by the input volumes.

Spayd et.al. [16] have developed a similar interstate traffic model for the Montgomery to Birmingham interstate segment using CORSIM [17]. CORSIM was originally developed by the Federal Highway Administration to analyze both freeway and arterial traffic flow conditions. CORSIM models traffic flow based on complex car following, gap acceptance, and lane-changing theories. CORSIM also incorporates the randomness that can occur within a network by including different types of drivers, vehicles and traffic system characteristics.

Under non-congested conditions, CORSIM and ProcessModel operate similarly. For oversaturated conditions, CORSIM clearly replicates actual traffic conditions more effectively than ProcessModel. CORSIM is also more effective in being able to incorporate complex lane geometries as well as merging, weaving, and other vehicle maneuvers requiring lane changes that ProcessModel cannot handle.

ProcessModel does offer some high-level advantages over CORSIM. A ProcessModel network does not need to exist in a certain scale. Therefore, a network modeling I-65 could easily be converted to model an interstate in a different state in shorter time than it would take to develop a CORSIM network with new ramps and freeway links. The ProcessModel output file is simple to read, can track trucks and passenger cars separately, and does not require link aggregation to compile stats as CORSIM network frequently require.

ProcessModel seems to be better equipped to handle the expected demand volumes of long corridors (provided conditions are not oversaturated) than CORSIM since CORSIM relies on an internal gravity model for each vehicle's routing decision and can require detailed origin-destination modifications in order to attain the desired volumes.

3.2.3 Experimental Design

Table 3-5 gives the experimental design. The Baseline Run1 simulates the current peak hourly traffic going north from Montgomery. At peak traffic, 3,770 cars and 419 trucks arrive every hour at the start of the ProcessModel (See Figure 2-7). The remaining Runs2-6 increase the number of car and truck arrivals entering the model at the first segment by 10%, 20%, 30%, 40% and 50%, respectively.

Table 3-5 Experimental design

Experiment	Description
Baseline Run1	Peak hourly traffic
Run2	10% increase in vehicles entering at segment 1
Run3	20% increase in vehicles entering at segment 1
Run4	30% increase in vehicles entering at segment 1
Run5	40% increase in vehicles entering at segment 1
Run6	50% increase in vehicles entering at segment 1

3.2.3.1 Baseline Run1 Results

Table 3-6 gives the results for the Baseline Run1. Most traffic planners consider a rural interstate segment congested when the volume to capacity (V/C) ratio exceeds 75%. Likewise, an urban segment is considered congested when the volume to capacity ratio exceed 90%.

For the Baseline Run1, the volume to capacity ratios were below 75%. Consequently, the average speeds for all segments were 60 mph and above with the exception of Segments E181-E186 and E228-231 with speeds of 58 mph and 53 mph, respectively. The first three road segments had three lanes. The fourth Segment (E181-E186) reduced to two lanes. As a result, the reduction in the number of lanes from three to two lowered the average speed. The speed slowly increased in the subsequent northern lanes. The speed was lower for Segment E228-E231 because more cars and trucks began entering the segment. These road segments were on the outskirts of Birmingham where traffic began increasing.

Table 3-6 Baseline Run1 Results

Road Segment	Length (miles)	Average Speed (mph)	Volume / Capacity Ratio (%)
E173-E176	3	60	52
E176-E179	3	62	46
E179-E181	2	63	41
E181-E186	5	58	64
E186-E200	14	62	54
E200-E205	5	61	48
E205-E208	3	62	44
E208-E212	4	63	39
E212-E219	7	65	36
E219-E228	9	64	41
E228-E231	3	53	54
E231-E238	7	61	53

3.2.3.2 Run2-5 Results

Table 3-7 gives the results for Runs2-5. No congestion above 75% occurred for Run2. However, the volume to capacity ratio reached 75% in Segment E181-E186 for Run3, increased to 80% for Run4 and 86% for Run5. Also, the congestion increased to 72% for Segment E173-E176 and 70% for Segment E186-E200. No queues occurred at any segment for Runs2-5.

Table 3-7 Run2-5 Results

Road Segment	Average Speed (mph)				Volume/Capacity Ratio (%)			
	Run2	**Run3**	**Run4**	**Run5**	**Run2**	**Run3**	**Run4**	**Run5**
Increase in traffic	10%	20%	30%	40%	10%	20%	30%	40%
E173-E176	60	58	57	56	55	63	67 676	72
E176-E179	61	60	59	58	49	54	58	63
5E179-E181	62	61	60	59	43	48	50	54
E181-E186	57	55	54	53	68	**75**	**80**	**86**
E186-E200	61	62	59	59	56	61	66	70
E200-E205	62	60	59	58	50	54	57	61
E205-E208	63	61	60	59	45	49	52	54
E208-E212	61	62	62	62	40	44	46	47
E212-E219	64	64	63	63	37	40	42	43
E219-E228	64	63	63	62	42	45	47	48
E228-E231	53	53	53	53	54	58	59	60
E231-E238	61	60	60	60	54	57	58	60

3.2.3.3 Run6 Results

Table 3-8 gives the results for Run6. Segments E173-E176 and E181-E186 had volume to capacity ratios that exceeded congestion levels of 75%. Also, Segment E186-E200 approached the congestion level with a volume to capacity ratio of 72%.

The speeds dropped considerably especially at the congested road segments. The average speed was 54 mph for Segment E173-E176 and 47 mph for Segment E181-E186.

The congestion for Segment E181-186 reached 99% for Run6. This was the only segment that experienced a vehicle delay with a ProcessModel queue content. The average queue content was 74 vehicles with a maximum queue content of 236 vehicles. The average waiting time was 1.2 minutes. Also for Run6, the volume to capacity ratio for Segment E173-E176 reached 79% and Segment E186-E200 reached 72%.

Table 3-8 Run6 results

Road Segment	Length (miles)	Average Speed (mph)	Volume / Capacity Ratio (%)
E173-E176	3	54	**79**
E176-E179	3	57	68
E179-E181	2	59	58
E181-E186	5	47	**99**
E186-E200	14	58	72
E200-E205	5	58	63
E205-E208	3	59	56
E208-E212	4	61	49
E212-E219	7	63	44
E219-E228	9	62	50
E228-E231	3	53	62
E231-E238	7	59	61

3.2.4 Comparison of Runs

Figure 3-11 is a plot of the volume to capacity ratios for the Baseline Run1, Run3, and Run6. Figure 6 is a plot of the average speeds for these same runs. Segment 1 is E173-E176, Segment 2 is E176-E179 and so on.

As can be seen in Figure 3-11, Run3 resulted in congestion above 75% for Segment E181-E186. This segment is the first two-lane segment north of the three segments with three lanes of traffic. After this segment, the volume to capacity ratio dropped considerably in subsequent road segments.

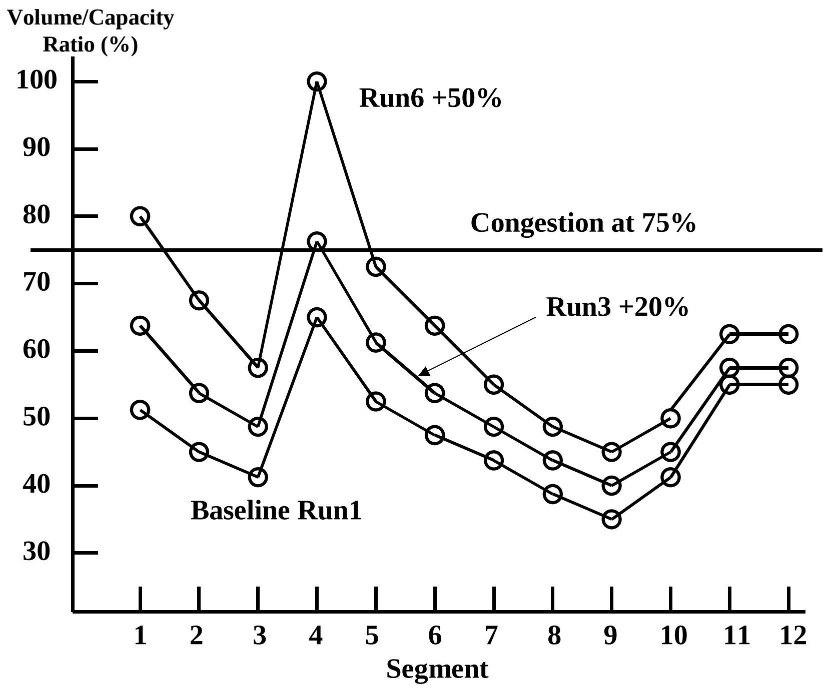


Figure 3-11 Volume to Capacity Ratios for Selected Runs

As shown in Figure 3-12, the speed in a segment is directly related to the volume to capacity ratio. As the volume to capacity ratio increased, the corresponding speed decreased. For example when the volume to capacity ratio for Run6 reached 99% for Segment E181-E186, the speed reduced to 47 mph. The speed continued to increase after Segment E181-E186 when the congestion dissipated

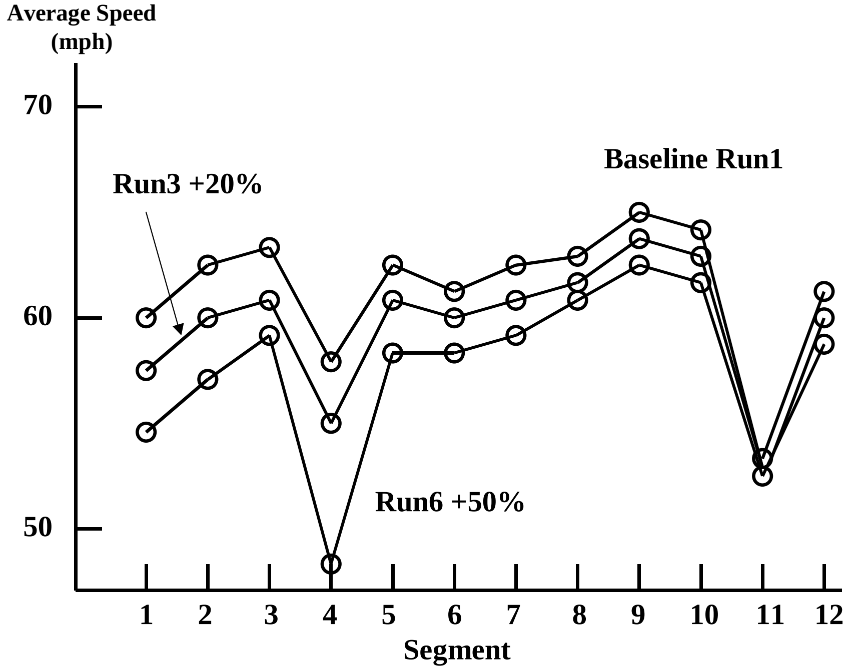


Figure 3-12 Average Speeds for Selected Runs

In summary the following observations are made:

- The submodel framework greatly reduced development and verification and validation times. A submodel represented a road segment between two exits. Therefore, the northbound Interstate I-65 from Montgomery to Birmingham, AL was modeled by connecting twelve submodels.

- A submodel basically consisted of only one ProcessModel activity block. Embedded in the activity block was a set of logic statements for computing congestion, speed, and travel time. Each submodel contained four additional activity blocks for routing vehicle entities off the exit. These four activities had zero times.

- No congestion was observed for the Baseline Run1. Run2 with a 10% increase in incoming traffic also resulted in no congestion.

- Congestion started occurring with a 20% increase in traffic (Run3) and continued increasing through Run5 (75% and 86% respectively at Segment E181-E186). This segment was the first road segment just after the interstate reduced from three to two lanes.

- Run6, with a 50% increase in traffic, had 99% congestion that resulted in a queue of vehicles.

- Run6, with a 50% increase in traffic, also had 79% congestion on the first road segment.

It appears that the northbound lane of Interstate I-65 will begin to reach congestion on one segment with an approximate 20% increase in traffic. However, the other segments are well below the 75% congestion level. The primary cause of this one congestion point is the reduction from three to two lanes at Segment E181-E186. Therefore, it would appear that there is still no explicit demand for commuter rail between Birmingham and Montgomery. Additional research found that the actual daily travel between these two cities is currently less than 400 vehicles per day. Until more demand is present, it would appear that commuter rail will not be a priority project.

3.3 Evaluation of the Utilization of the International Intermodal Center in Huntsville, AL as an Inland Container Facility for the Port of Mobile.

The opening of the container port operations in Mobile, Alabama will have a profound impact on traffic on Alabama roadways. This subtask will focus on the initiation of an idea for utilizing Huntsville as an inland port in much the same way Front Royal, Virginia is used as a portal for the Port of Norfolk. The research team took the approach of understanding the issues and outcomes of other inland port operations as a first step in potentially bringing this concept to Alabama.

North Alabama offers convenient access to river, rail, and road transportation infrastructure as well as abundant flat land. North Alabama can facilitate receiving freight, processing, warehousing, and distributing freight through the southeastern and mid-western U.S. while minimizing impact on overcrowded highways. Requirements for these "logistics provider" type services could bring higher value jobs to regions in need of innovative economic development.

3.3.1 Background

An inland port is an inland facility that allows for the staging and transfer of intermodal, international freight. Containers coming into congested ports of entry are moved to the inland facility by train and then transferred to truck or other modes for distribution around the country. Inland ports are designed to relieve congestion at busy border ports by diverting truck traffic off the road network and also to move the transportation and distribution infrastructure closer to commerce centers. Other related services commonly located at inland ports are manufacturing space, customs and border control functions, and distribution and warehousing facilities.

The U.S. Department of Transportation (USDOT) has called for smarter transportation solutions with the focus on improving efficiency, achieving results, and increasing accountability. Traffic congestion is a growing threat to our economic well-being. The U.S. Chamber of Commerce has said that traffic congestion is one of the biggest problems facing our economy. More congestion, increased pollution, and increased accidents all hamper economic growth. Transportation bottlenecks and congestion damage air quality, slow commerce, increase energy consumption, and threaten our quality of life causing Americans to waste significant time and money. U.S. global maritime trade is expected to double and U.S. foreign trade in goods is expected to grow by more than half its current tonnage by 2020.

Major congestion that now occurs in and around marine ports and terminals at specific times will increase. 10,000 more trucks per day are projected to be traveling the I-95 corridor by 2020. This growth not only applies to the eastern seaboard but also in Alabama. The International Intermodal Center in Huntsville reached a new annual record for volume in 2003 and set a new monthly record for cargo lifts in January 2004. At the same time, barge traffic on Alabama inland waterways has steadily declined for more than 9 years. Interstate highway traffic through Alabama has significantly increased in both commercial and passenger categories.

There is not a true Intermodal system for the movement of freight in the southeast, but an aggregation of public and private modes. Each of these modes are “stove-piped” within their own individual areas of interest with little or no communication and coordination. There is not a transportation system, but rather a series of transportation entities that must be evaluated and negotiated to execute the movement of cargo.

The movement of freight through a system is where the economies of synergy and speed will provide a competitive advantage to Alabama logistics partners and provide the fertile ground for economic growth of Alabama industry. The need is for a systems approach to efficiently and profitably move freight to promote economic growth and social well being in Alabama.

The feasibility of developing an inland intermodal transportation network hub through objective research and models of existing transportation infrastructure should be undertaken. This research could establish a basic set of requirements on which federal, state, and local parties could begin serious consideration of the feasibility and priority of such a project.

3.3.2 Benefits

Benefits of an inland port could include:

- New, good-paying jobs for the region suited for the development.
- Rapid movement of freight into and through the Port of Mobile resulting in less congestion in and around the docks.
- Lower transportation and handling cost to shippers and customers by connecting and better balancing the use of river, rail, and road infrastructure.
- Reduced road congestion on interstate highways and state roadways in areas where traffic volumes currently exceed capacity, most often found in and around urban centers.
- Attraction of additional carriers and their related equipment to the southeast which increases access to freight transportation options while potentially reducing cost of transportation.
- Incorporating the management of the return of empty containers, delivering the containers just-in-time to the port(s). There they will be loaded on container ships for their return home.

3.3.3 Virginia Inland Port (VIP)

Any review of inland port activities must include one of the most successful examples of an inland port, The Virginia Inland Port (VIP). The VIP is located on 161 acres, 220 miles from the Hampton Roads Port of Virginia (Figure 3-13). Norfolk Southern Railroad runs 5 days a week from Hampton Roads to VIP. The VIP location has 17,820 feet of rail on 5 parallel tracks (Figure 3-14).

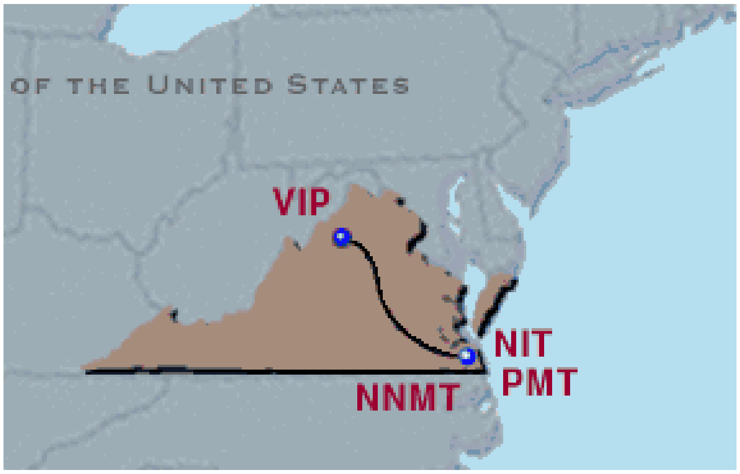


Figure 3-13 Location of the VIP

VIP is a Foreign Trade Zone (FTZ) and a U.S. Customs Port of Entry, with a full range of customs functions available. The VIP was developed with funding from the Virginia Transportation Trust Fund which allowed the project to begin operations without a debt load.

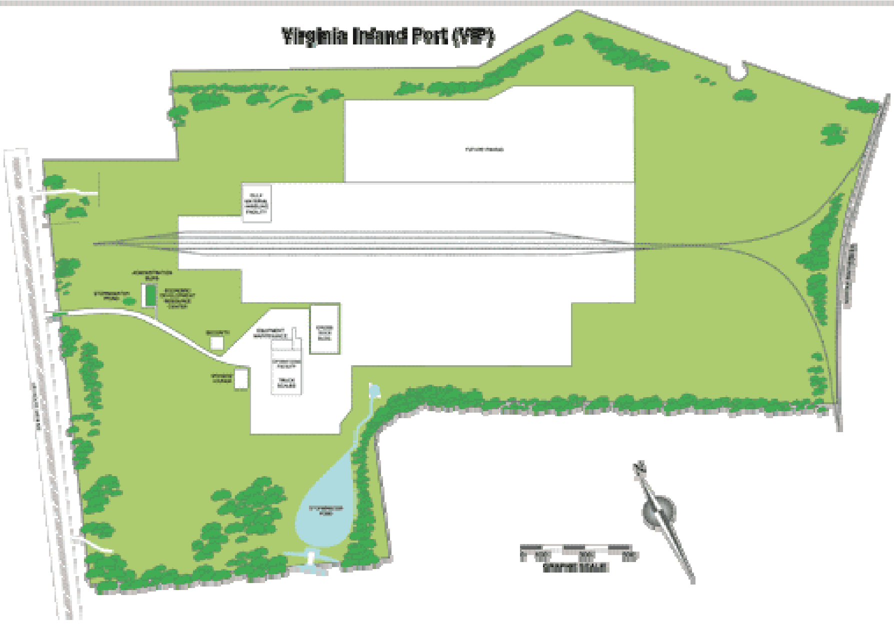


Figure 3-14 Layout of the VIP

The impact of the VIP has been impressive:

- 39 major companies have located near VIP
- Over $747,000,000 investment
- 8,500,000 square feet of buildings
- Employment of over 8,000
- Initial volume of 9,000 containers (1989); 20,000 by 1999.

3.3.4 International Inland Port of Dallas (IIPOD)

The IIPOD is a public-private partnership and is the third phase of regional intermodal development in Dallas, Texas. It is a key driver in making Dallas the nation's premier logistics and distribution center. IIPOD is a catalyst for investment, job growth, and development of sustainable communities with a goal of increasing the local tax base and employment.

Located in Southern Dallas County, the entire project's impact area covers 234,000 acres and encompasses 12 municipalities. The project takes advantage of the region's transportation infrastructure, including five interstate highways and two Class I railroads (Union Pacific and Burlington Northern Santa Fe), and is focused at the confluence of Interstates 35, 45, and 20.

When completed, the project will utilize an Agile Port System to speed processing from deep-water port locations inland, enhanced security (through technology) to facilitate the customs process, and expanded Foreign Trade Zone acreage. The total project is estimated to take 30 plus years to complete.

The focus of this inland port is to position Dallas to be the point where cargo from vessels too large to traverse the Panama Canal can be distributed throughout the United States. Each of these super container vessels can take up to twenty mile long trains to handle all of the containers destined for U.S. locations. Now instead of storing goods in the harbor of Long Beach, shippers can offload containers onto trains for transporting to the Port of Dallas where they are unloaded and put onto semi-trailers for shipments across America.

3.3.5 Critical Needs at an Inland Port - Huntsville Inland Port Analysis

Critical needs of an inland port have been identified by the Center for Transportation Research, University of Texas-Austin. The main items of concern are 1) Modal Capabilities, 2) Existing Demand, 3) Geographic Location Advantages, 4) International Trade Facilitation, and 5) Management Plan. Each of these items are presented below for the Port of Huntsville, International Intermodal Center (IIC).

3.3.5.1 Modal Capabilities

<u>*Highway Connectivity*</u>

North Alabama and the Huntsville/Decatur area is served by several U.S. Highways, including 31, 20,72, 231, 431 and an Interstate highway spur, I-565. I-565 links the two cities of Huntsville and Decatur to I-65. Figure 3-15 shows the access availability of the Huntsville/Decatur area, indicated by the star on the map.

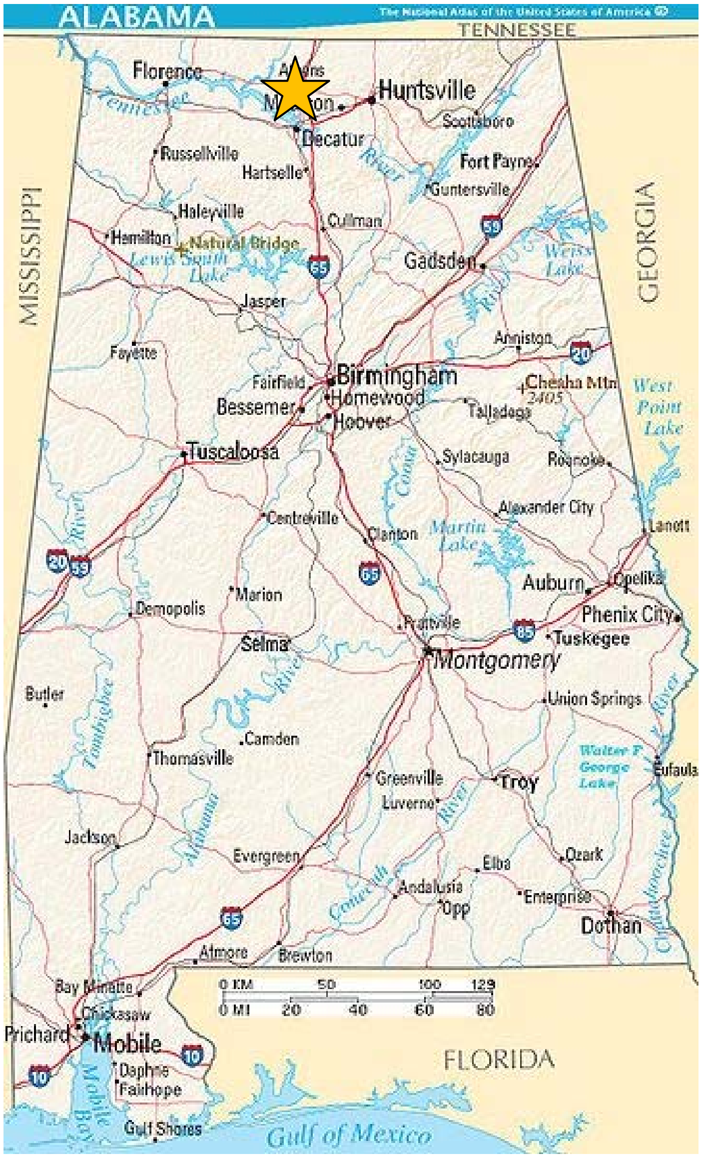


Figure 3-15 Map Indicating Access to North Alabama and Beyond

Figure 3-16 presents a closer look at the modality opportunities of the Port of Huntsville. Table 3-9 shows the distances and drive times to major roadways.

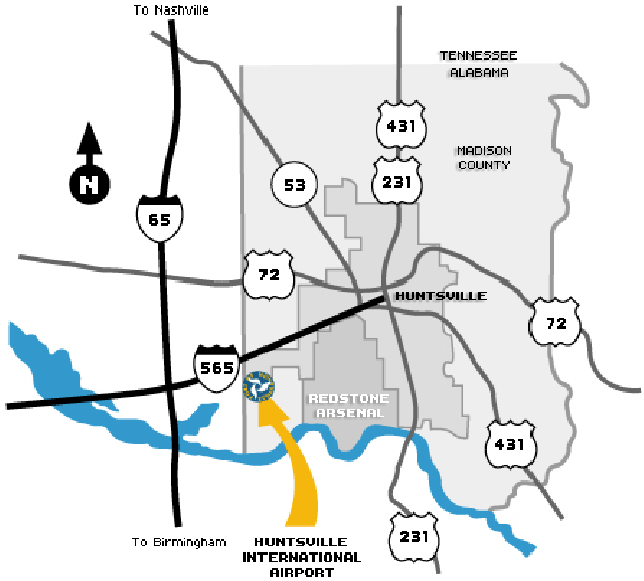


Figure 3-16 Closer View of Port of Huntsville Location

Table 3-9 Distances and Drive Times

ADHS Corridor or Interstate	Distance (miles)	Drive time
Corridor V East, I-565	1.5	3 minutes
Corridor V West, SR72	1.2	3 minutes
I-65	8.4	10 minutes
I-75	122	2.4 hours
I-40/I-81	123.8	2.4 hours

Proximity to rail, air or waterway transportation is a key component of the Modal Connectivity category.

Rail
The International Intermodal Center (IIC) at the Port of Huntsville contains 4 parallel tracks totaling 6 miles (31,680 ft). Rail connectivity is provided by Norfolk Southern. The IIC operates its own shortline railroad.

Air
The Huntsville International Airport is ranked 18 out of nearly 200 U.S. airports in annual international air cargo. The air cargo facilities are located immediately adjacent to the intermodal rail yard. The location has facilities for receiving storing, transferring and distributing air cargo as well as ground support equipment and acreage for future expansion.

Waterway:
The port of Huntsville lies in close proximity to Wheeler Lake along the Tennessee River, theoretically giving it access to the Tennessee-Tombigbee Waterway (Tenn-Tom). The Tenn-Tom waterway connects the Port of Mobile with several other river systems and provides an alternate route from the Gulf of Mexico. However, the Wheeler Lake Wildlife Refuge lies between the port and the river which makes it uncertain that access through the Wildlife Refuge will be authorized.

Figure 3-17 Port of Huntsville in Relation to Waterways

3.3.5.2 Existing Demand

Existing Cargo Shipped
In 2008, the port moved 162,191,361 tons of freight and conducted 46,303 container lifts.

Existing Motor Carriers or Freight Forwarders
The Swiss freight forwarder, Panalpina, uses the Huntsville airport as its North American air cargo hub and operates 18 B747 flights weekly. Fourteen steamship lines and 20 drayage companies serve the Huntsville International Intermodal Center. An additional 9 freight forwarders are located at or near the location.

3.3.5.3 Location Advantages

The North Alabama/South-Central Tennessee area has a larege population base. A 50-mile radius of the Huntsville metro area contains 899,893 persons. A 100-mile radius contains approximately 4.2 million people.

Freight with origins and destinations within a 600-mile radius is normally trucked to and from Huntsville. Huntsville's air cargo capabilities and rail connections can accommodate origins and destinations beyond 600 miles. Figure 3-18 indicates the area and distances served by the Port of Huntsville.

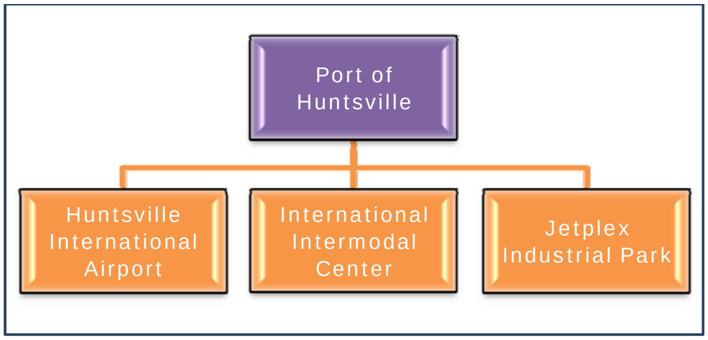
Figure 3-18 Distances from Port of Huntsville

3.3.5.4 International Trade Facilitation

The U.S. Customs and Border Protection provides 24-hour services to the IIC. USDA inspectors are also available at the port. The IIC offers Public Use Foreign Trade Zone No. 83.

3.3.5.5 Management Plan

Since this is one of the first reviews of utilizing the Port of Huntsville as a inland port connection with the Mobile container port, a management plan is not yet in place.



3.3.6 Summary

The Port of Huntsville is a principle transportation hub in the Southeastern U.S. with amenities particularly attractive to businesses dealing with international cargo. This intermodal complex provides excellent aviation, rail, and road connectivity. The port has most of the infrastructure needed to establish itself as an inland port to the Port of Mobile. Going forward, the important considerations are:

- The level of rail service – is it sufficient?
- Funding needed for upgrades – what are the sources available?
- Impact on road network and port – does it justify the project?
- Marketing – a plan needs to be developed to promote the use of the Port of Huntsville.

3.4 Section 3 References

[1] Bruzzone, A., and P. Giribone, (1995). “Decision Support Systems and Simulation for Logistics: Moving Forward for a Distributed, Real-Time, Interactive Simulation Environment,” *Proceedings of Summer Computer Simulation Conference*. Ottawa, CA, USA.

[2] ProcessModel, 1999: *Users Manual*, ProcessModel Corp., Provo, UT.

[3] Harris, G., A. Holden, B. Schroer, and D. Moeller, 2007: “Coal Terminal Simulation,” *Proceedings of 2007 Huntsville Simulation Conference*, Huntsville, AL, October.

[4] Sanchez, C., R. Uribe and J.Espinal, (2007). “Port Simulation Model for the Discharge and Delivery of Imported Coal for a Thermal Power Plant Located in Lazaro Cardenas Port, Mexican Pacific Coast,” *Transactions of Wessex Institute*, http://library.witpress.com

[5] Loyd, N. Application of Lean Enterprise and Six Sigma as an Amalgamated Improvement Strategy. *Lean Management: Concepts and Industry Perspectives*. Icfai University Press, 2007, pp 23-48

[6] NIST, 1998: *Principles of Lean Manufacturing with Live Simulation Users Manual*, NIST Manufacturing Extension Partnership, Gaithersburg, MD.

[7] Ohno, T. *Toyota Production System*. Productivity Press, Portland, OR, 1988.

[8] Womack, J, and D.T. Jones. *Lean Thinking*. Simon & Schuster, New York, NY, 1996.

[9] Rother, M., and J. Shook. *Learning to See*. The Lean Enterprise Institute, Brookline MA, 1999.

[10] Harris, G., A. Holden, B. Schroer and D. Moeller, 2008: "A Simulation Approach to Evaluating Productivity Improvement at a Seaport Coal Terminal," *Transportation Research Record, Journal of the Transportation Research Board No. 2062, Ports and Waterways*, pages 19-24.

[11] Harris, G., L. Jennings, B. Schroer, and D. Moeller, 2007: "Container Terminal Simulation," *Proceedings of 2007 Huntsville Simulation Conference*, Huntsville, AL, October.

[12] Harris, G., B. Schroer, M. Anderson and D. Moeller, 2009: "Resources to Minimize Disruption Caused by Increased Security Inspection of Containers at an Intermodal Terminal: Application of Simulation." Accepted for Publications in the *Transportation Research Record, Journal of the Transportation Research Board, Paper Number 09-2126*

[13] Schroer, B., G. Harris, W. Killingsworth, M. Anderson and D. Moeller, 2009: "Simulation of an Intermodal Container Center Served by Air, Rail and Truck," *Journal of Advanced Transportation,* accepted for publication in 2009.

[14] *Highway Capacity Manual.* 2000: Transportation Research Board, Washington, D.C.,

[15] *ProcessModel Users Manual*, 1999: ProcessModel Corp., Provo, UT.

[16] Harris, G., M. Spayd, M. Anderson, B. Schroer and D. Moeller, 2008: *Discrete Event Simulation of Interstate Traffic: Fidelity Comparison with CORSIM*, Research Report, University of Alabama in Huntsville, Huntsville, AL.

[17] Holm, P., D. Tomich, J. Sloboden, C. Lowrance, 2007: *Traffic Analysis Toolbox Volume IV: Guidelines for Applying CORSIM Microsimulation Modeling Software,* Federal Highway Administration. Washington, D.C.

4. Enhancement and Expansion of the Application of Continuous Improvement Principles for Port Operations

Since 2003, UAH has worked with the Alabama State Port Authority (ASPA) to apply continuous improvement concepts, primarily Lean Enterprise, to improve overall port operations. The application of these continuous improvement concepts have included strategic planning, training, and implementation in a wide range of port operations such as coal terminal operations, short-line railroad operations, general cargo operations, and support functions such as maintenance, garage, and corporate accounting and payroll.

In the 2005 report on *Transportation Infrastructure in Alabama - Meeting the Needs for Economic Growth* to the USDOT, UAHuntsville researchers identified Logistics and Transportation Systems as one of the industry clusters with the most potential to provide vibrant economic growth for Alabama. In the 2006 report *Transportation Infrastructure in Alabama – Tools for Solutions* to the USDOT, UAHuntsville researchers identified and explained the need for continuous improvement in our transportation and logistics operations to achieve the economic growth potential in this industry cluster.

In the 2007 report on *Transportation Infrastructure in Alabama – Bridging the Data and Information Gap* to the USDOT, UAHuntsville research focused on relating how the concepts of continuous improvement that are considered part of the Lean Enterprise approach to continuous improvement apply to logistics and transportation entities. The UAHuntsville team provided a summary of the application of Lean principles over the past five years at the Port of Mobile, AL.

In FY 2008, the successes and lessons learned from this extensive experience were integrated into an 8-hour Lean Principles for Port Operations training course. Container terminals are a vital part of many of the nation's port operations. An enhancement of the current Lean Principles for Port Operations training course to include experience and examples related to container terminal operations would make the training more beneficial and applicable for all ports. The current 8-hour training course provides an excellent overview of the benefits of applying continuous improvement concepts at port operations. However, expanding the training offerings to include more detailed instruction on the "how-to" aspect of implementation would allow ports to develop internal resources to assure the sustainment of improvements.

Research performed during this period of performance was to enhance and expand the existing research on continuous improvement in seaport operations by going beyond the bulk handling activities of the Port of Mobile to include container handling activities

4.1 Enhancement of Lean Principles in Port Operations Training Class to Include Container Terminal Operations

Previous UAHuntsville research in the field of continuous improvement in seaport operations was based on the application of Lean Enterprise principles at the Port of Mobile, Alabama—a port whose operations are primarily oriented around bulk cargo handling. In order to make the research more comprehensive to seaports in general, further research was needed in the area of container terminals. During this research period, the UAHuntsville team gained knowledge in the area of container terminals through visiting and participating in continuous improvement efforts at multiple container-handling facilities. Finally, this experience was utilized to enhance the previous research and to develop and document a one-day *Lean 101 for Seaport Operations* training course.

4.1.1 Research and Data Gathering Through Visits to Container Terminals for Observation

In April 2009, UAHuntsville researchers traveled to Mobile, Alabama for the purpose of observing daily operations at the Mobile Container Terminal. Prior to arriving at the terminal, arrangements were made with the terminal director to strategically schedule the observation trip in order to observe the largest ship Mobile Container services each week.

Upon arrival, the terminal director provided the UAHuntsville team with a general overview of the daily activities at the terminal and a tour of the office/support area. Observations were made relative to technology and methods used to coordinate the terminal's logistics. These technologies included their modern camera system to inspect arriving truck/trailers and a customized software system to manage terminal activities. The research team was then escorted around the facility and given a general overview of the layout and the typical operational activities.

The UAHuntsville team was introduced to one of the crew supervisors and performed ship-side observations of the container unloading/loading process. Next, the observation focused on the processes of storing, loading, and unloading containers in the terminal yard. Observations were made regarding the software system used to manage inventory, the information flow of the process, and the methods involved in physically loading/unloading and storing containers. The visit concluded with a tour of the maintenance building where repairs are made to all equipment on-site.

The UAHuntsville research team was able to observe for approximately 8 hours and document best practices, opportunities for improvement, and general comments by making notes, interviewing experienced personnel, and taking digital pictures. The observational visit served to provide a deeper understanding of container-handling operations and also provided valuable experience, examples, and materials to broaden existing training on lean in seaport operations.

4.1.2 Research and Data Gathering Through Participation in Continuous Improvement Events at Container Terminals

In order to gain further exposure to container handling operations, the UAHuntsville research team offered the application of their existing Lean Enterprise services to interested container facilities. UAHuntsville Lean Enterprise services include comprehensive lean assessments, a variety of general lean training courses and facilitation of improvement activities. The Dole Fresh Fruit facility in Gulfport, MS agreed to participate by having the UAHuntsville researchers conduct a full lean assessment in July 2009. Two UAHuntsville lean research engineers spent 2 days on-site at the Dole container facility collecting data and performing the assessment with input from key Dole personnel. The executive summary of the assessment is included below.

4.1.2.1 Assessment Purpose

The purpose of this assessment was to provide Dole Fresh Fruit Gulfport (Dole) with a "Lean Enterprise" assessment of their Banana/Pineapple operation in Gulfport, Mississippi. A lean enterprise assessment provides a snapshot analysis of where a company is currently in regards to efficient and effective operations. The assessment also evaluates the facility against recognized best practices found in operations throughout the country who are successfully implementing Lean Enterprise.

This assessment focused on several areas of operations including, but not limited to communication within the organization, workplace organization, visual systems, standardized work, Total Productive Maintenance, and inventory management. This assessment identified areas of opportunity for improvement, focused on the tools and methodology of lean enterprise, and provided recommendations to determine the best approach to achieve lean excellence.

Lean enterprise transformation is achieved through vision, training, implementation, and discipline. The process begins with the establishment of a customer-focused vision that all personnel involved in the Gulfport operations can embrace (including contract union labor, stevedores, tugboat services, etc.).

Training is employed to achieve a common level of language and knowledge for all personnel involved in the Gulfport operation. Value Stream Mapping is employed to identify areas for improvement and develop an improvement plan. The preferred method of implementation is through kaizen, employee involved, team oriented, fast paced, continuous improvement events. The transformation is sustained through discipline by adhering to new, improved processes/procedures, and management conveying the importance of Lean improvements to all employees.

Successful implementation of lean enterprise benefits organizations by producing results relative to reduced operating cost, increased productivity, improved quality, and enhanced customer satisfaction.

4.1.2.2 Assessment Implementation

This assessment was performed on July 13-14, 2009 with the objective of evaluating Dole Fresh Fruit Gulfport's daily operations. During our visit, we observed a well managed seaport operation. All Dole employees we interviewed seem very competent and knowledgeable of their area of responsibility. There was good communication within Dole's management team and with the contract union labor supporting the operation. The research team observed very detailed planning and flexibility to efficiently unload/load the vessel and there was a seemingly effective maintenance program in place for all onsite equipment.

Although this is a well managed operation, several opportunities for improvement were also observed. The first of these opportunities was the absence of a visible company vision/mission statement anywhere on the facility. From a strategic standpoint, the presence of a vision and mission statement gives a reference point by which to focus efforts and make decisions.

The next observed opportunity identified was the absence of a management steering committee to coordinate and direct improvement activities. Although terminal management and staff meet on a regular basis there is no formal team-based ownership of continuous improvement activities. The next opportunity observed was the absence of value stream mapping. Proper value stream management is critical to a successful operation. Typically, a lean organization's management steering committee comprises of the managers of each value stream and key operational executives.

Next, was there were no standard operating procedures (SOPs) posted anywhere on the facility. Although most employees know what to do, the fact that no SOPs are being used contributes to errors/mistakes being made and a heavy dependence on-the-job-training (OJT) for all new employees. This typically results in inconsistent work methods and increased time to accomplish proper training.

Improvement opportunity was observed in the lack of posted performance metrics in the work areas. Dole collects and manages to certain performance data related to each process. Yet none of the information is clearly posted so that the people who have the most influence on this data know at a glance how well they are doing. For example, during the unloading/loading of the vessel, data is collected for lifts per hour from each crane. This data is used very well at Dole to make adjustments to the unloading/loading plan based on each crane's performance. This information should be posted visibly each hour so every employee involved in the unloading/loading operation knows the current status of the operation.

There was a gap found in the lack of a Total Productive Maintenance program (TPM) for the equipment on the ship (specifically the cranes). Both gantry cranes on the ship are the lifeblood of the unloading/loading activities yet they break down occasionally. A TPM event for the gantry cranes would establish a complete maintenance program for each crane and greatly reduce unplanned downtime.

Another area identified was the absence of visuals in the warehouse operations. Simple visual communication (signs, charts, lines on the floor, visual work instructions, etc.) allows every employee to have immediate understanding of a situation or process.

The last area observed was in the maintenance building/tent where chassis maintenance was being preformed. Even though the maintenance management at this location is superior to most maintenance facilities we visit, there is opportunity to improve workplace organization. At a glance, the area appears to be clean but the application of a systematic workplace organization system could greatly reduce time spent searching for needed tools and equipment for repairs. Ultimately, this could result in less time to perform repairs meaning critical equipment can return more quickly to its operation.

The full assessment can be found in Appendix A

4.1.3 Documentation and Integration of Knowledge and Experience Gained Through Observation and Participation at Container Terminals to Make the Lean Principles for Seaport Operations 8-Hour Training Course More Comprehensive

The container terminal information and materials gained from tasks 4.1.1 and 4.1.2 combined with the UAHuntsville staff's vast expertise in general seaport operations from over 6 years of research at the Port of Mobile, Alabama, resulted in the development of a training course, *Lean 101 for Seaport Operations*. This 8-hour training course consists of over 100 PowerPoint slides and a collection of hands-on exercises to train port professionals on the principles, techniques, and benefits of applying Lean Enterprise concepts to seaport operations. Below is a course description.

4.1.3.1 Lean 101 for Seaport Operations - Course Description

The principles of Lean Enterprise are demonstrated through lecture and real-world case studies focused specifically on seaport operations. The Lean Enterprise Implementation Model for Seaports is introduced and serves as the guideline for successful transformation. The key managerial components for successfully sustaining the benefits of Lean Enterprise in seaport operations are discussed and emphasized in a systematic approach.

Objectives/Topics

- Introduction and background of Lean Enterprise
- Why Lean at Seaports?
- The Eight Deadly Waste in Seaport Operations
- Lean Enterprise Implementation Model for Seaports
- Workplace Organization Tools
- 5S System
- Visual Workplace
- POUS
- Workplace Analysis Tools
- Layout
- SMED Principles (Internal and External Activities)
- Standardized Work
- Workplace Optimization Tools
- Quality at the Source
- Total Productive Maintenance
- Continuous Improvement Culture
- Kaizen

- Teamwork and Lean Workforce Culture
- Customer Focused Management
- Value Stream Management
- Benefits of Lean Enterprise at Seaports

Course Style and Format
This course demonstrates the benefits of Lean Enterprise by providing extensive examples and real-world case studies for each topic relative to seaport operations. The instructors' knowledge and experience provide depth and credibility to the benefits that can be obtained in the industry by following the implementation model.

4.2 Expansion of Lean Training Offerings Customized for Seaport Operations

The Toyota Production System by Taiichi Ohno discusses at length the importance of developing internal resources to champion the efforts of implementing their continuous improvement philosophies. The UAHuntsville team's experience and research in implementing those same principles, Lean Enterprise, with a variety of industries and organizations over the past 10 years only strengthens this idea. The UAHuntsville researchers developed a more in-depth, 3 day training course specifically designed for those practitioners at seaports who will charged with championing lean efforts. The following is an outline of this course.

4.2.1 Outline for Expanded (3 Day) Lean Enterprise for Seaport Operations Certificate Series

Day 1
Lean 101 for Seaport Operations- (8 hours) This course is the original Lean 101 for Seaports training course developed by UAHuntsville and serves as the foundation for the remainder of the training series. This one-day overview course provides discussion on the background of Lean Enterprise principles, challenges that are facing today's seaport operations, and how lean concepts address those challenges. The eight deadly wastes, which serve as the fundamental learning focus of any lean program, are related specifically to seaport operations with real-world examples and experience. Additionally, the UAHuntsville Lean Enterprise for Seaports implementation model is introduced, highlighting specific tools that have been proven to eliminate waste in the industry. Key learning points are reinforced through the illustration of real-world seaport case studies.

Day 2

Workplace Organization- (4 hours) The workplace organization tools of the UAHuntsville Lean Enterprise for Seaports implementation model are taught in this course. Workplace Organization is the foundation of successful lean transformation. Participants learn how to properly implement a workplace organization system utilizing the tools of 5s, point-of-use storage, and visual workplace. Participants are also be exposed to tools such as daily checklists and 5s audits that allow successful long-term management of a workplace organization system. Key learning points are reinforced with a hands-on simulation.

Total Productive Maintenance- (4 hours) Equipment is the lifeblood of most seaport operations. Equipment downtime directly affects loading, unloading, storage, and retrieval times and can dramatically slow down port velocity. This course equips participants to identify and manage the “6 big losses” categories of equipment downtime. The key performance measure of overall equipment effectiveness (OEE) is discussed. Additionally, participants learn how to integrate preventive and predictive maintenance methods to effectively manage OEE metrics while striving for zero unplanned equipment downtime. Key learning points are reinforced with a hands-on simulation.

Day 3

Standardized Work- (2 hours) In a continuous improvement environment, there can be no improvement without standardization. Many seaport operations face the challenges of having no formal training programs for new hires and having no formal documentation of the vast knowledge of its existing employees. This course emphasizes the importance of developing standardized work procedures, how to effectively develop standardized work procedures, and the benefits of utilizing standardized work procedures. Key learning points are reinforced through the illustration of real-world seaport case studies.

Value Stream Management- (6 hours) Value stream management is vital to the integration of lean into an organization’s overall structure and strategy. This course will address the topic of value stream management on two levels. First, the technique of Value Stream Mapping is introduced. Participants learn to properly identify value streams within an organization and construct current state and future state value stream maps. Strong emphasis is placed on developing a systematic value stream implementation plan to achieve the desired future state over a desired planning horizon. Next, participants learn critical concepts of value stream management. Management topics include identifying and tracking key performance metrics and using those metrics to follow-up and review the value stream implementation plan. Proper value stream management is essential to the achievement of desired future state results over the value stream planning horizon. Key learning points are reinforced through the use of a seaport value stream exercise.

4.3 Supplemental Activities Related to the Research Tasks

During the course of conducting the 2008-2009 research, the UAHuntsville research team's involvement with this research task allowed them to participate in additional activities. These include:

- Presentation of "*The Application of Lean Enterprise Principles to Improve Seaport Operations*" paper at the Transportation Research Board (TRB) national conference in Washington, D.C. in January 2009

- Presentation of "*Modern Continuous Improvement Methods to Improve Seaport Velocity and Productivity*" special presentation at the American Association of Port Authorities (AAPA) Port Operations, Safety, and Information Technology Seminar in Seattle, WA in June 2009

- Publication of "*Lean Enterprise Model Supplies Strategic Shift*" guest article in AAPA Seaports magazine

- Invitation to present on Lean Enterprise for Seaports at the Port Productivity Conference in Long Beach, CA, originally scheduled for April 2009, rescheduled for October 2009

- Invitation to present a 4-hour workshop on Lean Enterprise for Seaports at the AAPA Marine Terminal Management Training Program in Long Beach, CA in September 2009

5. Student Research Initiatives

Doctoral and Masters Students bring fresh ideas and concepts to research. UAH will utilize opportunities to support research with graduate student involvement in Tasks 1 – 3 above along with other freight transportation related projects currently ongoing and proposed. In addition, the student research initiatives have the potential to encourage the development of new ideas that can be expanded into further research efforts in the coming years. The papers presented in this section have been produced by graduate students in Civil and Environmental Engineering at UAHuntsville. They are presented here as they were submitted. In most cases, this work was their thesis upon completing their academic work for a Masters degree.

5.1 Using FAF2 Data to Analyze Freight Impact of Interstate 22

Dr. Michael D. Anderson, P.E.
Associate Professor
Civil and Environmental Engineering
The University of Alabama in Huntsville
Huntsville, AL 35899
256-824-5028
256-824-6724
mikea@cee.uah.edu

Mary Catherine Dondapati
Civil and Environmental Engineering
The University of Alabama in Huntsville
Huntsville, AL 35899
256-824-6854
256-824-6724
catherinemaryd@gmail.com

Dr. Gregory A. Harris, P.E.
Director Office of Freight, Logistics and Transportation
The University of Alabama in Huntsville
Huntsville, AL 35899
256-824-6060
256-824-6940
harrisg@uah.edu

ABSTRACT

Freight forecasting has recently become a major focus for infrastructure investment decisions. The focus of this paper is to examine the impacts of a multistate interstate construction project currently underway in Alabama and Mississippi that will have a major impact on travel patterns in the southeastern. This paper documents use of a national travel demand model and the Freight Analysis Framework Version 2 (FAF2) to identify the forecasted impact of Interstate 22. The paper concludes that the application of the large scale, low detail travel demand model and FAF2 data can be used to analyze freight impacts.

KEYWORDS

Freight
Freight Modeling
Statewide Modeling
Impacts

Using FAF2 Data to Analyze Freight Impact of Interstate 22

INTRODUCTION

Regional modeling on a multi-state scale is often not performed due to lack of necessity and data. In Alabama, interest has been raised relating to the freight transportation impact of completing future Interstate 22, between Birmingham, AL and Memphis, TN. This interstate link will provide new access to and between economic centers that previously required lengthy travel on non-direct routes. The Freight Analysis Framework Database Version 2 (FAF2), based on the Commodity Flow Survey, provides the best freight data currently available and includes annual kilo-tons of freight moved by mode segmented into 42 commodities.

The goal of this paper is to examine the freight impacts of opening Interstate 22 to vehicle traffic in 2015, as well as the unexpected consequences that will occur because of the additional infrastructure. The research performed utilizes a national-level travel demand model developed to analyze the traffic flow patterns and applies the FAF2 data as the basis for the freight flows. This paper identifies previously completed studies related to regional and statewide models as well as providing background into the FAF2 database. The paper then presents an analysis of the traffic flow patterns that are created as a result of adding Interstate 22. The paper concludes that the application of regional or national models and quality freight flow data can be a useful tool in examining changes in traffic patterns and the impacts of those changes on a grand scale.

BACKGROUND

To understand the issues of modeling in the grand scale, a brief review of statewide models and the FAF2 data are provided.

Statewide Models

Statewide models are often developed to examine traffic flows and support infrastructure investment decisions for analyses that extend beyond the boundaries of a Metropolitan Planning Organization. These models are often developed and operate similarly to travel demand models used in the urban areas as the goal of applying the model is to forecast future travel, but with less density in the network and larger, more aggregated zones. The following provides a brief listing of a few statewide models that have been developed in recent years.

- 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 [1].
- In another recent study in Mississippi, a prototype simulation model of freight movements was developed [2]. This model used the Commodity Flow Data, Cargo Density Database (U.S. Department of Transportation 2000) and Vehicle Inventory Used Survey data (U.S. Department of Commerce 1997) as freight inputs. Simulations were performed in TransCAD to model the transportation system performance using the traditional four-step transportation planning process.
- 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 for freight flow projections [3]. Basic model assumptions are that the demand for truck transportation is assumed to not be the same for different economic regions, i.e. the truck traffic interacts independently.
- The Intermodal Statewide Highway Freight Model is intended to serve as a planning tool for the identification and measurement of truck activity within the state in support of providing adequate highway connection to other modes and regional freight hubs. The explicit consideration of intermodal connectivity is required in planning facility improvements for the Florida Intrastate Highway System (FIHS) and the proposed Florida Intrastate Transportation System (FITS) [4].

As can be seen by the studies, the thrust behind developing these statewide models is to assess the impacts of traffic growth and infrastructure needs. However, there is limited ability in any of the models to assess the impact of infrastructure improvements that occur in one state, the ramification that might occur in neighboring states. In addition, many statewide models identify a limited ability to forecast external freight flows because these values are not available through traditional surveying methods.

FAF2 Database

The foundation of any reasonable prediction for freight activity in an area is based on the availability of accurate and verifiable freight flow data. Currently, the best available data for this use is available from the Federal Highway

Administration's Freight Analysis Framework (FAF) database.

The second generation of the Freight Analysis Framework (FAF), known as FAF2, is a continuation of the original Freight Analysis Framework developed by the U.S. Department of Transportation, Federal Highway Administration (FHWA) [5]. Whereas the original FAF provided the public with generalized freight movement and highway congestion maps without disclosing the underlying data, FAF2 provides a commodity flow origin-destination (O-D) and freight movement data on all highways within the FAF2 highway network. The FAF Commodity Origin-Destination Database estimates tonnage and value of goods shipped by type of commodity and mode of transportation for 114 FAF2 zones (shown in Figure 1) 7 international trading regions and 17 additional international gateways, [5]. The 2002 estimate is primarily derived from the Commodity Flow Survey (CFS) with some of the data voids in the CFS filled in by analysis of the Economic Census and other data sources. Forecasts are included for 2010 to 2035 in 5-year increments [5]. The data are available in Microsoft Access format and contain values in millions of dollars of value and thousands of short tons.

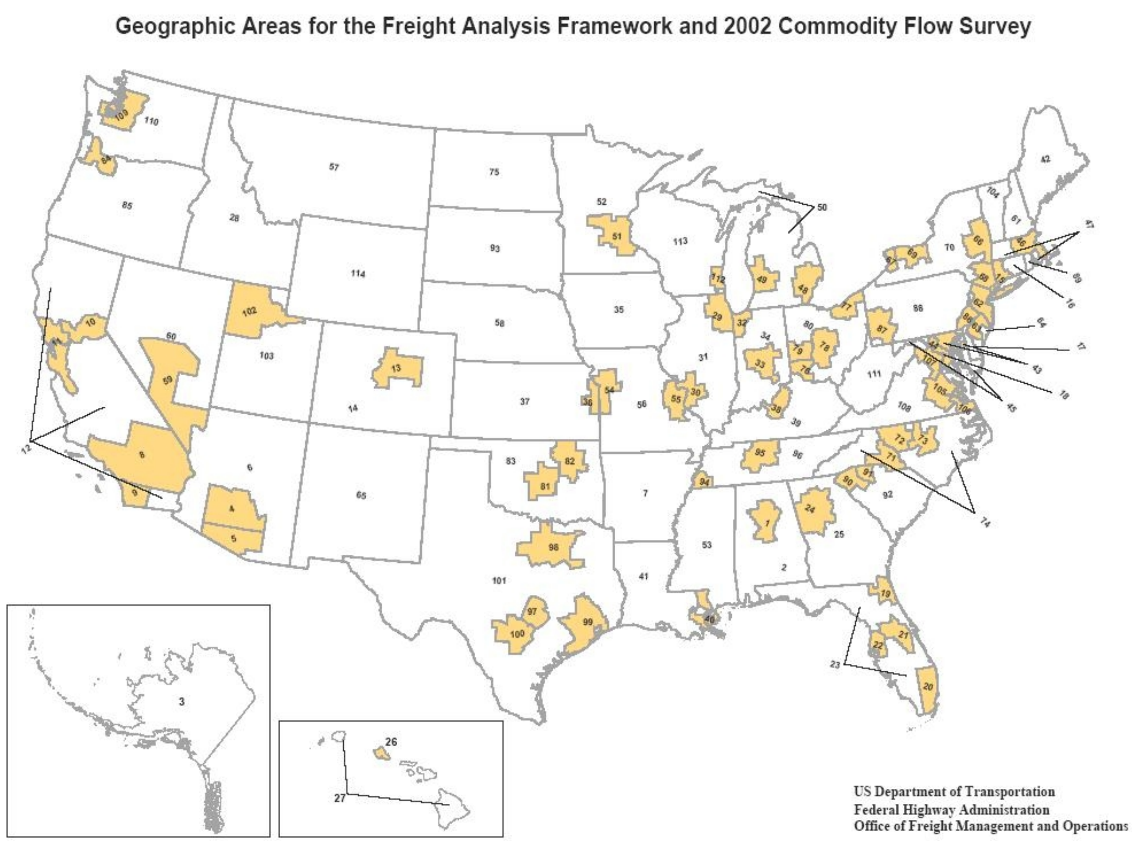


FIGURE 1 Geographic locations for FAF2 data [6].

The use of the FAF2 database for national level freight modeling has yet to be addressed. This study presents the first of potentially many studies that can benefit from the collection and distribution of this dataset.

CASE STUDY: INTERSTATE 22

Interstate 22 will be constructed to connect the urban areas of Birmingham, AL and Memphis, TN and is expected to be open for traffic between 2010 and 2015. The interstate is intended to replace U.S. Highway 78 with a high-speed, controlled access facility. The location of the interstate can be seen in Figure 2.

To model the freight flow patterns that will be impacted by the construction of Interstate 22, a national-level travel demand models was created using the FAF2 zone descriptions and existing interstate facilities. The 114 zones were selected as the traffic analysis zones for the model as the data from the FAF2 are designated using these locations as the base for which the freight data had been aggregated. The existing interstate infrastructure was used to represent the transportation network using the travel model. The roadway segments in the model were attributed with distance (using a scale factor because of the large distances) and the speeds for vehicles on the interstates. The nationwide network used in the process can be seen in Figure 3. An alternative network was developed for purpose of this study that included a link for Interstate 22 from Birmingham to Memphis.

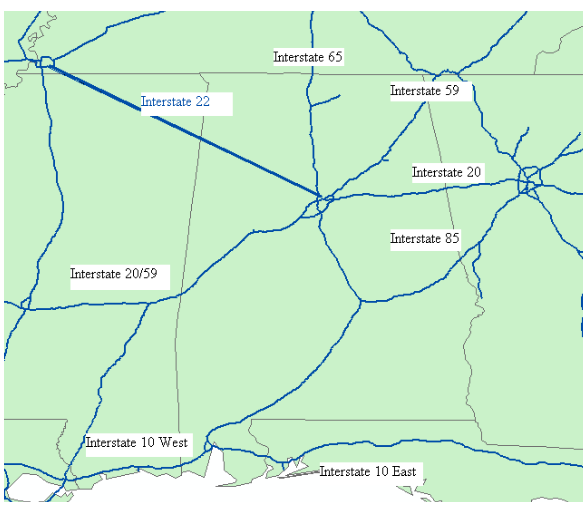


FIGURE 2 Location of Interstate 22.

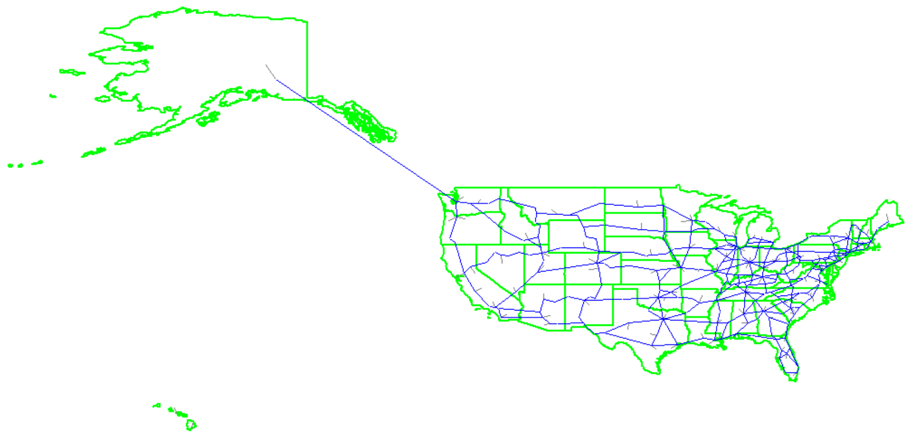


FIGURE 3 Nationwide travel demand model network.

Assigning the data from the FAF2 database and focusing on the amount of freight passing through Alabama, it can be seen that there is an increase in annual tons of freight expected to pass through Alabama as a result of the completion of the interstate. Table 1 shows the increases expected to cross the state in five year increments, as collected and maintained in the FAF2 database.

TABLE 1 Total annual tons of freight passing through Alabama

Model	2015	2020	2025	2030	2035
Without I-22	432,874,110	484,783,310	552,931,760	639,775,080	744,630,330
With I-22	460,402,630	514,947,390	586,649,260	677,702,680	787,057,710
Percent Increase	6	6	6	6	6

Examining the road-by-road impact of Interstate 22, it can be seen that there are a variety of increases and decreases. Table 2 shows the differences in annual toms expected for each roadway after the completion of Interstate 22 (a positive number means additional freight, a negative numbers means a decrease in freight).

TABLE 2 Difference in Annual Tons for each Alabama interstate.

Interstate	2015	2020	2025	2030	2035
I-22 Between Birmingham and Memphis	17,655,520	19,464,200	21,624,380	23,953,370	26,446,160
I-65 North of Birmingham	-6,176,640	-6,949,890	-7,744,380	-8,589,850	-9,473,720
I-20 Between Birmingham and Atlanta	10,318,240	11,264,150	12,481,860	13,835,430	15,333,990
I-10 Between Florida and Mississippi	-277,010	-361,070	-512,320	-651,280	-796,830

Examining the results, the completion of Interstate 22 will reduce freight transportation on both Interstates 10 and 65. This reduction in freight will not only affect Alabama, but will also impact roadways in Florida and Mississippi regarding Interstate 10 and Tennessee and Kentucky regarding Interstate 65. These future reductions in freight needs will have beneficial impacts regarding congestion and maintenance in Alabama as well as the neighboring states. The other interstates show a significant increase in freight transportation. These increases will affect how Alabama spends infrastructure money, but will also impact Georgia, Mississippi, and Tennessee as these interstates extend beyond the state line.

CONCLUSIONS

This paper examines the application of a national travel demand model and uses the Federal Highway Administration's Freight Analysis Framework Database Version 2 (FAF2). The results indicate that focusing on a statewide model examining one state, the impact of the completion of Interstate 22 may result in underestimates of freight transportation needs as the completion of the Interstate 22 route affects travel patterns on a regional level, beyond a single state. Additionally, the use of the FAF2 database for transportation planning activities identifies a novel use of the origin-destination freight flow data available. The notion of using the FAF2 dataset for regional or statewide travel models represents a tool that was not currently available in previous models. Overall, the contribution of this paper is the discussion of the ability to forecast regional or multi-state freight flows to support potential infrastructure decisions, improve the allocation of maintenance funds, or identify potentially congested roadways in future.

REFERENCES

1. Brogan, J. J., S. C. Brich, M. J. Demetsky, *Application of a Statewide Intermodal Freight Planning Methodology*, Report Submitted to Virginia Department of Transportation, 2001.
2. Tan, A. R. Bowden, Y. Zhang, *A Virtual Simulation of Statewide Intermodal Freight Traffic*, Report Submitted to Mississippi Department of Transportation and TRB 2004 Annual Meeting, 2003.
3. Souleyrette, R. R., Z. N. Hans, and S. Pathak, *Statewide Transportation Planning Model and Methodology Development Program*, Report Submitted to Iowa Department of Transportation, 1996.
4. Florida Intermodal Statewide Highway Freight Model http://webservices.camsys.com/freightmodel/freightmodel.htm
5. FAF2 Internet Page. http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/faf2userguide/index.htm
6. FAF2 Internet Page. http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/cfs_faf_areas.htm

5.2 Further Research on Disaggregation of Freight to a Local Level

Prepared for:
Dr. Michael Anderson

Author:
Tahmina Khan

1 Abstract

Growth of economy strongly depends on the effective and efficient movement of freight. Continued growth of the economy cannot occur without adequate and appropriate transportation infrastructure. This decision could be appropriately made if the forecast of freight volume in local level can be accomplished accurately. Difficulty of gathering local level freight flow impedes the planners to incorporate the freight into transport model. This study is to develop a method of disaggregation after understanding and identifying freight activity and factors affecting freight activity. The study has been conducted for Alabama using FAF2 database. The aim of this study is to do a further analysis on disaggregation of 2 FAF2 regions of Alabama at national level into 67 individual counties at the state level for use in a statewide or local transport model.

There are also some other research papers that describe factors, production, and attraction equations to disaggregate origin and destination flows. Looking at their applied factors and methods can give more information on new potential ideas for disaggregation. These help to include numbers of possible equations. Disaggregated data has been distributed and assigned on 661 roadways of Alabama using the modified CUBE/TRANPLAN model.

2 Introduction

2.1 Overview of Freight planning for truck

Growth of economy strongly depends on the effective and efficient movement of freight. Due to economic expansion, the increase in globalization of manufacturing and international supply chains, the growth in demand for freight transportation and truck traffic in the US are increasing at a significant rate and there is no end in sight (*1*).

Continued growth of the economy cannot occur without adequate and appropriate transportation infrastructure. This decision could be appropriately made if the forecast of freight volume in local level can be accomplished accurately (*1*). Before planning for future traffic, it is required to analyze the base year traffic volume and measure the deviation between the output and actual field count. The step by step planning process shown in Figure 1 can be carried out for a number of runs to get truck trips on the local roadways as close as ground count.

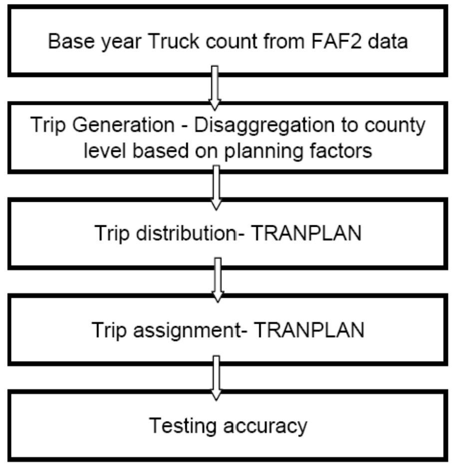


Figure 1 Planning Process

The best available data for freight is provided by the Federal Highway Administration's Freight Analysis Framework (FAF2) database.

Once the freight destined for, originating in, internal to, and passing through Alabama is compiled from FAF2 large zonal data, a method of disaggregation must be applied to determine what portion of the freight will be destined for or originating in points within Alabama (*1*).

This could be performed at (*1*):

- The county level
- The metropolitan level
- Freight Analysis Zones (FAZs)

In a state such as Alabama, it might be feasible to perform the disaggregation at a county level (*1*).

Therefore, in trip generation, FAF2 data needs to be disaggregated to local level and equations can be developed for disaggregating large zonal FAF2 data to local level depending on planning factors and their contribution level.

Each equation can generate number of produced and attracted truck trips by purposes and can be run on the networks which are created in the gravity distribution model. TRANPLAN distributes the volume and assigns the loads on roadways.

The measures of error between the model and actual count are used to determine the impact of local factors on the modeled freight flow.

If the underlying principles of freight demand generation can be discovered, the ability to accurately predict infrastructure requirements is enhanced (*1*).

2.2 Problem Statement

As the usefulness of FAF2 data is limited for smaller geographies rather than large ones, disaggregation of FAF2 regional database to county or metropolitan planning organizations (MPO) is an important undertaking (*2*).

So, large geographical FAF2 flows need to be spatially disaggregated to desired smaller zones to reduce the inaccuracy of freight flow assignments (*3*).

This study is to do a further analysis using the same methodology and resources from the paper "Using a Federal Database and New Factors for Disaggregation of Freight to a Local Level" (*4*) after incorporating essential findings from other available research papers. It can be called a base paper that suggests the future work of similar analyses after the modification of modeling software.

The study of disaggregation has been conducted for Alabama using FAF2 database. The FAF2 commodity origin-destination database includes 2002 and every 5 year forecasted tons and value of commodity movements among regions by mode of transportation and type of commodity and has 2 FAF2 regions in Alabama (*2*).

Difficulty of gathering local level freight flow impedes the planners to incorporate the freight into transport model. So, disaggregation is required for 2 FAF2 regions of Alabama at national level into 67 individual counties at the state level. Disaggregation technique involves understanding and identifying freight activity and factors affecting freight activity (*4*).

There are also some other research papers that describe factors, production, and attraction equations to disaggregate origin and destination flows. Looking at their applied factors and methods can give more information on new potential ideas for disaggregation. These help to include numbers of possible equations. Disaggregated data has been distributed and assigned on 661 roadways of Alabama using the modified CUBE/TRANPLAN model.

3 Objectives

The objectives of the study were:

- To identify potential factors those are responsible for production and attraction of freight, incorporating findings from literature review
- To determine the contribution level of each factor that can minimize the error and can be used for disaggregation of forecasted data

4 Literature Review

The following research papers have been reviewed to identify any potential factors and equations for production and attraction:

- Iowa Disaggregation method (*3*)
- FL Disaggregation method (*2*)
- NJ Disaggregation method (*5*)
- NJ commodity specific disaggregation method (*6*)
- Base paper (*4*)

4.1 Iowa Disaggregation Method

It is one of the sections of Chapter 6 from a PhD thesis dissertation (*3*).

Iowa DOT elected to use flows to and from Iowa, developed at the BEA level in Iowa and adjacent states. These flows were aggregated at a higher spatial level at further distances from Iowa and were not sufficient for a statewide freight model as it involves inaccuracy to assign freight flows. In order for the model to be useful, the data had to be spatially disaggregated to match the commodity analysis zones (CAZ) developed for the statewide freight model in Iowa. Flows to or from the BEAs that were contained within the Iowa borders had to be disaggregated to the 99 CAZs (*3*).

The disaggregation method assumes that flows to or from a larger spatial area (BEA) can be separated into smaller spatial areas (CAZ) by proportioning the total flows by indicator values that are measures of the production or consumption of a particular commodity group. These indicator values are measures of production or consumption that were determined for both the BEA and the CAZ. The following formulas indicate the method used to disaggregate origin flows (*3*):

$$O_{CAZ} = O_{BEA}\left(\frac{p_{CAZ}}{p_{BEA}}\right)$$, where:

OCAZ is the tons of flow at the originating CAZ;
OBEA is the tons of flow at the originating BEA;
P_{CAZ} is the measure of production of commodity group at the CAZ; and
P_{BEA} is the measure of production of commodity group at the BEA.
Similarly, the disaggregation of the destination flows was done as specified (*3*):

$$D_{CAZ} = D_{BEA}\left(\frac{C_{CAZ}}{C_{BEA}}\right)$$, where:

DCAZ is the tons of flow with destinations at the CAZ;
DBEA is the tons of flow with destinations at the BEA;
C_{CAZ} is the measure of consumption of commodity at the CAZ; and

C_{BEA} is the measure of consumption of commodity at the BEA.

In this model, the separated disaggregation ratios for origins (production) and destinations (attractions) were developed by commodity group based on combinations of employment measures, population, and others indicators (*3*).

Examining, producing and consuming sectors helped to get the top consuming sectors of a commodity and effects of multiple employment measures for a statewide model (*3*).

Table 1 shows the measures that were used to develop the ratios for disaggregation (*3*).

Table1 Final Commodity Groups and Disaggregation Measures (*3*)

STCC	Commodity Description	Productions	Attractions
11	Field Crops	Acres of Farm Land	Farm product raw materials (SIC515)
112	Bituminous coal or lignite	Population	Employment in electric services and gas production and distribution (SIC 491, 493)
201	Meat or poultry, fresh or chill	Employment in SIC 201	Population
202	Dairy products	Employment in SIC 202	Population
204	Grain mill products	Employment in SIC 204	Population
209	Misc. food preparations	Employment in SIC 209	Population
262	Paper	Employment in SIC 260-265	Employment in newspapers, periodicals, books (SIC 270-279)
281	Industrial chemicals	Employment in SIC 516	Employment in industrial and agricultural chemicals (SIC 281, 286, 289, 282)
287	Agricultural chemicals	Employment in SIC 287	Acres of farm land
291	Products of petroleum refining	Employment in SIC 517	Population
307	Miscellaneous plastics products	Employment in SIC 307-308	Employment in knitting mills, textiles, carpets, rugs (SIC 221-229)
324	Cement, hydraulic	Employment in SIC 324	Employment in residential, highway, masonry construction (SIC 151, 152,161, 162, 174, 177, 138,148)
331	Steel mill products	Employment in SIC 331	Employment in Iron and steel foundries, fabricated metal products (SIC 332, 339, 343, 344)
352	Farm and garden machinery	Employment in SIC 352	Acres of Farm Land
371	Motor vehicles and equipment	Employment in SIC 371	Population

After extracting all records of the selected commodity group by STCC (Standard Transportation Commodity Classification) from TRANSEARCH, the actual mechanics of disaggregating of database was a two-step process using a combination of queries in a Microsoft Access database. The origin records were disaggregated by the calculated ratios, and then the destination flows were disaggregated by their ratios. A simple example is shown in Figure 2 (*3*).

Step 1:			Step 2:	Ratio of Indicator Variables				
				0.25	*0.40*	*0.10*	*0.25*	
Ratio of Indicator Variables	From BEA C- CAZ (tons)	To BEA D (tons)	From /To	D-1	D-2	D-3	D-4	*Total*
0.6	C-1	60	C-1	15	24	6	15	60
0.0	C-2	0	C-2	0	0	0	0	0
0.2	C-3	20	C-3	5	8	2	5	20
0.2	C-4	20	C-4	5	8	2	5	20
Total		100	*Total*	25	40	10	25	100

Figure 2 Sample of disaggregation procedure (*3*)

4.2 FL Disaggregation Method

This paper provides a method to disaggregate FAF2 data to county level geography. The results of this methodology should be applicable for both planners and modelers for a variety of transportation planning applications including regional travel forecasting (*2*).

It concludes that the Vehicles Miles Travelled (VMT) approach from Battelle Institute seemed to be inappropriate, because it did not address the actual allocation of freight, through trucks and individual commodity separately (*2*).

Methodology for Disaggregating Florida FAF2 Data

Aggregated employment data were used to find mathematical relationships between FAF2 commodity shipments and employment by industries in that FAF2 region. The availability of employment data by industry can be used with these equations to estimate the expected production and attraction of freight tonnage in a FAF2 region and the units of smaller geography in that FAF2 region. The shares of the smaller units of geography tonnage to the regional tonnage can then be used to disaggregate the freight flows from FAF2 regions to the smaller units of geography within those FAF2 regions. This method is suitable for disaggregating the FAF2 regional flows to and from Florida counties (*2*).

Direct and indirect factors, the nature of commodity supply (employment) and demand (consumer) can affect freight flows. FL 14 commodity groups of freight demand model have been regrouped into 13 groups, followed by estimating 1000 tons (domestic, border and sea) of P and A by each group to each of the 114 FAF2 regions using regression equations. These equations include explanatory variables population (2000), employment by three digit NAICS (statistically significant at 95% Confidence Level), and total employment. The equations also have other employment data as independent variables (consumer, durable, non durable manufacturing, transportation, wholesale and retail trade etc.) (*2*).

Linear regressions with zero intercept were developed using the tonnages originating (produced) and destined (attracted) and the employment by industry in each of 114 FAF2 regions opposed to the 5 data points of FL as the data for the regressions (*2*).

The results of P and A with the value of t-stat are given in Table 2 and Table 3 respectively. The terms used in Tables 2 and 3 are as follows (*2*):

Productions (Commodity Group) = Coefficient1*Variable1 +

Coefficient2*Variable2 + Coefficient3*Variable3

Attractions (Commodity Group) = Coefficient1*Variable1 + Coefficient2*Variable2

Where, coefficient is the annual thousands of tons produced, or consumed, by an employee in that industry (*2*).

Table 2 Production Equations (2002 thousands of tons) (*2*)

Commodity Group Name	Coefficient 1 (t-stat)	Variable 1	Coefficient 2 (t-stat)	Variable 2	Coefficient 3 (t-stat)	Variable 3	R^2
Agricultural Products	3.058 (4.16)	NAICS11 (Agriculture, Forestry, Fishing & Hunting)					0.13
Minerals	2.647 (6.11)	NAICS21 (Mining)					0.25
Coal	7.063 (7.63)	NAICS212 (Mining except coal & gas)					0.34
Food	0.891 (6.72)	NAICS311 (Food Manufacturing)					0.29
Non-Durable Manufacturing	0.029 (16.70)	Non Durable					0.71
Lumber	6.032 (19.31)	NAICS113 (Forestry & Logging)	0.165 (1.87*)	NAICS321 (Wood Product Manufacturing)	0.223 (3.51)	NAICS337 (Furniture & Related Products)	0.94
Chemicals	0.737 (7.16)	NAICS325 (Chemical Manufacturing)					0.31
Paper	0.362 (21.53)	NAICS322 (paper manufacturing)					0.8
Petroleum Products	24.484 (21.53)	NAICS324 (Petroleum & Coal Products Manufacturing)					0.8
Other Durable Manufacturing	0.151 (18.54)	Durable Manufacturing					0.75
Clay, Concrete, Glass & Stone	2.092 (13.27)	NAICS327 (Nonmetallic Mineral Product Manufacturing)					0.61
Waste	0.0078 (27.78)	Total Employment					0.87
Miscellaneous Freight & Warehousing	0.117 (16.29)	Wholesale Trade					0.7

* Significant at 90% Confidence Level

Table 3 Attraction Equations (2002 thousands of tons) (*2*)

Commodity Group Name	Coefficient 1 (t-stat)	Variable 1	Coefficient 2 (t-stat)	Variable 2	R^2
Agricultural Products	0.531 (9.80)	NAICS311 (Food Manufacturing)			0.46
Minerals	0.743 (4.61)	NAICS236 (Construction of Buildings)	1.64617 (3.33)	NAICS327 (Nonmetallic Mineral Product Manufacturing)	0.67
Coal	0.374 (3.49)	NAICS221 (Utilities)			0.09
Food	0.294 (3.20)	NAICS311 (Food Manufacturing)	0.00099 (1.80*)	Census 2000 population	0.33
Non-Durable Manufacturing	0.01065 (7.7)	Consumer Manufacturing	0.00299 (4.67)	Wholesale Trade	0.75
Lumber	0.873 (16.41)	NAICS321 (Wood Product Manufacturing)			0.7
Chemicals	1.945 (4.28)	NAICS324 (Petroleum & Coal Products Manufacturing)	0.0105 (1.87*)	Retail Trade	0.32
Paper	0.064 (4.56)	NAICS322 (Paper Manufacturing)	0.043 (4.59)	NAICS323 (Printing and Related Support Activities)	0.76
Petroleum Products	10.561 (16.16)	NAICS324 (Petroleum and Coal Products Manufacturing)	0.111 (4.11)	Transportation	0.85
Other Durable Manufacturing	0.054 (4.86)	Wholesale Trade	0.028 (3.08)	Durable	0.66
Clay, Concrete, Glass & Stone	0.089 (6.20)	Wholesale Trade	0.399 (2.03)	NAICS327 (Nonmetallic Mineral Product Manufacturing)	0.61
Waste	0.028 (4.59)	Durable Manufacturing	0.0017 (9.10)	Census 2000 population	0.88
Miscellaneous Freight & Warehousing	0.045 (1.30^{+})	Transportation	0.050 (2.19)	Wholesale Trade	0.68

* Significant at 90% Confidence Level ; $^{+}$ Not Significant

Some commodity groups show strong relationship between tonnage with the producing and consuming industries while few commodity groups have poor statistical relationship because of insufficient detail in the CBP (*2*).

Summation of each county tonnage of P and A for each commodity group calculated from the above equations has been done to get the ratio of county P and A to FAF2 zone P and A which expands the 114 by 114 FAF2 zonal database to 176 by 176 zone database (67 FL counties as zones instead of 5 zones) (*2*).

The methodology to disaggregate FAF2 data to county level geography should be applicable for both planners and modelers that use CBP and Census 2000 PUMS files along with a bridge developed between the NAICS and SCTG (*2*).

A comparison is made between the percentage distributions of county flows resulting from the disaggregation of the FAF2 database to the county flows available from TRANSEARCH to validate the proposed method and the result is supported by a FHWA research study (*2*).

4.3 NJ Disaggregation Method

This paper presents seven methods for disaggregating the FAF2 data to the county level of the State of New Jersey by including combination of Truck Vehicle Miles Traveled (TVMT), employment and income adjusted population to use for freight flow trend and directional analysis, and to integrate this work into the statewide freight planning process (*5*).

They found that most frequently used primary factors are some form of employment, population, and farm acreage etc. Truck Vehicle Miles Traveled (TVMT) approach uses the proportion of zonal TVMT within a county in that zone to disaggregate the FAF2 flows (*5*).

Disaggregation Procedure

A proportional approach is outlined and the process followed to obtain county level commodity flows for New Jersey is as follows (*5*):

- Extract NJ FAF2 O or D data for dom, sea and bor
- Add and combine unique FAF2 zone IDs
- Divide them by 7 modes
- Import matrices into TransCAD
- Disaggregate by using matrix-disaggregate function in TransCAD based on the approaches

Table 4 outlines the seven different disaggregation approaches that have been proposed (*5*):

Table 4 NJ Disaggregation methods (*5*)

Disaggregation Method	Description
D1	Origins factored by employment and destinations factored by population.
D2	Origins factored by employment and destinations factored by population of 25 to 54 year olds.
D3	Origins factored by employment and destinations factored by income adjusted population of 25 to 54 year olds.
D4	Origins and destinations factored by Truck Vehicle Miles Traveled (TVMT).
D5	Origins factored by employment and TVMT and destinations factored by income adjusted population of 25 to 54 year olds and TVMT.
D6	Origins factored by number of trucks going out and destinations factored by number of trucks coming in
D7	Origins factored by TVMT out and destinations factored by TVMT in

TransCAD requires two inputs: the base FAF2 origin-destination matrix and a lookup table showing the New Jersey county disaggregation factors which are the proportions of New Jersey county to FAF2 zone for each of the approaches (*5*).

A comparison of the disaggregation results of all seven methods were done by the coefficient of determination (R^2) method, which measures the variability between the commodity flows. In this comparison, R^2 is defined as the proportion of variability in the disaggregated FAF2 dataset that can be accounted for by the Transearch data (*5*).

The paper developed methods to disaggregate FAF2 commodity data and it compared to Global Insight's Transearch Database showing clear discrepancies at the disaggregated level (*5*).

Identifying potential reasons behind the discrepancy between the disaggregated FAF2 and Transearch is one of the areas of this study that demands further research. Additionally, the authors plan to look at incorporating impedances between the counties in future methods (*5*).

4.4 NJ commodity specific Disaggregation Method

The proportional weighting disaggregation methods require three main inputs: extracted NJ flows from the FAF2 origin-destination database, two databases of disaggregation factors for each combination of 2-digit SCTG commodity code and New Jersey county (one database for origins or productions and another for destinations or attractions) (*6*).

Methods D8 through D13 were developed during the second year study and attempt to improve disaggregation by using industry specific employment to disaggregate each commodity type separately (*6*).

Origin and destinations were remapped for international flows (BRD and SEA tables) to represent just the domestic leg of the trip (*6*).

Domestic Disaggregation Factors are shown in Table 5 (*6*).

Table 5 Domestic Disaggregation Factors (*6*)

Disaggregation Method	Domestic Origin (Production) Factors	Domestic Destination (Attraction) Factors
D8	NAICS 6-digit commodity specific industry employment	NAICS 6-digit commodity specific industry employment
D9	NAICS 6-digit commodity specific industry employment	Total Employment
D10	NAICS 6-digit commodity specific industry employment	Population
D11	NAICS 3-digit commodity specific industry employment	NAICS 3-digit commodity specific industry employment
D12	NAICS 3-digit commodity specific industry employment	Total Employment
D13	NAICS 3-digit commodity specific industry employment	Population

The coefficient of determination (R2) can be defined as the proportion of variability in the 2002 tonnage flows in the FAF2 database that can be explained (accounted for) by the 2001 tonnage in the Transearch database (*6*).

Despite a great deal of variability between the disaggregated FAF2 commodity flows and the Transearch database, some definite patterns for disaggregating the productions or flow origins and the attractions have been identified that yielded better results (*6*).

Further research was suggested to determine the factors that can reduce those discrepancies (*6*).

4.5 Base paper

This paper attempts to develop disaggregation techniques using a collection of local factors like, population, employment, personal income, and value of shipments by analyzing FAF2 database. A case study addresses the disaggregation for Alabama, comprising two zones at the national level into 67 counties at the state level (*4*).

The disaggregation is a process of defining the data into nine unique trips purposes which include internal-internal, originated from and destined to, and through traffic for Zone 1 and Zone 2 of Alabama (*4*).

A travel demand model network was developed in CUBE/TRANPLAN and used to assign the trips obtained from the FAF2 database. A gravity distribution model has been incorporated to distribute the trips between the counties using the nine trip purposes described previously. The assignment is performed using an all-or-nothing assignment (*4*).

The methodology for this research consists of three major tasks, namely (*4*)

- Generating the input (INPUT): the number of freight carrying trucks visiting each county PA_i. These productions and attractions are a function of initially assumed factors that can affect the freight traffic. The equation is given below (*4*):

  $$PA_i = (NFD) * \left[\frac{W_1 * P_i}{\sum P_j} + \frac{W_2 * PI_i}{\sum I_j} + \frac{W_3 * E_i}{\sum E_j} + \frac{W_4 * VOS_i}{\sum VOS_j} \right]$$

  It should satisfy some specific constraints such as total number of trucks after and before disaggregation must be the same, weights must be within 0 and 1 and summation of weights must be 1 (*4*).
- Running the modeling software (PROCESS): Gravity distribution and assignment of input was done by a travel demand model developed in CUBE/TRANPLAN (*4*).
- Analyzing the output (OUTPUT): Varying the input, i.e. the contribution level of factors, can change assigned roadways data randomly. This deviation is measured with respect to actual truck counts. Metrics used to measure the accuracy are Root Mean Square Error, Nash Sutcliffe's (NS) coefficient etc (*4*).

It can be noted that the total number of trucks used as the input is always constant and none of the interactions are significant (*4*).

Limited impact of the coefficients found for 30 tons/vehicle led to look at the Nash Sutcliffe's coefficient variation with the change in tonnage. Finally, 10 tons/vehicle was selected to do a similar micro level analysis as it yielded the truck counts closest to the actual truck count and the best Nash Sutcliffe's value was recorded for the attribute 10 tons/vehicle (*4*).

The model used in the paper concluded that changing factor proportions did not have an impact over the modeled truck traffic in the state of Alabama (*4*).

It has been suggested that the model should be corrected and a similar analysis could be performed in the future to deduce what factors might be impacting the freight flow (*4*).

5 Studies

5.1 Collection of required data

The papers reviewed in previous section, except the base paper, have considered the variables by commodity groups. The following table summarized the factors that have been used in most cases:

Table 6 Most Frequently Used Factors

Production	Attraction	Paper
NAICS 2 and 3	Population, NAICS 1,2 and 3	Iowa (*3*)
NAICS 1,2 and 3	Population, NAICS 3	FL (*2*)

NJ method suggests using the following methods (*5*):

Table 7 Suggested Factors (*5*)

Productions	Attractions	Remarks
TVMT & EMP and	TVMT & Income Adjusted POP 25 to 54	VMT is criticized in FL paper
Trucks Going Out	Trucks Coming In	It is not possible to get these data

NJ commodity specific method suggests the following conclusions (*6*):

- For disaggregating the productions or flow origins, 6-digit employment factor yielded better results for trucks
- For attractions; other non-commodity specific factors such as truck vehicle miles traveled, total employment, or adjusted population generally yielded better results.

The new factors selected after reviewing the above findings to start the analysis phase are:

- NAICS 1
- NAICS 2
- NAICS 3

The collection of employment data for 67 counties of Alabama followed by incorporating those in the old spread sheet has been done in such a way that match the line up of other factors with counties.

5.2 Identification of possible Iterations

Factors examined earlier are population, employment, personal income, and value of shipments. Based on different combination of these factors along with above ones, equations have been developed for production and attraction as separate equations or same equation. Though these papers include commodity specific equations for production and attraction separately, factors used in most places have been considered for this analysis as generalized factors regardless of type of commodity. The equations should satisfy the following constraints that were strictly maintained in base paper (*4*):

1. $\sum_{i=1}^{4} W_i = 1$

2. $W_i = Range(0,1)$

It can be noted that no interaction is presented as significant in any of the papers. The general form of the equation is given below (*4*):

$$PA_i = (NFD_{ab}) * \frac{(WF) * Factor_i}{\sum Factor_{ij}}$$

Where,

PA_i = Truck passing County i

NFD_{ab} = Truck Counts from Zone-a to Zone-b taken from the National Freight Flow

WF = Weight of the factor (or) importance of the factor (or) proportion of the factor considered for disaggregating

$Factor_i$ = Factor level for county i

$\sum Factor_{ij}$ = Total Factor level for the corresponding Zone of county i

i= county number (1, 2, 3, 4……67)

j= Zone number (1, 2)

A total of 135 iterations have been run and can be divided into the following four categories:

Table 8 Four Divisions of 135 iterations

No of iterations	Factors	Remarks
19	Population, Personal income, value of shipments and employment.	Same equation for Production and attraction
55	Population, Personal income, value of shipments, NAICS 1, 2 and 3	Same equation for Production and attraction
38	Purchase power, employment, value of shipments	Same equation for Production and attraction, Purchase power is equal to the product of population and personal income
	Purchase power, value of shipments, NAICS 1, 2 and 3	Same equation for Production and attraction
23	Using of above iterations	Separate equation for Production and Attraction

The weights of above iterations are shown in the following output section.

5.3 Generation of formatted input

Available excel spread sheet was updated to include the value of new factors. And it can automatically provide number of trucks by county and by purpose for any combination of factors. Those sheets were formatted by FORTRAN to feed as an input in modeling software.

A sample of processing input is given in Appendices 1 through 3 for one iteration.

5.4 Running the software model

A travel demand model network was developed in CUBE/TRANPLAN and used to assign the trips obtained from the FAF2 database. The roadways are attributed with posted speed limits and capacities, using approved ALDOT capacities for travel modeling purposes, shown in Figure 3. As mentioned, the model contains 67 internal zones, representing each county in Alabama and has 15 external roadways connecting Alabama with the remainder of the nation. A gravity distribution model has been incorporated to distribute the trips between the counties using the nine trip purposes previously described. The assignment is performed using an all-or-nothing assignment as the assumption is made that freight will not deviate from the shortest path because there is not necessarily knowledge regarding shortest path alternative when assigning trips for potential out-of-town shippers (*4*).

Figure 3 Modeling Network (*4*)

5.5 Extraction of the output and testing the accuracy

The output that is the truck number of 661 roadways has been extracted from the model as an Excel form. Analyzing the output involves comparing the modeled values with ground counts of 352 roadways as the other actual counts are not available. The metrics that have been calculated to measure the deviation and test the accuracy are:

- Root Mean Square Error (RMSE): Root Mean Square Error (RMSE) is a common measure of the variability in the error (difference between model and ground counts) of any model. As a result, this was used as one of the metrics. Greater the RSME, less accurate is our model (*4*). The equation can be given as follows (*3*):

$$RMSE = \frac{\sqrt{\sum_j (Model_j - Count_j)^2 / (NumofCounts - 1)} * (100)}{\sum_j Count_j / NumofCounts}, \text{ where:}$$

RMSE	is the root mean square error;
$Model_j$	is the model count on link j;
$Count_j$	is the ground count on link j; and
NumofCounts	is the number of links with counts;

- Nash Sutcliffe's (NS) coefficient: This coefficient gives us a measure of scatter variation from the 1:1 slope line of modeled truck counts vs. the ground counts. More the deviation of points from the slope line, lesser will be the coefficient. Greater the NS-value, better is our forecast. The equation is as follows (*4*):

NS-Coefficient = $1 - \frac{\sum_{1}^{n}(ModeledCounts - GroundCounts)^2}{\sum_{1}^{n}(GroundCounts - MeanGoundCounts)^2}$

The results of each category are presented in the following Tables. The iterations are shown in an ascending order of RMSE values.

Table 9 Results of First Category

Base runs	RMSE	NS-Coefficient	Population	Personal Income	Value of Shipment	Employment
base2	66.55285	0.681897401	0	1	0	0
base14	66.823	0.679309685	0.125	0.625	0.125	0.125
base7	66.85647	0.678988344	0	0.5	0.5	0
base9	66.93674	0.678217066	0.33333333	0.333333	0.333333	0
base3	66.95244	0.678066143	0.5	0.5	0	0
base6	67.02802	0.677338873	0	0.5	0	0.5
base11	67.05199	0.677108051	0	0.333333	0.333333	0.33333333
base8	67.06848	0.676949165	0.33333333	0.333333	0	0.33333333
base12	67.14339	0.676227192	0.25	0.25	0.25	0.25
base16	67.18479	0.675827745	0.125	0.125	0.625	0.125
base13	67.23107	0.675381039	0.625	0.125	0.125	0.125
base5	67.24756	0.675221711	0.5	0	0.5	0
base18	67.26111	0.675090829	0	0	1	0
base15	67.2823	0.674886116	0.125	0.125	0.125	0.625
base10	67.33605	0.674366435	0.33333333	0	0.333333	0.33333333
base1	67.34829	0.674248088	1	0	0	0
base19	67.37525	0.673987139	0	0	0.5	0.5
base4	67.3848	0.673894805	0.5	0	0	0.5
base17	67.53703	0.672419706	0	0	0	1

Table 10 Results of Second Category

RUNs	RMSE	NS-Coefficient	Population	Personal Income	Value of Shipment	NAICS 1	NAICS 2	NAICS 3
Run54	**65.28631878**	**0.693889481**	**0.5**	**0**	**0**	**0**	**0.5**	**0**
Run21	**65.63468562**	**0.690613963**	**0**	**0.333333**	**0**	**0**	**0.333333**	**0.333333**
Run14	**65.69866758**	**0.690010478**	**0**	**0.333333**	**0.333333333**	**0**	**0.333333**	**0**
Run36	**65.73990799**	**0.689621182**	**0**	**0.125**	**0.125**	**0**	**0.375**	**0.375**
Run33	**65.7719297**	**0.68931874**	**0.125**	**0**	**0.125**	**0**	**0.375**	**0.375**
Run34	65.80449841	0.689010979	0	0.125	0.125	0.375	0.375	0
Run31	65.80780763	0.6889797	0.125	0	0.125	0.375	0.375	0
Run18	65.83519133	0.688720805	0.333333333	0	0	0	0.333333	0.333333
Run19	65.85207753	0.688561103	0	0.333333	0	0.333333	0.333333	0
Run11	65.91762963	0.687940754	0.333333333	0	0.333333333	0	0.333333	0
Run24	65.97009691	0.687443788	0	0	0.333333333	0	0.333333	0.333333
Run8	65.97309045	0.687415422	0.25	0.25	0.25	0	0.25	0
Run28	65.97488677	0.687398399	0	0.25	0.25	0.25	0.25	0
Run22	65.99625305	0.687195891	0	0	0.333333333	0.333333	0.333333	0
Run2	66.00439604	0.687118696	0	0.125	0	0.291667	0.291667	0.291667
Run16	66.01211999	0.687045463	0.333333333	0	0	0.333333	0.333333	0
Run1	66.03985885	0.686782396	0.125	0	0	0.291667	0.291667	0.291667
Run50	66.08944701	0.68631184	0	0.25	0	0.25	0.25	0.25
Run25	66.0992291	0.686218973	0.25	0	0.25	0.25	0.25	0
Run44	66.12927094	0.685933684	0	0.1	0.1	0.266667	0.266667	0.266667
Run52	66.12944695	0.685932012	0	0	0	0.333333	0.333333	0.333333
Run30	66.14599305	0.685774828	0	0.25	0.25	0	0.25	0.25
Run27	66.16197571	0.685622959	0.25	0	0.25	0	0.25	0.25

RUNs	RMSE	NS-Coefficient	Population	Personal Income	Value of Shipment	NAICS 1	NAICS 2	NAICS 3
Run3	66.17511605	0.685498071	0	0	0.125	0.291667	0.291667	0.291667
Run43	66.20773343	0.685187962	0.1	0	0.1	0.266667	0.266667	0.266667
Run49	66.22105016	0.685061309	0.25	0	0	0.25	0.25	0.25
Run48	66.27862628	0.684513422	0	0.2	0.2	0.2	0.2	0.2
Run51	66.29632777	0.684344881	0	0	0.25	0.25	0.25	0.25
Run5	66.30939947	0.684220393	0	0.625	0	0.125	0.125	0.125
Run47	66.41383806	0.683224892	0.2	0	0.2	0.2	0.2	0.2
Run42	66.41410213	0.683222372	0	0.375	0.375	0	0.125	0.125
Run40	66.50820216	0.682324072	0	0.375	0.375	0.125	0.125	0
Run46	66.62388526	0.681217992	0	0.35	0.35	0.1	0.1	0.1
Run39	66.66702612	0.680805018	0.375	0	0.375	0	0.125	0.125
Run37	66.69011312	0.680583903	0.375	0	0.375	0.125	0.125	0
Run4	66.69265262	0.680559576	0.625	0	0	0.125	0.125	0.125
Run6	66.80281271	0.679503429	0	0	0.625	0.125	0.125	0.125
Run45	66.89695443	0.678599474	0.35	0	0.35	0.1	0.1	0.1
Run13	67.12961867	0.676359956	0	0.333333	0.333333333	0.333333	0	0
Run15	67.14668212	0.676195406	0	0.333333	0.333333333	0	0	0.333333
Run9	67.20318663	0.675650208	0.25	0.25	0.25	0	0	0.25
Run41	67.2055814	0.675627091	0	0.375	0.375	0.125	0	0.125
Run20	67.28589225	0.674851375	0	0.333333	0	0.333333	0	0.333333
Run10	67.4237154	0.673517993	0.333333333	0	0.333333333	0.333333	0	0
Run12	67.43939956	0.673366082	0.333333333	0	0.333333333	0	0	0.333333
Run55	67.44469366	0.673314797	0.5	0	0	0	0	0.5
Run7	67.50431181	0.672736991	0.25	0.25	0.25	0.25	0	0
Run17	67.51575683	0.67262601	0.333333333	0	0	0.333333	0	0.333333
Run38	67.51907174	0.672593862	0.375	0	0.375	0.125	0	0.125
Run29	67.58057649	0.671997107	0	0.25	0.25	0.25	0	0.25
Run35	67.59752792	0.671832538	0	0.125	0.125	0.375	0	0.375

RUNs	RMSE	NS-Coefficient	Population	Personal Income	Value of Shipment	NAICS 1	NAICS 2	NAICS 3
Run23	67.67666718	0.671063689	0	0	0.333333333	0.333333	0	0.333333
Run53	67.74877	0.670362418	0.5	0	0	0.5	0	0
Run26	67.80044138	0.669859403	0.25	0	0.25	0.25	0	0.25
Run32	67.90788217	0.668812251	0.125	0	0.125	0.375	0	0.375

Table 11 Results of Third Category

RUNs	RMSE	NS-Coefficient	Value of Shipment	Employment	NAICS 1	NAICS 2	NAICS 3	Purchase power POPXINCOM
run33	**65.51234**	**0.69176632**	**0.5**	**0**	**0**	**0.5**	**0**	**0**
run29	65.86383	0.688449922	0.125	0	0.375	0.375	0	0.125
run24	65.8844	0.688255297	0	0	0.333333	0.333333	0	0.333333333
run31	65.99972	0.687163044	0.125	0	0	0.375	0.375	0.125
run36	66.10716	0.686143667	0	0	0	0.5	0	0.5
run28	66.11955	0.686026005	0.1	0	0.266667	0.266667	0.266667	0.1
run27	66.161	0.685632269	0	0	0.25	0.25	0.25	0.25
run26	66.20246	0.685238115	0	0	0	0.333333	0.333333	0.333333333
run22	66.22087	0.685062989	0	0	0	1	0	0
run20	66.34009	0.683927993	0.2	0	0.2	0.2	0.2	0.2
run38	66.72369	0.680262163	0.35	0	0.1	0.1	0.1	0.35
run9	67.08281	0.676811112	0.5	0.25	0	0	0	0.25
run18	67.0988	0.676657046	0.8	0	0	0	0	0.2
run3	67.11491	0.676501723	0	0	0	0	0	1
run10	67.13468	0.676311146	0.25	0.5	0	0	0	0.25
run4	67.14908	0.676172254	0.5	0	0	0	0	0.5
run8	67.1526	0.676138359	0.25	0.25	0	0	0	0.5

RUNs	RMSE	NS-Coefficient	Value of Shipment	Employment	NAICS 1	NAICS 2	NAICS 3	Purchase power POPXINCOM
run6	67.15349	0.676129731	0.666666667	0.166666667	0	0	0	0.166666667
run2	67.16249	0.676042896	0.166666667	0.166666667	0	0	0	0.666666667
run1	67.16286	0.676039355	0.333333333	0.333333333	0	0	0	0.333333333
run12	67.17144	0.675956561	0.8	0.1	0	0	0	0.1
run19	67.17779	0.67589528	0.2	0	0	0	0	0.8
run11	67.19721	0.675707869	0.1	0.1	0	0	0	0.8
run7	67.19872	0.675693286	0.166666667	0.666666667	0	0	0	0.166666667
run5	67.21475	0.675538604	0	0.5	0	0	0	0.5
run17	67.22163	0.675472144	0	0.2	0	0	0	0.8
run16	67.2309	0.675382626	0	0.8	0	0	0	0.2
run13	67.27842	0.674923635	0.1	0.8	0	0	0	0.1
run14	67.2795	0.674913162	0.8	0.2	0	0	0	0
run35	67.42986	0.673458457	0	0	0.5	0	0	0.5
run15	67.44349	0.673326477	0.2	0.8	0	0	0	0
run25	67.45821	0.673183797	0	0	0.333333	0	0.333333	0.333333333
run37	67.49343	0.672842513	0	0	0	0	0.5	0.5
run34	67.59747	0.671833091	0.5	0	0	0	0.5	0
run23	67.88937	0.668992808	0	0	0	0	1	0
run30	67.90153	0.668874173	0.125	0	0.375	0	0.375	0.125
run32	68.013	0.667786109	0.5	0	0.5	0	0	0
run21	69.02199	0.657856064	0	0	1	0	0	0

Table 12 Results of Forth Category

The equations that have been used in this category are shown bold in above tables.

RUNs	RMSE	NS-Coefficient	Production	Attraction
run8	65.20307	0.694669605	Run54 (from 2nd category)	Run36 (from 2nd category)

RUNs	RMSE	NS-Coefficient	Production	Attraction
run15	65.24638	0.694263918	Run54 (from 2nd category)	Run33 (from 2nd category)
run5	65.27499	0.693995742	Run54 (from 2nd category)	run 33 (from 3rd category)
run6	65.33325	0.693449205	Run54 (from 2nd category)	Run21 (from 2nd category)
run16	65.45013	0.692351408	Run54 (from 2nd category)	Run34 (from 2nd category)
run7	65.477	0.692098727	Run54 (from 2nd category)	Run14 (from 2nd category)
run17	65.50137	0.691869533	Run54 (from 2nd category)	Run31 (from 2nd category)
run1	65.55389	0.691375171	run 33 (from 3rd category)	Run54 (from 2nd category)
run10	65.57958	0.691133246	Run14 (from 2nd category)	run 33 (from 3rd category)
run13	65.61316	0.690816846	run 33 (from 3rd category)	Run34 (from 2nd category)
run14	65.63414	0.690619113	run 33 (from 3rd category)	Run31 (from 2nd category)
run19	65.6683	0.690297019	Run34 (from 2nd category)	run 33 (from 3rd category)
run9	65.68905	0.690101224	Run21 (from 2nd category)	run 33 (from 3rd category)
run20	65.70153	0.689983461	Run31 (from 2nd category)	run 33 (from 3rd category)
run3	65.72291	0.689781659	Run14 (from 2nd category)	Run54 (from 2nd category)
run12	65.72544	0.68975778	run 33 (from 3rd category)	Run33 (from 2nd category)
run11	65.74358	0.689586546	Run36 (from 2nd category)	run 33 (from 3rd category)
run18	65.76045	0.689427192	Run33 (from 2nd category)	run 33 (from 3rd category)
run4	65.78734	0.689173174	Run36 (from 2nd category)	Run54 (from 2nd category)

RUNs	RMSE	NS-Coefficient	Production	Attraction
run2	65.7904	0.689144179	Run21(from 2nd category)	Run54 (from 2nd category)
run22	65.81966	0.688867611	Run34 (from 2nd category)	Run54 (from 2nd category)
run21	65.82067	0.688858123	Run33 (from 2nd category)	Run54 (from 2nd category)
run23	65.82836	0.688785421	Run31 (from 2nd category)	Run54 (from 2nd category)

5.6 Further testing of 10 best iterations

Out of 135 iterations, 10 iterations have been selected that give lower RMSE and higher NS coefficient value (given in Table 13). However, all the values are very close.

The RMSE for the all links can be divided for lower and higher volume roads. Because lowest volume links can have the highest RMSE that indicates a large, highly variable, error between the modeled volumes and ground counts. Large errors on low volume roads are usually acceptable, since these roads are not necessarily of interest for planning. For the higher volume roads, which are the principal freight distribution routes, the RMSE should be lower (*3*).

Table 13 Best Iterations

RUNs	RMSE	NS-Coefficient	Production	Attraction
run8	65.20307	0.694669605	Run54 (from 2nd category)	Run36 (from 2nd category)

RUNs	RMSE	NS-Coefficient	Production	Attraction
run15	65.24638	0.694263918	Run54 (from 2nd category)	Run33 (from 2nd category)
run5	65.27499	0.693995742	Run54 (from 2nd category)	run 33 (from 3rd category)
Run54 (from 2nd category)	65.28632	0.693889481	Same equation	
run6	65.33325	0.693449205	Run54 (from 2nd category)	Run21 (from 2nd category)
run16	65.45013	0.692351408	Run54 (from 2nd category)	Run34 (from 2nd category)
run7	65.477	0.692098727	Run54 (from 2nd category)	Run14 (from 2nd category)
run17	65.50137	0.691869533	Run54 (from 2nd category)	Run31 (from 2nd category)
run 33 (from 3rd category)	65.51234	0.69176632	Same equation	
run1	65.55389	0.691375171	run 33 (from 3rd category)	Run54 (from 2nd category)

The variation of RMSE with the different range of volume of links is presented in Appendix 4. And the scatter plots of above runs are shown in Appendix 5.

6 Conclusions and Recommendations

The following conclusions can be made from the results:

- Best iterations have been found where NACIS 2, NAICS 3, Value of shipments, Personal income and Population were present.
- It can also be seen that none of them can have any significant effect on the modeled traffic flows as the value of RMSE and NS coefficient resulted from the chosen factors and contribution levels, are almost constant.
- From Appendices 4 and 5, the same conclusion can be stated that the variation of RMSE with link volume has same trend for 10 best iterations. And the scatter plots look alike and cannot be distinguished easily.

It is suggested to include other new factors and test their effect on modeled traffic, following a similar disaggregation method.

References

1. Harris, G. *A Freight Planning Framework*, Office for Freight, Logistics & Transportation, University of Alabama in Huntsville, November 2008.
2. Krishnan Viswanathan, K. Daniel Beagan, V. Mysore, and N. Srinivasan. *Disaggregating FAF^2 Data for Florida: Methodology and Results*, Submitted to the 2008 Transportation Research Board Annual Meeting, 2008.
3. Monsere, C.M. *A GIS based multi-commodity freight model: Typology, model refinement and field validation*, Dissertation for Degree in Civil Engineering, Iowa State University, 2001.
4. Anderson, M., G. Harris, S. Jeereddy, S. Gholston, J. Swain, and N. Schoening. *Using a Federal Database and New Factors for Disaggregation of Freight to a Local Level*, University of Alabama in Huntsville, 2008.
5. Rowinski, J., K. Opie, and L. N. Spasovic. *Development of a Method to Disaggregate the 2002 FAF^2 Data down to the County Level for New Jersey*, Submitted for review for presentation at the 87th Annual Meeting of the Transportation Research Board (TRB) and publication in the conference proceedings, November 2007.
6. Opie, K., J. Rowinski, and L. N. Spasovic. *Commodity Specific Disaggregation of the 2002 FAF^2 Data to the County Level for New Jersey*, Submitted for review for Presentation at the 88th Annual Meeting of the Transportation Research Board and Publication in the Transportation Research Record, November 2008.

Appendix 1 Trip generation by purpose from excel

RUN	WTS	W1 =	W2 =	W3 =	W4 =	SUM Cons
36		0	0	0.5	0	1
			W5	W6	W7	W8
			0	0.5	0	0

Where,

W1	W2	W3	W4	W5	W6	W7	W8
Population	Personal Income	Value of Shipment	Employment	NAICS 1	NAICS 2	NAICS 3	Purchase power POPXINCOM

Production by purpose down to county level

1-1	1-2	2-1	2-2	1-all	2-all	all-1	all-2	through
5253	**2895**	**2012**	**627**	**1575**	**4505**	**2150**	**4053**	
62	34	0	0	19	0	0	0	0
97	54	0	0	29	0	0	0	0
41	23	0	0	12	0	0	0	0
0	0	16	5	0	36	0	0	0
0	0	46	14	0	102	0	0	0
10	6	0	0	3	0	0	0	0
14	8	0	0	4	0	0	0	0
128	71	0	0	38	0	0	0	0
36	20	0	0	11	0	0	0	0
11	6	0	0	3	0	0	0	0
0	0	51	16	0	115	0	0	0
25	14	0	0	8	0	0	0	0
30	17	0	0	9	0	0	0	0
17	10	0	0	5	0	0	0	0
10	6	0	0	3	0	0	0	0
32	18	0	0	10	0	0	0	0
79	44	0	0	24	0	0	0	0
9	5	0	0	3	0	0	0	0
5	3	0	0	1	0	0	0	0
45	25	0	0	13	0	0	0	0
13	7	0	0	4	0	0	0	0
0	0	128	40	0	287	0	0	0
14	8	0	0	4	0	0	0	0
91	50	0	0	27	0	0	0	0
128	71	0	0	38	0	0	0	0
27	15	0	0	8	0	0	0	0

85	47	0	0	25	0	0	0	0
48	27	0	0	14	0	0	0	0
13	7	0	0	4	0	0	0	0
198	109	0	0	59	0	0	0	0
15	8	0	0	4	0	0	0	0
9	5	0	0	3	0	0	0	0
11	6	0	0	3	0	0	0	0
25	14	0	0	7	0	0	0	0
86	47	0	0	26	0	0	0	0
73	40	0	0	22	0	0	0	0
0	0	1431	446	0	3205	0	0	0
23	13	0	0	7	0	0	0	0
37	20	0	0	11	0	0	0	0
78	43	0	0	24	0	0	0	0
89	49	0	0	27	0	0	0	0
88	49	0	0	26	0	0	0	0
61	33	0	0	18	0	0	0	0
58	32	0	0	17	0	0	0	0
275	151	0	0	82	0	0	0	0
25	14	0	0	7	0	0	0	0
30	16	0	0	9	0	0	0	0
140	77	0	0	42	0	0	0	0
458	253	0	0	137	0	0	0	0
81	45	0	0	24	0	0	0	0
142	78	0	0	43	0	0	0	0
199	110	0	0	60	0	0	0	0
6	4	0	0	2	0	0	0	0
19	11	0	0	6	0	0	0	0
19	11	0	0	6	0	0	0	0
19	10	0	0	6	0	0	0	0
23	12	0	0	7	0	0	0	0
0	0	106	33	0	237	0	0	0
0	0	121	38	0	271	0	0	0
41	23	0	0	12	0	0	0	0
697	384	0	0	209	0	0	0	0
47	26	0	0	14	0	0	0	0
978	539	0	0	293	0	0	0	0
0	0	112	35	0	251	0	0	0
69	38	0	0	21	0	0	0	0
20	11	0	0	6	0	0	0	0
42	23	0	0	13	0	0	0	0
0	0	0	0	0	0	173	325	2582
0	0	0	0	0	0	303	571	4534
0	0	0	0	0	0	352	664	5271
0	0	0	0	0	0	40	75	594
0	0	0	0	0	0	69	130	1035
0	0	0	0	0	0	211	398	3161

0	0	0	0	0	0	36	68	536
0	0	0	0	0	0	53	99	787
0	0	0	0	0	0	132	249	1977
0	0	0	0	0	0	394	744	5902
0	0	0	0	0	0	162	305	2424
0	0	0	0	0	0	49	92	734
0	0	0	0	0	0	79	149	1186
0	0	0	0	0	0	8	15	118
0	0	0	0	0	0	89	167	1329

Attraction by purpose down to county level

62	0	24	0	0	0	25	0	0
97	0	37	0	0	0	40	0	0
41	0	16	0	0	0	17	0	0
0	23	0	5	0	0	0	32	0
0	66	0	14	0	0	0	92	0
10	0	4	0	0	0	4	0	0
14	0	5	0	0	0	6	0	0
128	0	49	0	0	0	52	0	0
36	0	14	0	0	0	15	0	0
11	0	4	0	0	0	5	0	0
0	74	0	16	0	0	0	104	0
25	0	10	0	0	0	10	0	0
30	0	12	0	0	0	12	0	0
17	0	7	0	0	0	7	0	0
10	0	4	0	0	0	4	0	0
32	0	12	0	0	0	13	0	0
79	0	30	0	0	0	33	0	0
9	0	3	0	0	0	4	0	0
5	0	2	0	0	0	2	0	0
45	0	17	0	0	0	18	0	0
13	0	5	0	0	0	5	0	0
0	185	0	40	0	0	0	259	0
14	0	5	0	0	0	6	0	0
91	0	35	0	0	0	37	0	0
128	0	49	0	0	0	53	0	0
27	0	10	0	0	0	11	0	0
85	0	33	0	0	0	35	0	0
48	0	18	0	0	0	20	0	0
13	0	5	0	0	0	5	0	0
198	0	76	0	0	0	81	0	0
15	0	6	0	0	0	6	0	0
9	0	4	0	0	0	4	0	0
11	0	4	0	0	0	5	0	0
25	0	9	0	0	0	10	0	0
86	0	33	0	0	0	35	0	0

73	0	28	0	0	0	30	0	0
0	2060	0	446	0	0	0	2883	0
23	0	9	0	0	0	9	0	0
37	0	14	0	0	0	15	0	0
78	0	30	0	0	0	32	0	0
89	0	34	0	0	0	36	0	0
88	0	34	0	0	0	36	0	0
61	0	23	0	0	0	25	0	0
58	0	22	0	0	0	24	0	0
275	0	105	0	0	0	112	0	0
25	0	10	0	0	0	10	0	0
30	0	11	0	0	0	12	0	0
140	0	54	0	0	0	57	0	0
458	0	176	0	0	0	188	0	0
81	0	31	0	0	0	33	0	0
142	0	54	0	0	0	58	0	0
199	0	76	0	0	0	82	0	0
6	0	2	0	0	0	3	0	0
19	0	7	0	0	0	8	0	0
19	0	7	0	0	0	8	0	0
19	0	7	0	0	0	8	0	0
23	0	9	0	0	0	9	0	0
0	152	0	33	0	0	0	213	0
0	174	0	38	0	0	0	244	0
41	0	16	0	0	0	17	0	0
697	0	267	0	0	0	285	0	0
47	0	18	0	0	0	19	0	0
978	0	374	0	0	0	400	0	0
0	161	0	35	0	0	0	225	0
69	0	27	0	0	0	28	0	0
20	0	8	0	0	0	8	0	0
42	0	16	0	0	0	17	0	0
0	0	0	0	126	362	0	0	2582
0	0	0	0	222	635	0	0	4534
0	0	0	0	258	738	0	0	5271
0	0	0	0	29	83	0	0	594
0	0	0	0	51	145	0	0	1035
0	0	0	0	155	443	0	0	3161
0	0	0	0	26	75	0	0	536
0	0	0	0	39	110	0	0	787
0	0	0	0	97	277	0	0	1977
0	0	0	0	289	827	0	0	5902
0	0	0	0	119	339	0	0	2424
0	0	0	0	36	103	0	0	734
0	0	0	0	58	166	0	0	1186
0	0	0	0	6	16	0	0	118
0	0	0	0	65	186	0	0	1329

Appendix 2 Transferring county trips in a notepad

62	34	0	0	19	0	0	0	0
97	54	0	0	29	0	0	0	0
41	23	0	0	12	0	0	0	0
0	0	16	5	0	36	0	0	0
0	0	46	14	0	102	0	0	0
10	6	0	0	3	0	0	0	0
14	8	0	0	4	0	0	0	0
128	71	0	0	38	0	0	0	0
36	20	0	0	11	0	0	0	0
11	6	0	0	3	0	0	0	0
0	0	51	16	0	115	0	0	0
25	14	0	0	8	0	0	0	0
30	17	0	0	9	0	0	0	0
17	10	0	0	5	0	0	0	0
10	6	0	0	3	0	0	0	0
32	18	0	0	10	0	0	0	0
79	44	0	0	24	0	0	0	0
9	5	0	0	3	0	0	0	0
5	3	0	0	1	0	0	0	0
45	25	0	0	13	0	0	0	0
13	7	0	0	4	0	0	0	0
0	0	128	40	0	287	0	0	0
14	8	0	0	4	0	0	0	0
91	50	0	0	27	0	0	0	0
128	71	0	0	38	0	0	0	0
27	15	0	0	8	0	0	0	0
85	47	0	0	25	0	0	0	0
48	27	0	0	14	0	0	0	0
13	7	0	0	4	0	0	0	0
198	109	0	0	59	0	0	0	0
15	8	0	0	4	0	0	0	0
9	5	0	0	3	0	0	0	0
11	6	0	0	3	0	0	0	0
25	14	0	0	7	0	0	0	0
86	47	0	0	26	0	0	0	0
73	40	0	0	22	0	0	0	0
0	0	1431	446	0	3205	0	0	0
23	13	0	0	7	0	0	0	0
37	20	0	0	11	0	0	0	0
78	43	0	0	24	0	0	0	0
89	49	0	0	27	0	0	0	0

88	49	0	0	26	0	0	0	0
61	33	0	0	18	0	0	0	0
58	32	0	0	17	0	0	0	0
275	151	0	0	82	0	0	0	0
25	14	0	0	7	0	0	0	0
30	16	0	0	9	0	0	0	0
140	77	0	0	42	0	0	0	0
458	253	0	0	137	0	0	0	0
81	45	0	0	24	0	0	0	0
142	78	0	0	43	0	0	0	0
199	110	0	0	60	0	0	0	0
6	4	0	0	2	0	0	0	0
19	11	0	0	6	0	0	0	0
19	11	0	0	6	0	0	0	0
19	10	0	0	6	0	0	0	0
23	12	0	0	7	0	0	0	0
0	0	106	33	0	237	0	0	0
0	0	121	38	0	271	0	0	0
41	23	0	0	12	0	0	0	0
697	384	0	0	209	0	0	0	0
47	26	0	0	14	0	0	0	0
978	539	0	0	293	0	0	0	0
0	0	112	35	0	251	0	0	0
69	38	0	0	21	0	0	0	0
20	11	0	0	6	0	0	0	0
42	23	0	0	13	0	0	0	0
0	0	0	0	0	0	173	325	2582
0	0	0	0	0	0	303	571	4534
0	0	0	0	0	0	352	664	5271
0	0	0	0	0	0	40	75	594
0	0	0	0	0	0	69	130	1035
0	0	0	0	0	0	211	398	3161
0	0	0	0	0	0	36	68	536
0	0	0	0	0	0	53	99	787
0	0	0	0	0	0	132	249	1977
0	0	0	0	0	0	394	744	5902
0	0	0	0	0	0	162	305	2424
0	0	0	0	0	0	49	92	734
0	0	0	0	0	0	79	149	1186
0	0	0	0	0	0	8	15	118
0	0	0	0	0	0	89	167	1329
62	0	24	0	0	0	25	0	0
97	0	37	0	0	0	40	0	0

41	0	16	0	0	0	17	0	0
0	23	0	5	0	0	0	32	0
0	66	0	14	0	0	0	92	0
10	0	4	0	0	0	4	0	0
14	0	5	0	0	0	6	0	0
128	0	49	0	0	0	52	0	0
36	0	14	0	0	0	15	0	0
11	0	4	0	0	0	5	0	0
0	74	0	16	0	0	0	104	0
25	0	10	0	0	0	10	0	0
30	0	12	0	0	0	12	0	0
17	0	7	0	0	0	7	0	0
10	0	4	0	0	0	4	0	0
32	0	12	0	0	0	13	0	0
79	0	30	0	0	0	33	0	0
9	0	3	0	0	0	4	0	0
5	0	2	0	0	0	2	0	0
45	0	17	0	0	0	18	0	0
13	0	5	0	0	0	5	0	0
0	185	0	40	0	0	0	259	0
14	0	5	0	0	0	6	0	0
91	0	35	0	0	0	37	0	0
128	0	49	0	0	0	53	0	0
27	0	10	0	0	0	11	0	0
85	0	33	0	0	0	35	0	0
48	0	18	0	0	0	20	0	0
13	0	5	0	0	0	5	0	0
198	0	76	0	0	0	81	0	0
15	0	6	0	0	0	6	0	0
9	0	4	0	0	0	4	0	0
11	0	4	0	0	0	5	0	0
25	0	9	0	0	0	10	0	0
86	0	33	0	0	0	35	0	0
73	0	28	0	0	0	30	0	0
0	2060	0	446	0	0	0	2883	0
23	0	9	0	0	0	9	0	0
37	0	14	0	0	0	15	0	0
78	0	30	0	0	0	32	0	0
89	0	34	0	0	0	36	0	0
88	0	34	0	0	0	36	0	0
61	0	23	0	0	0	25	0	0
58	0	22	0	0	0	24	0	0
275	0	105	0	0	0	112	0	0

25	0	10	0	0	0	10	0	0
30	0	11	0	0	0	12	0	0
140	0	54	0	0	0	57	0	0
458	0	176	0	0	0	188	0	0
81	0	31	0	0	0	33	0	0
142	0	54	0	0	0	58	0	0
199	0	76	0	0	0	82	0	0
6	0	2	0	0	0	3	0	0
19	0	7	0	0	0	8	0	0
19	0	7	0	0	0	8	0	0
19	0	7	0	0	0	8	0	0
23	0	9	0	0	0	9	0	0
0	152	0	33	0	0	0	213	0
0	174	0	38	0	0	0	244	0
41	0	16	0	0	0	17	0	0
697	0	267	0	0	0	285	0	0
47	0	18	0	0	0	19	0	0
978	0	374	0	0	0	400	0	0
0	161	0	35	0	0	0	225	0
69	0	27	0	0	0	28	0	0
20	0	8	0	0	0	8	0	0
42	0	16	0	0	0	17	0	0
0	0	0	0	126	362	0	0	2582
0	0	0	0	222	635	0	0	4534
0	0	0	0	258	738	0	0	5271
0	0	0	0	29	83	0	0	594
0	0	0	0	51	145	0	0	1035
0	0	0	0	155	443	0	0	3161
0	0	0	0	26	75	0	0	536
0	0	0	0	39	110	0	0	787
0	0	0	0	97	277	0	0	1977
0	0	0	0	289	827	0	0	5902
0	0	0	0	119	339	0	0	2424
0	0	0	0	36	103	0	0	734
0	0	0	0	58	166	0	0	1186
0	0	0	0	6	16	0	0	118
0	0	0	0	65	186	0	0	1329

Appendix 3 Input from FORTRAN

GP	1	1	62	34	0	0	19	0	0	0	0
GP	2	1	97	54	0	0	29	0	0	0	0
GP	3	1	41	23	0	0	12	0	0	0	0
GP	4	1	0	0	16	5	0	36	0	0	0
GP	5	1	0	0	46	14	0	102	0	0	0
GP	6	1	10	6	0	0	3	0	0	0	0
GP	7	1	14	8	0	0	4	0	0	0	0
GP	8	1	128	71	0	0	38	0	0	0	0
GP	9	1	36	20	0	0	11	0	0	0	0
GP	10	1	11	6	0	0	3	0	0	0	0
GP	11	1	0	0	51	16	0	115	0	0	0
GP	12	1	25	14	0	0	8	0	0	0	0
GP	13	1	30	17	0	0	9	0	0	0	0
GP	14	1	17	10	0	0	5	0	0	0	0
GP	15	1	10	6	0	0	3	0	0	0	0
GP	16	1	32	18	0	0	10	0	0	0	0
GP	17	1	79	44	0	0	24	0	0	0	0
GP	18	1	9	5	0	0	3	0	0	0	0
GP	19	1	5	3	0	0	1	0	0	0	0
GP	20	1	45	25	0	0	13	0	0	0	0
GP	21	1	13	7	0	0	4	0	0	0	0
GP	22	1	0	0	128	40	0	287	0	0	0
GP	23	1	14	8	0	0	4	0	0	0	0
GP	24	1	91	50	0	0	27	0	0	0	0
GP	25	1	128	71	0	0	38	0	0	0	0
GP	26	1	27	15	0	0	8	0	0	0	0
GP	27	1	85	47	0	0	25	0	0	0	0
GP	28	1	48	27	0	0	14	0	0	0	0
GP	29	1	13	7	0	0	4	0	0	0	0
GP	30	1	198	109	0	0	59	0	0	0	0
GP	31	1	15	8	0	0	4	0	0	0	0
GP	32	1	9	5	0	0	3	0	0	0	0
GP	33	1	11	6	0	0	3	0	0	0	0
GP	34	1	25	14	0	0	7	0	0	0	0
GP	35	1	86	47	0	0	26	0	0	0	0
GP	36	1	73	40	0	0	22	0	0	0	0
GP	37	1	0	0	1431	446	0	3205	0	0	0
GP	38	1	23	13	0	0	7	0	0	0	0
GP	39	1	37	20	0	0	11	0	0	0	0
GP	40	1	78	43	0	0	24	0	0	0	0
GP	41	1	89	49	0	0	27	0	0	0	0

GP	42	1	88	49	0	0	26	0	0	0	0
GP	43	1	61	33	0	0	18	0	0	0	0
GP	44	1	58	32	0	0	17	0	0	0	0
GP	45	1	275	151	0	0	82	0	0	0	0
GP	46	1	25	14	0	0	7	0	0	0	0
GP	47	1	30	16	0	0	9	0	0	0	0
GP	48	1	140	77	0	0	42	0	0	0	0
GP	49	1	458	253	0	0	137	0	0	0	0
GP	50	1	81	45	0	0	24	0	0	0	0
GP	51	1	142	78	0	0	43	0	0	0	0
GP	52	1	199	110	0	0	60	0	0	0	0
GP	53	1	6	4	0	0	2	0	0	0	0
GP	54	1	19	11	0	0	6	0	0	0	0
GP	55	1	19	11	0	0	6	0	0	0	0
GP	56	1	19	10	0	0	6	0	0	0	0
GP	57	1	23	12	0	0	7	0	0	0	0
GP	58	1	0	0	106	33	0	237	0	0	0
GP	59	1	0	0	121	38	0	271	0	0	0
GP	60	1	41	23	0	0	12	0	0	0	0
GP	61	1	697	384	0	0	209	0	0	0	0
GP	62	1	47	26	0	0	14	0	0	0	0
GP	63	1	978	539	0	0	293	0	0	0	0
GP	64	1	0	0	112	35	0	251	0	0	0
GP	65	1	69	38	0	0	21	0	0	0	0
GP	66	1	20	11	0	0	6	0	0	0	0
GP	67	1	42	23	0	0	13	0	0	0	0
GP	68	1	0	0	0	0	0	0	173	325	2582
GP	69	1	0	0	0	0	0	0	303	571	4534
GP	70	1	0	0	0	0	0	0	352	664	5271
GP	71	1	0	0	0	0	0	0	40	75	594
GP	72	1	0	0	0	0	0	0	69	130	1035
GP	73	1	0	0	0	0	0	0	211	398	3161
GP	74	1	0	0	0	0	0	0	36	68	536
GP	75	1	0	0	0	0	0	0	53	99	787
GP	76	1	0	0	0	0	0	0	132	249	1977
GP	77	1	0	0	0	0	0	0	394	744	5902
GP	78	1	0	0	0	0	0	0	162	305	2424
GP	79	1	0	0	0	0	0	0	49	92	734
GP	80	1	0	0	0	0	0	0	79	149	1186
GP	81	1	0	0	0	0	0	0	8	15	118
GP	82	1	0	0	0	0	0	0	89	167	1329
GA	1	1	62	0	24	0	0	0	25	0	0
GA	2	1	97	0	37	0	0	0	40	0	0

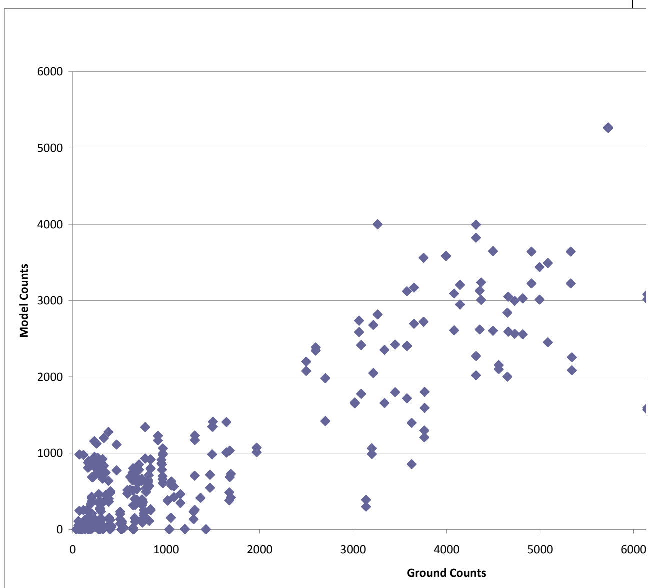
GA	3	1	41	0	16	0	0	0	17	0	0
GA	4	1	0	23	0	5	0	0	0	32	0
GA	5	1	0	66	0	14	0	0	0	92	0
GA	6	1	10	0	4	0	0	0	4	0	0
GA	7	1	14	0	5	0	0	0	6	0	0
GA	8	1	128	0	49	0	0	0	52	0	0
GA	9	1	36	0	14	0	0	0	15	0	0
GA	10	1	11	0	4	0	0	0	5	0	0
GA	11	1	0	74	0	16	0	0	0	104	0
GA	12	1	25	0	10	0	0	0	10	0	0
GA	13	1	30	0	12	0	0	0	12	0	0
GA	14	1	17	0	7	0	0	0	7	0	0
GA	15	1	10	0	4	0	0	0	4	0	0
GA	16	1	32	0	12	0	0	0	13	0	0
GA	17	1	79	0	30	0	0	0	33	0	0
GA	18	1	9	0	3	0	0	0	4	0	0
GA	19	1	5	0	2	0	0	0	2	0	0
GA	20	1	45	0	17	0	0	0	18	0	0
GA	21	1	13	0	5	0	0	0	5	0	0
GA	22	1	0	185	0	40	0	0	0	259	0
GA	23	1	14	0	5	0	0	0	6	0	0
GA	24	1	91	0	35	0	0	0	37	0	0
GA	25	1	128	0	49	0	0	0	53	0	0
GA	26	1	27	0	10	0	0	0	11	0	0
GA	27	1	85	0	33	0	0	0	35	0	0
GA	28	1	48	0	18	0	0	0	20	0	0
GA	29	1	13	0	5	0	0	0	5	0	0
GA	30	1	198	0	76	0	0	0	81	0	0
GA	31	1	15	0	6	0	0	0	6	0	0
GA	32	1	9	0	4	0	0	0	4	0	0
GA	33	1	11	0	4	0	0	0	5	0	0
GA	34	1	25	0	9	0	0	0	10	0	0
GA	35	1	86	0	33	0	0	0	35	0	0
GA	36	1	73	0	28	0	0	0	30	0	0
GA	37	1	0	2060	0	446	0	0	0	2883	0
GA	38	1	23	0	9	0	0	0	9	0	0
GA	39	1	37	0	14	0	0	0	15	0	0
GA	40	1	78	0	30	0	0	0	32	0	0
GA	41	1	89	0	34	0	0	0	36	0	0
GA	42	1	88	0	34	0	0	0	36	0	0
GA	43	1	61	0	23	0	0	0	25	0	0
GA	44	1	58	0	22	0	0	0	24	0	0
GA	45	1	275	0	105	0	0	0	112	0	0

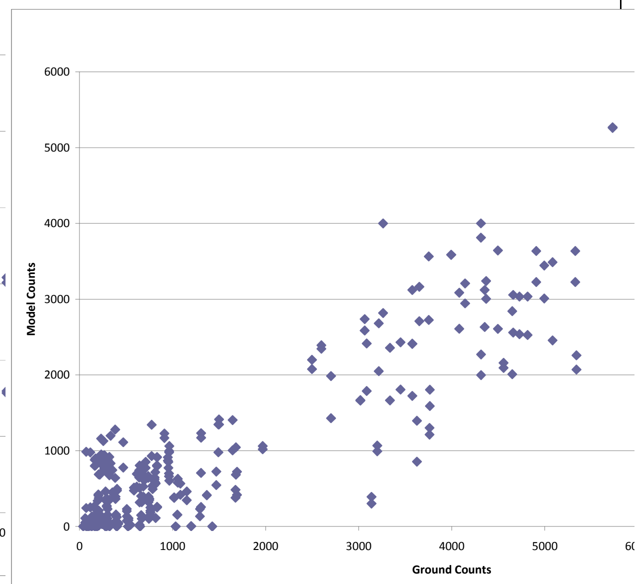
GA	46	1	25	0	10	0	0	0	10	0	0
GA	47	1	30	0	11	0	0	0	12	0	0
GA	48	1	140	0	54	0	0	0	57	0	0
GA	49	1	458	0	176	0	0	0	188	0	0
GA	50	1	81	0	31	0	0	0	33	0	0
GA	51	1	142	0	54	0	0	0	58	0	0
GA	52	1	199	0	76	0	0	0	82	0	0
GA	53	1	6	0	2	0	0	0	3	0	0
GA	54	1	19	0	7	0	0	0	8	0	0
GA	55	1	19	0	7	0	0	0	8	0	0
GA	56	1	19	0	7	0	0	0	8	0	0
GA	57	1	23	0	9	0	0	0	9	0	0
GA	58	1	0	152	0	33	0	0	0	213	0
GA	59	1	0	174	0	38	0	0	0	244	0
GA	60	1	41	0	16	0	0	0	17	0	0
GA	61	1	697	0	267	0	0	0	285	0	0
GA	62	1	47	0	18	0	0	0	19	0	0
GA	63	1	978	0	374	0	0	0	400	0	0
GA	64	1	0	161	0	35	0	0	0	225	0
GA	65	1	69	0	27	0	0	0	28	0	0
GA	66	1	20	0	8	0	0	0	8	0	0
GA	67	1	42	0	16	0	0	0	17	0	0
GA	68	1	0	0	0	0	126	362	0	0	2582
GA	69	1	0	0	0	0	222	635	0	0	4534
GA	70	1	0	0	0	0	258	738	0	0	5271
GA	71	1	0	0	0	0	29	83	0	0	594
GA	72	1	0	0	0	0	51	145	0	0	1035
GA	73	1	0	0	0	0	155	443	0	0	3161
GA	74	1	0	0	0	0	26	75	0	0	536
GA	75	1	0	0	0	0	39	110	0	0	787
GA	76	1	0	0	0	0	97	277	0	0	1977
GA	77	1	0	0	0	0	289	827	0	0	5902
GA	78	1	0	0	0	0	119	339	0	0	2424
GA	79	1	0	0	0	0	36	103	0	0	734
GA	80	1	0	0	0	0	58	166	0	0	1186
GA	81	1	0	0	0	0	6	16	0	0	118
GA	82	1	0	0	0	0	65	186	0	0	1329

Appendix 4 Variation of RMSE with Link Volume

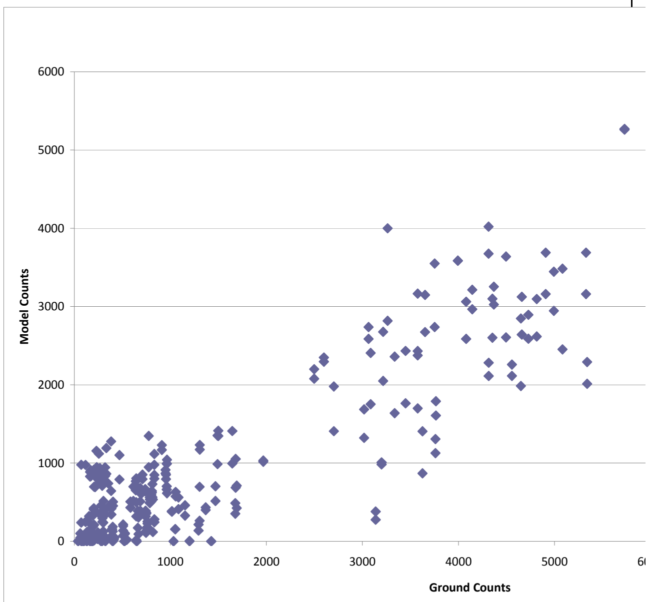
		Range					
		Link Volume 8000-7000	**Link Volume 7000-5000**	**Link Volume 5000-4000**	**Link Volume 4000-2000**	**Link Volume 2000-1000**	**Link Volume 1000-0**
Variation of RMSE	**run8**	36.15142	48.5952	38.6948	44.95847	64.49014	82.89061
	run15	36.26087	48.58894	38.77338	44.8801	64.52841	82.85016
	run5	35.99466	48.63179	38.47617	45.49466	64.80009	83.03195
	Run54 (from 2nd category)	36.42868	48.50588	38.65835	45.21271	63.83141	82.69662
	run6	35.93588	48.95263	39.18641	44.57882	64.86985	83.18583
	run16	37.20185	49.02607	38.39142	44.42862	64.44849	82.16032
	run7	36.20229	49.01519	38.95535	44.90793	64.85012	83.24645
	run17	37.26791	49.05094	38.4998	44.37578	64.41497	82.14854
	run 33 (from 3rd category)	35.47221	48.76263	38.78822	46.21993	65.33559	83.51733
	run1	35.95324	48.68387	38.99348	45.88036	64.3452	83.42982

Appendix 5 Scatter Plots

<table>
<tr><td>run8</td><td>run15</td></tr>
<tr><td>


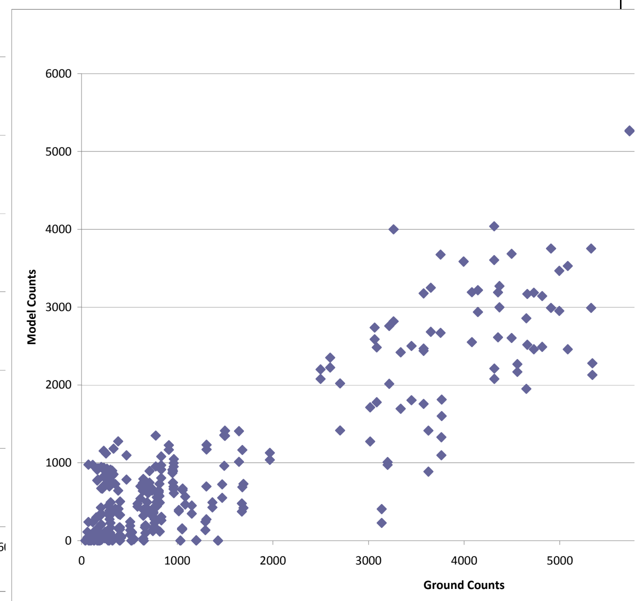
</td><td>


</td></tr>
<tr><td>run5</td><td>Run54 (from 2nd category)</td></tr>
</table>



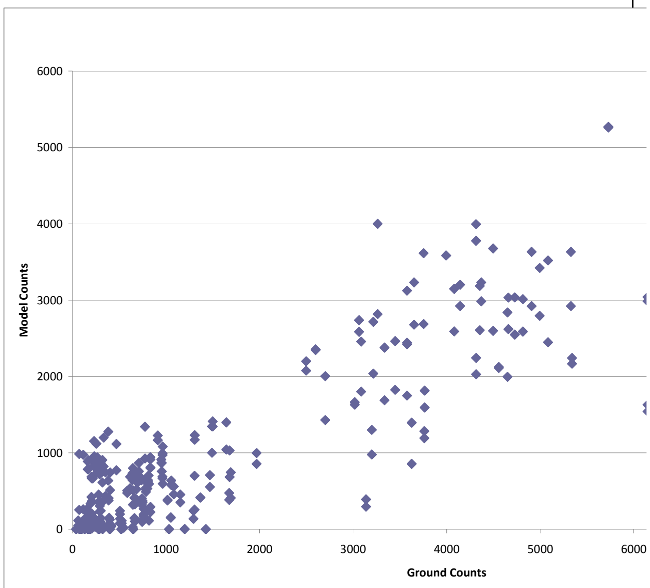
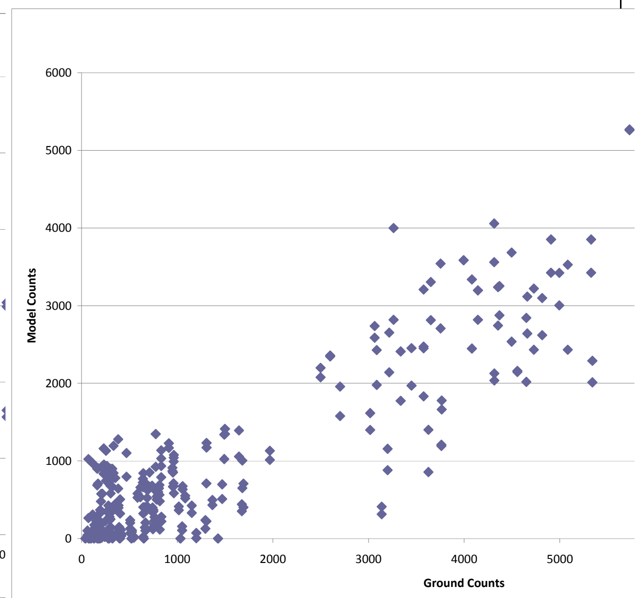
6000
5000
4000
3000
2000
1000
0
Model Counts
0
1000
2000
3000
4000
5000
Ground Counts

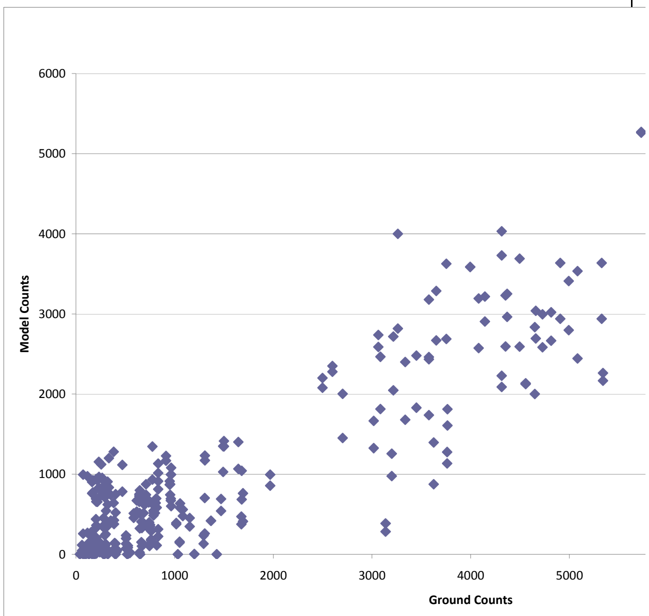
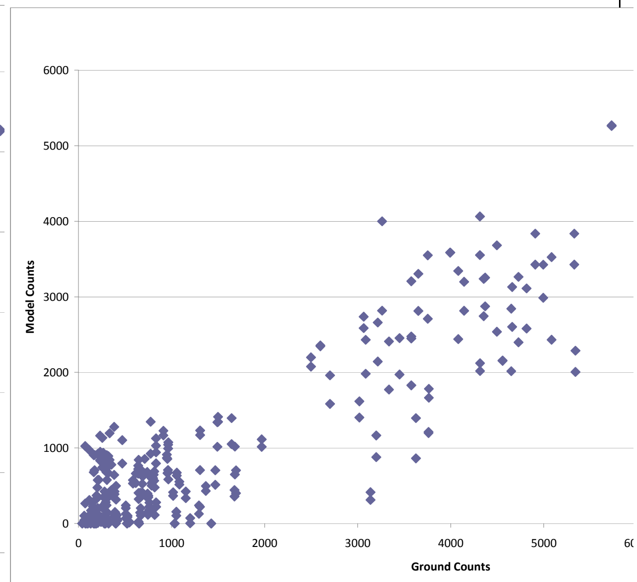
run6

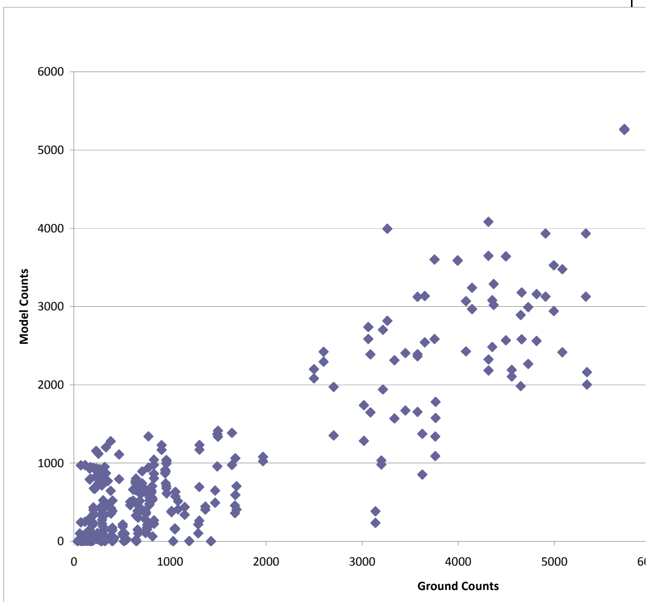


6000
5000
4000
3000
2000
1000
0
Model Counts
0
1000
2000
3000
4000
5000
Ground Counts

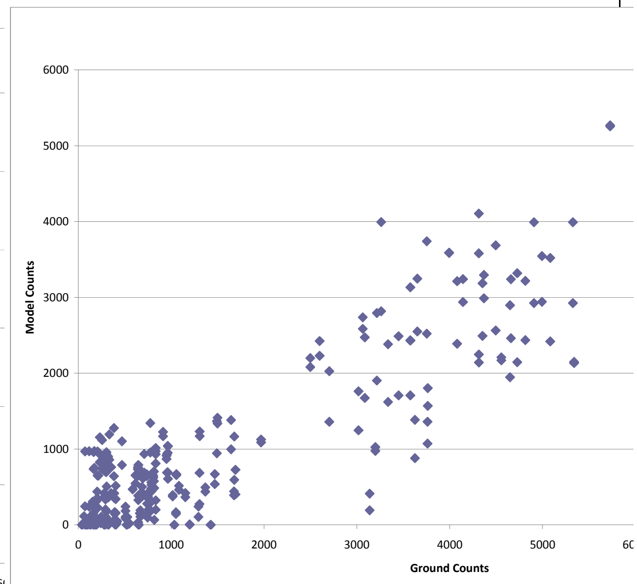
run16

<table>
<tr>
<td>
</td>
<td>
</td>
</tr>
<tr>
<td>run7</td>
<td>run17</td>
</tr>
</table>

	
run 33 (from 3rd category)	run1



6000
5000
4000
3000
2000
1000
0
Model Counts
0
1000
2000
3000
4000
5000
Ground Counts



6000
5000
4000
3000
2000
1000
0
Model Counts
0
1000
2000
3000
4000
5000
Ground Counts

6. List of Researchers

This research is the result of the professional efforts of the following team:

Gregory A. Harris, Ph.D., P.E., Principal Investigator
Director, Office for Freight, Logistics & Transportation, UAH

Michael D. Anderson, Ph.D., P.E.
Associate Professor, Civil and Environmental Engineering, UAH

Phillip A. Farrington, Ph.D.
Professor, Industrial & Systems Engineering, Engineering Management, UAH

Anthony Holden
Research Scientist, Alabama Technology Network, UAH

Lauren J. Neppel
Research Scientist, Office for Freight, Logistics & Transportation, UAH

Nicholas Loyd
Principal Research Scientist, Alabama Technology Network, UAH

Allison Mote
Research Associate, Alabama Technology Network, UAH

Niles C. Schoening, Ph.D.
Professor, College of Business Administration, Economics, UAH

Bernard J. Schroer, Ph.D., P.E.
Principal Research Scientist, Office for Freight, Logistics & Transportation, UAH

Jeff Siniard
Principal Research Scientist, Alabama Technology Network, UAH

James J. Swain, Ph.D.
Professor, Industrial & Systems Engineering, Engineering Management, UAH

Jeff Thompson
Principal Research Scientist, Strategic Business Services, UAH

Karen Yarbrough
Research Scientist, Strategic Business Services, UAH

This is a *draft compilation* of the research completed for Project No. AL-26-7262-02.

7. Journal Articles and Conference Papers

Journal Articles

1. "Developing Freight Analysis Zones at a State Level: A Cluster Analysis Approach," *Journal of Transportation Research Forum*, submitted April 2009 (G. Harris, M. Anderson, P. Farrington, N. Schoening, J. Swain, and N. Sharma).

Conference Papers

1. "Developing Freight Analysis Zones at a State Level: A Cluster Analysis Approach," *Proceedings of the 49th Annual Transportation Research Forum*, March 17-19, 2008, Houston, Texas, (G.A. Harris, M.D. Anderson, N.S. Schoening, J.J. Swain).

8. Appendices

8.1 Appendices for Section 2-1

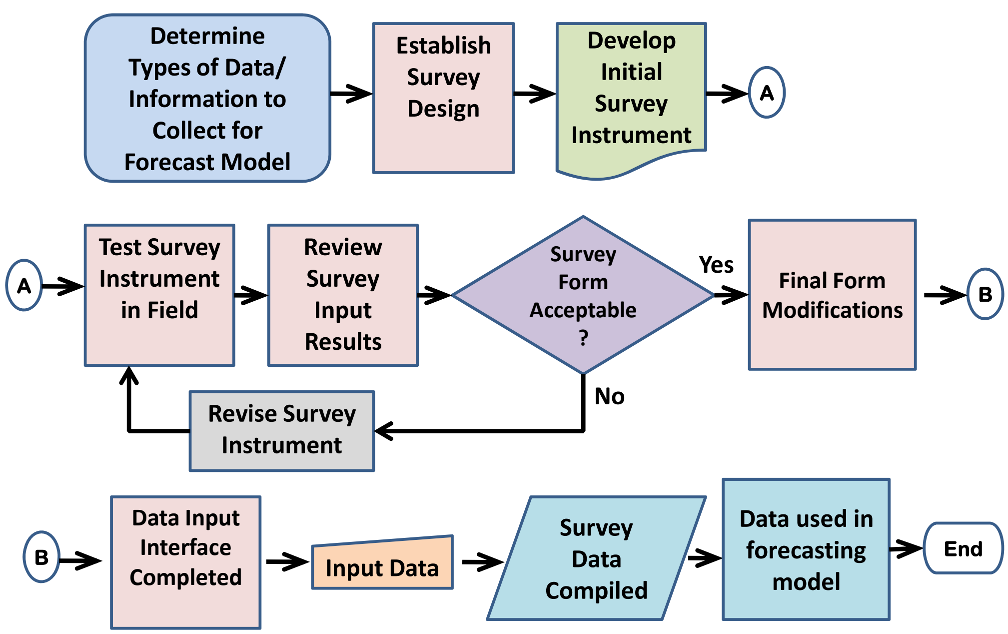
8.1.1 Appendix A

INDUSTRY SURVEY INSTRUMENT DEVELOPMENT
Overview of Survey Development Process Steps

Estimated Data Needed for Two SCTG Categories without NAIC counterparts

Combining economic and freight movement data together to provide the transportation planner with enough detail to allocate traffic by industrial sector found that two SCTG categories lacked NAIC counterparts. Those two SCTG categories, mixed freight and waste and scrap, require separate estimations using other sources. The use of company surveys was the research method chosen to gather key input to determine estimations for the mixed freight SCTG category. The following narrative provides an overview of the industry survey instrument development process detailed below.

Industry Survey Instrument Development
Overview of Survey Development Process



Specific Data Requirements Determined to Develop Mixed Freight Estimations

The initial step of the survey instrument development process was the identification of types of data and information to gather from companies that could provide insight for the SCTG mixed freight category.

Major data groups were determined with specific types of specific data to request within each data group that could be addressed in the company survey. A list of the data groups and types of specific data to request are shown in the chart below.

Data Groups	Types of Specific Data to Request
Plant Information	address, contact, size, employment
Freight	value & volume
Shipments	in/out bound, original destinations, modes, weight, carriers
Business cycles	seasonality, time of day
Transportation Issues & Needs	

Determination of the Survey Design

The second step of the industry survey instrument design process was three-fold; determine the type of companies to be surveyed; and within those companies – which company representative level would have the greatest knowledge of the information needed and could be targeted for interviews; and selection of a method for data collection.

The SCTG mixed freight category represents a broad range of freight that does not fit into other SCTG categories. Information concerning movement of freight from distributors or from the manufacturers to retail was needed.

Based on the types of specific data that would need to be collected, the company representatives interviewed would be managers or supervisors of logistics or have working knowledge of their company's freight transportation activities. Considering the types of companies and the types of company representatives targeted, it was determined to develop, test, and utilize a written survey questionnaire and perform a mix of in-person and telephone interviews utilizing the same survey instrument for consistent quality of input.

Types of questions used in survey design included multiple choice, numeric open ended and text open ended multiple choice questions. Some questions included rating scales and agreement scales. These multiple types were chosen to keep the discussion focused on the issue of freight transportation needed. The order of questions and grouping within the survey were chosen to encourage company representatives cooperation. And, survey questions were limited in number to facilitate completion of the data gathering with each contact. The early questions in the survey are designed to build rapport with the interviewer. The more detailed or sensitive questions were placed later in the survey to improve response sharing.

http://www.surveysystem.com/sdesign.htm#methods

Major Data Groups

The types of data sought through the survey process included these groups:

- Plant/facility information – address, contact name, size, and employment
- Freight type – value & volume
- Shipments – inbound and outbound, origins/destinations, modes, weight can carriers
- Business cycles – seasonality, time of day fluctuations
- Transportation issues and needs – open ended problems or potential transportation problems

Testing the Instrument

An initial draft of the survey form was created and used to conduct ten (10) interviews. The purposes of the test were to evaluate ease of use, clarity of phrasing, usefulness of data gathered, order and pace of the questions, and suitability for gathering the needed information. After the initial interviews were conducted, the researchers reviewed the interview experiences, responses to the questions, and relevance of each question.

The first revision removed irrelevant questions such as plant or store number, separate inbound and outbound shipment weights (for a simple estimate of the percentage of capacity used in the vehicle delivering the freight. Additionally, the seasonality and time of day questions found little variation across the year or day respectfully. Instead, a simple discussion of their "busiest" season was substituted.

Revising & Re-Testing the Instrument

The revised survey instrument was used to conduct a 24 more interviews. Again, the post test phase included tweaking the order of the questions as well as making the form easier to complete during the interview process. Specifically, the number of shipments by type of carrier did not provide any insight as most interviewees did not know the answer nor did they track that type of information for inbound shipments. However, "vessel" was added to the types of carries, as several respondents used port facilities and received and shipped goods by ship.

While the exact point of origin for freight was important, the respondents often did not know from where a shipment originated or could not generalize about origins as there freight “came from all over”. The form was modified to record the compass direction (N, E, W, S) by relative percentage of freight shipped and received.

The average size of shipments inbound and outbound questions were rephrased to better capture responses in a format that could be used in the database. Volume occupied by their freight and types of vehicles used for their freight were data points that respondents frequently knew. By using this information with the fully loaded weight of the particular vehicle, an approximation of the shipment weight could be made.

Full Deployment of the Survey Process

The third version of the survey form was used to conduct the remaining 40 interviews in the initial data gathering phase of this project. The data was collected and entered into the database for analysis. The 34 earlier interview forms were translated into the latest format which was used for completing the database design. During these interviews, notes were made in the white space of the forms to capture important information or clarification about any data point. These notes were used to complete the fourth version of the survey form. The fourth version was created by adding the specific names of the three local ports so they could be circled instead of written. Finally, the form was formatted with color and various font treatments to facilitate interviewer use.

Survey and Database Consistency

The final version of the completed survey was then compared to the data input screens for the database. Tweaks like page breaks, question flow, and default values were made to the database input screens to reduce keypunch error and facilitate ease of data entry.

Results

A survey form that facilitates discussion through an interview in person or by phone improves the quality of data gathered. Experience with the data form (testing) is an important process that should not be omitted when developing an new data collection tool. Although further changes may made to the data collection form in the future, the current version was a valuable tool in gathering data for the two SCTG categories (mixed freight and waste/scrap) for which there was no easy translation to NAICS categories which prevented using the normal economic variables as proxies to distribution freight.

8.1.2 Appendix B

ID Code: ______

Freight Forward Transportation Survey UAH – Office for Freight, Logistics and Transportation

	FILL IN BEFORE VISIT:	DATE OF SURVEY:	_____/____/_____
1	Company Name:	______________________________	
2	Street Address:	______________________________	
3	City	______________________________	
4	State	______________________________	
5	Zip	______________________________	
6	Phone:	______________________________	
	COMPLETE AT INTERVIEW:		
7	Contact Name:	______________________________	
8	Contact Title/Position:	______________________________	
9	Email Address:	______________________________	
	BEGIN SURVEY QUESTIONS:		

10 Does your company at this location: Ship products to retail locations within the State of Alabama? YES NO

11 What is the number of stores served from this location
Total Stores
Alabama Stores:

12 What geographic region (by state or within AL - by county) does this location/warehouse serve?
All States Served: 1.___________ 2._________3.___________4._________ 5._________
6._________ All AL counties served: 1.___________ 2._________3.___________4._________
5._________ 6.______
(Ask for a list of Stores Served)
Note: ____

13 From what other location(s) does your company ship retail goods into State of Alabama?

#1 Location Name/City :

____

#1 Location Contact Name:

____

#1 Location Phone Number:

____

#2 Location of Warehouse # 2:

____

#2 Location Contact Name:

____

#2 Location Phone Number:

____

14 Does your company control the transportation of freight in and out of this facility?

YES NO

15 What is the total square footage at this location?

Square footage: ____________________

16 What percentage of capacity of this location is being used?

Today (circle one) 1-25% 26-50% 51-75% 76-100%

In Five Years (circle one) 1-25% 26-50% 51-75% 76-100%

Note:

____

17 Do you anticipate an expansion within 5 years (2012) at this location?

(Cycle one) No Expansion expected Double Current Size or Increase of ___________ sq ft or %

Note:

____

18 Does this location monitor inbound/outbound truck weight?

Inbound YES NO Avg truckload weight ? ________lbs

Outbound YES NO Avg truckload weight ? ________lbs

Freight Forward Transportation Survey UAH – Office for Freight, Logistics and Transportation

FILL IN BEFORE VISIT: **DATE OF SURVEY:** _____/____/_____

1 Company Name:

19 What is the total value of goods handled last year (2006) at this location?
(round to nearest $1000): $________________ (=) value of goods - Retail or Wholesale Value?

20 What was the annual INBOUND volume at this location:

last year - 2006?	Number	Avg $ Value/Load	Primary Product	Primary Origin	Product Categories
Full Truck loads from Alabama					Apparel
Full Truck loads from outside Alabama					Auto Parts
LTL Trucks from Alabama					Books
LTL Trucks from outside Alabama					Electronics
Common Carriers (UPS, FEDEX)					Furniture
Rail CARS or CONTAINERS					Mixed

Note: ____

five years ago - 2001?	Number	Avg $ Value/Load	Primary Product	Primary Origin	Product Categories
Full Truck loads from Alabama					Apparel
Full Truck loads from outside Alabama					Auto Parts
LTL Trucks from Alabama					Books
LTL Trucks from outside Alabama					Electronics
Common Carriers (UPS, FEDEX)					Furniture
Rail CARS or CONTAINERS					Mixed

Note: ____

21 What do you expect the annual volume to be 5 years (2012) from now?

(in # of inbound shipments) #__________

Note: ____

FILL IN BEFORE VISIT:	DATE OF SURVEY:	_____/____/_____
1 CompanyName:		

22 What is the source of inbound shipments to your facility?

Manufacturer ________%

→ Your Distribution Center →

Distributor/Freight handler ________%

Total = 100%

23 Please rank each quarter's volume level of goods moving in/out of this location.

(By calendar year - 1 being least amount of activity & 4 being the most amount of activity) Jan-Mar _______ Apr-Jun _______ Jul-Sept _______ Oct-Dec _______

24 Please rank the busiest time of day for your location?

(1 being least amount of activity & 3 being the most amount of activity)

8 a.m. to 4 p.m. ______ 4 p.m. to midnight ______ Midnight to 8 a.m. ______

25 Average length of time of goods stay at this location?

Crossdocked goods ________ unit ______ (hrs, days, etc.)

Inventoried goods ________ unit ______ (hrs, days, etc.)

Note: ____

26 What percentage of inbound shipments are cross-docked?

_________% inbound shipments

27 What percentage of current volume is transported by company-vehicle ?

Inbound ________% of current volume Outbound ________% of current volume

Note: ____

28 What percentage of current volume is transported by common carrier ?
Inbound ________% of current volume Outbound ________% of current volume

Note: ____

29 How many employees work at this location?
Full-time employees: ____________________
Part-time employees: _________________

30 What transportation related problems are you currently experiencing in shipping or receiving your products from this location/warehouse?

31 What transportation infrastructure improvements are needed in Alabama to better serve your current and future needs?

THANK YOU

8.2 Appendices for Section 2-4

8.2.1 Appendix A

Rail Performance Measures

Association of American Railroads Performance Measures

Performance Measure	Definition
Cars On Line	The average of the daily online inventory of freight cars.
Car Type On Line	The average of the daily online inventory of freight cars by type, such as box car, covered hopper, gondola, intermodal, multi-level, open hopper, tank, and other.
Car Ownership	Whether the train cars are System Cars meaning they are owned by the railroad on which they are located, Foreign Cars which are owned by rail companies other than the rail line they are on, and Private Cars which are owned by a non-railroad.
Train Speed	Measures the line haul movement between terminals. The average speed is calculated by dividing train miles by total hours operated, excluding yard and local trains, passenger trains, maintenance of way trains, and terminal time. Train speeds are given for the following train types: Intermodal, Manifest, Multi-level, Coal Unit, Grain Unit, and All trains.
Terminal Dwell Hours	The average time a car resides at the specified terminal location expressed in hours. The measurement begins with a customer release, received interchange, or train arrival event and ends with a customer placement (actual or constructive), delivered or offered in interchange, or train departure event.

Federal Railroad Administration Performance Measures

Safety	• Grade Crossing Incidents • Human-Factor Train Accidents • Track-Caused Train Incidents • Equipment-Caused Train Accidents • Signal/Misc Train Accidents • Non-Accident Hazmat Releases

NCHRP Report 446 Performance Measures

Accessibility	• Miles of track in operation (by FRA rating) • Existence of railroad electrification
Mobility	• Origin-destination travel times • Total travel time • Average travel time from facility to destination • Average speed • Delay per VMT • Delay due to incidents • Reserve Capacity • Queuing of vehicles and its relationship to overall delays • Interference of movement at grade crossings – delay time and speed • Percentage of on-time performance • Minute variation in trip time • Fluctuations in traffic volumes • Percentage of scheduled departures that do not leave within a specified time limit • Ton miles of rail freight into/through metropolitan areas • Traffic at border crossings • Delay per ton mile traveled • Capacity restrictions • Facility usage by mode(V/C)
Economic Development	• Percent of state gross product • Economic costs of pollution • Economic costs of accidents • Economic costs of fatalities • Economic costs of lost time • Economic costs of congestion • Tonnage originating and terminating
Quality of Life	• Tons of pollution generated
Environmental & Resource Conservation	• Number of accidents involving hazardous waste
Safety	• Number of fatalities and injuries occurring on the rail system • Exposure (AADT and daily trains) factor for rail crossings • Accidents at major intermodal crossings • Railroad/highway at-grade crossings

	• Grade crossing safety improvements • Number of accidents per VMT • Number of accidents per year • Number of accidents per trip • Number of accidents per capita • Number of accidents per ton mile traveled • National rank for accident, injury, fatality rates • Fatality (or injury) rate of accidents
Operational Efficiency	• Rail freight revenue versus operating expenses • Additional revenue earned by producers when shipping via rail • Line-haul speed • Average travel time between intermodal facility and rail • Number of carloads shipped/received on rail project lines • Public cost for transportation system • Private cost for transportation system • Total public expenditures on modal systems (freight vs. passenger) • Cost/benefit of existing facility vs. new construction • Infrastructure maintenance expense • Average cost per mile • Insurance costs • Value of fuel savings • Productivity and utility by mode
System Preservation	• Track condition • Miles of track not useable by certain traffic because of design or condition deficiencies • Miles of track in operation (by FRA rating) • Track miles abandoned • Track miles under threat of abandonment • Miles of rail line acquired and rehabilitated for rail service • Remaining service life • Capacity/remaining useful life index • Present serviceability rating • Maintenance condition as measured against departmental standards • System condition • Customer perception of condition of system • Maintenance hours • Current average maintenance costs

Waterway Performance Measures

U.S. Department of Maritime Administration Performance Measures

US Waterborne Trade	• Foreign container imports and exports • Domestic container coastal, inland, and lake
US/Foreign container trade by US Port of entry	
US and Global Waterborne Trade	• coal • iron ore • petroleum • grain • container • liquefied natural gas
Vessel Calls at US Ports	• tanker • product • crude • container • dry bulk • ro-ro • gas • combo • general
Container ship calls at US ports	
US flag vessel calls at US ports	
Vessel calls by US coast	
North American cruise passengers by departure port	
Employment in water transportation and port services	
Water transportation gross output	
Energy inputs by mode	

U.S. Army Corps of Engineers Performance Measures

Performance Measure	Definition
Delay at river locks and dams	A mobility measure. The average delay in time for vessels moving through river locks and dams.
Locking time by dam	A mobility measure. The average locking time at each dam in the waterway system.
Dams in need of structural upgrade	A system preservation measure. The number of dams in need of structural upgrade.
Operating ports and terminals	An economic development measure. The number of operating ports and terminals in the waterway system.
Collisions and maritime injuries	A safety measure. A 5 year average of the number of collisions and maritime injuries occurring in the waterway system.
Compliance with the Maritime Transportation Security Act	A safety measure. A measure of an agency's compliance with the Maritime Transportation Security Act
Cargo Volume by Port	An economic performance measure. The volume of cargo handled by each port, containerized, tonnage, bulk, etc.

NCHRP Report 446 Performance Measures

Accessibility	• Number of ports with railroad connections • Lift capacity (annual volume)
Mobility	• Number of dockage days at seaports • Origin-destination travel times • Total travel time • Average travel time from facility to destination • Average speed • Delay per VMT • Delay due to incidents • Reserve Capacity • Percentage of on-time performance • Minute variation in trip time • Fluctuations in traffic volumes • Percentage of scheduled departures that do not leave within a specified time limit • Delay per ton mile traveled

	• Capacity restrictions • Facility usage by mode(V/C)
Economic Development	• Number of cruise embarkations • Percent of state gross product • Economic costs of pollution • Economic costs of accidents • Economic costs of fatalities • Economic costs of lost time • Economic costs of congestion • Tonnage originating and terminating
Quality of Life	• Tons of pollution generated
Environmental & Resource Conservation	• Number of accidents involving hazardous waste
Safety	• Accidents (or injuries or fatalities) caused by waterborne transportation • Shipping accidents occurring on waterways • Number of accidents per VMT • Number of accidents per year • Number of accidents per trip • Number of accidents per capita • Number of accidents per ton mile traveled • National rank for accident, injury, fatality rates • Fatality (or injury) rate of accidents
Operational Efficiency	• Average cost for vehicle on ferry system • Customs and administrative processing time • Public cost for transportation system • Private cost for transportation system • Total public expenditures on modal systems (freight vs. passenger) • Cost/benefit of existing facility vs. new construction • Infrastructure maintenance expense • Average cost per mile • Insurance costs • Value of fuel savings • Productivity and utility by mode
System Preservation	• Miles to be dredged • Remaining service life

	• Capacity/remaining useful life index • Present serviceability rating • Maintenance condition as measured against departmental standards • System condition • Customer perception of condition of system • Maintenance hours • Current average maintenance costs

<u>Air Performance Measures</u>

Federal Aviation Administration – Aviation System Performance Measures

Huntsville International Airport Performance Measures

Performance Measure	Definition
Departures	Percentage of on time departures.
Arrivals	Percentage of on time arrivals.
Efficiency	The efficiency of the Airport, its departures, and its arrivals.
Capacity	The capacity of arrivals, departures, and the total number.
Traffic Counts	Traffic counts on all scheduled operations.
Times (Average Minutes)	Time in average minutes for departure activities such as Gate Delay, and Taxi Out Delay. Time in average minutes for arrival activities such as Airborne Delay, Taxi In Delay, Block Delay, and Arrival Delay.
Facility Reported Operations	Air Carrier, Air Taxi, General Aviation, Military, Total
AFSS Customer Satisfaction Rating	The resulting survey rating based on a series of questions gauging customer satisfaction with the quality, timeliness, accuracy, customer service, and relevance of overall and specific services received.
Number of Operational Errors	The sum of the operational errors year to date as defined in FAA Order 7210.56, Air Traffic Quality Assurance, attributed to SP performance.
Number of Operational Deviations	The sum of the operational deviations year to date as defined in FAA Order 7210.56, Air Traffic Quality Assurance, attributed to SP performance.

Aviation System Performance Measures by Geoffrey D. Gosling

Commercial Service	General Aviation
Mobility and Accessibility	

Travel Time • Percent of air trips in markets served by nonstop flights • Percent of air trips in markets without nonstop service but served by connections through an airline hub or one-stop service • Percent of air trips in markets with at least six nonstop, one-stop or connecting flights per day • Number of international destinations served with nonstop flights with daily departures • Number of international destinations served with nonstop flights with at least three weekly departures *Delay* • Average delay experienced in traveling to and from the airport, measured as the average difference between actual access/egress highway travel times and free-flow travel times, weighted by the distribution of trip ends • Average delay experienced during the flight, expressed as the difference between actual flight times and scheduled flight times during periods of light traffic *Access to Desired Destinations* • Percent of air trips in markets served by three or more carriers with nonstop, one-stop or connecting service • Percent of international departures in	• Average delay experienced in traveling to and from the airport, measured as the average difference between actual access/egress highway travel times and free-flow travel times, weighted by the distribution of based aircraft owner locations • Average delay per flight, estimated from the ratio of annual aircraft operations to the Annual Service Volume of the airport • Percent of regional/statewide based aircraft at airports with available hangar space • Percent of regional/statewide based aircraft at airports with available tie-down space • Percent of regional/statewide itinerant operations at airports with a control tower • Percent of regional/statewide itinerant operations at airports with an instrument approach capability • Percent of regional/statewide itinerant

markets with at least two carriers □Percent of air trips for which the nearest commercial airport provides direct or connecting air service through one intermediate hub □Percent of air trips for which the nearest commercial airport provides direct jet service to the destination or to an intermediate hub with direct service to the destination □Average additional distance to access the nearest airport with direct air service to the destination, or connecting air service through an intermediate hub when the destination is not served directly, compared to the distance to the nearest commercial airport *Access to the Airport System* □Percent of air trip ends within 45 minutes highway travel time of the nearest commercial service airport □Percent of air trip ends within 45 minutes highway travel time of the commercial service airport used □Average airport access/egress highway travel times under free-flow travel conditions, weighted by the distribution of trip ends □Percent of air trip ends within 5 miles of stops served by scheduled airport ground transportation services, including rail	operations at airports with approach and runway lighting □Percent of aircraft owners within 30 minutes of a general aviation airport, under free-flow travel conditions □Percent of population within 30 minutes of a general aviation airport with instrument landing capability, under free-flow travel conditions

transit and express airport bus services Percent of air trip ends in communities served by airport shared-ride van services Percent of air passenger airport access/egress trips using shared-ride public transportation	
Reliability	
Percent of flights arriving more than 15 minutes late Percent of flights arriving more than 30 minutes late Average departure delay per flight Standard deviation of highway airport access/egress travel times, weighted by the distribution of trip ends	
Cost Effectiveness	
Average fare paid per mile for intrastate air trips Average fare paid per mile for air trips **from** California to domestic destinations outside the state Average fare paid per mile for air trips **to** California from domestic origins outside the state	Average annual hangar space rental cost Average annual tie-down space rental cost Average cost per gallon paid for aviation gasoline Average cost per gallon paid by general aviation for jet fuel
Economic Well-Being	
Commercial airport productivity in terms of equivalent passengers per dollar of annual operating cost, including airline station costs and annualized cost of capital investments in airport and air traffic control infrastructure	General aviation airport productivity in terms of aircraft operations per dollar of annual operating cost, including annualized cost of capital investments and provision of air traffic control services

Sustainability	
Average percentage of household income spent on commercial air travel Average percentage of gross state product spent on commercial air transportation Average fuel consumption per ton-mile of all commercial flights originating in California Percent of airfield pavement at commercial service airports in California in fair condition, as reported in the FAA Airport Safety Data Program Percent of airfield pavement at commercial service airports in California in poor condition, as reported in the FAA Airport Safety Data Program	Average cost of owning and operating a private aircraft used primarily for personal flying Average cost of owning and operating a private aircraft used primarily for business purposes Percent of airfield pavement at general aviation airports in California in fair condition, as reported in the FAA Airport Safety Data Program Percent of airfield pavement at general aviation airports in California in poor condition, as reported in the FAA Airport Safety Data Program
Environmental Quality	
Number of households exposed to aircraft noise levels exceeding 65 dB California Noise Equivalent Level (CNEL) near commercial service airports Number of households exposed to aircraft noise levels exceeding 60 dB CNEL near commercial service airports Tons per year of carbon monoxide (CO) generated by aircraft operations at commercial service airports in the state Tons per year of volatile organic compounds (VOC) generated by aircraft operations at commercial service airports in the state Tons per year of nitrogen oxides (NOx) generated by aircraft operations at	Number of households exposed to aircraft noise levels exceeding 65 dB CNEL near general aviation airports Number of households exposed to aircraft noise levels exceeding 60 dB CNEL near general aviation airports Tons per year of criteria pollutants (CO, NOx, VOC and SO2) generated by aircraft operations at general aviation airports in the state Vehicle-miles of travel per year by automobiles making trips to and from general aviation airports

commercial service airports in the state Tons per year of sulfur dioxide (SO_2) generated by aircraft operations at commercial service airports in the state Tons per year of greenhouse gases generated by commercial aircraft operations departing from airports in the state Vehicle-miles of travel per year by automobiles making trips to and from commercial service airports Vehicle-miles of travel per year by diesel or gasoline powered buses or passenger vans making trips to and from commercial service airports Vehicle-miles of travel per year by low emission buses or passenger vans making trips to and from commercial service airports Vehicle-miles of travel per year by trucks making trips to and from commercial service airports	
Safety and Security	
Accident rate on commercial airline flights, expressed as the moving average five- year probability of being killed on a commercial flight taken at random from a California airport	Accident rate to general aviation operations, expressed as the number of fatal accidents per flight hour
Equity	
Ten-year moving average of federal Airport Improvement Fund grants at each commercial	Ten-year moving average of state airport development grants to general aviation airports in each county, expressed as a ratio of the

service airport, expressed as a ratio of the enplaned passenger traffic at the airport Ten-year moving average of aircraft noise mitigation program expenditures by airport authorities in communities adjacent to the airport, expressed as a ratio of the number of households within the 60 dB CNEL contour Ten-year moving average of airport ground access/egress traffic mitigation program expenditures by airport authorities, expressed as a ratio of the enplaned passenger traffic at the airport	number of registered aircraft owners with addresses in the county Ten-year moving average of state airport development grants to general aviation airports in each county, expressed as a ratio of the number of based aircraft at airports in the county
Customer Satisfaction	
Air passenger satisfaction index Air cargo shipper satisfaction index	Aircraft owner satisfaction index

NCHRP Report 446 Performance Measures

Accessibility	• Air transportation capacity • Amount of scheduled service between major cities • Number of cities over one million population served directly by nonstop commercial airline flights from airports in state • Airport improvement and cost scheduled at airport • Airports within 30 minute drive of agricultural centers capable of supporting twin-engine piston powered aircraft • Percent of aviation community reached through aviation service programs • Percent of general aviation needs funded • Percent of jobs within 45 minutes of airports • Minimum layover times at airports or passenger terminals • Access time to passenger facility • Transfer distance at passenger facility

	• Existence of information services and ticketing • Availability of intermodal ticketing and luggage transfer • V/C of parking spaces during daily peak hours for bus, rail, park and ride, or other passenger terminal lots • Parking spaces per passenger • Parking spaces available for loading/unloading vehicles • Number of pick-up and discharge areas for passengers
Mobility	• Delay time at primary commercial airports • Origin-destination travel times • Total travel time • Average travel time from facility to destination • Average speed • Delay per VMT • Delay due to incidents • Reserve Capacity • Percentage of on-time performance • Delay per ton mile traveled • Capacity restrictions • Facility usage by mode(V/C) • Minute variation in trip time • Fluctuations in traffic volumes • Percentage of scheduled departures that do not leave within a specified time limit
Economic Development	• Percent of state gross product • Economic costs of pollution • Economic costs of accidents • Economic costs of fatalities • Economic costs of lost time • Economic costs of congestion • Tonnage originating and terminating
Quality of Life	• Tons of pollution generated
Environmental & Resource Conservation	• Number of accidents involving hazardous waste
Safety	• Accidents (or injuries or fatalities) caused by air transportation

	• Percentage of airports that meet federal and state planning and design standards • Number of landing areas inspected • Number of airports where weather information is collected for dissemination to pilots • Total annual attendance at pilot safety seminars • Number of accidents per VMT • Number of accidents per year • Number of accidents per trip • Number of accidents per capita • Number of accidents per ton mile traveled • National rank for accident, injury, fatality rates • Fatality (or injury) rate of accidents
Operational Efficiency	• Delay time at primary commercial airports • Cost per ton mile as it compares to cost per air, water, or rail mile • Enplanements per aviation system employee • Public cost for transportation system • Private cost for transportation system • Total public expenditures on modal systems (freight vs. passenger) • Cost/benefit of existing facility vs. new construction • Infrastructure maintenance expense • Average cost per mile • Insurance costs • Value of fuel savings • Productivity and utility by mode
System Preservation	• Runway resurfacing frequency • Hours or days out of service • Remaining service life • Capacity/remaining useful life index • Present serviceability rating • Maintenance condition as measured against departmental standards • System condition • Customer perception of condition of system • Maintenance hours

	• Current average maintenance costs

Intermodal Performance Measures

Huntsville Intermodal Center Performance Measures

Trains	• Inbound loads • Outbound loads • Inbound empties • Outbound empties • Inbound transfers • Outbound transfers
Trucks	• Inbound gate activity • Outbound gate activity • Gate activity per hour
Cranes/Lifts	• Total rail lifts • Total secondary lifts

NCHRP Report 446 Performance Measures

Accessibility	• Average distance to intermodal terminals from different community shipping points • Number of intermodal facilities • Capacity of intermodal terminals • Average travel time between intermodal facility and rail • Amount of turning radius from major highway to intermodal facility • Number of TEUs that can be stored on the premises of the intermodal facility • Number of trucks that can be loaded with bulk material per hour of loading time • Types of modes handled • Freight dock availability • Track capacity • Double stack capacity • Number of intermodal facilities that agency assists in development
Mobility	• Average transfer time/ delays • Dwell time in intermodal facilities • Truck turnaround time at intermodal facilities • Avg. processing time for shipments at intermodal terminals

	• Delay of trucks at facility per VMT • Delay of trucks at facility per ton mile • Frequency of delays at intermodal facilities • Customs delays • Tons of commodity undergoing intermodal transfer • Avg. travel time between intermodal facility and rail • Origin-destination travel times • Total travel time • Average travel time from facility to destination • Average speed • Delay per VMT • Delay due to incidents • Reserve Capacity • Percentage of on-time performance • Minute variation in trip time • Fluctuations in traffic volumes • Percentage of scheduled departures that do not leave within a specified time limit • Delay per ton mile traveled • Capacity restrictions • Facility usage by mode(V/C)
Economic Development	• Percent of state residents aware of intermodal opportunities • Percent increase in intermodal facility use • Percent of state gross product • Economic costs of pollution • Economic costs of accidents • Economic costs of fatalities • Economic costs of lost time • Economic costs of congestion • Tonnage originating and terminating
Quality of Life	• Tons of pollution generated
Environmental & Resource Conservation	• Number of accidents involving hazardous waste
Safety	• Number of accidents per VMT • Number of accidents per year

	• Number of accidents per trip • Number of accidents per capita • Number of accidents per ton mile traveled • National rank for accident, injury, fatality rates • Fatality (or injury) rate of accidents • Number of accidents per intermodal transfer
Operational Efficiency	• Percent of transfers between modes to be under ‘X’ minutes and ‘N’ feet • Transfer times between modes • Number of users of intermodal facilities • Percent of intermodal connecting points and facilities accurately placed on a map • Average processing time for shipments at intermodal terminals • Public cost for transportation system • Private cost for transportation system • Total public expenditures on modal systems (freight vs. passenger) • Cost/benefit of existing facility vs. new construction • Infrastructure maintenance expense • Average cost per mile • Insurance costs • Value of fuel savings • Productivity and utility by mode • Tons transferred per hour • Average transfer time/delays • Average processing time for shipments at intermodal terminals
System Preservation	• Remaining service life • Capacity/remaining useful life index • Present serviceability rating • Maintenance condition as measured against departmental standards • System condition • Customer perception of condition of system • Maintenance hours • Current average maintenance costs

8.3 Appendices for Section 4

8.3.1 Appendix A

Lean Assessment

July 13-14, 2009

Dole Fresh Fruit
Gulfport, Mississippi

Stuart Jablon
Vice President of Terminal Operations
Dole Fresh Fruit
Wilmington, DE

Prepared by:
Jeff Siniard and Nicholas Loyd
University of Alabama in Huntsville
Center for Management and Economic Research

(256) 824-6202
Jeff.Siniard@uah.edu

(256) 824-3025
Nicholas.Loyd@uah.edu

I. PURPOSE:

The purpose of this assessment is to fulfill requirements set forth in the US DOT grant issued to The University of Alabama Huntsville (UAH) and to provide Dole Fresh Fruit Gulfport (Dole) with a "Lean Enterprise" assessment of their Banana/Pineapple operation in Gulfport, Mississippi. A lean enterprise assessment provides a snapshot analysis of where a company is currently. The assessment also evaluates the facility against recognized best practices found in operations throughout the country who are successfully implementing Lean Enterprise.

This assessment will focus on several areas including but not limited to communication within the organization, workplace organization, visual systems, standardized work, Total Productive Maintenance, and inventory management. This assessment will identify areas of opportunity for improvement, focus on the tools and methodology of lean enterprise, and provide recommendations to determine the best approach to achieve lean excellence.

Lean enterprise transformation is achieved through vision, training, implementation, and discipline. The process should begin with the establishment of a customer-focused vision that all personnel involved in the Gulfport operations can embrace (including contract union labor, stevedores, tugboat services, etc.). Training is employed to achieve a common level of language and knowledge for all personnel involved in the Gulfport operation. Value Stream Mapping is employed to identify areas for improvement and develop an improvement plan. The preferred method of implementation is through kaizen, employee involved, team oriented, fast paced, continuous improvement events. The transformation is sustained through discipline by adhering to new, improved processes/procedures and management conveying the importance of Lean improvements to all employees.

Successful implementation of lean enterprise, benefits organizations by producing results relative to reduced operating cost, increased productivity, improved quality, and enhanced customer satisfaction.

II. <u>ASSESSMENT:</u>

This assessment was performed on July 13-14, 2009 with the objective of evaluating Dole Fresh Fruit Gulfport's daily operations. During our visit we observed a well managed seaport operation. All Dole employees we interviewed seem very competent and knowledgeable of their area of responsibility. There was good communication within Dole's management team and with the contract union labor supporting the operation. We observed very detailed planning and flexibility to efficiently unload/load the vessel and there was a seemingly effective maintenance program in place for all onsite equipment.

Although this is a well managed operation, several opportunities for improvement were also observed. The first opportunity we observed was the absence of a visible company vision/mission statement anywhere on the facility. From a strategic standpoint, the presence of a vision and mission statement gives a reference point by which to focus efforts and make decisions.

The next opportunity observed was the absence of a management steering committee to coordinate and direct improvement activities. Although terminal management and staff meet on a regular basis, there is no formal team-based ownership of continuous improvement activities.

The next opportunity observed was the absence of value stream mapping. Proper value stream management is critical to a successful operation. Typically, a lean organization's management steering committee exists of the managers of each value stream and key operational executives.

The next opportunity observed was there were no standard operating procedures (SOPs) posted anywhere on the facility. Although most employees know what to do, the fact that no SOPs are being used contributes to errors/mistakes and a heavy dependence on-the-job-training (OJT) for all new employees. This typically results in inconsistent work methods and increased time to accomplish proper training.

The next area observed was the lack of posted performance metrics in the work areas. Dole collects and manages to certain performance data related to each process Yet none of the information is clearly posted so that the people who have the most influence on this data know at a glance how well they are doing (For example during the unloading/loading of the vessel, data is collected for lifts per hour from each crane. This data is used very well at Dole to make adjustments to the unloading/loading plan based on each crane's performance. This information should be posted visibly each hour so every employee involved in the unloading/loading operation knows the current status of the operation).

The next area observed was the lack of a Total Productive Maintenance program (TPM) for the equipment on the ship (specifically the cranes). Both gantry cranes on the ship are the lifeblood of the unloading/loading activities yet they breakdown occasionally. A TPM event for the gantry cranes would establish a complete maintenance program for each crane and greatly reduce unplanned downtime.

The next area observed was the absence of visuals in the warehouse operations. Simple visual communication (signs, charts, lines on the floor, visual work instructions, etc.) allows every employee to have immediate understanding of a situation or process.

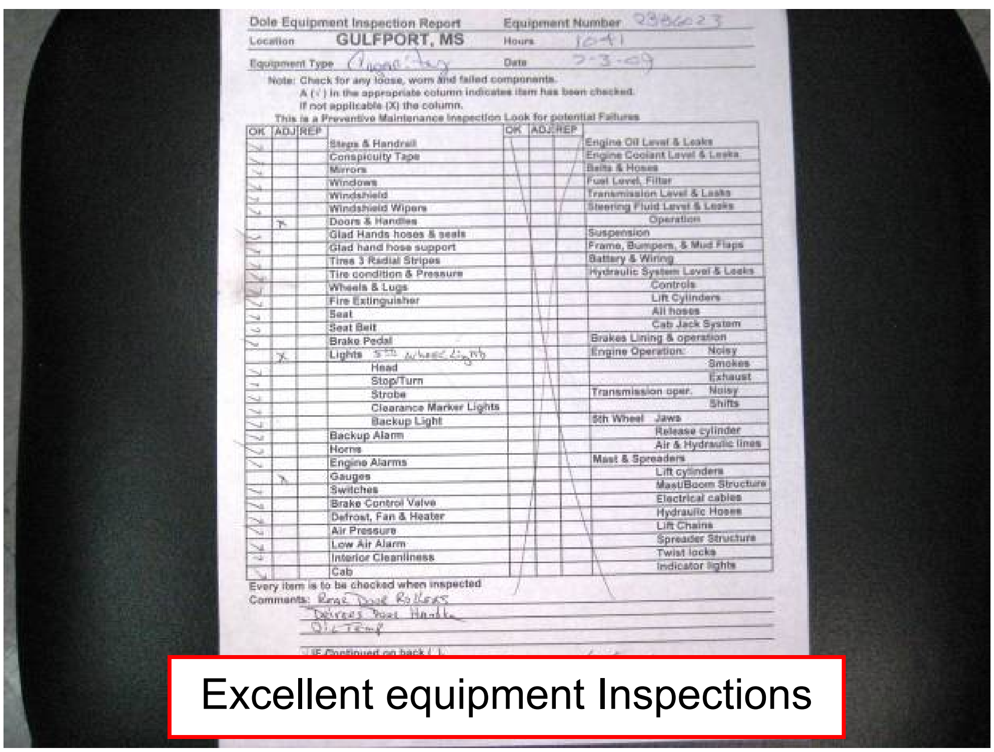
The last area observed was in the maintenance building/tent where chassis maintenance is being preformed. Even though the maintenance management at this location is superior to most maintenance facilities we visit, there is opportunity to improve workplace organization. At a glance, the area appears to be clean but the application of a systematic workplace organization system could greatly reduce time spent searching for needed tools and equipment for repairs. Ultimately, this could result in less time to perform repairs, meaning critical equipment can return more quickly to its operation.

Below are pictures supporting the observation:

Absence of visual communication at the vessel area (vision/mission statement, performance metrics, SOPs, etc.)

Unplanned crane downtime

Good visuals in the yard, drivers can locate container quickly



Excellent equipment Inspections

Absence of visuals and organization in the warehouse creates excess searching for correct material to load

True workplace organization states everything should have a place, everything should be in its place and it should be very obvious when it is not. Most items (tool boxes, test equipment, etc.) in the maintenance area did not have a clear home.

III. RECOMMENDATIONS:

1. Establish a vision/mission statement that is clearly posted and communicate to all personnel (this includes all contract union labor, stevedores, etc.)

A clear vision/mission statement properly communicated and posted throughout the facility that all employees can embrace will equip every employee with a better understanding of Dole's commitment of meeting their customers' needs by eliminating waste and improving at all levels of the organization.

Example: Strategic Vision posted and visible to all employees

2. Establish a management steering committee:

A Management Steering Committee will provide guidance and resources for all continuous improvement initiatives. It will be represented by all levels of the organization and it will include people from Management, Production, Scheduling, Maintenance, etc. A strong and committed Management Steering Committee is a practical and proven way to ensure success.

Example: Management steering committee roles

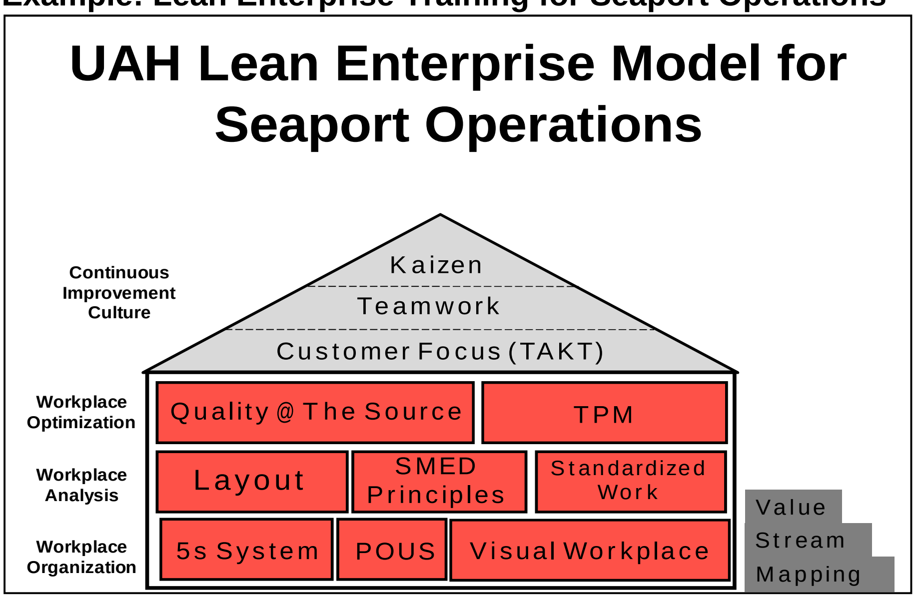
Roles of a Management Steering Committee

- **Understanding Lean Enterprise**
  - Training: Management, Facilitators/Lean Leaders, Employees
- **Setting Goals**
  - Identify opportunities and estimate savings
- **Conducting Improvement Events**
  - Projects
  - Resources/Support
- **Tracking**
  - Tracking System
  - Person Responsible
- **Sustaining**
  - Enforcing changes / recommendations
  - Mechanism to review and generate new project ideas

3. Train all employees on Lean Concepts for Port Operations:

Employees get an overview of the background of lean, the eight deadly wastes that exist in most processes, the lean tools used to eliminate those wastes relative to port operations, and the company will have a workforce that has a common language and understanding of wastes and how to eliminate them.

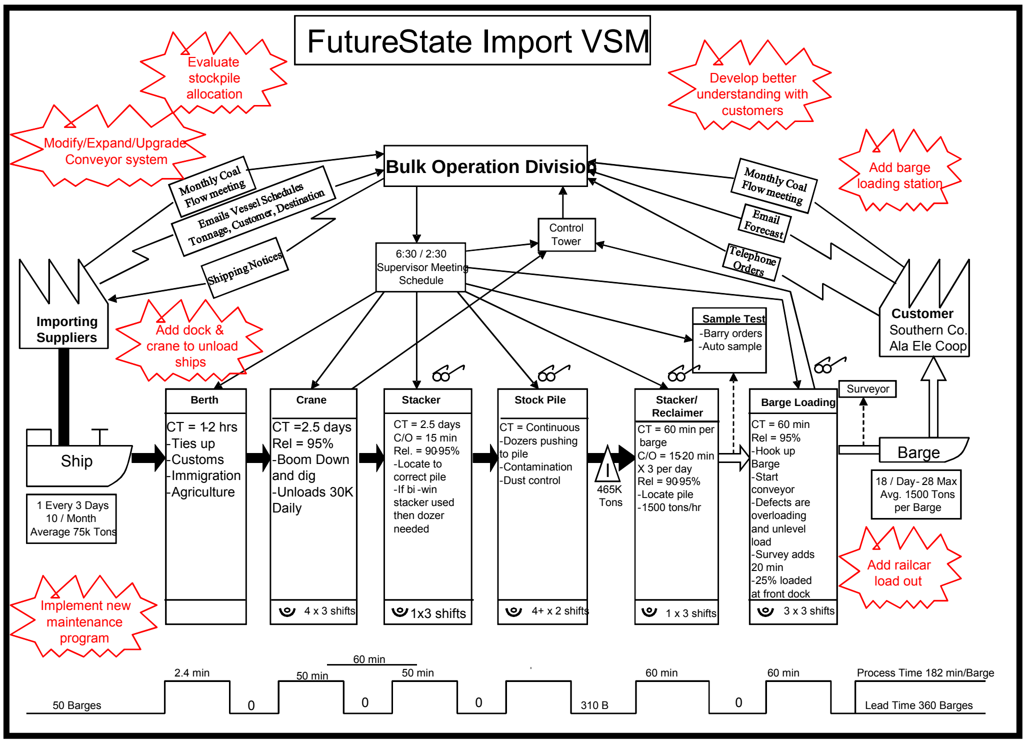
Example: Lean Enterprise Training for Seaport Operations



4. Map your Value Streams (fresh fruit and commercial cargo):

Proper value stream management is critical to any successful company. Value Stream Mapping (VSM) is a planning tool to help employees focus on when and where they should apply Lean concepts to get the most impact.

Example: Value Stream Map



5. Conduct improvement events or projects on the ship cranes (TPM event), maintenance tent/building (5s/workplace organization event), warehouse (visual workplace event), facility-wide (visual communication event), and develop visual standard operating procedures for all processes:

Kaizen is the vehicle to implement the tools learned in Lean Concepts. It is a focused process that utilizes a team-based approach empowering employees to make improvements.

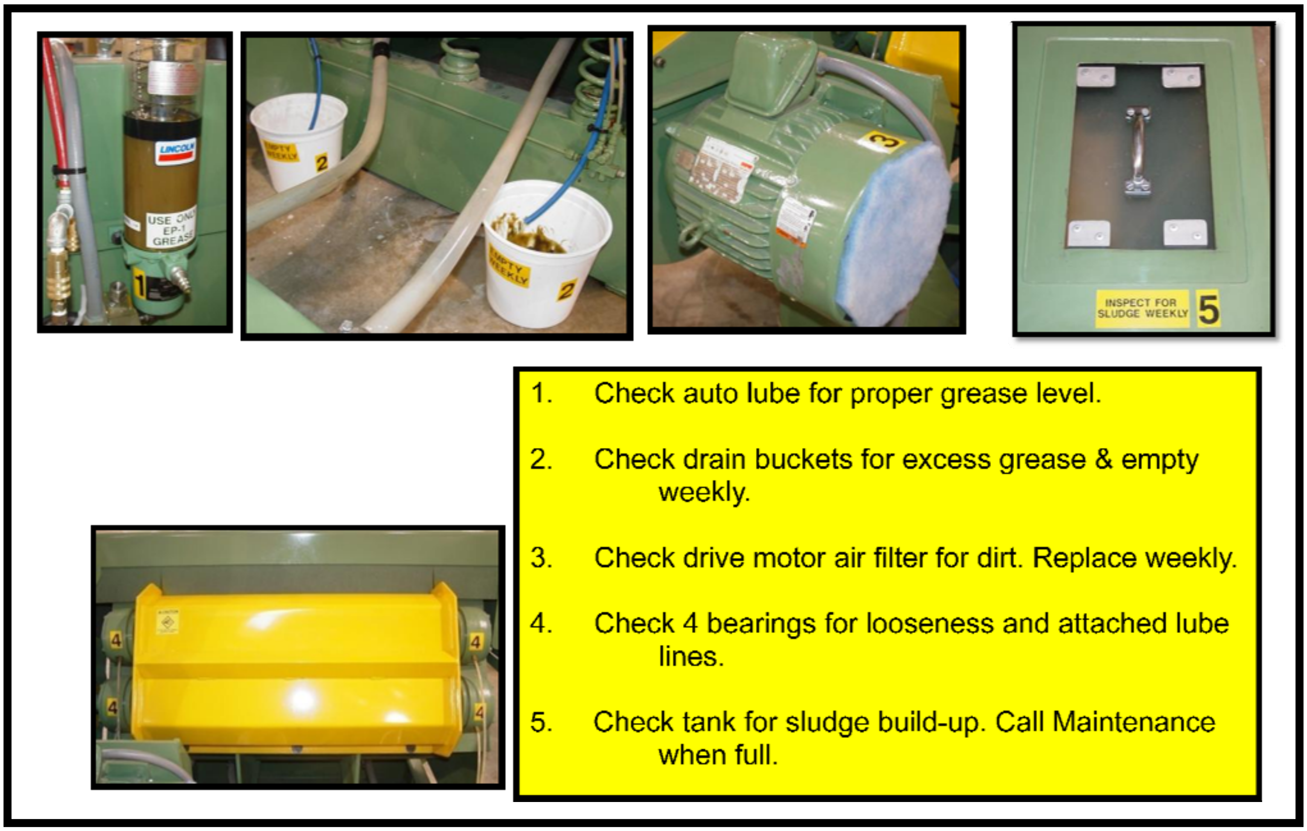
Examples: **Workplace Organization event**

8 Call loaders to send coal

9 Load coal until the bottom of the pile builds up to the weld line on the wall of the barge (Note: Keep coal out of the corners of the bow)

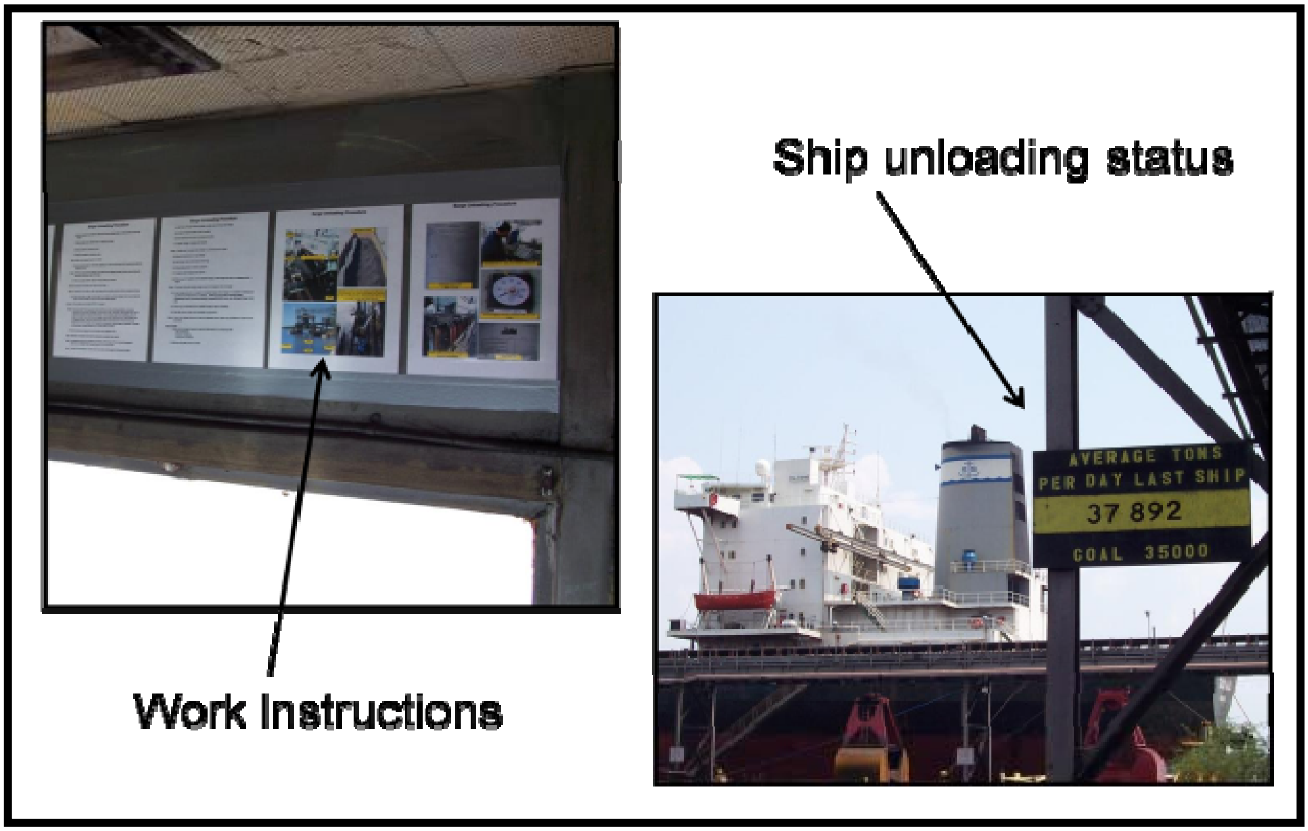
10 Once the first pile is the correct height move the barge north keeping the pile consistent height (Note: Monitor barge list and correct as needed by positioning chute in shore/out shore)

Barge Loading SOP Event



TPM Visual Checklist

Visual Workplace



The Office for Freight, Logistics & Transportation
Shelby Research Center, Suite 129
Huntsville, Alabama 35899
www.uahcmer.com