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The Development of an Integrated Freight Planning Framework

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Abstract

Using national freight data at the local level is challenging due to the high level of aggregation, its proprietary nature and the need to apply proxy factors to allocate freight for system planning. Planning factors used in freight system analysis must be capable of describing the freight generation and attraction characteristics of the region. Employment as a planning factor has come under scrutiny due to the inability of this factor to accurately estimate the effect of productivity improvements made by a company to increase production without increasing employment. Economic data from different sources can be used to allocate freight volume into smaller zones from freight traffic volumes provided by national databases and this output can be used to model freight and integrate freight into existing transportation planning activities at the state and local level.

Keywords
Freight Data, Freight Modeling, Transportation Planning, System performance

1. Introduction
The use of national freight data at the local level is challenging due to the high level of aggregation. National freight databases aggregate information to the individual states or major communities. Most methods of utilizing this freight data depend on applying proxy factors to allocate freight to the transportation system. These proxies become the planning factors used in freight system analysis and 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 its inability to estimate accurately the effect of productivity improvements made by a company to increase production without increasing employment [1].

This research was undertaken to discover the relationships between transportation infrastructure and economic growth and sustainability. It is quickly evident that data for freight analysis, and the tools needed to include freight in the conversation, are not available to the researcher or the transportation planner. It was determined that there was a need for the establishment of methods to discover the data required and develop the tools needed to integrate freight into the transportation planning process.

2. Overview of the Integrated Freight Planning Framework
This identified freight data and tool gap led to the development of the Integrated Freight Planning Framework (IFPF) shown in figure 1. The IFPF uses a systems approach for integrating the freight element as a major component in transportation planning and modeling. 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.

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. 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.

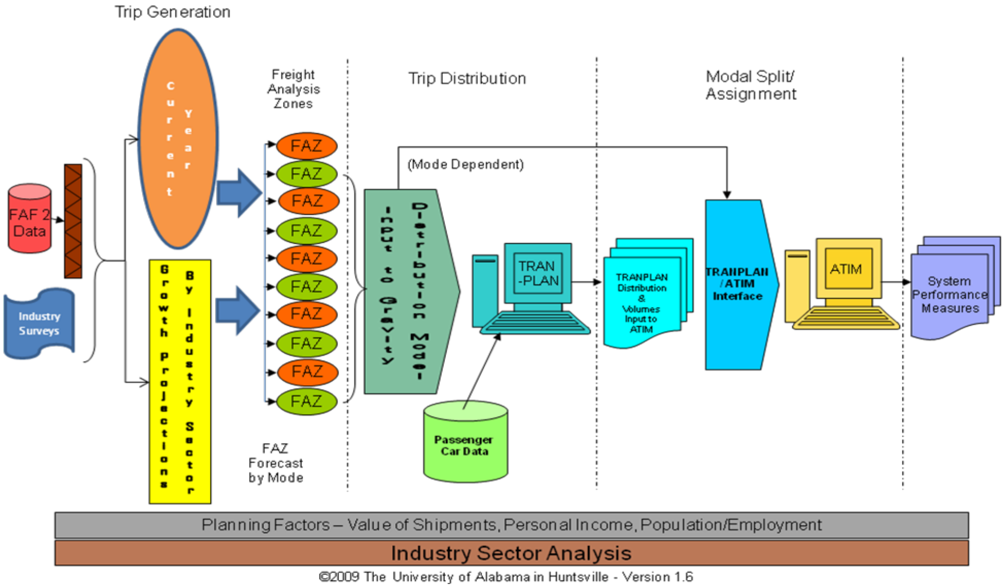

Figure 1: The Integrated Freight Planning Framework

Traditional transportation planning activities often ignore freight transportation in the modeling process or are 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 IFPF methodology utilizes a combination of multiple public data sources and analysis tools bundled together to generate validated data and models for use in transportation planning. 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.

2.1. Value of Shipments

Value of Shipments (VoS) captures an increase in the output of a plant resulting from productivity improvements, which is not captured by a traditional measure such as employment. 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.

2.2. 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. 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**.**

2.3. Population/Employment

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.

3. IFPF Elements

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 focuses on data collection, manipulation and analysis to provide input to the transportation planning process.

3.1. Trip Generation - Development of Freight Data and Analysis Methodologies and Tools

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 [2] 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 addition to the national level data, the IFPF utilizes local freight information to develop the view of freight activity. The two freight data sources, national and local, need to be established in a single geographic area that is beneficial to the use of both. Two criteria were used to choose the geographical basis of the 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. 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. The approach to develop Freight Analysis Zones (FAZs) utilizes a clustering process where similar counties can be combined to form larger freight zones. A guiding principle in the development of FAZs is that the zones should be homogeneous within the cluster but diverse from the surrounding clusters. Results from Harris, et al. [3] demonstrate that a statewide model does not lose accuracy when counties are clustered in FAZs.

The Standard Classification of Transported Goods (SCTG) is used to categorize freight in the FAF2 Commodity O-D Database [2]. 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. Fourteen of the 43 SCTG codes have counterparts under the NAICS classification at the three digit level. 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.

Various sources can be used to project the value of sales and personal income from the base year to the end year. 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 [4]. 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 and can be found on their website [5]. 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 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 a 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.

3.2. Trip Distribution

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 IFPF uses standard origin/destination pairs for the trips (trip distribution) and route for the trip (traffic assignment) [6]. The FAF2 data and local freight data are used to distribute and assign freight trips to the transportation network. Passenger cars are included in the process to provide realism and maintain the data that existing transportation professionals are comfortable in collecting and using.

3.3. Modal Split and Assignment –Simulations

The implementation environment for mode split and assign is Java using the Eclipse Integrated Development Environment. Java was chosen 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. 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.

The simulation is a highly flexible and extensible agent-based model of freight traffic on Alabama road, rail and river networks. Agent-based modeling [7] 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 in video games, but recently agents have been used more broadly, even as system maintenance monitors in large simulation projects. In the case of this research, the agent is a unique driver agent in each vehicle. 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.

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. This is based purely upon informal conversations with rail managers around the state. More detailed exploration of these loading distributions will be an important component of the future work on the model.

3.3 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 a tool developed 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. 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.

4. Future Needs and Directions of Research and Development

This research has shown that local economic data from diverse sources can be employed to allocate freight volume into smaller FAZs from the commodity 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. 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 described in this paper can easily be replicated by other states and metropolitan planning organizations. Future research will need to focus on finding the set of economic variables that best predicts present freight movements into and out of these FAZs and consequently increase the accuracy of predicting future freight movements. Research into these additional freight planning factors must include the improvement made in the overall disaggregation of the data and the improvement in modeling capabilities. Future research into the concepts of Freight Analysis Zones needs to continue through the examination of freight data disaggregation methods and travel model results. The various methodologies to disaggregate freight to the FAZs will help identify the impact of the using these larger measurement units and the modeling of freight data will provide a mechanism to validate the various FAZs options.

Further research is needed into the application of agent based, discrete event simulation for transportation system evaluation, planning and design. Additionally, an optimal set of performance measures are needed to determine improvement in system performance.

5. Summary & Conclusions

Rather than basing transportation infrastructure decisions upon backward looking trend line forecasting, the IFPF is designed to incorporate the interaction between economic activity, infrastructure, population, and congestion of a given region using a forward-looking industry cluster based analysis. The concept of using industry sectors for freight planning is relatively straightforward. By understanding how an industry creates the need to access the transportation infrastructure for freight, it is possible to develop relationships that can be used to determine freight needs anywhere that industry sector is present. Aggregating the known freight behaviors for all major industry sectors in an area provides a better approximation of the freight needs in that area. The IFPF builds upon the traditional four-step transportation planning process by creating a forward looking approach to trip generation.

The ability to plan and forecast freight demand for transportation infrastructure is limited by the lack of available data at the level of detail that is meaningful to the transportation planner. The FAF2 database, based upon the Commodity Flow Survey, is a highly aggregated freight database with 114 zones nationwide (and most states having two zones or less) and 17 ports of entry. The ability of the State or Metropolitan Planning Organization transportation planner to use the data is limited. But, rather than conceding the use of freight data in transportation planning and modeling, or being satisfied with the current state of freight data and analysis, this research developed approaches, processes and methodologies to utilize available data, and develop additional data sources to provide the freight information needed to model transportation systems at the local Metropolitan Planning Organization level and at the statewide level.

Industry sector based planning factors used in the IFPF approach are Value of Shipments, Personal Income, Population, and Employment. These four factors are used because one single factor cannot adequately define the demand for freight system requirements. The use of employment as a proxy for the generation of freight does not take into account the effects of increased productivity associated with productivity or technology improvement activities of a company.

In addition to FAF2, industry surveys are conducted to supplement the data. The surveys provide a clearer understanding of the activity of industries in a region, and the factors that affect freight generation and attraction. Appropriate conversion factors for determining the number of vehicles the data represents must be developed to use the FAF2 and survey data successfully.

Because the FAF2 database is highly aggregated, the usefulness of this data is limited for sub-state freight planning. It is important to derive the potential freight volume destined for, originating from, passing through, and internal to a state, and then disaggregate the data to a smaller geographic level. 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 cause the introduction of excessive error. The initial use of counties as the disaggregation level for the freight data looked promising and has easy initial understanding until the number of counties creates a data matrix that becomes excessively large and unwieldy. The development and use of Freight Analysis Zones provides a more efficient and effective way to organize the data into user-friendly form. The disaggregation of the FAF2 is accomplished through the development of Freight Analysis Zones (FAZ) to capture the level of freight activity in an area. The FAZs are also the basis for the forecast, by industry sectors, used to predict the freight volume for periods in the future. To do this, an industry sector forecast for the state is needed that can be segmented at the NACIS level and applied at the local level.

The local freight projections are distributed using a gravity model for both the base and future year alternatives. The freight origin/destination matrix is assigned to the transportation infrastructure network to determine the travel paths. Passenger car volumes are added to the freight traffic for separate roadway segments using a separate travel model. With the freight volume distributed and assigned to specific roadways, the next step is to understand how the freight traffic affects, and is affected by, the transportation network and the built-in constraints of the system. This understanding is achieved by employing simulation resources. The tool used in the IFPF is the Alabama Transportation Infrastructure Model (ATIM), an agent-based, discrete event simulation of the statewide multi-modal freight transportation system, with the ability to rapidly evaluate the impact of system decisions.

Finally, the IFPF provides the ability to measure the performance of the transportation system. The IFPF is a tool for continuously improving the transportation system's ability to efficiently, effectively and safely move people and freight. Improvement does not take place without a measurement system in place to quantify the performance.

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