1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle: Transportation Responses to Increased Latin American Trade		5. Report Date: 11/03/04
		6. Performing Organization Code
7. Author/s: William H. McAnally, Mississippi State University Yunlong Zhang, Mississippi State University Albert J. Allen, Mississippi State University Royce O. Bowden, Jr. PhD, Mississippi State University Aaron Tan, Mississippi State University		8. Performing Organization Report No.
9. Performing Organization Name and Address: National Center for Intermodal Transportation: A partnership between University of Denver and Mississippi State University Dr. Royce Bowden, Deputy Director P.O. Box 9542 Mississippi State, MS 39762		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DTRS98-G-0017
12. Sponsoring Organization Name and Address: U.S. Department of Transportation Research and Special Programs Administration 400 7th Street, SW Washington, D.C. 20590-0001		13. Type of Report and Period Covered: Final Research Project 02/15/03-09/30/04
		14. Sponsoring Agency Code
15. Supplementary Notes		

Abstract: The objective of this work is to provide: 1) A plan for collaborative intermodal transportation investment decision analysis tools for both traditional and nontraditional intermodal system improvements that will accommodate expected increases in Latin American trade shipments through northern Gulf of Mexico ports, 2) A framework for choosing a good mix of intermodal alternatives so that public and private sector officials are able to collaboratively plan system upgrades at the state, sub-region, and regional level that serve the public interest.
This report summarizes several related projects and shows how the component pieces of research fit together to accomplish the desired overall goal of an optimizing virtual intermodal transportation system. As such, it represents a foundation for the further work that will be required to make the envisioned system a reality. The Latin America Trade and Transportation Study (LATTS) results showed that increased trade with Latin America would test the United States transportation network's ability to safely and economically transport freight.

17. Key Words: Intermodal, Transportation Planning	18. Distribution Statement Contact NCIT for details	
19. Security Classification (of this report) N/A	20. Security Classification (of this page) N/A	21. No. of Pages 85 22. Price

Transportation Responses to Increased Latin American Trade

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A Report Submitted to the

National Center for Intermodal Transportation: A partnership between the
University of Denver and Mississippi State University

EXECUTIVE SUMMARY

The objective of this work is to provide:

- A plan for collaborative intermodal transportation investment decision analysis tools for both traditional and nontraditional intermodal system improvements that will accommodate expected increases in Latin American trade shipments through northern Gulf of Mexico ports.
- A framework for choosing a good mix of intermodal alternatives so that public and private sector officials are able to collaboratively plan system upgrades at the state, sub-region, and regional level that serve the public interest.

This report summarizes several related projects and shows how the component pieces of research fit together to accomplish the desired overall goal of an optimizing virtual intermodal transportation system. As such, it represents a foundation for the further work that will be required to make the envisioned system a reality.

The Latin America Trade and Transportation Study (LATTS) results showed that increased trade with Latin America would test the United States transportation network's ability to safely and economically transport freight. Trade between the two regions is primarily by water, with 80 percent of the tonnage transported between the 16-state Alliance region and Latin American is sea-borne, while 20 percent moved cross-border by truck and rail. A small amount moved by air. Estimates of future port needs indicate that freight throughputs in the region will exceed capacity by the year 2020. Results from the highway needs analysis indicate that the member states highway network will need almost $67 billion dollars invested in the system to handle the projected traffic. Rail has generally been shrinking in the region as major lines sell or close unprofitable lines. The report did not show any analysis of the waterway system, but it is generally recognized that there is unused capacity in the lower Mississippi River and Tennessee-Tombigbee Waterway, among others, while the upper Mississippi and Illinois Waterways are congested. The report emphasized that the region's transportation system become a more interconnected multimodal system than it is now in order to provide current as well as potential customers the freight mobility that is currently required and expected in future to enhance the region's competitiveness.

The LATTS report and data were used as a base to begin analyzing an intermodal mix of water, rail, and highway transportation modes in Alabama, Mississippi, and Louisiana, with possible later extension to more complex situations and larger regions. The LATTS study report identified a clear need to increase the capacity of the Alliance states to transport freight, and increasing capacity requires intensive planning. Transportation officials are faced with making decisions on which transportation modes will become critical points in the overall transportation system and where funds should be invested in order to maximize economic development and safety while minimizing costs and preserving environmental quality. For any given demand, there are many possible plans that could accommodate the demand and identifying the appropriate mix of highway, railway, and waterway transport capacities is a challenge. Add the complication that multiple entities – federal, states, localities, and private firms are making decisions nearly independently, and a rational solution seems beyond reach. The situation amounts to a modern Tower of Babel, and a common planning language and understanding are much needed.

Transportation planning is the process of gathering data and executing procedures and methodologies that lead to the decision of transportation policies and programs. One of the major goals of the transportation planning process is to develop transportation improvement strategies and plans to promote transportation and economical development, while also serving community goals and objectives. A number of computerized tools are available to assist in the planning process, including the commonly employed TransCAD GIS-based system.

Planning by the Alabama Department of Transportation designated a network of twin trailer truck routes that facilitates inter- and intrastate freight movements. The truck routes include 13 U.S. routes and 21 state routes. Railroads were also included in the statewide plan, with the planning effort concentrated on preserving branch lines that support some of the state's most important industries, such as wood products, that depend heavily on rail transportation. Rail transportation as part of a multimodal service was recognized, as both trailers on flat cars and containers on flat cars combines the cost effectiveness of long-distance rail with the flexibility of truck pick up and delivery.

The Mississippi Department of Transportation is preparing the Mississippi Unified Long Range Transportation Infrastructure Plan (MULTIPLAN) and the Phase I report identifies the following emerging issues in statewide transportation planning: performance-based planning; land use considerations; planning and NEPA linkages; environmental justice; air quality issues (attainment/non-attainment); freight movement issues; innovative finance options; management and operations; safety; and impacts of technology.

The Louisiana Department of Transportation and Development concluded that based on commodity projections and comparisons with terminal capacities, expansion would be necessary, especially for the grain sector which was already operating at high levels of capacity utilization. Rail-highway intermodal terminals were operating at relatively low levels of utilization and their capacities are sufficient until 2010. Highway access to the state's major public marine and rail-highway transfer terminals however were suffering from congestion in major metropolitan areas, and upgrading in this area is needed.

Each of the transportation modes – highway, rail, waterway, air, and pipeline -- has performance metrics specific to that mode and its stakeholders, but many of those metrics are not directly applicable to other modes. A rigorous analysis requires a common set of measures that indicate the level of performance for any mode to which it is applied and can be directly compared with the same metric for an alternate mode. Further, inter-mode comparisons will be significantly easier if metrics can be expressed in common units, such as dollars or time, or in dimensionless indices. The metrics should function in a forecasting mode as well as a hindcasting mode. They should also be usable as a subset of metrics, if for example, a private sector planner prefers to consider only corporate economic benefits instead of overall public economic benefit. Fourteen intermodal metrics are proposed in five categories: Mobility and Reliability, Safety, Environment, Cost Effectiveness, and Economic Growth.

The manner in which people and freight move through a transportation network is subject to many interdependencies. Changes to one part of the network, such as adding a lane to a state highway or increasing the capacity of a port, can generate unanticipated consequences in another part of the network. Simulation provides a means to model interdependences and variation and avoid many of the pitfalls that are often encountered in the start-up of a new system or the modification of an existing system. In a previous research project, the National Center for Intermodal Transportation developed a modeling methodology for building simulation models for a statewide intermodal freight transportation network. The technology is called the Virtual Intermodal Transportation Simulation (VITS) and simulates the movements of trucks, trains, barges, and ships on the transportation network as well as the transference of freight between the different modes. A pervious study implemented the VITS for Mississippi as a demonstration and a three-state compilation of major highways, railways, and waterways was prepared to begin developing a broader simulation capability. A port model was integrated in the VITS prototype for demonstration of its utility, using the Port of Gulfport, Mississippi as an example.

A system simulation of a transportation network of links (airways, highways, railways, and waterways) and nodes (airports, transfer stations, terminals, and ports) requires that each link and node be characterized in a similar fashion. Because of their different histories, each mode has developed its own terms and measures. For this effort a list of link and node characteristics for each of the three freight transport modes was compiled, then melded into a single set of intermodal characteristics to the extent possible.

Optimization provides a way to balance the competing needs of society in the planning process so that alternative mixes of intermodal transportation that best serve the public interest can be identified. This can be called optimization of alternatives; even though in the strictest sense optimization means that a given solution can be proved to be the best of all possible solutions. The fourteen intermodal metrics provide a basis for establishing a ranking among alternative intermodal transportation network plans. A single measure, the intermodal efficiency index, is proposed, in which the metrics are non-dimensionalized and allowed to vary only between zero and one when comparing alternatives. The various stakeholders in transportation may value each of the metrics differently, so a weighting system is employed to allow each user or group of users to stress those metrics of primary interest. Different weights may produce dramatically different results, but the weights are legitimate subjects of negotiation and compromise among stakeholders when public decisions are made. An optimization procedure has been proposed to serve as a framework for making intermodal investment decisions in a collaborative manner.

The following are recommended:

- The intermodal metrics described here should be tested on highway, railway, waterway, and intermodal transfer station data to examine their effectiveness and identify data gaps.
- The VITS simulation should be expanded to allow simulation of the northern Gulf transportation system in Texas, Louisiana, Arkansas, Mississippi, Tennessee, Alabama, Georgia and Florida.
- Trial VITS simulations should be made to provide data for evaluation of the recommended intermodal metrics.

- Alternatives, including expanding highway, railway, waterway, and transfer station capacity, are examined on a regional basis to identify innovative solutions for the expected increase in Latin American trade.

PREFACE

The work described here was funded by the National Center for Intermodal Transportation (NCIT), a United States Department of Transportation research center operated by the University of Denver and Mississippi State University (MSU), the Mississippi Department of Transportation (MDOT), and the Mississippi Transportation Research Center (TRC) and Department of Agricultural Economics of MSU. Dr. Royce O. Bowden of NCIT, Mr. W. Ray Balentine of MDOT, and Dr. Thomas W. White of TRC provided guidance and liaison to the project.

The project was performed during 2003 by Drs. William H. McAnally and Yunlong Zhang of the MSU Civil Engineering Department, Dr. Albert J. Allen of the MSU Agricultural Economics Department, and Dr. Royce O. Bowden and Mr. Aaron Tan, MSU Industrial Engineering Department.

The authors express their appreciation to all those who contributed needs and ideas to the formulation of this report – personnel of the departments of transportation in Mississippi and Louisiana, the Ports of New Orleans and Gulfport, and the Metropolitan Planning Organizations of Memphis, Jackson, Forrest County, and Mississippi Gulf Coast.

CONTENTS

1. INTRODUCTION

Objectives

The objective of this work is to provide:

- A plan for collaborative intermodal transportation investment decision analysis tools for both traditional and nontraditional intermodal system improvements that will accommodate expected increases in Latin American trade shipments through northern Gulf of Mexico ports.
- A framework for choosing a good mix of intermodal alternatives so that public and private sector officials are able to collaboratively plan system upgrades at the state, sub-region, and regional level that serve the public interest.

Background

United States - Latin America trade is expected to triple[1] by 2020, and if the present 85% of that trade moving by sea increases by that amount, congestion of transportation routes is a certainty. Less certain is how that trade will be distributed by region and inland mode, since the goods flow distribution will be strongly affected by how well the transportation infrastructure accommodates the increases. Federal, state, and local transportation officials in the northern Gulf of Mexico are faced with critical decisions on which transportation modes and connectors to improve and how to improve them so that the increased transport occurs safely, securely, effectively, and efficiently in an environmentally sustainable manner. Tools to make infrastructure improvement decisions are needed. Mr. Harry Caldwell of the U.S. Department of Transportation has expressed[2] the need for a "multimodal investment analysis system" to assist decision-making.

Intermodal Transportation is defined here as: the shipment of cargo and the movement of people involving more than one mode of transportation during a single, seamless journey. Multimodal transportation is defined as consisting of more than one mode, either parallel or sequential.

Some components of multimodal investment analysis are available. Traffic flow projections and modal capacity shortfalls were produced by the Wilbur Smith and Associates study cited above. The TVA's River Efficiency Model estimates the comparative environmental consequences of waterway usage.[3] The U.S. Army Corps of Engineers is examining new ways to measure levels of service on inland waterways that are more representative than ton-miles and more comparable to highway level-of-service indices.[4] Companion studies funded by the National Center for Intermodal Transportation have developed the Virtual Intermodal Transportation System (VITS)[5] and a draft set of metrics for multimodal transportation links.[6] These tools and others offer a singular opportunity to assemble a set of modal analysis tools for transportation officials that can support intermodal investment decision-making over the next quarter century.

The need for the research described here is underscored by a Government Accounting Office report[7] to the United States Senate, which recommended that the U.S. Secretary of Transportation:

> *Develop evaluation approaches for state and local planners to use in making freight-related and other transportation investment decisions and actively work with transportation planners to achieve implementation of these approaches. In developing these approaches, DOT should promote the incorporation of key elements of effective planning, including systematic cost-benefit analyses, evaluation of non-capital alternatives, inclusion of external benefits (e.g., congestion and pollution costs), and routine performance of retrospective evaluations.*

1) The ultimate goal is a transportation system that is not only effective, but also is what Mr. Gil Carmichael, former U.S. Federal Railroad Administrator and advocate for intermodal transportation, calls an ethical transportation system, one that "doesn't kill people, doesn't pollute, and doesn't cost too much."[1]

Approach

An interdisciplinary team of researchers and end-users examined economic, engineering, safety, and environmental factors by transportation mode use, and devised mathematical and simulation science tools to synthesize the results to provide the expected outcomes of "what-if" scenarios for investment decision support.

The focus was on ports as key nodes in the transportation process, with their throughput dependent on port characteristics and capacity of transportation modes and links from the ports to destinations. Three sets of deepwater ports were considered for the initial development – those at Mobile, Alabama, Gulfport, Mississippi, and Baton Rouge to the Gulf, Louisiana. The latter includes the ports of New Orleans, South Louisiana, Baton Rouge, three parish ports and the proposed Millennium Port. They share common inland water systems, trunk highways, and rail systems to serve the central U. S.

A planned Phase II of the work will revise and extend the analysis system's capabilities and applicability.

<u>Tasks</u>

The following tasks were performed in support of the objectives:

- Data Review. Obtained and reviewed data compiled during the LATTS study on future traffic loads in the region, existing and future capacity of the several transportation modes serving the target ports. Obtained federal, state, and local projections and plans.
- Needs Definition. Involved transportation officials in Alabama, Mississippi, and Louisiana plus others at the national level in defining meaningful required levels of service and information needs for investment decisions.

[1]Based on personal communication with Mr. Carmichael on June 23, 2003.

- Algorithms. Prepared a proposed algorithm that computes a network efficiency index for future intermodal traffic loads, including environmental and economic consequences of multimodal traffic.
- Simulation Tool. Adopted a simulation tool to display transportation routes and modes under various scenarios of modal splits and extended the tool to port simulation. Prepared an example simulation of a port.

Scope

This report begins the process of providing tools to aid mode and connector investment decisions by transportation officials in three states with related ports[2] in the northern Gulf of Mexico Region. It provides proposed metrics and a framework for an expanded investment analysis and optimization system in support of economical and secure cargo movement in the region. It does not explicitly address air transport.

This report summarizes several related research projects and shows how the component pieces of research fit together to accomplish the desired overall goal of an optimizing virtual intermodal transportation system. As such, it represents a foundation for the further work that will be required to make the envisioned system a reality.

[2] Ports at Mobile, Alabama, Gulfport, Mississippi, and Baton Rouge to the Gulf, Louisiana that share common intermodal connections and serve the inland waterways tributary to those ports.

2. LATIN AMERICAN TRADE

LATTS Report

The Latin American Trade and Transportation Study[1] (LATTS) had two general purposes: (1) to evaluate the opportunities for trade between the Southeastern Transportation Alliance and Latin America; and (2) to determine transportation investment needs for the Southeastern Transportation Alliance to capitalize on such trade. To accomplish the objectives of this study, Wilbur Smith Associates consulting firm, an organization that regularly analyzes the world's economies, made forecasts for 1997-2020 to indicate some of the changes that might occur during the study period so that the Southeastern Transportation Alliance can better position itself for the changes that might occur as a result of the changes in the Latin American Trade Area.

The Southeastern Transportation Alliance is an organization of the state transportation agencies in the states/commonwealths that are located in the Southeastern Region of the United States and includes the cooperating federal agencies United States Department of Transportation and the Federal Highway Administration. The Southeastern Transportation Alliance is an informal agreement between these partners to provide a means of financing and conducting the Latin America Trade and Transportation Study (LATTS).

The study performed by Wilbur Smith Associates with assistance from the firm DRI/McGraw-Hill provided data and information to the Southeastern Transportation Alliance so that members could make better informed decisions in preparation for the potential increase in trade. The firms accomplished this task by:

- Investigating and identifying trade opportunities between the United States and other countries, with special emphasis on Latin America;
- Identifying how the economies of the Southeastern Transportation Alliance States could benefit from the potential increase in Latin America;
- Evaluating existing relevant transportation infrastructure and its ability to meet the increased demands associated with growth in Latin American Trade; and
- Developing strategies to optimize investments in the Southeastern Transportation Alliance States' Region transportation infrastructure include ports, waterways, airports, railroads, major highway corridors, and intermodal facilities.

The structure of the LATTS report included the following topical areas:

<u>Section A –Introduction and Overview</u>

Section A of the report provided information on the study setting, purposes, public outreach, and study team approach. Also, this section of the report provided a summary of the trade and economic development opportunities, LATTS strategy transportation system; investment needs perspectives, and investment strategies.

Section B-International Trade and Development Opportunities

The purpose of Section B was to provide information to the Alliance about the characteristics of existing trade patterns and provide trade forecasts of the trade that might exist in the future. Also, the consultants performed analyses for tourism, business and service travel. Additionally analyses were made to identify the economic impact of increased trade opportunities with Latin America on the Alliance.

Section B1-Existing Trade Flows: Results from the analysis of existing trade patterns indicate that, in 1996, the Alliance trade with Latin America totaled 338 million metric tons. This volume of trade was valued at $ 164 billion. This amount of tonnage and value of trade between the Alliance and Latin America implies that a large portion of the area's employees and employers are highly dependent on the continued trade between the two regions for economic livelihoods. On a modal perspective, most of the trade between the two regions is primarily by water. For example, results from the study reveals that 80 percent of the tonnage transported between the Alliance region and Latin American is sea-borne, while the rest, 20 percent, moved cross-border by truck and rail. The authors did mention that a small amount of tonnage was moved by air. In addition to discussing the total amount of tons moved by water, the authors also provided information on the sea-borne exports and imports, tonnage by commodity group, commodity group by value, and other related information that dealt with the sea-borne trade.

Section B2-Latin American Trade Forecasts: This subsection of the report provides information on the estimated trade flows that will likely occur between the Alliance Region and the Latin American countries. For the accomplishing the objective of this subsection, the consultants adopted two scenarios: (1) The "Base Case" and (2) "High Case." In the base case scenario the authors assumed a continuation of recent trends and conditions until 2020. In the high case, the consultants assumed that significant events would occur. The increased liberalization of trade would continue. For example, the expected formation of the Free Trade Area of the Americas was included. Higher economic growth trends for Latin American and the United States and changes in U.S. policies regarding trade and investment with Cuba were also included in the "High Case."

Results from the base case analysis indicate that in the year 2020 the Southeastern Alliance Gateway exports to the Latin American countries would total 340.9 million metric tons or a net increase of about 242 million metric tons over the 1996 trade exports. On a country basis, Mexico will continue to be the leading export market for the Alliance Gateway exports followed by Brazil and Colombia. Commodity-wise, primary commodities are expected to be the major exports from region to the Latin American countries in the year 2020. The second leading commodity group that will be exported to the Latin American countries in the year 2020 is the primary manufactured commodities group.

In the year 2020, imports, based on base model forecasts, from the Latin American countries are expected to total about 590.2 million metric tons or a net increase of 349.2 million metric tons over the year 1996. Most of the imports into the Southeastern Alliance Gateway will come from Mexico, followed by Venezuela and Colombia in the year 2020. In the year 2020, primary commodities are expected to be the leading imports coming into the Southeastern Alliance Gateway, followed by primary manufactured commodities and manufactured commodities. Results from the high case model indicate that in the year 2020 the total amount of exports from the Southeastern Alliance Gateway to Latin American countries will be almost 457.3 million metric tons or a net increase of 358.4 metric tons over the 1996 yea's volume. Mexico will be the leading export market followed by Brazil, Venezuela, and Colombia. Projected imports will come primarily from Mexico, Venezuela, Brazil, and Colombia into the Southeastern Alliance Gateway in the year 2020.

Primary commodities will represent the dominant commodity group exported from the Southeastern Alliance Gateway to Latin American countries in the year 2020. On the import side, manufactured commodities will be the dominant commodity group brought into the Southeastern Alliance Gateway from various Latin American countries.

Section B3-Tourism, Business, and Services Travel: This section of the report provides information on the world and Latin American visits to the U. S., South American visits to the U.S. by major countries, and visitor expenditures. This section also provides information on Latin American tourists and the Southeastern Alliance. In this section, results show that the main purpose of visits to the Southeastern Alliance from the Latin American countries is leisure, followed by business. On a statewide basis, Florida led the Southeast Alliance in terms of leisure visits while Kentucky led in terms of visitors that came to the region for business purposes. Arkansas led the percentage of visits that were in the other category. The other visitor category was defined as study/teaching, government/military, religious and health reasons.

Latin American purchases of U.S. Business services were primarily by Mexico, followed by Brazil, Argentina, and Venezuela. In 1997, these countries, respectively 26-, 18-, 9-, and 9 percent of the total Latin American purchases of U. S. business services. In terms of business services demanded by Latin Americans in 1997, the construction-related was the largest type of business demanded in that year accounting for about 18 percent. The second leading business services demanded by Latin Americans were equipment installation and maintenance services category accounting for 16 percent of the total amount of business services demanded.

The consultants also provided information on the Southeastern Alliance travel to developing countries. Results from the consultants' analysis reveal that the share of the Alliance travel to developing countries was, by far, to the Latin American countries, followed by Asia. The percentage of visits to these areas was, respectively, 66 and 21 percent. The main purpose of the Southeastern Alliance visits to the Latin American countries was leisure. This category accounted for 58 percent of the visits in 1996. The second leading category of visitation to the Latin American countries was business. This category accounted for about 36 percent in 1996.

The state that had most visitors going to Latin American countries because of leisure was West Virginia. This state accounted for 71 percent of the total number of travelers going to the Latin American countries while the state of Arkansas accounted for about 53 percent of the business trips to the area. The state that leads in the "other" category was Mississippi accounting for 13 percent of the total number of visitors in this grouping.

The occupations of the travelers from the Southeastern Alliance to the Latin American countries were mainly executive/professional level. Over 72 percent of the Southeastern Alliance visitors were in this category. Also, the leading destinations of Southeastern Alliance visitors to the region were Mexico, Jamaica, Bahamas, and Guatemala.

The consultants provided information on cruise industry in terms of cruise berths, top American cruise ports, characteristics affecting cruise ports, metropolitan population, and growth in the Southeastern Alliance cruise industry. The consultants reveal that as the North American market for cruising grows, so will the fleets (number) of ships. For example, the number of ships is expected to increase from 127 ships in 1999 to 163 in 2003 or an increase of over 28 percent. This represents an increase of berths from 135,000 to nearly 190,000.

The top three busiest cruise ports in North America are located in Florida: Miami, Everglades, and Canaveral. In 1998, the Port of Miami, Port Everglades, and Port Canaveral served 3, 2.25, and 1.8 million passengers, respectively. These results may imply that these ports are primed for expansion in terms of passengers they currently are the busiest ports in North America and they are located in the Southeastern Alliance Gateway.

For the continued success of the aforementioned ports and possible others that might contemplating to increase their cruise business, the consultants discussed several characteristics that managers of cruise ports might want to take into considerations for future decisions: proximity to cruise destinations, port calls, airline service and arrival modes, local complementary attractions for in-and-out-going cruise passengers, population base of metropolitan areas, and the appropriateness of the physical attributes of the port for cruise ships. The consultants feel that these are important attributes that will make ports in the Southeastern Alliance attractive for growth and prosperity in the cruise industry.

Section B4-Economic Development Impact of Latin American Trade: The effect of Latin American trade on the Southeastern Alliance's economic growth was discussed in this section. In this section the consultants divided it into the following major topical areas: (1) Summary of Economic Development Impacts; (2) Economic Development Implications; (3) Clusters and Economic Development; (4) Hemispheric Integration-A Look at Trade Balances; and (5) Economic Impact. This section of the LATTS Study provides a brief summary of some of the impacts of Latin American trade on economic development in the Southeastern Alliance region. In 1997, results from the analysis indicate that the Southeastern Alliance had the largest combined real gross state product (RGSP) than any other region in the United States as a group. This area had an estimated RGSP of over 2 trillion dollars in that year. In addition, the consultants showed that the Southeastern Alliance as a group accounted for about 29 percent of the United States' total real gross domestic product (GDP). The second leading region was the North Atlantic region accounting for about 24 percent of the United States' total real GDP. In addition, the consultants projected that the Southeastern Alliance region's annual GSP growth will be above that of the United States. The Southeastern Alliance region is expected grow at an annual rate of 2.3 percent from 1997 to 2020, while the United States' GDP is projected to grow annually at almost 2 percent in the same time period.

Results also reveal that a key determinant of the Southeastern Alliance's ability to maintain and improve its competitiveness in an ever increasing global world economy in general, and specifically, in the Latin American economy will be the region's role in the development of the integration of the Western Hemisphere's economy in the Free Trade Area of the Americas or FTAA. The formation of this free trade area could have major implications for the region's trade relations in particularly when it comes to projected trade balances. The formation of the FTAA is expected to reduce trade and investment barriers for the Latin American economies and the United States' economy.

Projections reveal that the region is primed to improve its trade position in the trade of manufactured, primary manufactured, and primary commodities between 1996 and 2020. The projected annual change in trade balances is expected to be between 10- and 20 percent for the aforementioned commodity groups. The consultants provide three scenarios to project the economic impact of trade with Latin American countries and Southeastern Alliance on employment. The three scenarios were as follows: (1) Base Model-predictions of employment with continued trends in current conditions to the year 2020; (2) High Case-reflects the substantial increasing of trade with Latin American countries to the year 2020; and (3) No Exports- the impact on employment in the Alliance region when there no exports from the area to Latin American countries.

Projected results indicate that in the Base Case Model scenario employment will increase by 10 million jobs between the year 2000 and 2020 or an annual increase of 100,000 jobs per year. The High Export Case Model indicates that the jobs in the Southeastern Alliance region will increase by 11.7 million jobs, while the No Export Model indicates that employment will increase by 9 million jobs between 2000 and 2020. These model results suggest that there will be a significant growth in employment in the area whether there are exports from the Southeastern Alliance or not. For example, results indicate that the High Export Case Model will add 2.7 million more jobs than the No Export Case Model.

Section B6-Business Development Opportunities: The consultants for the LATTS Study state that as trade with Latin America and the rest of the world increase over the next twenty years, there will also be an increase in the amount of trade that passes the Southeastern Alliance. This pass through traffic should provide businesses in the region an ample opportunity for bringing the developments to fruition. The projected incremental growth component in the study represents an additional production capacity that has not been invested by businesses and individual investors.

Growth in exports passing through the Southeastern Alliance region presents businesses with a rational target to develop in terms of jobs, taxes, and incomes. Exports from the Southeastern Alliance are expected to grow from the current level of approximately 290 million tons to 660 million tons in 2020, or an increase of 370 million tons. This increase represents over $610 billion in value in 2020. Results indicate that over 40 percent of the increase in export tonnage is expected to originate outside the Southeastern Alliance region. This increase represents about $210 billion in export value passing through the Southeastern Alliance to Latin America and other regions of the world. Most of the exports from outside the region come from the Central States (Midwest) accounting for about 65 percent of the traffic passing through the region.

Major exports in terms of tonnage are agricultural and natural resource products. This group represents 51 percent of the total amount of export traffic coming through the region destined to Latin America and other regions of the world. In terms of value, manufactured products are by far the largest, accounting for about 83 percent of the total value of products coming through the region. The manufactured products include machinery and industrial equipment, transportation equipment, electrical machinery, food products, rubber and plastics, fabricated metal products, and instruments. These exported products usually represent high paying jobs.
The consultants forecasted that over 66 percent of the growth in exports passing through the region would be destined to Latin American countries, particularly Mexico, Brazil, and Venezuela. Mexico is expected to capture about 60 percent of the pass through exports, while Brazil and Venezuela are expected to capture 14 and 8 percent respectively. Asia and Europe are expected to capture most of the pass through exports destined to areas other than the Latin American countries.

The consultants also stated that the Southeastern Alliance region needed to remain competitive to capture its share of the pass through traffic so that it can generate employment, taxes, and incomes for businesses and individuals associated with the area. Competitiveness, like the consultants emphasized, depends on a number of factors, one of which is transportation. The region needs to continue to invest in the transportation system so that it can continue to provide the shippers that are exporting from the region and those shippers that are passing exports through the region with a low cost, efficient, competitive, and complementary transportation system. The continued investment in the transportation system is a key step toward businesses competing for the projected traffic that will be passing through region from outside areas.
Since Latin America offers substantial export opportunities for businesses in the Southeastern Alliance region, the consultants provided a brief summary of the various countries in Latin America. For example, the consultants reveal that the annual economic growth of Cuba is expected to be 2.3 percent over the 1997-2020. Tourism has become the country’s most important sector. In addition, exports are expected to grow strongly as economic reforms ease trading practices especially those in the United States.

<u>Section C- LATTS Strategic Transportation System</u>.

This section of the report deals with strategic transportation system effects on the competitiveness of the Southeastern Alliance. This section of the report is divided into the following areas based on the specific transportation infrastructure: (1) Section C1-LATTS Strategic Port System; (2) Section C2-LATTS Strategic Airport System; (3) Section C3-LATTS Strategic Rail System; and (4) Section C4-LATTS Strategic Highway System.

Section C1-LATTS Strategic Port System: In this section of the LATTS strategic transportation system, the consultants describe the process that was used in selecting the ports to be included in the report. One of the criteria used to select the ports for analysis included all National Highway System (NHS) water-ports and complexes with channel depths of 35 feet or more and shallow-draft facilities that handled 500,000 tons of waterborne Latin American cargo annually. Another criterion used by the consultants to select ports for inclusion in the LATTS study was any proposed water-ports that the representative state/commonwealth believes would meet the previous criterion and any realistic proposals within the next 10-15 years. For satisfying this criterion, state legislation funding should have backed up the proposals or a detailed implementation scheduled had to be revealed by the state legislation.

The third criterion used by the consultants for port selection dealt with the most significant water-port within any Southeastern Alliance member that did not have a facility that meets the aforementioned major gateway port criteria. The fourth criterion included those ports to be of particular interest to each Southeastern Alliance member. To make sure that this criterion would not overly used; the consultant team limited each member in the Southeastern Alliance up to 5 facilities.

Based on the criterion that each port selected must have a depth of 35 feet or more, 27 ports were identified. In addition, four more ports included for the study but they did not meet the 35-foot or more criterion. These ports were included primarily because they exceeded the shallow draft facility requirements. Results further show that the state of Florida had nine ports included, While Texas followed with eight. Alabama and Virginia had the least amount of ports included that fitted the 35-foot criterion. The states had one each.

The LATTS study also identified shallow draft/inland ports that had as of 1996 or were projected to 500,000 tons or more in 2020. This group included ports in Tennessee, Arkansas, Kentucky, Louisiana, and West Virginia. Most of the ports that were included in this category were in Louisiana. Overall, based on the criteria mentioned in this section of the report, 52 ports were used in the finally analysis of the LATTS Strategic Port System. Of that total, 35 were deep-water/coastal port facilities. The report by LATTS did not show any analysis on the waterway system itself such as the Mississippi River, Tennessee-Tombigbee Waterway, and other rivers and tributaries. Also, the report did not report any information on the type of barges and other water carriers that bring goods to and from the port facilities.

Section C2-LATTS Strategic Airport System: The LATTS study provides information on the criteria that were used to facilitate the study of airports in the Southeastern Transportation Alliance Region. The criteria used to select the airports included the following: (1) all airports that had non-stop flights to/from Latin America (passenger and/or cargo); (2) all existing airports that had physical features capable of serving long-stage flights by planes with heavy loads (cargo and fuel); (3) any proposed air ports that the respective state/commonwealth meet criteria for inclusion in the study; (4) all airports that meet most of the criteria and only marginally fail to meet criteria for one or two others; (5) include one airport for any state which does not have an airport that meets the criteria set by the committee members, and (6) include those airports deem important by each Southeastern Alliance member.

Based on these criteria, 26 airports were identified that met or exceeded the criteria posed by the selection team. For example, Alabama had two airports that met or exceeded major criteria: Birmingham International and Huntsville International. Seven airports nearly met the criteria, while 15 airports definitely did not meet the necessary criteria. The state of Mississippi had one airport that nearly met the major criteria: Gulfport-Biloxi Regional and it had one airport that definitely did not meet the major criteria: Jackson International. The LATTS study did not show analysis of the various types of passenger and/or cargo planes that catered to the various airports that were included in the LATTS Strategic Airport System.

Section C3-LATTS Strategic Rail System: The LATTS Study identified the mainline railroad system plus major connections to port facilities in the Southeastern Alliance Region. The rail lines included in this section of the report were based on the following criteria: include that portion of the railroad system that was designated by the Federal Railroad Administration as principal railroads that had annual freight volumes exceeding 20 million gross ton-miles per mile; include all STRACNET (Strategic Rail Corridor Network) mainlines; include all those existing rail line connections to all ports in the LATTS Strategic Transportation System; include existing rail lines which function as part of the an inland port operation; and include additional lines which were deemed to be of special interest to the Southeastern Alliance members.

A summary of the LATTS rail traffic tonnage shows that cross-border traffic represents the fastest growing rail traffic segment in the year 2020. For example, this segment is expected to increase by 492 percent over the 1996 base year tonnage. The sea-trade carload traffic segment is expected to increase by 147 percent while the sea-trade intermodal traffic segment is expected to increase by 400 percent.

Results from the analysis indicate that the sea-trade carload flows are concentrated at the Gulf Coast ports with Southeast Louisiana being one of the major receiving areas for shipments to Latin America. Intermodal LATTS sea-trade rail traffic is concentrated in Florida, North Central Texas and Norfolk, Virginia. Cross-border traffic is another major category for rail shipments to and from Latin America. In the LATTS study, Texas is the only Southeastern Alliance member that borders on Latin America and thus has the only ports of entry for land based rail traffic. There are four-border crossings-El Paso, Eagle Pass, Laredo and Brownsville. These border crossings have a substantial amount of rail traffic going and coming from Latin America. The large border crossing traffic at these areas will be adversely impacted if the projected traffic that is expected to come to this area comes to fruition. This implies that much need to be done if this area is to be competitive.

The LATTS Strategic Rail System includes 22,285 miles of rail lines. The state of Texas accounts for 5,544 miles of that total while Georgia, which is second in mileage, accounts for 2,115 miles.

Section C4-LATTS Strategic Highway System: This section of the LATTS study contains the specific highways which comprised the LATTS Strategic Highway System. The criteria used to select the highways are as follows: (1) all interstate highways in the Southeast Alliance Region. This amount totaled 14, 602 miles of roadway; (2) National Highway System (NHS) Freeways. These facilities included fully access-controlled services, both free and tolled; (3) a few NHS Non-Freeways. These facilities represent an important segment of the highway system but they have not been upgrade. (4) ISTEA/TEA-21 High Priority Corridors within the Southeastern Alliance Region. These facilities represent the corridors that currently exist and those that are not in existence but are economically justified. Finally, the LATTS Strategic Highway System includes those NHS connectors linking a LATTS Strategic Highway with a LATTS airport or water port.

The components of the LATTS Strategic Highway System included Interstate, Intermodal Facility, NHS Connector, and NHS Freeway. The LATTS Strategic Highway System consisted of mostly the interstate highways accounting for 14, 602 miles while non-interstate miles totaled 8, 257 miles. In the non-interstate category, 8,172 miles were in the NHS system and 85 miles were in non-NHS arterials.

The LATTS Strategic Highway System mainline miles are located in Texas, followed by Florida. Also Texas had more miles in the interstate and non-interstate than any other state in the Southeastern Alliance Region. Results further reveal that LATTS trade corridors are generally multi-state in nature, connect significant freight endpoints such as Miami, New Orleans and Memphis, and both LATTS Corridors and LATTS highways serve regionally significant freight traffic, international crossings, and important economic centers.

<u>Section D-Investment Needs</u>

This section of the LATTS study provides an analysis of the investment needs required for the Southeastern Alliance in the port, airport, and highway strategic systems for the projected increase in trade with Latin America by to the year 2020. This information shows the magnitude and opportunities so that the members of the Southeastern Alliance can aid them in making better informed decisions about the future investments needs in the region and how they position themselves to meet challenges to increase the competitiveness in the area. This section is divided to the following: (1) Section D1-Investment Needs for the LATTS Strategic Port System; (2) Section D2-Invesment Needs for the LATTS Strategic Airport System; and (3) Section D3-Investment for the LATTS Strategic Highway System.

Section D1-Investment Needs for the LATTS Strategic Port System: In this section the consultants discussed the database, performance measures and methodology, calculated practical capacity, and maximum practical capacity. In addition current capacity and throughput estimates, future throughput estimates, LATTS projection model, general methodology, and future needs estimates of Southeastern Alliance were discussed.

Estimates of future needs indicate that container, break-bulk, neo-bulk, dry bulk, and liquid bulk throughputs in the region will exceed the capacity by the year 2020. The excess throughput was used to determine the number of terminal modules for the region. Results also show that Texas will need substantial container terminal acreage at ports to handle the projected traffic that is expected to originate in the region or outside the region. Texas is followed by Florida. The total estimated container needs for the area through 2020 are estimated to be $3.4 billion.

The Southeastern Alliance Region is expected to require ten-acre break-bulk modules that exceed 600. Most of this region's break-bulk terminal acreage will be needed by Florida followed by Louisiana. The estimated 20-year break-bulk infrastructure needs are estimated at $12.8 billion. Of that total, about $7.7 billion will be needed for Latin American trade. Further total infrastructure needs for the Southeast Alliance Region indicate that neo-bulk, dry bulk, and liquid bulk modules will cost 904.4 million, $2.4 billion, and $2.6 billion, respectively. In summary, total estimated infrastructure needs for the 20-year LATTS Strategy Port System will be $22.1 billion.

Section D2-Investment Needs for the LATTS Strategic Airport System: In this section, the authors discuss the procedure utilize to estimate baseline freight volumes (1996) and baseline cargo buildings. Results from the procedures developed by the researchers indicate that in 1996 Florida handled most of the Southeast Alliance Region's airborne freight with Latin America. This state handled about 1.2 million tons of freight with Latin American countries while the rest of the region handled 77,469 tons. This result is primarily due to closes of the state of Florida with Latin American countries relative to other states in the region.

As might be expected, most of the air cargo building space was located in Florida. This state was followed by Tennessee and Texas. Most of the air cargo building space in Tennessee and Texas is utilized for domestic cargo rather than for international cargo. Projections to the year 2020 indicate that Florida will still be the dominate gateway for trade with Latin America accounting for about 91.2 percent of the region's airborne cargo trade. Projections further indicate for the region combined, air cargo is expected grow from a base of 9.4 million tons in 1996 to almost 35.4 million tons in 2020 or an increase of 26 million tons. To accommodate this increase in airborne cargo tonnage the region is expected to need over 53 million square feet of air cargo building space. This represents an increase of 34.3 million square feet of air cargo building space from the 1996 estimate of 18.7 million square feet of air cargo space.

Cost estimates for the new cargo and ramp/apron reveal that the Southeast Alliance Region will be, respectively, $2.74 billion and $548 million. Therefore, the overall cost estimates for the air cargo infrastructure are almost $3.3 billion.

Section D3-Investment Needs for the LATTS Strategic Highway System: This section contains a discussion of the LATTS Strategic (Mainline) Highway System and the LATTS Highway Connectors (i.e., facilities that link a LATTS Strategic Highway with a LATTS airport or water-port). In the LATTS Strategic Highway System, the authors discussed the network database and projected the amount of truck volumes that will be associated with the Latin American trade for the year 2020. In this section, the researchers were able to assign truck flows to specific highway facilities using GIS generated shortest time paths.

Results from this process indicate that the following corridors will have the heaviest truck traffic of Latin American trade: (1) I-10 corridor through Texas, Louisiana, Florida, Alabama, and Mississippi; (2) I-35/I-37 corridor in Texas; and (3) I-95 from Florida to Washington, D.C. Also, results indicate that more than twice the amount of LATTS truck traffic in vehicle miles of travel (VMT) will be carried on I-10 from West Texas to Jacksonville. In addition, a substantial amount of LATTS truck miles will be on I-95 from South Florida to Washington, D.C. and I-3/I-37 from South Texas to the Plains. Projections indicate that Texas will carry the most of the LATTS truck miles in 2020, followed by Florida and Louisiana.

LATTS results for traffic by functional classification indicate that most of the traffic in 2020 will be carried on rural interstate while the second most used function will be the urban interstate system. These results imply that most of the truck traffic will be moving to and from long distance markets in 2020, as it was in 1997.

The highway needs analysis performed by the consultants was organized into two general categories: level of service-capacity and pavement. Results from the highway needs analysis indicate that the LATTS Highway Network will need almost $67 billion dollars invested in the system to handle the projected traffic in the area.

The LATTS Highway Connectors section provides an inventory of the linkage of LATTS intermodal facilities with the mainline LATTS Strategic Highway System. Most of the airport and water-port connectors are under the jurisdiction of local/other institutions while the rest are under state's jurisdiction. This means that most of the maintenance and improvements are under the authority of the local institutions that may not have access to the necessary funding, as they would be if they were under the jurisdiction of the state. As might be expected, the connectors that are under the local jurisdiction have more pavement problems than those under the state jurisdictions. Also, the connectors with at-grade railroad crossing problems are at the water-ports that are under local jurisdiction while connectors to airports are mostly under the state jurisdiction. Finally, LATTS connectors with traffic operations and safety problems are mostly under the state jurisdiction rather than under the local jurisdiction.

Section E-Alliance Region Investment Strategies

This section of the LATTS report provides information on the various types of strategies that can be used by members of the Southeast Alliance to achieve the overall goal of supporting economic development through improved transportation for trade. To accomplish this goal, the LATTS study team put seven objectives forward:

- Regional competitiveness: The study team indicates that the members of the Southeast Alliance Region have a distinctly location advantage relatively to other regions in the United States with regard to trade with Latin American countries. However, in order for the region to maintain and improve its competitiveness relative to other regions in the United States that might be vying for the projected increase in Latin American trade with the United States, in general, and specifically the region itself, the region must, at least, have a strong well-educated labor force, favorable environment for industry and commerce and an adequate transportation system.
- Freight mobility: The transportation system, that the region has and its anticipated improvement through strategic investments by members of the Southeast Alliance, must be adequately planned and implemented to accommodate the projected increase in the volume of trade with Latin American countries, but it also must accommodate the diversity of cargo origin/destinations, shipment types, and service and handling requirements associated with this projected increase in trade with Latin American countries. Thus, the transportation system that is improved with strategic and timely investments should ensure that the region would continue to take advantage of economic opportunities regarding freight mobility.
- Interconnected multimodal system: The team emphasized that the region must make its transportation system a more interconnected multimodal system than it is now in order to provide current as well as potential customers the freight mobility that is currently required and expected in future to enhance the region's competitiveness. The interconnected multimodal transportation system will provide the modal alternatives and operational efficiencies that translate into faster connections, greater flexibility, and safer

connections. This type of transportation system would allow the carriers of different modes of transportation to compete on an individually basis, but also would allow the carriers of different modes of transportation to provide complementary services to move freight in the most economically efficient and timely manner.

- Efficiency: The continued competitiveness of the region, in many situations, will depend upon the efficiency of area's transportation system. For example, the efficiency in the area's transportation system is embodied by a number of features which includes, among others, directness of routing, responsiveness of transit time requirements, capacity, freight handling needs, and transit reliability. These transportation determinants affect the transportation costs of freight, which in turn, affects the competitiveness of the industries engaged in the Latin American trade.
- Environment: The improvement in the area's transportation system will contribute to employment, tax revenues, regional and national economic growth, land values, incomes, and tourism. However, these benefits must not come at the expense of the environment in the region. The transportation industry is a source of pollution. Therefore, through adequate and coordinated planning by members of the Southeast Alliance Region individually, and collectively, will minimize these problems so that the projected increase in trade volumes moved by the various modes of transportation will be harmonized with the region as well as the nation's environmental requirements.
- Safety: The research team explicitly and implicitly states that whatever transportation system that is planned and implemented to handle the increase in trade with Latin American countries, safety of people as they travel should not be compromised. Therefore, appropriate measures must be planned and implemented by members of the Southeast Alliance Region so that freight and people will be able to travel in harmony without any undue risk for either. The LATTS team openly states that decisions on the topic of transportation investments must evaluate all considerations so that the region's planners and implementers appropriately address safety-related projects.
- National security: Although the LATTS report was published before the terrorist's attack on the United States on September 11, 2001, the research team did have the foresight to demonstrate that the Southeast Alliance Region's transportation system must be able to respond to major surges in demand especially those associated with emergency national security needs I do not believe many of us in the United States including the LATTS team ever envisioned terrorists utilizing commercial airplanes to carry out their missions. On that date as you may recall, hijacked commercial airlines crashed into the twin towers of the World Trade Center, the Pentagon, and, in an apparent failed attempt at a high profile target in Washington, D.C., a field in southern Pennsylvania. As a result of these attacks, more than 3,000 U.S. citizens and other nationals lost their lives. Since that date, the threat of terrorism, not necessarily the actual event has become a major concern of not only people in this country but also in other countries. Thus, the implementation of the LATTS investment strategies must not only improve the efficient movement of freight and people during peaceful times, but the area's transportation system must improve the capability of the nation's military forces to carry out their missions.

In addition to outlining and discussion the seven objectives for accomplishing the main goal of the LATTS study, the consultants provided as a guide for the development of investment strategies for each of the transportation mode and its infrastructure: Systems approach; Modal choice; and Dynamic economy. The systems approach, for example, means that the region must understand that it is part of an ever-increasing highly competitive global economy. Thus, its approach must be the systems approach where each component of the system is dependent upon the other for having an economically efficient operation system overall.

Alliance Report Appendices

The LATTS report contains six appendices: (1) Appendix I-Outreach and Coordination; (2) Appendix II-International Overview and Market Potentials; (3) Appendix III- Trade Policies in Latin America; (4) Appendix IV-Port Terminal Planning Modules; (5) Appendix V-Port Conceptual Development Cost Estimates; and (6) Appendix VI-Intelligent Transportation Systems. Two of the appendices are discussed below.

Appendix IV-Port Terminal Planning Modules: The LATTS team used various modules to represent cargo terminals typically associated with the LATTS Region. The process of utilizing the modules in this study reflects the conditions that exist in the Southeast and Gulf regions of the United States. The primary use of the modules was to associate identified capacities needs with the additional infrastructure required to accommodate such a need. The LATTS team developed modules for container, neo-bulk, break-bulk, dry-bulk, and liquid-bulk facilities.

Appendix V-Port Conceptual Development Cost Estimates: The purpose of this appendix was to provide information on the assumptions used to develop the five marine terminal modules found in Appendix IV-Port Terminal Planning Modules. In addition, the total budget cost for the five marine terminals are also included in the appendix. Results indicate that the container cargo terminal will cost $32 million; the break-bulk cargo terminal $20.6 million; the neo-bulk cargo terminal $14.6 million; the dry bulk cargo terminal $17.6 million; and the liquid bulk cargo terminal will cost an estimated $19.3 million.

Alliance Database

The freight database constructed for the LATTS analysis consists of three relational databases on U.S. imports and exports – air transport, water transport, and border crossings – by commodity groupings for 1992, 1995, 1996, and projections at 5-year intervals beginning in 2000. For exports the data include the mode used to move cargo from origin to port of departure.

Transportation Needs

The LATTS study report identified a clear need to increase the capacity of the Alliance states to transport freight. Its apportionment of the expected increase in trade was based on each state retaining its present share of the total trade; however, freight flows may easily differ from that apportionment as dictated by the interaction of economic conditions and capacity of the transportation system components. For example, Houston, Texas presently handles significantly more container traffic than other Gulf of Mexico ports, in part because much of the demand for containerized goods lies within the Houston economic zone. If that continues to be the case, improving container throughput capacity in other Gulf ports will have a lesser effect on their share of the Latin American container trade. However, if mid-western U.S. demand for containerized goods from Latin America increases dramatically and existing ports and highway/railway routes become so congested as to delay deliveries; then increasing capacity in some states may attract a significantly larger share of Latin American trade.

Transportation officials are thus faced with making decisions on which transportation modes will become critical points in the overall transportation system and where funds should be invested in order to maximize economic development and safety while minimizing costs and preserving environmental quality. For any given demand, there are many possible plans that could accommodate the demand and identifying the appropriate mix of highway, railway, and waterway transport capacities is a challenge by itself. Add the complication that multiple entities – federal, states, localities, and private firms are making decisions nearly independently, and a rational solution seems beyond reach. For example, highway capacity can be increased within jurisdictional boundaries, but there are many different alternative paths for improved highways that pass through different political jurisdictions. Meanwhile, responsibility for rail capacity improvements lies with the private rail companies, but their decisions are predicated in part on what public transportation organizations do about highways. If both railway and highway expansions occur, will the railway companies recoup their investment? Waterway capacity improvements are primarily a federal responsibility, but are usually made independently of decisions about highway and rail plans. Ports and waterway terminals are owned and operated by both public and private entities, and each makes its own decisions about improvements in light of expected traffic demand, their ability to connect with land modes, and the capacity of land modes to handle the traffic. The situation amounts to a modern Tower of Babel, and a common language and understanding are much needed.

3. TRANSPORTATION PLANNING

Transportation planning is the process of gathering data, information, and executing procedures and methodologies that lead to the decision of transportation policies and programs. One of the major goals of the transportation planning process is to develop transportation improvement strategies and plans to promote transportation and economical development, while also serving community goals and objectives.

Transportation planning is a comprehensive process of interaction between transportation and society that requires data and information from many different aspects. Needs must be identified, data must be gathered, procedures must be developed and carried out, and future improvements must be planned in order to serve the major transportation objectives of mobility, safety, accessibility, and environmental sustainability at an affordable cost.

- Mobility. Good planning practices will lead to the goal of promoting travel, increase the handling capacity of the network, and reduce delay and congestion. Considerations should be given to both passenger trips and freight trips, and private vehicles, commercial vehicles, and public transportation should be all considered in a coordinated fashion. Intermodal transportation is certainly an important issue to achieve optimal transportation network performance.
- Safety. Safe operation is always very critical for the transportation system. Cost of accidents and benefits of safety improvement is an integral part of transportation improvement decision-making process.
- Accessibility. One measure of accessibility of the transportation system can be evaluated by the time and cost of a trip with a specific origin and destination. Accessibility by modes is an important consideration in intermodal planning. Accessibility is also used to define whether users can get to a transportation system or not.
- Environmental sustainability. Using resources in a manner that preserves them for future generations is a basic societal goal, but its expression and implementation are often controversial. Past practice in transportation has been to state the accepted goals of effectiveness and efficiency and then tack on a statement about minimizing adverse environmental impacts; however, many public agencies are adopting environmental sustainability as a goal[3] even if the definition remains somewhat fluid.

Other, related planning considerations include the following:

- Economic development
- Energy conservation
- Finance
- Equity
- Practicability

Transportation planning is carried out at different level and scope, from activity-based studies such as parking study and transit studies, to corridor studies, urban transportation planning to

[3] See for example, the U.S. Army Corps of Engineers statement of Environmental Operating Principles at www.hq.usace.army.mil/cepa/envprinciples.htm. Sustainability was a focus of the U.S. DOT during the 1990's but does not appear to be a priority at present.

regional and statewide transportation planning. Depending on the planning horizon, there are short-range planning with specific goals for existing problems to long-range strategic planning for the future transportation system and long-range improvements. Based on trip type, we have passenger travel planning and freight transportation planning. From the perspective of transporting mode, there are highway network planning and intermodal transportation planning. The major tasks of the planning process at any level are to predict future travel demand and propose new and improved components of the transportation system. Transportation planning is one of the functional areas of transportation engineering that also include design of the transportation infrastructures, operations of the transportation facilities, and research of transportation phenomena.

Planning Tools and Procedures

Two general approaches to planning are discussed in the literature. The common approach of system analysis includes the following steps:

- Establish the study scope, purpose, and goals.
- Collect data and analyze existing conditions.
- Identify existing problems and needs.
- Forecast and define future conditions and needs.
- Develop and analyze options and improvements.
- Select preferred options and recommend plans for implementation.

On the other hand, performance-based planning processes are commonly used in recent years to monitor and evaluate existing transportation systems and to assess improvement options and allocation of resources. To apply a performance-based planning process, a set of performance measures is needed. The performance measures are defined before data are collected. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) requires that states implement a performance-based planning process.

Transportation models are integral component of a transportation planning process. Models are used to analyze elements of the planning process and to aid decision–making in evaluating alternative options.

Regional travel demand forecast models are commonly used, with the “Four-Step” modeling process being used in most projects and locations. In recent years, many modeling software packages were developed. Those packages are tools that are used to implement the models and modeling methods. Brief descriptions of the most commonly used transportation planning software packages are provided in the following.

<u>EMME/2</u>

EMME/2 is used for planning the urban and regional transportation of people on multimodal networks. It provides planners with a set of tools for demand modeling, network analysis and evaluation. In modeling multimodal networks, all modes are integrated into a consistent network, and full interaction is provided between transit and car modes. EMME/2 features: matrix manipulation tools, which allow implementation of a wide variety of travel demand forecasting models; assignment procedures, based on sound theories; interactive calculators, which allow implementation of evaluation and impact analysis methods; macro language; graphic display; network editors.

MINUTP

MINUTP is a travel demand modeling system for travel forecasting, alternatives analysis, environmental impact statement analysis, site impact analysis, traffic impact studies and other related purposes. It operates on any IBM-compatible microcomputers using the PC/MS-DOS operating system.

TP+

TP+ (Transportation Planning Plus) provides a general framework for implementing a wide variety of travel demand forecasting processes encompassing simple 4-step models to advanced travel models requiring thousands of zones and advanced features. TP+ features: compiler technology, which can dynamically process a comprehensive scripting language; network Calculator, which can simultaneously processing and merge up to 10 networks; highway Assignment, which can build zone-to-zone paths (and associated zonal matrices) and assign trips to highway network links; Matrix Calculator; public transit analysis, estimating zone-to-zone public transit paths, extracts level-of-service data along these paths and assigns trips.

TRANPLAN

TRANPLAN (TRANsportation PLANning) encompasses the four-step travel demand model of trip generation, trip distribution, mode choice, and trip assignment for both highway and transit systems. The public transit software utilizes coding and analysis techniques similar to the U.S. Department of Transportation's Urban Transportation Planning System (UTPS). TRANPLAN features: NIS (Network Information System), which is a graphics editor for displaying and maintaining spatial data, including highway and transit network descriptions, and area (polygon) boundary data; TPMENU (TranPlan MENU), which combines TRANPLAN functions, NIS and supplementary software to provide an integrated user interface.

TMODEL

TMODEL is used to construct and analyze multimodal transportation planning models. It is usually used to build a peak-hour model because it accounts for street and intersection (link and node) congestion in the development of travel times. This notion is best applied to peak hour rather than average daily traffic volumes. TMODEL is a mathematical model. It allows the user to select operating formulas and coefficients, to insert land use and street network data, and then to calibrate [iteratively adjust these coefficients and data] until the model produces traffic volumes that closely approximate known counts for the network.

TRIPS

TRIPS (TRansport Improvement Planning System) is a transportation planning package which enables strategic as well as detailed analyses of multimodal transportation networks. It provides a framework for implementing a wide range of travel demand forecasting models. The user has full control of the composure of the model structure and can set up this structure efficiently using a visual, flow chart style model management system. TRIPS main features:

- Flexible command language for implementing demand models
- Advanced, built-in functions for implementing standard modeling processes
- Intersection-based capacity restraint
- Dynamic traffic assignment
- Multi-path public transit assignment
- Matrix estimation functions for private and public transportation
- Aggregate and disaggregate model application- flexible and powerful model and data management system which visualizes and documents the modeling process
- Supports extremely large problem sizes
- True 32-bit design for Windows 95/98/NT/2000
- User interfaces in multiple languages.

<u>QRSII Version 6</u>

Quick Response System II runs the four-step planning process for highway and transit forecasting. Networks and data are entered and edited graphically using the powerful General Network Editor. It can provide traditional region-wide forecasting, as well as site impact analysis and corridor analysis. Among its advanced capabilities, QRS II performs equilibrium traffic assignment and stochastic multi-path transit trip assignment. QRS II is not specifically a sketch-planning tool.

<u>Trip Generation</u>

Trip Generation by Microtrans™, Version 5, software calculates traffic generation on the basis of the Institute of Transportation Engineers (ITE) *Seventh Edition, Trip Generation Report*, 2003. Transportation engineers and planners throughout the world have used this software since 1984 for:

- Traffic impact analyses
- Transportation and land use planning
- Site analysis
- Land use development
- Academic research

<u>ESTRAUS</u>

ESTRAUS is a computer model that simulates the operation of urban transportation systems. ESTRAUS determines a simultaneous combined network equilibrium using the most recent modeling and computational advances to overcome the well-known limitations of the classical 4-step transportation-planning paradigm. It is especially designed for the analysis and evaluation of strategic transportation plans. The type of plans that can be analyzed and evaluated with ESTRAUS include transportation projects and/or policies such as: subway lines, highways, roadway concessions, capacity change in urban roads, segregated transit corridors, road pricing, public transport fare integration, etc.

TransCAD

TransCAD is the first and only Geographic Information System (GIS) designed specifically for use by transportation professionals to store, display, manage, and analyze transportation data. TransCAD combines GIS and transportation modeling capabilities in a single integrated platform, providing capabilities that are unmatched by any other package. TransCAD can be used for all modes of transportation, at any scale or level of detail. TransCAD provides:

- A powerful GIS engine with special extensions for transportation
- Mapping, visualization, and analysis tools designed for transportation applications
- Application modules for routing, travel demand forecasting, public transit, logistics, site location, and territory management

TransCAD is used by the states of Alabama, Mississippi, and Louisiana.

Intermodal Freight Transportation Planning

Since the passage of ISTEA, many changes have occurred in the world of freight transportation, and freight transportation planning has become a more and more important component of transportation planning. Growth and changes in the national and regional economics, business production and distribution practice changes, and regional and global trade agreements have all contributed to the changes in freight movements in the nation's transportation network, and the growth of freight movement has consistently outpaced the growth of passenger trips in recent years. At the same time, the concept of multimodal and intermodal transportation has garnered more and more attention. As business practices have changed, so too have the modal competitors. Freight companies are turning to more intermodal arrangements, instead of rail only or trucking only approaches, to save transportation and operation costs. Transportation planning procedures need to reflect this recent development in intermodal freight movement. Also, as the nation's highways become more and more congested while other modes are relatively underutilized, it is important for planners and policy makers to plan for and encourage intermodal freight transportation to better utilize the potential capacities that can be provided by an integrated intermodal transportation network.

The difficulties, however, lie in the fact that consistent and reliable data normally required for a planning process is not readily available. Prior research on truck travel forecasting at the state level has been limited by the lack of comprehensive data. Obtaining Origin and Destination (O&D) data from surveys of different traffic modes is too time-consuming, expensive, and may not be practical in some instances.

States have tries to use different data sources other than travel surveys and accordingly developed different approaches to conduct freight transportation planning process. A commonly used method is to use commodity flow movement information to derive ODs of freight. Many of the statewide intermodal freight transportation planning methodologies are based on the Reebie Associates' TRANSEARCH database because it is assumed to be the best commodity flow data currently available.[8,9,10] Although TRANSEARCH database has the advantage of having the county level data (thus eliminating the trouble of developing a breakdown methodology from state level data), the database is very expensive and also has limitations. The Commodity Flow

Survey (CFS) data, published by Bureau of the Census, on the other hand, were also used by states to develop a more economical and flexible intermodal transportation planning methodology.[11,12]

The freight forecasting models typically fall into either the structured approach or the direct approach. The structured approach patterns itself after a typical four-step urban transportation planning study and derives freight demand from economic activities. Many of the studies using CFS database or privately owned TRANSEARCH database used the structured approach to forecast freight demand on the intermodal network. The direct approach, on the other hand, is a simplification of the structured model in which only specific freight types are considered instead of investigating the entire freight movements.

Under the stipulations of ISTEA and following Transportation Equity Act for the 21st Century (TEA-21) of 1998,[13,14] states are required to conduct intermodal transportation planning. The states in the corridor affected by Latin America trade all conducted some level of this planning effort, and the work done by the states of Louisiana, Mississippi, and Alabama is summarized in the following sections.

Louisiana

Louisiana developed its 1996 Statewide Intermodal Transportation Plan per requirement of the 1991 ISTEA. It is the official statewide plan, with funds being awarded to the state by the U.S. Department of Transportation (DOT) in 1992 and with initial planning work kickoff in 1993. Statewide freight intermodal transportation planning effort was detailed in the "Louisiana Statewide Intermodal Plan"[15] prepared by the Louisiana State University National Ports and Waterways Institute. The effort was focused on intermodal connections between marine and rail transportation at ports and rail-highway terminals.

The freight intermodal planning methodology starts with a baseline freight flow analysis. The study focused on intermodal freight flows that (1) originated in another state and destined for another state or country; (2) originated in Louisiana and destined to another state or country; (3) originated and terminated on other states or nations and passed through Louisiana; (4) originated and terminated exclusively within the State of Louisiana. Data were obtained for all varieties of domestic and foreign interstate and intrastate freight movements by rail and water, with an emphasis on intermodal movements or freight transfers. The baseline historical cargo flows were derived through extensive processing of raw data of the follow:

- Waterborne Commerce Statistics (WCSC), by U.S. Army Corps of Engineers
- Railroad Waybill Sample, by Interstate Commerce Commission (ICC)
- Transsearch Data Base, by Reebie Associates.

In addition to the three main sources of freight data on rails and waterways, secondary sources were also incorporated into the study, including data obtained through site visits, port publications, facility surveys, and direct contacts with terminal operators.

A link-node modal analysis was performed to identify intermodal transfer capacities at major terminals and transshipment locations. The purpose of this analysis is to identify potential points of congestion or underutilization. The second level of capacity analysis is a statewide corridor analysis that focused on aggregating individual facilities into geographic nodes of major transportation corridors for general cargo flows that constitute intermodal transportation in the state.

Forecasts to the year of 2020 of major commodity movements were made for six Business Economic Areas (BEAs). Variables for exogenous forecast included government policies, social and economic variables, industry variables and firm or location specific variables. Eleven commodity categories were identified, and annual average growth rates were prescribed for each commodity group on recent national forecasts adjusted to reflect new assumptions relevant to Louisiana. The growth rates were derived for the period of 1990 to 2000 based on the forecasts used by the U.S. Army Corps of Engineers, Energy Information Administration of the U.S. Department of Energy and McGraw-Hill estimates for container cargo.

Detailed capacity and requirements analyses were also conducted for terminals by major commodity groups and also for intermodal terminals. The demand and supply were compared for the terminals. The accessibility of rail and marine intermodal terminals was also studied by analyzing local roads connections and railroad connectors. Productivity and cost analysis was also conducted for intermodal transportation.

The study concluded that based on commodity projections and comparisons with terminal capacities, expansion would be necessary, especially for the grain sector which was already operating at high levels of capacity utilization. Rail-highway intermodal terminals were operating at relatively low levels of utilization and their capacities are sufficient until 2010. Highway access to the state’s major public marine and rail-highway transfer terminals however were suffering from congestion in major metropolitan areas, and upgrading in this area is needed.

Mississippi

The Mississippi Department of Transportation (MDOT) initiated the Mississippi Unified Long Range Transportation Infrastructure Plan (MULTIPLAN).[16] An overview of the MULTIPLAN is given below.

Chapter 1: Best Practices. The purpose of this chapter was to discuss best practices in statewide transportation planning, and how these best practices may impact the planning process in Mississippi. Specifically this chapter covers the provisions of ISTEA that are continued in TEA-21, provisions of ISTEA that are modified under the auspices of TEA-21, and emerging statewide planning issues and impacts on Mississippi. The chapter begins by discussing the provisions that were in ISTEA and are continued in the TEA-21. For example, the federal government still relies on the statewide transportation process as the primary decision-making tool in a particular state. This provision implies that the local and state decision-makers should have a better understanding of the issues, opportunities and problems that might be affecting a state’s transportation planning process than the federal government since these decision-makers are closer to the issues and opportunities at hand.

This chapter also discusses some of the major modifications of the TEA-21. The major modifications of TEA-21 include: state consultations with local officials; revenue forecast:

consolidation of planning factors; ITS technology investments; environmental justice; and freight issues. TEA-21 calls for state officials to consult with local officials so that they can be informed about what is going in terms of the planning process so that the local officials can some input in the transportation planning process since the implementation of the activities in the planning process may adversely impact their local areas. Another issue addressed in TEA-21 is environmental justice, with the intention of ensuring that transportation planning officials put more emphasis on the participation of low-income persons, the elderly, persons with disabilities, and minority communities, in planning, programming, and project development. The goal of the modification in TEA-21 is to primarily reduce the adverse impacts of transportation investments on these groups.

The section titled "Emerging Statewide Planning Issues and Impacts on Mississippi" provides a discussion of the following emerging issues in statewide transportation planning: performance-based planning; land use considerations; planning and NEPA linkages; environmental justice; air quality issues (attainment/non-attainment); freight movement issues; innovative finance options; management and operations; safety; and impacts of technology. The primary focus of this section of the chapter was on performance-based planning. The performance-based planning is a result of the strengthen emphasis on multimodal transportation planning in TEA-21. This emphasis has lead to a major push towards performance-based planning.

Performance-based planning includes: Identification of goals and quantifiable objectives; definition of measures that relate to the goals and objectives; identification of analytical methods and data required to generate the performance measures; and application of the measures in a process of alternatives evaluation, decision support, and ongoing monitoring.

Examples of statewide performance-based transportation planning include the Minnesota DOT, Florida DOT, and the California DOT. These performance-based transportation planning was primarily examined to illustrate the central role efficient management of transportation systems and operations have on the decision-making process. The Minnesota DOT performance-based transportation planning is based on time-related, safety, infrastructure condition, access and level of service, environment, and socio economics measures to reflect the range of outcomes influenced by transportation system performance. In the time-related measure a predictable travel time for length of trip is maintained so that the customer expectations are met.

The second area of performance-based transportation planning contained in this chapter is at the metropolitan level. Although the performance-based planning at the metropolitan level differs in scale and scope from the statewide applications, the metropolitan performance-based transportation planning can be a useful supplement to the analysis of statewide applications. An example of performance-based transportation planning at the metropolitan level is Albany, New York. In this example, a set of core performance measures was grouped into three categories: transportation service quality; resource requirements; and external effects. The transportation service quality category contains the core performance measures access, accessibility, congestion, and flexibility. These core performance measures reflect the degree to which the transportation system is operating at acceptable levels at metropolitan areas and how the importance these attributes play in aiding the decision-making process.

Another important area that this chapter emphasizes is customer satisfaction with the transportation system overall and with state DOT's. This area has become increasingly important over the past decade in transportation policy, management and planning activities. Several state transportation agencies including the Minnesota DOT has an extensive program through which customer satisfaction surveys are conducted and analyzed. The surveys provide data and information to transportation decision-makers on how well the transportation investments are being utilized to generate comfort, efficiency, effectiveness, and safety. In addition transportation planners gain insight on the areas of weakness and strengths and how these might be improved over time to make a better transportation environment for their customers.

Chapter 2: Goals, Strategies, and Action Steps. This chapter provides information on the reviews of the 1996 Long Range Transportation Plan (LRTP), summary results of interviews with stakeholders and MDOT staff, revisions to the LRTP, and MULTIPLAN goals, strategies and action steps. Interviews with stakeholders were summarized in the following categories: (1) strengths of the existing transportation system; (2) weaknesses of the existing transportation system; (3) barriers to multimodal implementation, and (4) freight and trucking industry needs. Results indicate that stakeholders felt that the 1987 Four-Lane Highway Program was a major strength of the transportation system in the state. Another strength was the 1994 Gaming Roads program. These programs were put in effect to improve the access of Mississippians so that they can be able to conduct business as well as for recreational and other activities around gaming facilities.

Stakeholders also felt that there were some weaknesses in the present transportation system in the state. These included more cooperation between MDOT and the state legislature, more flexibility of MDOT in the decision-making process dealing with the Four-Lane Highway Program. Barriers to multimodal implementation included the cost or financial constraints, current focus on highway facilities at the expense of other modes, and lack of plan implementation.

Interviews with the MDOT provided information on the status of specific programs and projects identified in the 1996 LRTP. The results of the interviews of the MDOT were categorized as mobility, safety, economic development, system management, maintenance and preservation, environment and energy, and finance. In the economic development category MDOT staff revealed that the Gaming Roads Program had been implemented, but the staff felt that it was not adequately funded. In addition, the staff indicated that the Economic Development Highways Program had not been implemented.

Focuses of the revisions to the 1996 LRTP Goals, Strategies, and Action Steps are on the customer, safety, and flexibility. In the customer (traveling public) focus, the goal of improving and enhancing the transportation network, and addressing any deficiencies and inefficiencies is a primary one that directly impacts the traveling public. This focus is addressed through the revisions of the GSAS towards more external, outcome-oriented measures as opposed to internal, output-oriented measures. The focus on safety will be geared toward improving the state's highway safety record since Mississippi continues to rate poorly nationally in the highway safety area.

The MULIPLAN goals reviewed in this chapter are revisions and additions to those formulated with the 1996 LRTP. The goals include: Accessibility and Mobility; Safety; Maintenance and Preservation; Environmental Stewardship; Economic Development; Awareness, Education, and Cooperative Processes; and Finance. The MULTIPLAN goals also had the strategies posed and action steps necessary to achieve the goals were outlined in a matrix format. For example goal of accessibility and mobility had eight different strategies that could be used to improve and enhance this goal for the traveling public using the transportation system in Mississippi. One of the strategies mentioned in this chapter is to provide reasonable access to the state's highway system to all citizens. The action step for implementing this strategy is to complete construction and open to traffic Phases II-IV of the Four-Lane Highway Program by the adopted scheduled dates.

Chapter 3: Statewide Transportation Framework (STF). The purpose of this chapter is to identify Mississippi's Statewide Transportation Framework (STF). By identifying the STF evaluation can be made on the current transportation system as well on the system's future. The STF is a means by which transportation facilities in the state are identified and grouped by mode as being of state interest rather than of local and regional interests. However, the STF does not preclude state funding for and prioritization of local and regional transportation facilities. The STF provides a mechanism for describing transportation needs so that decision-makers can make better informed about investing in the transportation facilities in the state.

The criteria utilized in selecting the Mississippi highways to be included in the STF were as follows: Functional classification-interstate, principal arterial, minor arterial and others; Average daily traffic-ADT; Connectivity/proximity to other facilities and population centers; and Truck traffic. Results reveal that 100 percent of U.S. Interstate mileage, National Highway System (NHS) including all NHS Intermodal Connectors, and rural Principal Arterial highway mileage has been included in the STF.

The criteria used to allocate Mississippi rail facilities to the STF include the following for Passenger Service: Existing Amtrak service passing through the state and providing connections to/from out-of-state destinations/origins; USDOT designated High Speed Rail corridors; and MDOT planned High Speed Rail corridors. For example, one of the passenger rail services identified was the City of New Orleans, which serves the cities of Greenwood, Yazoo City, Hazlehurst, Brookhaven, and McComb. For the Freight Service rail facilities, the STF includes the freight rail lines that connect with major interstate markets, or connect with state interest identified public ports; or serve principal rail-highway intermodal facilities.

The STF includes the existing general passenger-related facilities and systems that address areas of service and employment-related concerns within the state. Transit components of the STF include urban, rural, and intercity elements. Local fixed-route systems in large urbanized areas are included in the STF to identify transportation clusters and multi-county rural transit systems are also included to recognize areas with major trip destinations. The criteria utilized in allocating Mississippi transit facilities to the STF include intercity bus facilities-locations; urban fixed-route/paratransit systems of state interest; and rural multi-county transit systems of state interest. Intercity bus locations that are included in the STF are Aberdeen, Durant, Iuka, Natchez, and Shelby. In total there are 79 locations included in the STF.

Rural, multi-county public transit systems of state were identified on the following criteria to be included in the STF: service area population; service area square mileage; transit rider-ship; and transit mileage. Based on these criteria, 10 transit systems were identified.
The airport system levels identified to be included in the STF were based primarily on two criteria: location and level of service and activity. The location criterion refers to the geographic location of the airport and the location of several demand centers, which may provide activity for an airport. The second criterion refers to the level of service and facilities expected for various categories of airports within the statewide system. Based on these two criteria, three airport system levels were identified: Type I-General Purpose Airports; Type II-Business Airports of Local Impact; Type III-Business Airports of Regional Impact; and Type III Enhanced-Business Airports of State Impact. The airports identified as part of the STF totaled 17.

The Ports and Waterways section of this chapter explains the criteria that were used to select the ports that were included in the STF. Criteria used to select ports that had state interest include: ports with deep-draft capacity; ports with barge capacity and facilities; ports of industrial significance; and ports with connections to the national highway system. These criteria generated 14 ports to be included in the STF. Of that total, two are state owned: Port of Gulfport and Yellow Creek State Inland Port. The remaining 12 ports are locally owned and operated.

Chapter 4: Economic and Transportation Trends. The primary purpose of this chapter was to provide information on the interdependence of the Mississippi's transportation system and the global economy that includes the economy of Mississippi and the rest of the world. To accomplish the objective, this chapter provides information and data on the linkage of investment in transportation infrastructure with that of economic development. By providing such information will allow stakeholders as well as the MDOT examine opportunities in the areas of policy and finance to position the state for enhancing its economic growth and quality of life for its mainly rural stakeholders.

The first section of this chapter is titled "Economic Trends and Relationships" and provides information and data on the following topical areas: economic development and transportation infrastructure linkages; international trade and transportation infrastructure linkages; and manufacturing and production trends. In the first topical area, the chapter reveals that increases in economic output and growth are partly the result of the investment in a state's capital stock. A state's capital stock consists of two major investment components: direct productive investments and supplemental investments. Direct productive investments include factories, machinery, and equipment while supplemental investments are generally considered infrastructure investments such as transportation, electricity, water, communications, sanitation, and education.

Before going further in review of this part of the chapter, it is important to note that education is a significant component of human capital. The term human capital can be defined as the knowledge and skills that individuals acquire through education, training, and experience to increase productivity. Human capital is perhaps the most important and most neglected part of supplemental investments. Marketing addresses products, services, prices, promotion, distribution (place), but we rarely ever talk about the human capital aspect of those items. Without highly knowledge and skilled people, we basically could not have the high standard of living in this country. In general, the Southeastern Region falls short in the human capital area in which education is a major component of that area. It is generally ranked very low relatively to other areas in the country in many categories such as investment in public education.

The linkage between economic development and infrastructure investment such as transportation enables stakeholders and MDOT as planners to more efficiently and effectively invest in those transportation facilities that will enhance the productive activities for the state. This type of investment will allow stakeholders such as businesses to generate employment, tax revenues, output, and incomes to support the various direct productive and supplemental investments that will enhance the state's economic growth and the quality of life.

The second topical area deals with the linkage between international trade and transportation infrastructure. In this area, the anticipated increase in trade with Latin American and the world in general puts more emphasis on the importance of the state's transportation system to accommodate the anticipated traffic that will be coming from within the state or through traffic that will originate elsewhere in the country. Regardless of the source, the state must prepare itself to take advantage of these opportunities so that it can get its fair share of that traffic especially the Latin American traffic since Mississippi as a gateway state has benefited from international trade trends. The anticipated increase in international trade will directly impact ports, highways, railways, and airports in the state. Therefore, transportation planners must focus on the modal impacts of increased freight traffic coming through and out of the state in order for the stakeholders and the citizens in Mississippi to optimally benefit from this traffic.

Manufacturing and production trends are another major area that influences transportation and freight networks. For example, changes in products and services demanded by producers and consumers influence the way the transportation system provides its services. In this section of the chapter information is provided on how the movement toward a more service-oriented economy and away from a manufactured economy, redistribution of industrial production centers, and changes in manufacturing practices affect the transportation system and the transportation planning process. For example, where firms locate their facilities to produce their products have major impacts on the way in which goods flow. This in turn generates new freight densities and corridors that may benefit some modes of transportation but not all modes of transportation. Therefore, state planners, transportation carriers, and public must be able rise to the occasion so that these challenges and opportunities will not be overly burdensome to them.

The section titled "Transportation Trends" is the second part of the chapter that deals with the relation of transportation and economic trends. This section is divided into two major subsections: Transportation Investment and Environmental Goal Linkages and Expanding the Transportation Financing Base.

The subsection on the linkage of transportation and environmental goals emphases the fact that, as beneficial as it may be, transportation planners must factor in environmental externalities in their decision making process because many stakeholders are placing more on the quality of life attributes than they did in the past. Some of transportation's environmental externalities include air pollution, water pollution, land use, sprawl, and habitat, and threatened lands and buildings. These byproducts of transportation are facts of life, but it does not mean that the public must tolerate excesses. Therefore, it is crucial that transportation planners in Mississippi knowledge these externalities of transportation and be receptive to growing concerns for the quality of life and deal with these environmental externalities swiftly and transparency. The strategies that this chapter provides to deal with environmental externalities include: providing transportation choices; smart growth; and innovative traffic management.

The subsection that deals with expanding the transportation financing base places emphasis on the fact that transportation planners must become more creative and innovative in obtaining financial resources to provide the type of transportation system that is demanded by stakeholders in Mississippi. These innovative approaches are becoming more and more necessary as the traditional ways of funding transportation facilities are going by the wayside as more and more people are resisting user-based taxes. Some of the ways that transportation planners may get around raising user-based taxes include: privatization; state infrastructure banks-SIBs; innovative taxing and user fees; federal and state responsibilities; and use of intelligent transportation systems.

One of the innovative ways in which transportation planners may be able to generate the necessary funding for projects are the use of state infrastructure banks (SIBs). SIBs are infrastructure investment funds formed at state or regional levels to provide states or regions with a new financing capability to complement other parts of the US DOT Program. SIBs are formed with federal seed money (also known as capitalization grants), offer a menu of loan and credit enhancement assistance, and give state/local agencies greater flexibility regarding financial management of projects.

Chapter 5: Highways and Bridges Modal Assessment. The purpose of this chapter is to provide information and data on the highways and bridges in Mississippi. With this information and data, stakeholders can evaluate the strengths and weaknesses of the highway and bridge system in the state to determine whether areas need to be maintained or improved to enhance the future prosperity state's economy so that it can compete globally.

The chapter is divided into the following topical areas: Four-lane highway program; Gaming roads program; Highway system characteristics; and Peer state review. Most of the information and data provided in this chapter is focused on the "highway system characteristics." In this section of the chapter information and data is provided on the following areas: Jurisdiction and functional classification; Traffic volume; Truck traffic; Congestion; Pavement condition; Bridge condition: Safety; and National highway system. Due to this emphasis placed on the section, the summary report of this chapter will primarily geared toward this subsection.

One of the results shows that counties own 72 percent of the state's highway network, while the state and cities own 15 and 12 percent respectively. On a functional basis, the local functional class of highways in Mississippi account for slightly over 68 percent while collectors comprises 21 percent. Traffic volume in the state is primarily moved in Mississippi in the rural areas. For example results show that almost 70 percent of the vehicle miles traveled in the state are in the rural areas. The results further show that less than 31 percent of the vehicle miles traveled in the state is on the urban network.

Truck traffic results show that the largest volume of heavy truck traffic is on the state's rural and urban interstates. Results show that heavy truck traffic accounts for nearly 20 percent of Mississippi's rural traffic and slightly more than 10 percent of urban traffic. The state's high ranking of heavy truck traffic as a percentage of traffic volume illustrates the dependence of freight transport on Mississippi highway network.

Another important area that helps the prosperity of the state's economy is the condition of the bridges in the state. Mississippi has 16,934 bridges that place it in the top 15 nationally. Of that total, 5,401 are under the jurisdiction of MDOT and the remaining 10,993 are under the jurisdiction of local governments. Results show that about 75 percent of the bridges under the jurisdiction of local governments are deficient while the remaining 25 percent are under the jurisdiction of MDOT. These results suggest that the local governments need to reduce this large percent of the deficient bridges in their jurisdiction so that the technical as well as economic efficiency can be enhanced in the movement of freight over the bridge systems in their areas.

The section on the peer state review compares the condition of Mississippi's highway and bridge networks with neighboring and/or demographically similar states. The peer states were not only selected by their geographic diversity but also on their land area, population, personal income, gross state product, and highway system characteristics such as highway mileage, lane-miles, daily vehicle miles traveled and average daily traffic. Results reveal that Mississippi does not experience congestion to the same degree as the average state and on the rural highway network experiences congestion at negligible levels. The largest percentage of congested highway mileage identified is found on the state's urban highway network that is similar to national and peer state trends. Overall, Mississippi has lower congestion levels than both the average state and most peer states.

Chapter 6: Ports and Waterways Modal Assessment: The purposes of this chapter are to provide a general assessment of Mississippi's ports, evaluate the ports as an important element in the total freight logistics chain and identify the options required to enhance the state's port system. This chapter is divided into Systems Assessment, System Overview, Port Facilities, Rail Access-Mississippi Ports, Roadway Access, Port Markets, Port Investment Opportunities and Funding Mechanisms.

The 16 public ports in Mississippi are divided into three distinct regions: the coastal ports along the Gulf of Mexico; the Mississippi River ports and the Tennessee-Tombigbee Waterway ports. Results from this section reveal that all of Mississippi's ports are expected to increase international trade tonnages by the year 2025. Therefore, stakeholders that need ports to serve as a crucial linkage in the international trade of commodities and products must plan accordingly to take advantage of this projected increase. From the present to 2005, the average increase in tonnage is expected to be approximately 4.9 percent for international trade and approximately 1.09 percent for domestic trade. The overall trade increase is expected to be 4.3 percent. Results further reveal that ports in Mississippi are expected to account for over 4,600 jobs and over $113 million in payroll earnings. This represents a 146.9 percent increase over 25 years.

Intermodal links by truck and rail will be key components to the growth of the port sector and its continued contributions to the economic viability of the state's economy. Intermodal capability will stimulate international trade and generate a combination of out-of-state cargo development and statewide industrial growth. Therefore, the port's ability to contribute to the state's economic viability will hinge to a large extent on the improvements in their operational and physical capabilities.

Chapter 7: Aviation Modal Assessment. This chapter is divided into key issues, current air service, and general aviation airports. Mississippi has 78 ports that range in size and scope from international airports serving commercial airlines to small turf strips accommodating aerial applicators and general aviation aircraft.

Key issues that could have major impacts on aviation in the state were identified as airline consolidation and financial instability; flight training and pilot licensing; funding priorities; security issues; and North American Free Trade Agreement (NAFTA). Results from this chapter reveal that it is important to understand the key issues affecting general aviation since virtually all of the airports in Mississippi have a general aviation presence. For example since the mid-1990s there has been a resurgence of general aviation. This means that airports must gear up for accommodating this type of traffic that it will not be lost to competing regions and states. This will allow the airports serving this type of aviation to provide employment, tax revenues, output, and incomes. These attributes will enable airports in the general aviation industry in the state to continue their contributions to the economic viability of the state's economy.

The impacts of NAFTA will continue to encourage investment in the civil/general aviation infrastructure of the Gulf Coast/Gateway States. As demand for goods and services in the developing countries of Latin America increases and as trade with Mexico continues its growth, it is imperative that airports in Mississippi be prepared to accommodate increases in passenger as well as air cargo demands with these countries as well as with other trading partners that utilize the aviation infrastructure in the state.

In the current air service section of this chapter, results reveal that there are 21 passenger airlines that serve Mississippi at seven commercial service airports. Besides passenger service to Mississippi, air cargo is transported in and out of the state on passenger aircraft and all air-cargo carriers. Commodities generally transported by these carriers include but not limited to software, textiles-garments, and perishables-flowers, fruit, vegetables and fish.

General aviation in Mississippi supports a host of activities that are crucial to the economic viability of the state's economy. Some of the aviation activities at the state's general aviation airports include air cargo activity, medical evacuation, real estate tours, forest firefighting, and pipeline patrols.

Chapter 8: Transit Model Assessment. This chapter presents an inventory of all public transit services and facilities in Mississippi. Also this chapter provides information on the operating characteristics of each type of service in the state. The public transit service in Mississippi is composed of urban transit service; rural transit service; Elderly and persons with disabilities service; and intercity service. Each of these types of services is described in the following discussions.

The urban transit service in Mississippi is located in Jackson, Mississippi, served by Jatran; Biloxi/Gulfport, Mississippi, served by Coast Transit; and Hattiesburg, Mississippi, served by Hub Transit. Results indicate that Jatran generated 803,470 passenger trips in the year 2000. Results further reveal that Jatran generated 1,247,547 revenue miles, 80,771 revenue hours, and operating expenses of $4,021,532 in 2000. Funding for Jatran's operations comes from fares that represent 16 percent and local sources. Jatran does not receive any federal funding for its operations due the population of Jackson, Mississippi being over 200,000. Additionally, no MDOT funds are available for this operation.

Coast Transit Authority (CTA), which serves Biloxi, Gulfport, and Ocean Springs, Mississippi, generated 802,817 passenger trips, 1,424,554 revenue miles, 101,135 revenue hours, and operating expenses of $3,690,844 in 2000. CTA receives its local funding from Biloxi, Gulfport, and Ocean Springs plus Harrison County. Other cities in the area are eligible for services but have not participated in the CTA services. Federal Transit Administration (FTA) funding is used for operations, with CTA receiving approximately $2 million per year from that source. Also results indicate that no MDOT funding was used for operating or capital expenses. No operating performance statistics were provided on the Hub City Transit system in Hattiesburg. The funding for the system comes from a 0.5 mil property tax assessment that is dedicated to the transit system.

In Mississippi, there are 17 FTA funded providers of rural transit services. These providers do not provide make available rural transit services to all areas of the state, but they do provide services to 50 of the 82 counties in the state or 61 percent of the total counties in the state. The Aaron Henry Community Health Services Center, for example, provides transit service to Bolivar, Coahoma, Desoto, Panola, Quitman, Tallahatchie, Tate, and Tunica counties. The headquarter city for this rural transit provider is located in Clarksdale, Mississippi.

The size of the providers of rural transit ranges from United CAC, carrying 10,715 passengers per year, to Pearl River Valley Opportunity, transporting 274,220 passengers per year. Also, the size of the transit providers' fleets of vehicles ranges from four vehicles for United CAC to 32 vehicles for the Pearl River Valley Opportunity.

Results reveal that MDOT funds 53 grantees using "pass-through" funds from FTA Section 5310 Elderly and Persons with Disabilities Program for the transportation of the elderly and persons with disabilities. The funds the purchase of vehicles and requires a 20 percent local match. No supplemental MDOT funds are provided. Results further reveal that all 82 counties in Mississippi have at least one recipient under this program while many counties have several recipients of this program.

Greyhound and its affiliated companies primarily provide the intercity bus services in the state of Mississippi. Delta Bus Lines in Greenville, Mississippi operates Route 777. These two bus companies provide service to 79 cities and towns in 53 counties. Results show that Jackson, Mississippi has the highest frequency of bus service available. For example, Jackson has 41 daily trips while Meridian has the second highest level of bus service with 36 daily trips. Results reveal that Mississippi has 11 cities that have population greater than 25,000. The population of the cities ranges from 25,944 in Columbus, Mississippi to 184,256 in Jackson, Mississippi in 2000. All of the eleven major cities in the state have transit service except the cities of Vicksburg, Pascagoula, and Columbus. Although Vicksburg, Pascagoula, and Columbus do not have public transit service available, they do have elderly and disabled service and intercity bus or rail service available. These cities, also, do not have any connecting city bus service.

Results reveal that federal funding for public transit services have been increasing over the years. For example, the Urban Area Program increased from $3,869,437 in fiscal year 1999 to $4,371,759 in fiscal year 2001 or an increase of almost 13 percent. The federal funding for rural transit services in the state increased from $3,775,797 in fiscal year 1999 to $4,362,349 in fiscal year while funding for the bus capital increased from $5,458,750 to $10,051,697 over the same time period.

Chapter 9: Passenger/Freight Rail Modal Assessment. The purpose of this chapter is to describe how the statewide rail system operates in a functional capacity, how it interchanges with the other modes of transportation, and identify some of the deficiencies in the system that may affect the efficient operations of the total transportation system in the state. This chapter is composed of two main areas: Rail passenger service and Rail freight service. The rail passenger service in Mississippi is described by discussing the existing Amtrak service, potential passenger's service by Amtrak, and high-speed rail. The rail freight service is also divided into several areas: rail carriers; the shrinking rail system; regional and short line railroad creation; connections with other modes-intermodal services; and commodities transported by rail carriers in Mississippi.

Amtrak has three passenger trains that serve various cities of the state. Amtrak has the *City of New Orleans*, the *Crescent*; and the *Sunset Limited*. The *City of New Orleans* runs over the Canadian National/Illinois Central (CN/IC), and serves the cities of Greenwood, Yazoo City, Jackson, Hazlehurst, Brookhaven and McComb in Mississippi on its route between Chicago and New Orleans. The *Crescent* runs over the Norfolk Southern track and serves Meridian, Laurel, Hattiesburg, and Picayune in Mississippi on its route between New Orleans and New York. The *Sunset Limited* operates over the CSX Transportation tracks along the Gulf Coast and serves the cities of Bay St. Louis, Gulfport, Biloxi, and Pascagoula in Mississippi between New Orleans and Jacksonville, Florida. The train also operates to Los Angeles and in Florida it extends south of Jacksonville to Orlando, Florida.

In the potential Amtrak passenger service section of this chapter, information is provided on the announced intention of Amtrak to establish a new route between Meridian and Dallas/Fort Worth. The train would be an extension of the *Crescent* and it would be named the *Crescent Star*. The route through Mississippi would come through the cities of Jackson and Vicksburg in Mississippi and operate on the Kansas City Southern trackage. In addition to this potential new service to Mississippi, there is the possibility of high-speed rail service to the state. The Gulf Coast Corridor running from Houston, Texas to Mobile, Alabama is a federally designated high-speed rail corridor under Section 1103(c) of TEA-21. The Southern Rapid Rail Transit Commission is studying the route and issuing an RFP to conduct a Major Investment Study (MIS) for the Gulf Coast portion.

The section on rail freight service in the state indicates that there are 24 line-haul railroads and terminal or switching companies that make up the rail system in the state. Out of that total, there are five Class-I major railroads, one regional, and the remaining 18 are classified as local carriers. The five Class-I major railroads have 1,938 route miles, the regional railroad has 146 route miles, and the remaining 18 local railroads have 501 route miles in Mississippi. The 844 route miles that the Canadian National/Illinois Central (CN/IC) has in Mississippi represent 33 percent of the statewide rail system. The Kansas City Southern has the second largest percentage of route miles (23 percent) in the state while the Norfolk Southern has eight percent of the route miles within the state. Overall, the Class-I major railroads account for 75 percent of the route miles in the state.

Since 1973, the rail system in Mississippi has lost a total of 1,046 miles. This lost is equivalent to 40 percent of the state's present rail system. The rail system in Mississippi shrunk primarily because Class-I major carriers were not receiving high enough return on their investment in the state therefore it was feasible for them to divest low density and unprofitable lines by abandoning or selling them. With the selling of the lines or in some cases leasing the lines to other operators, principally short line railroads have enable local rail lines to continue the service to the state in profitable ways in which the Class-I major rail carriers were not able to do. For example, the regional or short line railroad companies formed or expanded from the lines sold or leased by the Class-I major carriers in the state do not have to use unionized employees and they can be much more responsive to customers needs than the Class-I majors. These attributes have enabled the regional or short line rail carriers to reduce their operating costs and increase revenues. These results have, in turn, enabled the short line rail carriers to maintain service in the state at profitable levels.

This chapter provides the information on railroad intermodal activities in the state because at the state and national levels, the transportation systems have been built and promoted on the basis of separate modes. Different modes have dissimilar strengths and weaknesses. Therefore policy makers as well as investors need information on the railroads intermodal activities to evaluate expansion of an intermodal system that will build upon the strengths of each mode while at the same time enhancing mobility in a way that is environmentally sound and efficient. Such a system will enhance the state's competitiveness in the global economy and, at the same time, reduce the overall adverse impacts of the transportation system in the state.

Railroads, through their connections with other modes of transportation, are involved in many intermodal traffic movements that many refer to as intermodalism in the state. Intermodalism can be defined as the cooperation and coordination of two or more modes of transportation in moving a single shipment of freight from an origin to a destination. For rail carriers, these connections and facilities take many different forms: TOFC/COFC; Water ports; Bulk facilities; and Team tracks. For example, many intermodal movements are related to piggyback (TOFC-trailer on flat car) and container (COFC-container on flat car) intermodal services. The latest innovation in the latter concept is the highly publicized double-stack service, where containers are stacked two high on specially designed cars. In Mississippi and states across the country, with the increased use and investment of containers has led to the forming of hub centers. Such a facility is located in Jackson, Mississippi. Nearby terminals are located in New Orleans, Mobile, Memphis, and Birmingham.

The final section of this chapter deals with the major commodities originating and terminating in Mississippi by rail for the year 1999. Results reveal that rails originated over 14 million tons of freight and terminated over 16 million tons in that year. Lumber or wood products accounted for almost 5 million tons of originated traffic by carriers while coal accounted for largest amount of tons terminated in the state. This volume accounted for over 4.1 million tons.

Chapter 10: Bicycle/Pedestrian Modal Assessment. The purpose of this chapter is to provide information on bicycle/pedestrian activities and issues. With this information transportation planners will be much more aware of the need to balance the transportation infrastructure that it provides access to all and safety in each mode of travel whether motorized or non-motorized. Although non-motorized modes represent a small portion of Mississippi's transportation network, it is important to institutionalize planning for such facilities. The chapter is divided into the following areas: Existing conditions; Design policy; and Financing for discussion.

The section dealing with existing conditions provides information that shows how the state of Mississippi is trying to incorporate the non-motorized modes into an overall comprehensive transportation system. Mississippi has had a Bike and Pedestrian Coordinator since 1992 whose primary duty is to make the public aware of the importance of the non-motorized modes to the state's economy and the viability of its citizens especially those that believe that biking and walking can improve the health of the state's consumers and business employees.

The chapter reveals that there is no advisory committee within MDOT to specifically address bicycle and pedestrian issues. However, the committee appointed to review and recommend enhancement projects for funding includes the Bicycle Advocacy Group of Mississippi (BAGM). The BAGM is a statewide bicycle and pedestrian advocacy group that has several objectives that deal with bicycle and pedestrian issues. One of the objectives of the group is to increase public awareness of non-motorized alternatives to the private automobile.

The chapter also reveals that, due to Mississippi's rural nature, there has not been sufficient use or demand to justify the consistent development of bicycle and pedestrian facilities, aside from select urban and university areas. Therefore, the state has not heavily invested in the facilities to support bike and pedestrian needs.

Funding of bicycle and pedestrian projects can be obtained from almost the entire major Federal-aid highway, transit, safety and other programs. Some of the funding sources in the Federal-aid Highway Program include National Highway System, Surface Transportation Program, Transportation Enhancement Activities, and Hazard Elimination and Railway-Highway Crossing Program.

Chapter 11: Intelligent Transportation Systems. The first part of this chapter provides the state's vision for the incorporation of a strategic plan for fully implementing Intelligent Transportation Systems (ITS) within the framework of Mississippi's long-range multimodal transportation plan. Intelligent Transportation Systems are expected to play a bigger role in the efficient and effective operations of the transportation systems around the state than it has in the past. Intelligent transportation systems are innovative solutions that address contemporary transportation problems. They are characterized by information, dynamic feedback and automation that allow people and goods to move efficiently. They encompass the full scope of information technologies used in transportation, including control, computation and computation, as well as the algorithms, databases, models and human interfaces (Journal of Intelligent Transportation Systems, 2004). With ITS incorporated in the strategic plan for Mississippi, this should provide the state with a tool to better operate and manage its capital assets such as roadways, intermodal ports, airports and transit facilities. This improvement will allow for the movement of freight and people efficiently, effectively, and safely within, to, and from Mississippi for recreational as well as for business purposes.

This chapter also identifies and evaluates ITS Market Packages (as defined by the U.S. DOT in the National ITS Architecture) that will support the goals and ITS strategies developed through the statewide ITS Vision process. A Market Package represents the collection of equipment capabilities that interact to deliver a specific transportation service. The National ITS Architecture defines 63 Market Packages in the following general groups: Traffic Management; Traveler Information; Commercial Vehicle Operations; Archived Data; Emergency Management; and Advanced Vehicle Safety Systems.

For Mississippi purposes, a screening process was used to prioritize the Market Packages to fit the state's needs. The screening process utilized four steps: Mississippi's ITS Vision/Strategies; Similar State Review/Lessons Learned; MDOT Functions/state level applications; and SWOT Analysis. The SWOT analysis examined the potential for each Market Package to be implemented successfully in Mississippi.

The last part of this chapter explains the ITS Concepts Plan. The purpose of the Concepts Plan is to organize and prioritize Market Packages that were relevant to the Mississippi environment. Results reveal that 35 Market Packages were identified as appropriate applications that support the ITS objectives formulated in the Statewide ITS Vision. The Concepts Plan organizes the Market Packages into recommended Program Areas to assist MDOT in structuring its ITS program and in clarifying roles and responsibilities with respect to multi-agency coordination. The recommended ITS Program Areas fall into two major categories: Local/District Programs and Statewide Programs. The local/district programs include systems operations/maintenance while the statewide programs include ITS planning/policy/administration.

Alabama

In a 1996 Alabama DOT report on statewide transportation planning[17], addressing needs of improvement for freight movements was identified as a component of the Statewide Transportation Improvement Program (STIP). Existing network conditions on all modes were profiled and improvement plans were discussed in the same report.

In response to the Surface Transportation Assistance Act of 1984 (STAA), Alabama designated a network of twin trailer truck routes that facilitates interstate and intrastate freight movements. The truck routes include 13 US routes and 21 State routes. Railroad element was also included in the statewide plan, with the planning effort being concentrated on preserving branch lines that vital to continued rail service to urban and rural communities, and to support some of the state's most important industries, such as wood products, that depend heavily on rail transportation.

Rail transportation as part of a multimodal service was recognized, as both trailers on flat cars and containers on flat cars combines the cost effectiveness of long-distance rail with the flexibility of truck pick up and delivery. Intermodal transfer locations in Birmingham, Mobil, and Huntsville were examined. The state's ports and waterway systems were also profiled the report.

The effort of systematic statewide planning that addresses the freight transportation growth and its impact on overall network was not found in the literature. The state did, however, sponsor an intermodal planning needs study project, entitled "Multimodal Transportation Planning Needs Survey."[18]

Special Planning Needs

Officials from state departments of transportation, metropolitan planning organizations, and ports identified a number of planning needs beyond those addressed above. The following needs were highlighted in personal communications with the authors:

- Improved communication with people working in different modes so as to develop a common understanding of the impacts that decisions in one mode will have on other modes.
- Understanding of what happens if the percentage traveling by each mode changes
- Compatibility with TransCAD and both ArcGIS and Intergraph GIS.
- Consider enhancing environmental quality instead of just avoiding damage
- Ability to zoom in to examine details, such as allocation of space at terminals, and out to see the big picture impacts associated with local decisions.
- Ability to input local or proprietary data.
- Software that runs on desktop computers.

The first bullet above was a common theme of the interviews. Communications among people involved in different transport modes was described as frustrating, not just because of different perspectives, but because of a lack of common data, lack of mutual understanding of the challenges, and gaps in responsibility. For example, port officials were concerned about connector and local highway traffic congestion because it affected their throughput; whereas state officials focused on overall highway congestion effects, including rural highways. Further, dialog is hampered by an inability to communicate among private entities (e.g. rail and shippers), public (e.g. state and local officials), quasi-public (e.g., ports) in a common performance language. This need can be addressed by a common set of performance metrics and a common, transparent method of calculating the impacts of changes to components of the system.

The following sections of this report present a system of metrics, simulation, and local optimization intended to address the needs expressed in this section.

4. INTERMODAL TRANSPORTATION METRICS

Each of the transportation modes – highway, rail, waterway, air, and pipeline -- has performance metrics specific to that mode and its stakeholders, but many of those metrics are not directly applicable to other modes. For example, airline safety is often expressed in terms of accidents per number of take-offs and landings, which has no counterpart in any other transport mode. A rigorous analysis requires a common set of measures that indicate the level of performance for any mode to which it is applied and can be directly compared with the same metric for an alternate mode. Further, inter-mode comparisons will be significantly easier if metrics can be expressed in common units, such as dollars or time, or in dimensionless indices.

The purpose of this discussion of intermodal transportation metrics is to formulate an inclusive list of measures, some or all of which will prove useful to transportation planners in evaluating future transportation investments. Thus the metrics should function in a forecasting mode rather than a hindcasting mode. They should also be usable as a subset of metrics, if for example, a private sector planner prefers to consider only corporate economic benefits instead of overall public economic benefit.

System Metrics

A companion study to this one, funded by the National Center for Intermodal Transportation, developed proposed mode-independent performance metrics and recommended[6] those in Table 4.1. They are expressed or weighted by the ton-miles product for cargo and person-miles product for passengers, with the distance expressed as the “miles required” which is the geographic distance between origin and destination rather than the miles traveled. Thus the measures are weighted by ton-miles required (TMR) or person-miles required (PMR), but some are not expressed with units of “per ton-mile”, as discussed further below.

The proposed performance measures of Table 4.1 represent a bold attempt to forge new metrics that apply to all transportation modes. Their application presents some challenges, as will any significant revision of metrics. For example, they employ some parameters that are not routinely available. One such parameter occurs in the measure “Air emissions per ton-mile required” under Category 3, Environmental Impact. Average emissions per ton-mile <u>traveled</u> and estimated total emissions for a given geographic area are available for past periods from the EPA.[19] Either may be approximately converted to emissions per TMR in hindcasting mode using available data, but the miles required must be derived from origin-destination data, which are not always available. Further, comparing emissions for future alternative transportation networks will require the use of emissions for ton-miles traveled in order to identify those plans that provide the most benefit at least environmental cost. For example, to a manufacturer shipping products, the actual path traveled from origin to destination isn’t usually a significant concern as long as the time is minimized; however, to a state transportation planner the traveled path may be important because of habitat impacts or other reasons. Thus the twelve metrics of Table 4.1, while useful in many contexts, do not include all the considerations that affect selection of an optimum intermodal transportation plan.

Table 4.1 Performance Measures Proposed by Jin et al.[6]

Category	Performance Measures	Definition of the Performance Measures
1. Mobility and Reliability	Average travel time per mile	$M = \dfrac{\sum_{(i,j,n)\in N} p_{i,j,n} T_{i,j,n}}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$
	Coefficient of variance of travel time	$R = \sqrt{\dfrac{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j} \left(\dfrac{T_{i,j,n}}{l_{i,j}} - M\right)^2}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j} - 1}} \Big/ M$
	Coefficient of unpredictable variance of travel time	$R_u = \sqrt{\dfrac{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j} \left(\dfrac{T_{i,j,n} - f_{i,j,n}}{l_{i,j}}\right)^2}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j} - 1}} \Big/ M$
2. Safety	Fatalities per *TMR (PMR)*	$S_F = \dfrac{\sum_{(i,j,n)\in N} F_{i,j,n}}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$
	Number of injuries per *TMR (PMR)*	$S_I = \dfrac{\sum_{(i,j,n)\in N} I_{i,j,n}}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$
	Property damage cost per *TMR (PMR)*	$S_P = \dfrac{\sum_{(i,j,n)\in N} D_{i,j,n}}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$

(continued)

Table 4.1 Performance Measures Proposed by Jin et al.[6] (concluded)

Category	Performance Measures	Definition of the Performance Measures
3. Environmental Impact	Tons of mobile emissions from on-road motor vehicles per *TMR (PMR)*	$P = \dfrac{\sum_{(i,j,n)\in N} po_{i,j,n}}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$
	Percent of people affected by noise produced by vehicles per *TMR (PMR)*	$L = \dfrac{P_a}{P_T}$
4. Long Term Transportation Cost Efficiency	Vehicle operation cost per *TMR (PMR)*	$VC = \dfrac{\sum_{(i,j,n)\in N} (GC_{i,j,n} + VI_{i,j,n} + VM_{i,j,n} + VA_{i,j,n} + VO_{i,j,n})}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$
	Cost of transportation facility per *TMR (PMR)*	$FC = \dfrac{ATC}{\sum_{(i,j,n)\in AN} p_{i,j,n} l_{i,j}}$
5. Economic Growth and Employment Improvement	Economic growth approximation resulted from construction of transportation infrastructures	$EG = \dfrac{TEG}{TI}$
	Number of job opportunities created by transportation system per 1 million dollar investment	$J = \dfrac{TJ}{TI}$

Notation used in Table 4.1 and units for each parameter are:

ATC – Annual equivalent total cost in present dollars of construction and maintenance (dollars)

AN – number of trips per year

C – design carrying capacity of a transportation link (variable units, but same as *V*)

$D_{i,j,n}$ – Property damage cost caused by accidents in trip (i,j,n) (dollars)

EG – Economic growth index denoting total economic growth per dollar of investment (percent per dollar)

FC – Facility cost per operation cost *TMR* or *PMR* (dollars per ton mile required or dollars per passenger mile required)

$F_{i,j,n}$ – Fatalities for specific trip *n* between each origin and destination

$f_{i,j,n}$ – Expected travel time for a specific trip *n* between origin and destination pair *i* and *j* (hours)

GC_p – Fuel consumption cost involved in trip (i,j,n) (dollars)

i – trip index denoting origin

$I_{i,j,n}$ – Number of injuries for a specific trip *n* between each origin and destination

j – Trip index denoting destination

J – Job improvement index denoting number of job-years created by transportation per dollar of investment

k – Index corresponding to a link in a transportation network

K – Number of links traveled in a trip between origin and destination

L – Community livability index denoting the percent of people affected by transportation system

L^* – Traffic Load (no units) as given by $L^* = f^*(V/C)$ where $f^*()$ is a function to obtain the traffic load based on *V/C* ratio (volume over capacity ratio) which may be determined either by observation or by simulation.

$l_{i,j}$ – Geographic distance between origin and destination (miles)
M – Mobility (hours per mile)
n – Index denoting a particular trip
N – The set of all trips
P – Pollutants index denoting tons of mobile source emissions per *TMR* or *PMR*
P_a – Number of people that are negatively affected by transportation systems
PMR – Passenger-miles required which is the multiplication of $p_{i,j,n}$ and $l_{i,j}$
P_t – Total number of people using the transportation system
$PO_{i,j,n}$ – Tons of mobile pollutants involved in trip *(i,j,n)* (tons)
$p_{i,j,n}$ – Number of tons or passengers involved in trip *i,j,n*, where *i* is the origin, *j* is the destination, and *n* is the index of the trip with the same origin and destination
R – Reliability (no units)
R_u – Reliability due to unexpected travel delay (no units)
S_F – Fatality rate denoting the number of fatalities per *TMR* or *PMR*
S_I – Injury rate denoting the number of injuries per *TMR* or *PMR*
S_p – Property damage cost caused by accidents in trip *(i,j,n)* (dollars)
TEG – Total economic growth
TI – Total investment (dollars)
TJ – Total created job years due to the transportation system
TMR– Ton-Miles Required which is the multiplication of $p_{i,j,n}$ and $l_{i,j}$
$T_{i,j,n}$ – Total travel time (hours) between each origin and destination for a specific trip *n* as given by $T_{i,j,n} = \sum_{k=1}^{K_{i,j,n}} T_k(L^*)$
T_k – The traveling time on link *k* for the n^{th} trip between each origin and destination (hours)
V – Volume of traffic on a transportation link (variable units, but same as *C*)
$VA_{i,j,n}$ – Vehicle aging cost involved in trip *(i,j,n)* (dollars)
VC – Vehicle operation cost per *TMR* or *PMR* (dollars per ton mile required or dollars per passenger mile required)
$VI_{i,j,n}$ – Vehicle insurance cost involved in trip *(i,j,n)* (dollars)
$VM_{i,j,n}$ – Vehicle maintenance cost involved in trip *(i,j,n)* (dollars)
$VO_{i,j,n}$ – Other vehicle operation cost involved in trip *(i,j,n)* (dollars)

The following modifications to the metrics of Table 4.1 are proposed. Revised metrics are listed in Table 4.2.

The environmental quality impacts of metric Category 3 are obtainable as discussed above, but other environmental impacts must be considered in evaluating alternative plans. Airports, highways, railways, and constructed waterways all have the potential to affect water quality and habitat. For example, highways contribute nonpoint sources of water pollution from engine leaks and minor spills, de-icing materials, tire wear, and breakdown of the roadway surface.[20] Paving of any kind decreases pervious surface area and increases rainfall runoff, and earthwork alters drainage patterns, which can cause increased sediment loading to streams and loss of wetlands.

Accounting for separate air and water pollution contributions has been added to the metrics as shown in Table 4.2, where *pa* is tons of air pollutants released in the trip (or link) and *pw* is tons of liquid and solid pollutants released.

Any large constructed project, including transportation facilities, may fragment habitat and impact wildlife ecology, either negatively or positively.[4] Each transportation mode impacts these aspects of the environment differently, and their costs must be considered in a comprehensive evaluation of alternate modes. Habitat destruction can be easily defined as the footprint area of the project in some cases, as in paved roads, but others are more difficult to quantify. For example, should the unpaved right-of-way on a highway count as destroyed habitat or as modified? A dredged waterway channel replaces shallow habitat with deeper habitat, but it's not obvious how to classify the change. Habitat fragmentation is even more difficult an issue, but it is recognized that two separate parcels of habitat are usually inferior to one parcel with area equal to the sum of the two. There are numerous metrics for habitat fragmentation, such as mean patch size and edge density (related to the length of the edge, a fractal problem) but they appear to be scale-dependent and species dependent.[21,22] For purposes of this report, two metrics, A_r for habitat area destroyed, and A_f, for habitat area fragmentation, are used as placeholders, to be replaced by more specific metrics in subsequent efforts. A trial expression is given in Table 4.2, Equation 4.9.

The environmental effects of noise from transportation is typically expressed in the U.S. by the Total Day-Night Sound Exposure, or DNL, metric, which is the sum of daytime (0700-2200 hours) sound and a multiple of the nighttime (2200-0700 hours) sound. As a descriptor of total environmental effect it is limited, usually related to thresholds of human annoyance rather than overall environmental impact; however, it is adopted in a modified form here until a better descriptor is defined. The European Union is considering a slightly modified form that separates daytime noise levels into daylight and evening hours,[23] but we recommend the standard U.S. version for now. The interim metric is given in Table 4.2, Equation 4.10, and employs standard measures of long-term average noise level in decibels for the daytime, *LD*, and nighttime, *LN.*

Cultural impacts are even more difficult to quantify, given that they tend to be values-based and there are few societal common denominators on the values. Cemeteries are commonly moved to accommodate construction projects, but historical buildings and neighborhoods are seldom movable. Federal law protects historically significant shipwrecks, and navigation projects are aligned to avoid them, but assigning numerical values to historical artifacts has not been attempted. We have chosen to neglect cultural impact metrics for the present.

The long term cost efficiency of Table 4.1 is based on the direct cost of a transportation system rather than a comprehensive model, which includes the external impact on the environment or the influence on community livability. The measures of Table 4.1 can be used to estimate costs for transportation movements and handling of intermodal shipments of cargo if the variables for fuel consumption, insurance, etc. include costs of the specialized equipment and facilities needed at intermodal terminals. Berwick[24] describes the supporting equipment that is generally needed

[4] As an example of the latter, stone dikes used to train currents in waterways are considered to have positive habitat effects since they provide niches at a variety of scales ranging from the spaces between stones to the scour holes that develop at the structure's tip.

for an intermodal facility. Thus, the costs per TMR (VC) in Table 4.1 are considered to include the costs of the links (highways, railways, etc.) and the costs of the nodes (ports and transfer terminals).

The remaining metrics are expressed in the same form as given Table 4.1, except that the economic metrics are inverted. In Chapter 6 the metrics are used to calculate an overall system efficiency, and in that use it is convenient to have the same goal for all of them – to either minimize or maximize the metrics. The preceding metrics indicate a better outcome if they are smaller, so metrics 5a and 5b in Table 4.1, in which large values are more desirable than smaller values, are inverted to make them consistent with the others.

The revised metrics are all presented for completeness in Table 4.2.

Identification of useful metrics is only a first step in the process of effectively measuring transportation. Useful metrics must employ parameters that can be both practically measured and predicted, and a final judgment on their usefulness can only be determined by applying them and carefully assessing the results.[6,23] For purposes of this report, in which an evaluation framework is proposed, we have not limited parameter selection to those that are already measured, since progress in this area probably requires changing what we measure. However, we have attempted to include only parameters which can be measured or predicted, even if they are not commonly available at present.

Terminal Metrics

The metrics of Table 4.2 are intended for application to a system, including both links (highways, waterways, etc) and nodes or terminals (ports, transfer stations, etc.). They are also applicable to individual links in the system, if the "miles" part of the metric is given as the length of the link instead of distance between origin and destination. However, if they are to be applied to nodes, which have minor length compared with links, the distance terms in the expressions are no longer useful, and can be dropped. For example, Equation 4.1, mobility, can be expressed as shown by Equation 4.15 in Table 4.3, where and M becomes M_t, the weighted (by tons or persons) mean transfer time through the node. Node-based versions of each metric are given in Table 4.3. All that are expressed in terms of ton-miles (or person-miles) in Table 4.2 become expressed in terms of tons (or persons) in Table 4.3. The economic measures remain the same, since they were not weighted by miles.

Table 4.2 Proposed Performance Measures for System and Links

Category	Performance Measure	Performance Measure Expression*	Equation
1. Mobility and Reliability	a. Weighted average travel time per mile	$M = \dfrac{\sum_{(i,j,n)\in N} p_{i,j,n} \sum_{k=1}^{K_{i,j,n}} T_k\left(L^*\right)}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$	4.1
	b. Coefficient of variance of weighted travel time	$R = \sqrt{\dfrac{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j} \left(\dfrac{\sum_{k=1}^{K_{i,j,n}} T_k\left(L^*\right)}{l_{i,j}} - M\right)^2}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j} - 1}} \Bigg/ M$	4.2
	c. Coefficient of unpredictable variance of weighted travel time	$R_u = \sqrt{\dfrac{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j} \left(\dfrac{\sum_{k=1}^{K_{i,j,n}} T_k\left(L^*\right) - f_{i,j,n}}{l_{i,j}}\right)^2}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j} - 1}} \Bigg/ M$	4.3
2. Safety	a. Fatalities per TMR (PMR)	$S_F = \dfrac{\sum_{(i,j,n)\in N} F_{i,j,n}\left(L^*\right)}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$	4.4
	b. Number of injuries per TMR (PMR)	$S_I = \dfrac{\sum_{(i,j,n)\in N} I_{i,j,n}\left(L^*\right)}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$	4.5
	c. Property damage cost per TMR (PMR)	$S_P = \dfrac{\sum_{(i,j,n)\in N} D_{i,j,n}\left(L^*\right)}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$	4.6

Table 4.2 Proposed Performance Measures for System and Links (concluded)

Category	Performance Measure	Performance Measure Expression*	Equation
3. Environment	a. Air Quality Impacts per TMR (PMR)	$E_a = \frac{\sum_{(i,j,n)\in N} pa_{i,j,n}\left(L^*\right)}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$	4.7
	b. Land and water Impacts per TMR (PMR)	$E_w = \frac{\sum_{(i,j,n)\in N} pw_{i,j,n}\left(L^*\right)}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$	4.8
	c. Habitat Impacts per TMR (PMR)	$E_h = \frac{A_r + A_f}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$	4.9
	d. Noise Impact per TMR (PMR)	$E_n = \frac{log\left(\frac{15}{24}10^{LD/10} + \frac{9}{24}10^{(LN+10)/10}\right)}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$	4.10
4. Cost Efficiency	a. Vehicle operation cost per TMR (PMR)	$VC = \frac{\sum_{(i,j,n)\in N}\left(GC_{i,j,n} + VI_{i,j,n} + VM_{i,j,n} + VA_{i,j,n}\right)}{\sum_{(i,j,n)\in N} p_{i,j,n} l_{i,j}}$	4.11
	b. Transportation facility cost per TMR (PMR)	$FC = \frac{ATC}{\sum_{(i,j,n)\in AN} p_{i,j,n} l_{i,j}}$	4.12
5. Economic Growth	a. Construction cost per unit of economic growth	$EG' = \frac{TI}{TEG}$	4.13
	b. Investment per job created	$J' = \frac{TI}{TJ}$	4.14

* variables as defined above and in Notation section.

Table 4.3 Selected Performance Measures for Nodes

Category	Performance Measure	Performance Measure Expression*	Equation
1. Mobility and Reliability	a. Weighted average transit time	$M_t = \dfrac{\sum_{(i,j,n)\in N} p_{i,i,n} \sum_{k=1}^{K_{i,i,n}} T_k\left(L^*\right)}{\sum_{(i,i,n)\in N} p_{i,i,n}}$	4.15
	b. Coefficient of variance of weighted transit time	$R_t = \sqrt{\dfrac{\sum_{(i,i,n)\in N} p_{i,i,n}\left(T_{i,i,n}\left(L^*\right)-M_t\right)^2}{\sum_{(i,i,n)\in N} p_{i,i,n}-1}} \Big/ M_t$	4.16
	c. Coefficient of unpredictable variance of weighted transit time	$R_{ut} = \sqrt{\dfrac{\sum_{(i,i,n)\in N} p_{i,i,n}\left(T_{i,i,n}\left(L^*\right)-f_{i,i,n}\right)^2}{\sum_{(i,i,n)\in N} p_{i,i,n}-1}} \Big/ M_t$	4.17
2. Safety	a. Fatalities per ton (person)	$S_{Ft} = \dfrac{\sum_{(i,i,n)\in N} F_{i,i,n}\left(L^*\right)}{\sum_{(i,i,n)\in N} p_{i,i,n}}$	4.18
	b. Number of injuries per ton (person)	$S_{It} = \dfrac{\sum_{(i,i,n)\in N} I_{i,i,n}\left(L^*\right)}{\sum_{(i,i,n)\in N} p_{i,i,n}}$	4.19
	c. Property damage cost per ton (person)	$S_{Pt} = \dfrac{\sum_{(i,i,n)\in N} D_{i,i,n}\left(L^*\right)}{\sum_{(i,i,n)\in N} p_{i,i,n}}$	4.20

(continued)

Table 4.3 Selected Performance Measures for Nodes (concluded)

Category	Performance Measure	Performance Measure Expression*	Equation
3. Environment	a. Air quality impacts per ton (person)	$E_{at} = \dfrac{\sum_{(i,i,n)\in N} pa_{i,i,n}\left(L^*\right)}{\sum_{(i,i,n)\in N} p_{i,i,n}}$	4.21
	b. Land and water impacts per ton (person)	$E_{wt} = \dfrac{\sum_{(i,i,n)\in N} pw_{i,i,n}\left(L^*\right)}{\sum_{(i,i,n)\in N} p_{i,i,n}}$	4.22
	c. Habitat impacts per ton (person)	$E_{ht} = \dfrac{A_r + A_f}{\sum_{(i,i,n)\in N} p_{i,i,n}}$	4.23
	d. Noise impact per ton (person)	$E_n = \dfrac{log\left(\frac{15}{24}10^{LD/10} + \frac{9}{24}10^{(LN+10)/10}\right)}{\sum_{(i,i,n)\in N} p_{i,i,n}}$	4.24
4. Cost Efficiency	a. Equipment operation cost per ton (person)	$VC_t = \dfrac{\sum_{(i,i,n)\in N}\left(GC_{i,i,n} + VI_{i,i,n} + VM_{i,i,n} + VA_{i,i,n}\right)}{\sum_{(i,i,n)\in N} p_{i,i,n}}$	4.25
	b. Transportation facility cost per ton (person)	$FC_t = \dfrac{ATC}{\sum_{(i,i,n)\in AN} p_{i,i,n}}$	4.26
5. Economic Growth	Aa Construction cost per unit of economic growth	$EG' = \dfrac{TI}{TEG}$	4.13
	b. Investment per job created	$J' = \dfrac{TI}{TJ}$	4.14

* variables as defined in Notation section.

5. TRANSPORTATION SIMULATION

The manner in which people and freight move through a transportation network is influenced by many interdependencies. Changes to one part of the network, such as adding a lane to a state highway or increasing the capacity of a port, can generate unanticipated consequences in another part of the network. Many seemingly random events also produce significant variation in the performance of the transportation system from one day to the next. Simulation provides a means to model interdependences and variation. The *Oxford American Dictionary* defines simulation as a way "to reproduce the conditions of a situation, as by means of a model, for study or testing or training, etc." Transportation simulation models are computer programs designed to mimic the behavior of an actual or proposed system.

The key to sound transportation planning is the ability to accurately predict the outcomes of alternative system designs. Simulation gives transportation planners this ability. By using a computer to model a system before it is built or to test operation policies before they are implemented, many of the pitfalls that are often encountered in the start-up of a new system or the modification of an existing system can be avoided.[25]

Virtual Intermodal Transportation System – VITS

While many transportation planning, modeling and simulation packages can help evaluate a transportation network and the related infrastructures, there are often deficiencies in most of these tools when it comes to region-wide intermodal freight transportation planning. Many transportation analysis packages lack the capability to effectively analyze means of transportation other than highway systems. In other cases, they are focusing only on particular highway corridors and/or arterials for a localized study. In most cases, either the network information for waterways and railways are not readily available, or the software simply does not handle these modes or do mode transfers. This limits the ability for a comprehensive region-wide freight transportation analysis with consideration for intermodalism.

There are numerous research reports on port simulations, highways simulation models, intermodal terminal issues, traffic flow, transportation performance measures, commodity flow studies and trip generation, and also vehicle routing models. What is lacking is a concerted effort to combine the research results into the building of a region-wide intermodal freight transportation simulation model. In a previous research project, the National Center for Intermodal Transportation developed a modeling methodology for building simulation models for a statewide intermodal freight transportation network. The technology is called the Virtual Intermodal Transportation Simulation (VITS) and was used to develop a prototype simulator of the Mississippi statewide freight system.[5] The VITS simulates the movements of trucks, trains, barges, and ships on the transportation network as well as the transference of freight between the different modes. Figure 5.1 shows an example screenshot of the prototype VITS's animation graphic, and Figure 5.2 illustrates the major components of the VITS.

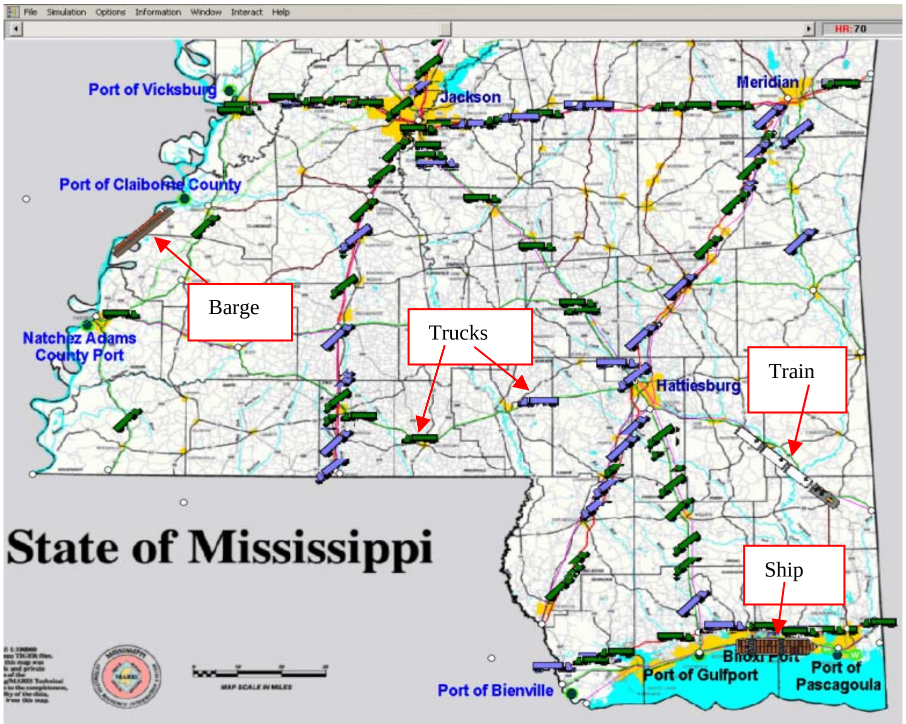

Figure 5.1 Animation Screenshot of the Prototype VITS Showing the Movements of Barges, Trucks, Trains, and Ships over the Mississippi Transportation Network.

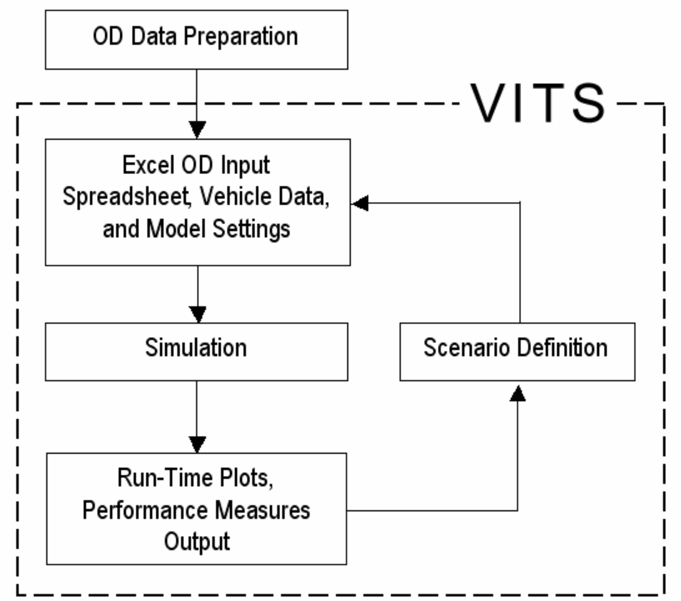

Figure 5.2 Flowchart of the Components in the VITS.

Intermodal System Simulation

System Characteristics

A system simulation of a transportation network of links (airways, highways, railways, and waterways) and nodes (airports, transfer stations, terminals, and ports) requires that each link and node be characterized in a similar fashion. Because of their different histories, each mode has developed its own terms and measures. For this effort a list of link and node characteristics for each of the three freight transport modes was compiled, then melded into a single set of intermodal characteristics to the extent possible. Table 5-1 shows the list of link characteristics and how they are manifested in highway, railway, and waterway modes.

For nodes, ports and other intermodal transfer points, another set of characteristics is needed, as exemplified by the following:

- Identification
    - Node number
    - Name
    - Type
    - Ownership
    - Data source
- Capacity. For each cargo type and mode:
    - Present Capacity Measures.
        - Unloading rate
        - Loading rate
        - Yard handling rate
        - Direct transfer rate
        - Storage capacity
        - Connector types and constraints (e.g., max vessel size, number of vessels)
    - Planned Capacity. By date, expected capacity as listed above.
    - Limiting, or maximum practical capacity, as above.
- Connectors
    - List of links by mode and cargo category
    - Connecting link capacity and constraints
- Usage. For each cargo type and handling method (offload, store, load or direct transfer):
    - Present use
    - Projected use by date
- Costs
    - Node cost by cargo type to:
        - Unload
        - Load
        - Handle
        - Store
    - Node charges to shippers per category above

Table 5-1a. Link Characteristics Part 1: Classification

CLASSIFICATION	HIGHWAY	RAILWAY	WATERWAY
ID Number	ID Number	ID Number	ID Number
Link Number	Link Number	Link Number	Link Number
Name (Primary And Local)	Name	Name	Name
Number	Number	Number	Number
Owner	Owner	Owner	Owner
Classification		Class I, II, III	Shallow/Deep
Type	Arterial, Freeway	Major RR; Shortline/Regional RR	Federal/Private
Data Source	Data Source	Data Source	Data Source

Table 5-1a. Link Characteristics Part 2: Capacity

CAPACITY	HIGHWAY	RAILWAY	WATERWAY
Number of Lanes	Number of Lanes	Number of Rail Lines	Number of Lanes
Lane width	Lane width	NA	Channel width
1 or 2 way	1 or 2 way	NA	1 or 2 way
Median	Median	NA	NA
Surface	Type of surface	NA	NA
Shoulder width	Shoulder width	NA	NA
Length	Length	Length	Length
Signal control	Signal control	Signal control	NA
Nominal depth	NA	NA	Nominal depth
Control depth	NA	NA	Controlling depth
Control width	NA	NA	Controlling width
Avg. Water speed	NA	NA	Current speed
Topography of the terrain	Topography of the terrain	Topography of the terrain	NA
Avg. Speed per unit	Avg speed per truck	Avg speed per train	Avg speed per tow
L.O.S.	Level of Service	Level of Service	NA
Vertical clearance	Vc	Vc	Vc
Max units limit	Max no. of trailers	Max no. of rail cars	Max no. of barges
Avg size by cargo type and unit type	Avg size by cargo type and unit type	Avg size by cargo type and unit type	Avg size by cargo type and unit type
Number of units by type & ownership	No. of trucks by type & ownership	No. rail cars by type & ownership	No. tows by type & ownership

(continued)

Table 5-1a. Link Characteristics Part 2: Capacity (concluded)

CAPACITY	HIGHWAY	RAILWAY	WATERWAY
Shipment weight	Shipment weight	Shipment weight	Shipment weight
Shipment size	Shipment size	Shipment size	Shipment size
Shipment volume	Shipment volume	Shipment volume	Shipment volume
Number of bridges	Number of bridges	Number of bridges	Number of bridges
Number RR crossings	Number RR crossings	Number RR crossings	NA
Number of tunnels	Number of tunnels	Number of tunnels	NA
Carrying capacity of units	Carrying capacity of trucks	Carrying capacity of freight cars	Carrying capacity of barges
Carrying capacity of modes	Carrying capacity of roadways	Carrying capacity of rail lines	Carrying capacity of waterways
Power of units	Power of trucks	Power of locomotives	Power of tugs
Avg time in shipping yards	Avg time in shipping yards	Avg time in shipping yards	Avg time in ports
Interchange of freight and equip	Interchange of freight and equip	Interchange of freight and equip	Interchange of freight and equip
Utilization of units	Utilization of trailers	Utilization of cars	Utilization of barges
Distribution of units	Distribution of trailers	Distribution of cars	Distribution of barges

Table 5-1c. Link Characteristics Part 3: Usage

USAGE	HIGHWAY	RAILWAY	WATERWAY
Present usage by cargo type & direction	Present usage by cargo type & direction	Present usage by cargo type & direction	Present usage by cargo type & direction
Projected usage by date	Projected usage by date	Projected usage by date	Projected usage by date
Present usage by cargo type & unit type	Present usage by cargo type & unit type	Present usage by cargo type & unit type	Present usage by cargo type & unit type
Projected usage by cargo type and unit type	Projected usage by cargo type and unit type	Projected usage by cargo type and unit type	Projected usage by cargo type and unit type

Table 5-1d. Link Characteristics Part 4: Performance

PERFORMANCE FACTOR	HIGHWAY	RAILWAY	WATERWAY
Volume	Volume	Volume	Volume
Directional split	Directional split	Directional split	Directional split
Traffic composition	Traffic composition	Traffic composition	Traffic composition
% Passing allowed on 2 lane	% passing allowed on 2 lane	NA	% overtaking allowed on 2 lane
Hourly variation of traffic	Hourly variation of traffic	Hourly variation of traffic	Hourly variation of traffic
Daily variation of traffic	Daily variation of traffic	Daily variation of traffic	Daily variation of traffic
Travel time	Travel time	Travel time	Travel time
Delay time	Delay time	Delay time	Delay time
Link cost	Link cost	Link cost	Link cost
Shipper charge	Shipper charge	Shipper charge	Shipper charge
Energy consumption by unit cargo	Energy consumption by unit cargo	Energy consumption by unit cargo	Energy consumption by unit cargo
Water quality cost by unit cargo	Water quality cost by unit cargo	Intermodal and/or cost by unit cargo	Water quality cost by unit cargo
Employee compensation of mode crews	Employee compensation of mode crews	Employee compensation of mode crews	Employee compensation of mode crews
Fuel cost	Fuel cost	Fuel cost	Fuel cost
Costs of insurance due to loss, damage, injuries…	Costs of insurance due to loss, damage, injuries…	Costs of insurance due to loss, damage, injuries…	Costs of insurance due to loss, damage, injuries…

Modeling Intermodal Transfer Stations

A critical component within an Intermodal System Simulation is the modeling of intermodal transfer stations, which include waterway ports. Storing containers, allocating resources in the terminal, and scheduling vessel loading and unloading operations must be addressed in an intermodal container terminal simulation. One solution[26] defined an architecture composed of three strictly connected modules: a simulation model of the terminal, a set of forecasting models to analyze historical data and to predict future events, and a planning system to optimize loading and unloading operations, resource allocation, and container locations on the yard. The focus was on resource allocation problems where the authors described the modules for the optimization of the allocation process and for the simulation of the terminal. The Italian Contship La Spezia Container Terminal was used as a case study. Results from the case study simulation model showed that models developed for the analysis can provide another decision support tool which the authors deemed fundamental to improve terminal management: a job-shop algorithm which could generate the import and export stowage plans for each and train entering and leaving the terminal which would have to be coupled with a shorter-term reactive job-shop module which could manage the work sequences on each crane in the terminal.

The U.S. Department of Transportation Maritime Administration (MARAD) developed six modules that draw from average throughput of a small sample of U.S. ports. In the LATTS study[1] estimates of investment needs for the port systems were done in part using "Idealized Terminal Modules" that included Container, Neo-Bulk[1], Break-Bulk, Dry-Bulk, and Liquid-Bulk Facilities. The Louisiana Statewide Intermodal Study presented the "Stock and Flow" methodology to calculating capacities.[27] Prianka Seneviratne of Utah State University found that traditional rules-of-thumb and most commercially available software tools do not lend themselves to analyze problems related to intermodal transportation terminals.[28] He pointed out also that compared to highway and arterial simulation models, intermodal terminal simulation tools are few. He presented a microscopic level simulation tool called Access Traffic Simulation Model (ACTSIM) that was developed to evaluate alternative internal road layouts and traffic management strategies under variable demand conditions and different service area configurations for airport passenger terminals.

The MARAD port modules are basically templates (of different terminal types) that draw from the average capacities as sampled from actual throughput as reported by a small population of U.S. ports.[26] This information would be too aggregated to be applied to any particular statewide intermodal planning effort. The "Stock and Flow" methodology on the other hand, breaks down the terminal into more detailed components to better match the port of interest, although it assumes that the terminal components are independent of each other. This is to simplify the calculation of capacities using algebraic equations. The slowest component, being the bottleneck, therefore determines the capacity of the entire terminal. The LATTS study on the other hand, uses a collection of terminal features (such as the acreage, number of berths and berthing factors, types of cargo, etc.) to determine the capacities based on reference to industry standards.

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[1] Neo-bulk is a term that has come into usage at some ports, indicating a vessel and its cargo when a single type of break-bulk cargo, such as lumber, is carried. The term does not seem to be a useful addition to port vocabulary, since "break-bulk" adequately covers the category.

These estimates and averaged figures do not provide any information on the fluctuations that occur during the actual operation of the terminals. It is important to understand that capacity issues are highly influenced by interactions between terminal components, as well as subjected to random variations. Interactions occur when the operation of one component affects the performance of other component(s). Thus, the accuracy of the capacity estimates can be further improved using a port model that is integrated within an Intermodal System Simulation.

Hopp and Spearman[29] define variability as “the quality of nonuniformity of a class of entities” and states, in the context of a manufacturing environment that “variability impacts the way material flows through the system and how much capacity can be actually utilized”. This statement can also be applied towards terminals and ports as well. A simulation’s forte in this aspect is having the ability to consider the effects of interactions and variability in the analysis. For example, the throughput at the storage area is influenced by the throughput of the unloading process at the unloading area, due to the fact that arrivals of offloaded cargo to the storage area is a directly dependant on the throughput of the unloading area.

The flow diagram in Figure 5.3 illustrates the components and processes of a port model as an example of the implementation for an intermodal transfer station. The three-dimensional boxes represent locations within the simulation model and the diamond-shaped boxes represent logic/decision making process. They are:

- Location for Arriving Vessels – location where waterborne vessels arrive before being directed to the appropriate berth at the port. The type of cargo (container, break-bulk, etc.) and the priority of the shipment will be determined here.
- Queue Locations for Different Terminal Types – waiting areas. There are different queues corresponding to the different cargo terminal types. Ships will wait at the queue location until a berth that handles its cargo type is available.
- Berth Locations – locations in the port that the vessels are either loaded or unloaded. The logic at these locations will discern whether the particular vessel is to be loaded or unloaded. The subroutine will also update variables that keep track of available storage and the amount of cargo (in tons) currently stored.
- Rail Processing Location – location where the trains arrive and have the railcars either loaded or unloaded.
- Truck Waiting Location – location where the incoming trucks wait if the access gate is closed. This location simulates the trucks waiting in the proximity of the port (not necessarily a single physical location). A wait instruction is implemented at this location to have the trucks wait until the gate is open.
- Port Access Gate for Trucks – location where trucks stop and undergo a check-in or check-out procedure before being let in or out of the port. The capacity of this location represents the number of parallel processing lanes going through the gate.
- Truck Processing Location – location where trucks undergo the loading or unloading process.

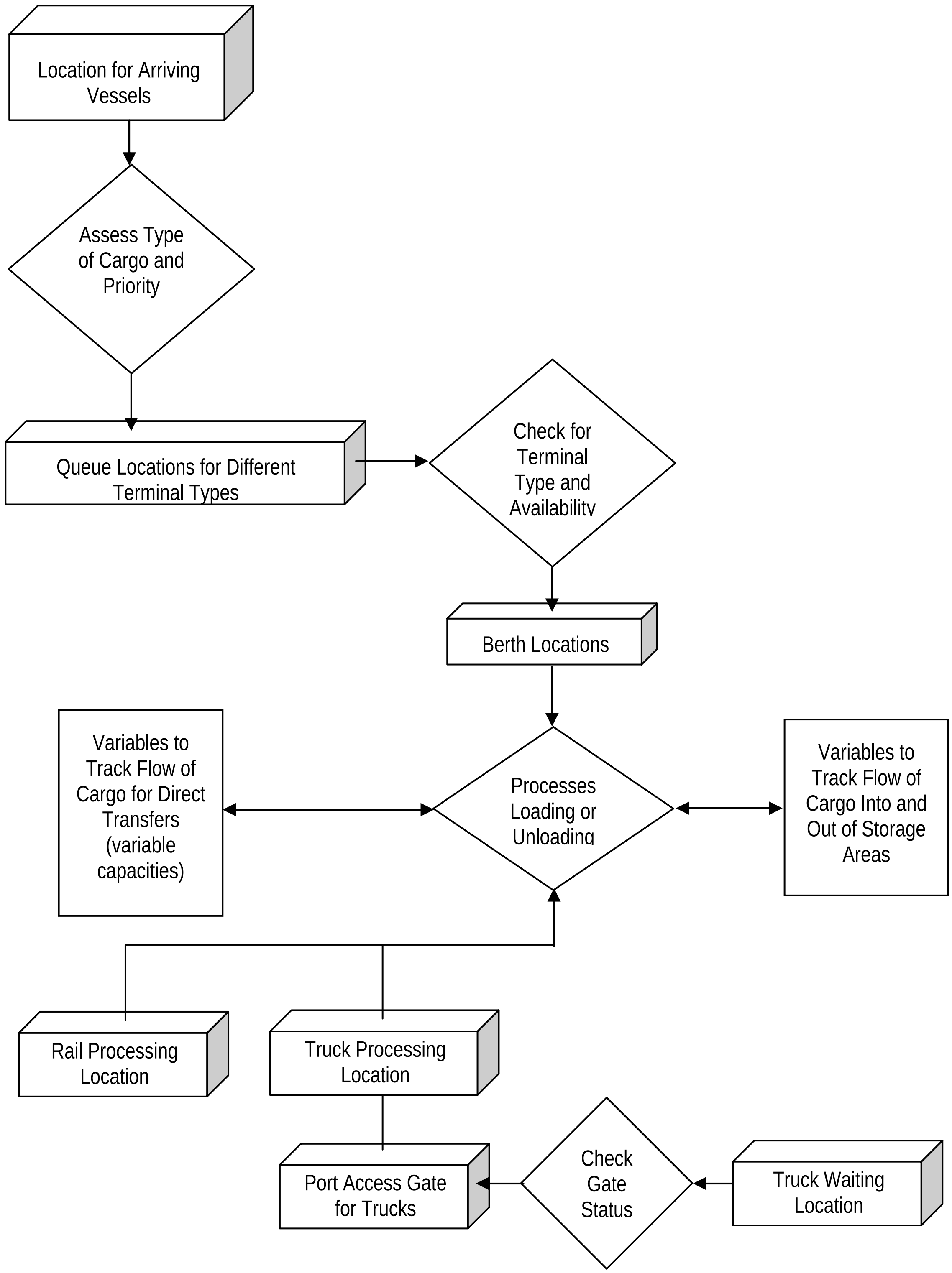

Figure 5.3: Example of a Flow Diagram for a Port Model

This simulation model does not include the possibility of ship to barge or barge to ship transfers, since the example port used does not have that type of operation at present; however, the logic will function essentially the same as that for truck transfers.

Tan integrated a port model in the VITS prototype for demonstration of its utility[30]. The study shows how a terminal model can be included in the framework of an Intermodal System Simulation, using the Port of Gulfport, Mississippi as an example.

In general, the primary functions or processes that occur at the terminals should be written as subroutines. The aim is to establish a modular implementation after the structure of the terminal operations has been determined. This allows fine-tuning and improvements to the terminal models as additional data becomes available or other improvements are identified. They are several key issues to be identified and addressed when constructing terminal models.

Availability of data concerning terminal freight flow. From the higher-level transportation planning processes that provide region-wide freight flow data, reasonably accurate data for the terminal model(s) must be derived as well. Public domain raw data concerning terminal operations are often available and must be considered in the transportation planning process since the factors affecting terminal traffic volumes may be different from the factors considered in a region-wide freight data study.

Information concerning private terminals and resources. Freight data related to private terminals and resources are an important part of analyzing freight flow. Some information may be confidential and a methodology has to be developed to estimate these flows and usage.

Information on all terminal resources and the level of detail required. This relates to the handling of different cargo types and the appropriate level of detail to distinguish between processing of each type. Assumptions may be required when resources are shared. Data on the processing times should be available and is largely dependant on the level of detail. For example, processing times at a berth for a highly detailed terminal model may include the movement times and availability of the cranes and yard hustlers while a less detailed terminal model may aggregate these two processes as a single loading/unloading process.

Scheduling of resources and terminal operations. The terminal will have constraints from the scheduling of operations. What are the key resources involved and the scheduling of operations on each one? The model should be flexible enough to accommodate different hours of operation on each resource.

Compatibility of the data with a large scale VITS simulator. If data for the terminal model are derived independently, will it cause problems if the terminal is integrated with a VITS simulation? Will the terminal model's handling of freight flow conflict with the way the VITS simulation collects statistics for the performance measures? These issues require careful planning.

Ideally, the terminal model development should be concurrent with the development of a higher-level VITS type simulation model. There are studies done on terminal simulation model such as the one conducted by Meinert et. al.[31] that presented a unique discrete event, microscopic level simulation of railway terminal component. Whether it is feasible to integrate this model with the VITS model is questionable since it was developed independently and may have data structure that cannot be easily merged.

The flexibility of manipulating freight flow changes to these terminals independently of other terminal models in the system. The terminal model should have provisions for altering the freight flow to observe different scenarios of the terminal. In the case of an integrated terminal model (in the context of a VITS simulator with several integrated terminal models), the user should be able to alter the freight flow that is only specific to that particular terminal. This is useful if a particular terminal in the region is expected to handle most of the increases in freight due to its characteristics, policies, or infrastructure available.

The issue of simulation level of detail (e.g. entity resolution). Simulation detail should be given thorough consideration especially if data is difficult to obtain. In the case of integration with a VITS simulation, the interfacing of the models and the different resolutions of entities that may exist should be examined. It is always best to have more detailed implements programmed in the model for future use should more data become available.

Screenshots of the port model in Tan's study[30] using the state of Mississippi and the Port of Gulfport as an example are shown in Figure 5.1, the main VITS simulation display with the Port of Gulfport shown as a location, and Figure 5.4 goes one level down to display what is going on in the port model itself that has been integrated with the VITS. Figure 5.5 zooms out to show the main highways, railways, and waterways of Louisiana, Mississippi, and Alabama plus intermodal terminals, including inland and coastal ports and land transfer terminals.

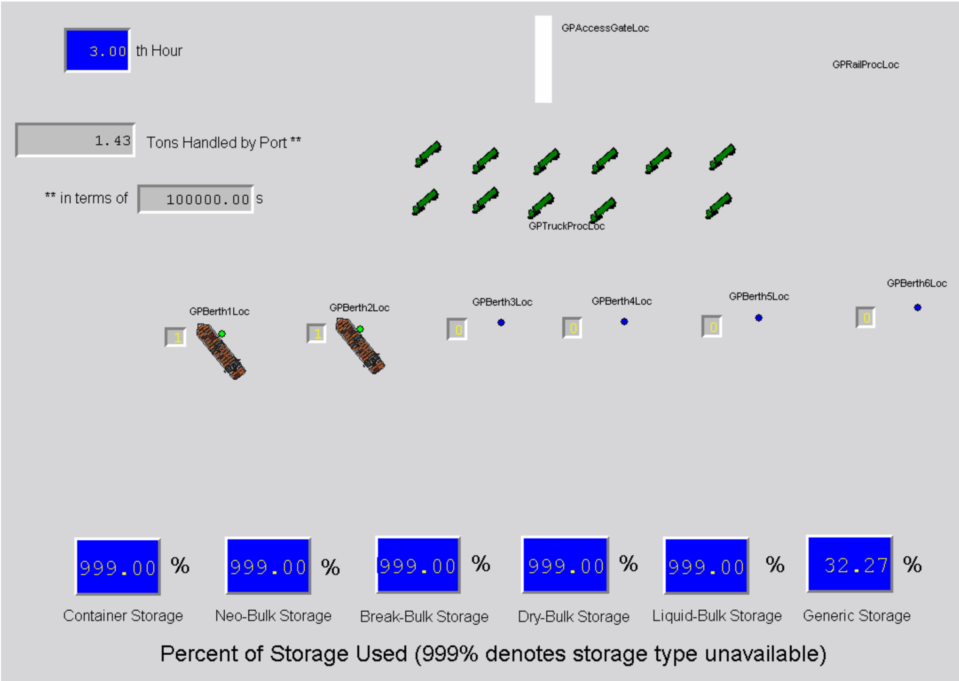

Figure 5.4 Screenshot of the Integrated Port Model Showing the Activity Indicators

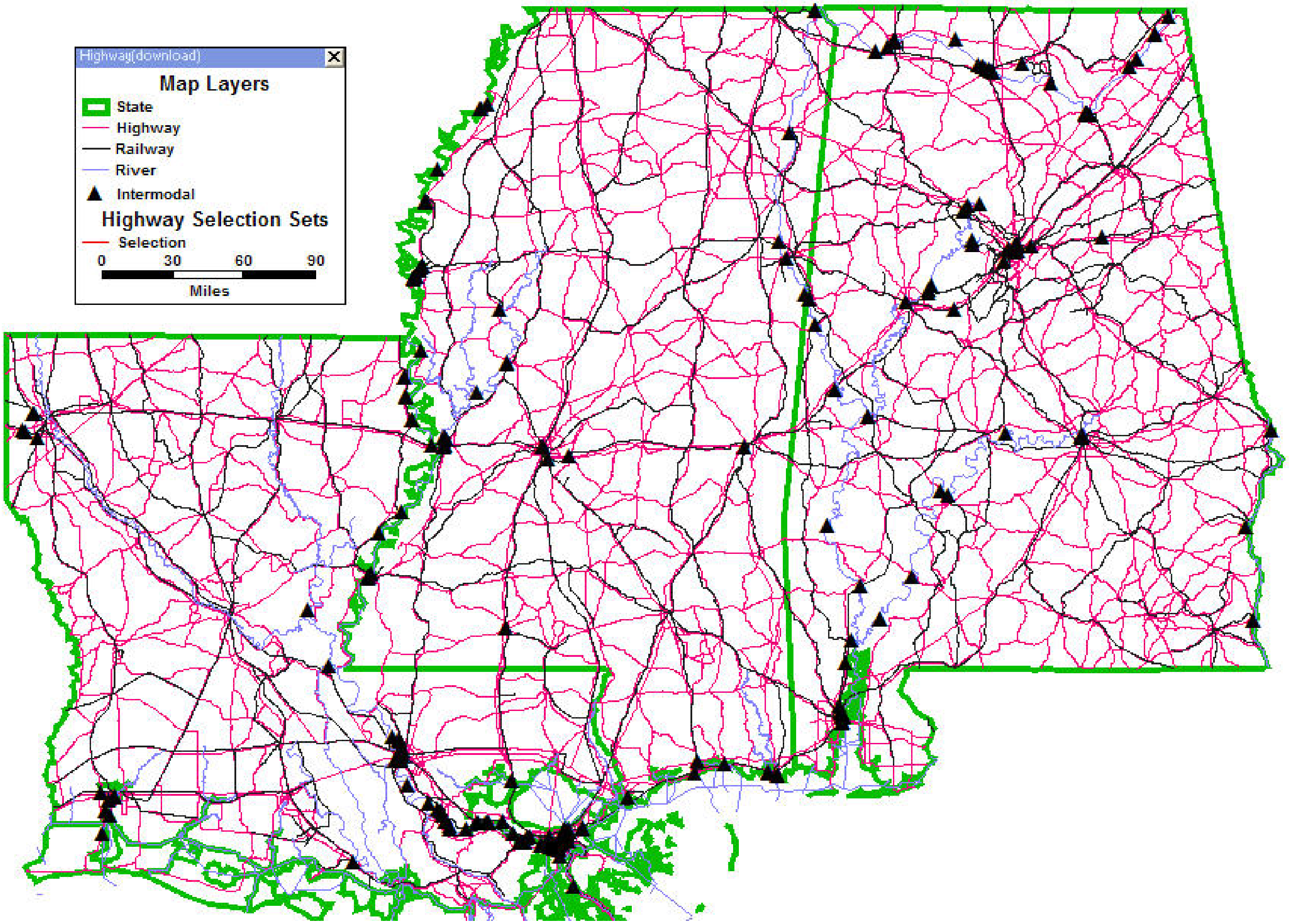

Figure 5.5. Louisiana, Mississippi, and Alabama with major highways, railways, and waterways plus intermodal terminals.

Waterway Simulation

Waterway links consist of open water channels, such as those in sea lanes, and channels constricted by width and depth. While sea lane capacity is not infinite, capacity is large in comparison with the capacity of ports to receive and process vessels. For simulation purposes, the sea lanes are considered unrestricted, i.e., they can accommodate whatever vessel traffic load is imposed.

Constricted channels require that vessels stay within marked channel limits to avoid grounding and collisions. Further, only vessels meeting channel-specific size restrictions may use a constricted channel. The size restrictions include:

- Draft (distance of deepest point on vessel below the waterline) less than or equal to the channel depth minus safe underkeel clearance.
- Beam (width of widest part of the vessel) less than lane clearance plus bank and vessel clearance safety allowances.

Thus, for example, an oil supertanker with 20 m draft cannot enter a general cargo port channel 15 m deep, and most general cargo vessels cannot travel on inland waterways, which are usually 3 to 4 m deep. Loaded vessels draw more water than unloaded vessels, so an empty or partially loaded ("light loaded") vessel may transit a waterway that would be closed to it if it were fully loaded. In tidal waters passage may be restricted to times of high water and in rivers passage may be limited when low flow periods occur.

Channels are designed for either one-way or two-way traffic of a specific design vessel, which must be accounted for in the simulation.

Navigation locks raise/lower vessels from one level to another or transfer vessels from one water body to another that are kept separate for reasons of water quality (e.g. salinity) or sedimentation. Vessel transit times through locks can be on the order of 2 to 6 hours[1], depending on wind and flow conditions, lock type, equipment, and condition, and vessel type and size. As an example of the locking process, the upbound vessel locking sequence consists of the following steps:

1. Vessel approaches
2. Lower gates open
3. Vessel enters the lock
4. Lower gates close
5. Lock chamber fills to level of upper pool
6. Upper gates open
7. Vessel exits
8. Vessel departs

If the next vessel approaches from the upstream side, the 8-step sequence can be reversed to pass it to the lower pool. If the next vessel to be locked is moving in the same direction as the first, the upper gates must be closed and the lock chamber drained to the level of the lower pool before executing the sequence.

[1] Vessel delays can be much longer than these times if traffic is heavy and queuing is required.

Inland barge tows, consisting of one to several non-powered barges lashed together and pushed or pulled by a towing vessel can exceed the size capacity of a lock. If so, the two must be fleeted – broken up into lockable sizes on one side of the lock, locked through in stages, and reassembled on the other side. Fleeting significantly increases lockage time and effectively prevents most other traffic from using the lock until the fleeting operation is complete.

Single locks allow traffic only one-way at a time, passing one vessel through before allowing another to approach and enter. Sequential, or tandem, locks operate in series to move vessels through large changes in elevation. Parallel locks can pass vessels in both directions at once. U.S. locks operate on a priority system in which vessel classes have the following precedence:

1. U. S. military vessels
2. Non-military U. S. government vessels
3. Commercial passenger vessels
4. Commercial cargo vessels
5. Recreational vessels

Within each class the locks are operated in a first-in, first-first out system.

Depending on the level of detail simulated, locks can either be simulated as independent links, passing traffic by the standard rules and steps above, or the average time associated with each lockage can be added to the total time required for a vessel to travel the waterway containing the lock(s). The latter option will not reflect slowdowns caused by congestion at locks.

Ting and Schonfeld have calculated delays and associated costs at locks caused by congestion and devised methods for scheduling tows through a system of locks using traffic speed control and shortest-processing-time or lock-chamber-packing rules at locks.[32] The algorithms they used might be embedded in a waterway simulation to calculate the time and cost of lockages under various scenarios. Alternatively, the port simulation described above could be adopted to simulate the locking process directly, so that random variables in the procedure could be more realistically captured.

Recent simulation modeling of waterways in the U.S. has mostly focused on experiential simulations useful for pilot training and channel design, and not on simulation of throughput. IN such simulation a single ship is simulated, with visual output similar to that experienced by a vessel pilot. While navigation simulation in this mode has become quite sophisticated, it does not apply to the intermodal planning process of concern here. Some small-scale simulation efforts have been pursued in the U.S., and limited proprietary work has been done in The Netherlands to simulate traffic around locks, but neither is sufficient to warrant further consideration here.

Rail Simulation

The intermodal combination of rail with other modes, especially rail with truckload trucking operation, offers advantages in terms of utilizing rail infrastructures and provides savings over trucking for long moves. Researchers in the past have addressed many aspects of rail-trucking intermodal operations, with most of the work done in the area of terminal analysis and simulation. Several research efforts in the area of network-wide rail simulation were also conducted.

A research conducted by Meinert et al. concentrated their effort on the simulation of the rail component of the intermodal transportation.[31] The authors used a discrete event simulation approach to analyze strategic issues including railhead location analysis in multi-facility settings and product mix analysis (container versus trailer) by railhead within rail network. The research model focuses on the effects of railhead location and mix on drayage efficiency relative to shipment density profiles provided by BNSF railway in the Chicago, IL area, and considered concurrently the multi-terminal network design and terminal activity such as hostling and train building. In addition to simulate railroad network capability, the simulation tools also have the capability of considering the truckload distribution network and intermodal rail facilities in an integrated way.

In recent years, MultiRail, a commercial planning and analysis tool for railroad operation, has become the system of choice among all of the North American Class I freight railroads[33]. MultiRail provides a fully integrated toolset to manage very complex problems of planning, designing and evaluating railroad operation strategies. It can be used as an evaluation tool for assessing impacts of operational changes in a freight rail plan. MultiRail has found applications from high-level strategic planning of railroad company to operational plan development and maintenance. MultiRail has schedule design tools that can compute the intermediate train locations and times. With a graphic network management system and a structured database, the package can capture and present information in train schedules, network and operation plan. Extensive analytical and simulation capabilities, such as computation and display of traffic volume over a railroad, along with its ability to generate system-wide statistics, such as estimates of car-miles, tonnage hauled, and yard throughput, as well as the capabilities to “route” traffic over a railroad network and auto-assign traffic to block, make MultiRail a comprehensive and easy to use railroad simulation and analysis tool.

6. OPTIMIZING INTERMODAL TRANSPORTATION

Optimization

In this chapter we examine a way to balance the competing needs of society in the planning process so that alternative mixes of intermodal transportation that best serve the public interest can be identified. This can be called optimization of alternatives; even though in the strictest sense optimization means that a given solution can be proved to be the best of all possible solutions. Proving any transportation solution best is essentially impossible, for there are too many possible definitions of "best" and too many possible alternatives to expect that any reasonable effort will evaluate all of them. The former obstacle occurs because there are so many points of view -- the best solution for shippers may not be the best solution for government or the individual. The latter occurs because there are may be hundreds of alternative transport paths for even a single origin and destination and millions for a nation. Finally, despite all efforts, there will be social and political aspects that defy our ability to quantify pros and cons. Therefore, the goal here is to outline a method that will find a set of good solutions, better than others we might otherwise select, that balance competing societal interests. We will call that process optimization.

Economic Optimization

Economic optimization can be seen as a process of choosing a good or service that has the best combination of quality and price. For different consumers, the optimal combination of quality and price depends on particular requirements and budget. Therefore, optimization involves the screening of variants or factors, eliminating the ones that do not fit into constraints, and keeping the ones that satisfy a goal, based on which one makes a decision. In fact, choosing the appropriate variants is the most important aspect of optimization, for which is necessary to gather needed information relevant to the particular decision one has to make.

The purpose of this section of the report is to provide information and data on studies that deal with the concept of economic optimization and performance measures. Economic optimization should always be understood to be with respect to the specifications and assumptions of an economic optimizing model. Thus different specifications, assumptions, or models yield different economic optimizing results. Economic optimizing models can be used to evaluate the feasibility of intermodal transportation and handling facilities and the economic impacts of intermodal facilities on an economy.

In this discussion, optimization is used as a method in the decision-making process using economic theory and mathematical models to achieve acceptable results, rather than decision-making based on experience only. However, in some cases, for example politics, political decisions are made in a complex environment with small amount of formal knowledge, where computerized economic/mathematical models can play only supportive role in the decision-making processes. The use of formal descriptions and models is an important part of optimization.

Optimization is considered to be an art, at least in part, since there are many obstacles on the way of implementing sophisticated optimization. These obstacles can be characterized as a lack of models, or the cost and time required to make such description and modeling can be prohibitive. In addition, models can be misused – by using wrong models, or even if they are good models they can be applied improperly, or results can be interpreted improperly.

The transportation systems of today are the result of about 200 years of development, governed by two main forces, namely, progress in vehicle technology and traffic network extensions. Each vehicle technology requires an appropriate network like a railway or highway network. However, despite technological advances and increase in transportation networks some problems gradually arose: road traffic started to suffer from congestion, residents complained about noise and pollution. Railways and other public transportation facilities were perceived as uncomfortable and tedious to use, while operation costs exploded. To resolve this crisis, the first reaction was to develop faster vehicles, emission reduction, and other technical measures, combined with network extensions, but it soon became clear that the benefits from technological progress and from additional investments in traffic networks were limited.

In spite of these problems, transportation demand is still rising, and as result one action is certain: individuals and businesses have to make better use of the world’s limited resources, thus these entities must optimize the transportation systems available to them. One way to do this is to improve the design and the operation of transportation systems by better planning.

The problems encountered in planning of transportation systems range from basic questions (i.e. traffic forecast) over strategic issues of system design and extension (e.g., decisions to build new subways, to construct new roads, or to buy a new fleet of busses), to operational problems such as timetables or vehicle and crew scheduling. The process of transportation economics optimization is usually a multi-disciplinary effort performed by engineers, social scientists, economists, administrators, and experienced practitioners, and involves a combination of vehicle and network technology, economics, computer science, and mathematical optimization. In addition there are different economic techniques to analyze transportation performance, ranging from cost benefit analysis, least-cost planning, multi-attribute analysis, dynamic optimization, linear and quadratic programming among others. However most of these techniques have their deficiencies and shortcomings, and perhaps the main and most important one is the fact that they are mode specific not intermodal-oriented and consequently is not useful to analyze the whole intermodal system. Despite this problem some techniques may be useful in the intermodal analysis with some minor changes, for which further research may be necessary.

A study by Berwick[24] provides a snapshot of truck/rail container intermodal shipping in and out of North Dakota. Cost estimates for an intermodal facility are also presented. The study revealed the benefits of intermodal transportation including:

- Lower overall transportation costs.
- Increased economic productivity and efficiency.
- Reduced congestion and burden on over-stressed highway infrastructure.
- Higher returns from public and private infrastructure investments.
- Reduced energy consumption.
- Increased safety.

Berwick developed a spreadsheet model to estimate costs associated with starting an intermodal loading facility in North Dakota. The model used for the study has many useful features. For example, costs can be estimated for different equipment configurations and sizes of facilities. The base model results showed that investment for the intermodal facility would cost more than $2 million and operating expenses at more than $400,000 annually. Sensitivity analysis was used to provide insight into investment decisions where the proportions of annual operating costs increased at a much lower rate than proportionately larger investment costs. This result led to the conclusion that under-investment would limit the capacity of the intermodal loading facility to handle larger volumes of commodities.

Yevdokimov[34] showed that intermodal transportation is an example of the so-called general-purpose technologies (GPTs) that are characterized by statistically significant spillover effects. Diffusion, secondary innovations, and increased demand for specific human capital are basic features of GPTs. The researcher states that eventually these features affect major macroeconomic variables, especially productivity. Based on recent literature that claims that in order to study GPTs, micro and macro evidence should be combined, Yevdokimov developed a computable general equilibrium model with an explicit transportation sector in order to study the benefits associated with intermodal transportation.

Results from the microeconomic simulation exercise showed that an increase in the volume of transportation within the existing transportation network has an impact on the overall productivity in both short-run and long run. Results further show that all microeconomic indicators, such as total production of the aggregate manufactured good, total sales revenue, total costs and profit improved in both runs.

The macroeconomic simulation showed that a one-time 10 percent increase in all basic characteristics of the transportation network due to intermodal transportation resulted in a permanent increase of the economy's growth rate. The growth rate was steadily increasing over the first 15 periods, reaching its maximum at value of 3.0 percent, and then it decreased with passage to time and settled down at 0.4 percent. This is a long-term contribution of intermodal transportation to economic growth.

Nachtmann[35] analyzed the economic impacts of port activities on the state of Arkansas and showed that Arkansas's inland waterways attract industries by offering low-cost transportation in a strategic location. The author developed an input-output model to analyze the economic impacts of port activities on the state of Arkansas. The author noted that input-output analysis is the most widely used and accepted method for conducting economic impact studies of water transportation.

The economic impact of an activity, such as port operations, can be broken into direct and indirect impacts. The direct economic impacts of an activity are measured as the direct economic contributions to the area where the activity is conducted such as the number of jobs attributed to that activity. Indirect impacts result from the direct economic impacts of an activity, where direct impacts support additional economic gains indirectly through purchasing and spending.

The researcher utilized the Regional Economic Modeling System II (RIMS II) to perform the input-output analysis for Arkansas. The author obtained the RIMS II input-output regional multipliers for the state of Arkansas system from the Bureau of Economic Analysis of the U.S. Department of Commerce. Results from the model indicate that Arkansas ports directly and indirectly contribute to the economic growth of the state, including economic value, earnings, and employment. The author concludes that the findings of the study show that the economic prosperity of Arkansas' economy is affected utilization of waterways.

A dissertation by Justice[36] addresses the issue of chassis logistics associated with containerized freight movements in the intermodal transportation industry. The focus of the associated research effort was to develop a model that provides solutions to chassis logistic problems that typically occur in the industry. Results from the model that the author developed show the potential for the application of CHREMAN in both the industrial and research environments.

The analysis applied in the industrial environment suggests that a minimum period of time for optimizing chassis reallocations using CHREMAN is the maximum time required for transporting a chassis between two ramps in the system. Results further reveal that when supplies and demands are known, minimum cost solutions for longer planning periods are preferred over a series of shorter periods.

The author states that the use of CHREMAN in research applications is demonstrated in his dissertation work. The software system has the ability to generate results quickly in designed scenarios. The model further has the flexibility needed to incorporate additional features that might be required for related studies by researchers and others.

The study by Mckenzie et al.[37] estimates the optimal flow of soybeans in Arkansas during 1993 using both survey data and a linear programming model. Results indicate that both approaches are consistent with each other, suggesting that the linear programming model adequately measures real world behavior and that Arkansas' elevators and sub-terminals are marketing soybeans in an optimal manner.

This study further reveals that the optimal mode of transporting soybeans to in-state soybean processors is truck. In contrast the optimal mode of shipping soybeans to the final destinations of Galveston and New Orleans, located out-of-state is by rail and barge respectively. This is explained by the fact that rail and barge offer lower rates than trucks on longer distances. Simulated increases in the quantity of soybeans suggest that the Arkansas soybean marketing and transportation infrastructure as of 1993 was deemed to be adequate to meet any possible increased export demand for soybeans moving to Galveston and New Orleans resulting from NAFTA.

The purpose of a study by Ozment[38] was to examine the role that intermodal transportation plays in today's logistics environment and to assess its potential for further growth and adoption by examining the potential for intermodal service based on total logistics costs. The author used different products as examples to assess the total cost of movements between hypothetical origins and destinations. The total logistics cost of truck-rail intermodal was compared to the total cost of shipping by truck. Data provided in the DOT's Commodity Flow Survey were then examined to show the potential for other products to benefit from intermodal transportation.

Results from the study provide insight into the potential impact of shifting freight from truck to truck-rail intermodal. Also, results suggest that the current demand for intermodal service is probably not sufficient to justify the development of additional intermodal facilities.

Based on these results the author suggests that government sponsored programs to educate shippers may be of more value than the creation of facilities that shippers are not likely to use. The author believes that once shippers understand the real value of intermodal transportation and are able to determine the best way to route their freight based on a total logistics cost approach, our economy will begin to realize many benefits associated with more efficient acquisition of raw materials and distribution of finished goods, not just those benefits associated with the use of intermodal transportation.

Moore et al.[39] developed a model to perform an economic analysis for the user. The analysis incorporates all the viable tangible and intangible cost entities to perform the true cost assessment. The developed methodology operates in conjunction with Cost Assessment of Intermodal Transportation Linkages (CAITL) software to determine the true least cost of freight transportation.

According to the authors the graphical user interface of the software provides the user with a visual display of the transportation mode being analyzed and the cost associated with that particular mode of transportation. The authors also reveal that the developed model allows for an individual cost assessment for all the modes. The model provides the user the mode or modal combination with the least cost. The authors also reveal that the methodology is designed to permit the expansion of the region.

The authors reveal that results of the analysis for the five states region of Alabama, Arkansas, Mississippi, Louisiana, and Tennessee are acceptable in that the obtained societal costs for truck and air transportation are higher than the published revenue per ton-mile. This is due to substantial government contributions to the infrastructure associated with these transportation modes. The societal costs for rail transportation are lower than the published revenue per ton-mile. The authors indicate that these results for the rail mode are due because government makes no contributions to the infrastructure of this transportation mode. The authors provide another reason for the rail results. The authors state that these transportation carriers have previously depreciated many of the large assets associated with rail transportation.

Environmental Optimization

Environmental evaluations of transportation projects tend to be either binary or qualitative. Binary evaluations consist of judgments that the project does/does not adversely affect water and air quality or that it does/does not encroach upon protected species habitat. Qualitative evaluations may offer some quantitative measures, such as a change in water temperature, but may base judgments on subjective measures such as "minimal impact." The environmental measure most commonly quantitative is emissions of engine exhaust gases. Qualitative and binary evaluations can be employed in optimization schemes, as, for example, in construction of "mitigation" wetlands to replace natural wetlands, but the tradeoffs tend to be unique to the individuals evaluating the issue. One set of experts may decide that replacing one acre of natural wetlands with 2 acres of constructed wetlands is sufficient, while another set of experts may insist that 3 acres is needed.

The Tennessee Valley Authority has attempted to balance waterborne traffic environmental effects by means of a River Efficiency Model[3] that expresses efficiency as the ratio of freight ton-miles to gallons of fuel consumed. So, for example, the Mississippi River from the Ohio River to Baton Rouge, Louisiana, at 614 ton-miles per gallon, is rated as more efficient than the Illinois River at 229 ton-miles per gallon, and could be identified as producing less air polluting emissions than the Illinois or some other mode of transport that produced fewer ton-miles per gallon. Metric 3a, emissions per ton-mile, of Table 4.2 will generate a similar result.

The environmental metrics of Table 4.2 and 4.3 include quantitative measures of air pollution, land/water pollution, habitat destruction/fragmentation, and noise pollution in order to incorporate environmental quality concerns into the intermodal transportation evaluations. They do not replace the need for Environmental Assessments/Environmental Impact Statements nor do they address show stopper issues such as threatened and endangered species. Like the other metrics, they are simply imperfect quantitative measures of one aspect of a transportation system that can be used to make informed decisions about the necessary tradeoffs among competing interests. They are not expected to be the final measures for environmental balance, but to be reasonable place-holders until better metrics can be formulated.

Overall Balance: Intermodal Efficiency Index

The metrics of Table 4.2 are the basis for establishing a ranking among alternative intermodal transportation network plans. Here we look at methods for integrating them into a single measure, the intermodal efficiency index.

Comparison of diverse metrics is complicated when the metrics have units or vary by orders of magnitude; therefore, the metrics are non-dimensionalized and allowed to vary only between zero and one when comparing alternatives. Therefore each of the metrics in Table 4.2 is normalized during the comparison of alternatives by dividing it by the maximum value of that metric among all the alternatives considered. A subscript asterisk indicates the normalized form of each metric, for example, metric 1a becomes:

$$M_* = \frac{\left[\dfrac{\sum\limits_{(i,j,n)\in N} p_{i,j,n} \sum\limits_{k=1}^{K_{i,j,n}} T_k\left(L^*\right)}{\sum\limits_{(i,j,n)\in N} p_{i,j,n} l_{i,j}} \right]}{M_{max}} \qquad 6.1$$

An alternative normalization procedure is to use the existing performance as a normalizing parameter, so the existing condition, or Base Condition, has normalized metrics all equal to one. Then, normalized alternative metrics greater than one are quickly identified as worse than the Base and metrics less than one are better than the Base.

The various stakeholders in transportation may value each of the metrics differently. For example, an industry shipping perishable goods will place more importance on travel time, metric 1a, than on 5b, investment per job created; and a state environmental agency will place more importance on 3a – 3c, the environmental quality metrics, than on metric 1b, the travel time variance. For these reasons, the overall efficiency index is defined as:

$$I_e = \frac{\sum_{m=1}^{14}\left(W_m N_{*m}\right)}{\sum_{m=1}^{14}\left(W_m\right)} \qquad 6.2$$

Where W_m is the weight assigned to metric *m*, N_m^* is the normalized value of metric *m*, and *m* is the metric number, from 1 to 14, in Table 4.2. By this formulation, the absolute values of the weights are not significant; rather, it is the relative magnitude that affects the index result. If efficiency is weighted 10 times higher than economics, then the economic metric will have little impact on the index. Obviously, different weights may produce dramatically different results, but the weights are legitimate subjects of negotiation and compromise among stakeholders when public decisions are made.

Ranking solutions

With equation 6.2 as the objective function to be minimized, we seek to find the best transportation alternative out of those identified as possible solutions. If only a few alternatives are identified, they can be individually simulated as described in Chapter 5, their intermodal efficiency calculated, and the best alternative selected. If a large number of combinations are under consideration, then a more elaborate search technique may be required, such as Response Surface Methodology (e.g., see Meyers and Montgomery).[40] In the present effort we have not selected a search technique, since that selection will require an analysis of how the various metrics behave under various plausible scenarios, the subject of future research.

In its simplest form, the ranking can be done in a spreadsheet, as shown by the fictitious example of Table 6.1. Weights and weighted values for each non-dimensional metric are given, and the efficiency index for each of four alternatives is shown at the bottom. In this case, alternatives 2 and 3, with I_e values of 0.26 and 0.21, appear to be better than alternatives 1 and 4, at least for the chosen weights.

Table 6.1 Example Spreadsheet Calculation of Efficiency Index.

Metric	Weight	Alternatives - Weighted Metrics			
		1	2	3	4
M	10	3.00	3.00	0.60	0.18
R	5	3.00	0.90	0.36	0.22
R_u	5	1.00	0.50	0.10	0.08
S_F	100	40.00	16.00	16.00	9.60
S_l	50	35.00	21.00	18.90	75.60
S_p	10	7.00	5.60	3.92	3.53
E_a	10	4.00	0.80	0.40	0.40
E_w	10	5.00	0.50	0.10	0.02
E_h	8	6.40	5.12	4.61	2.30
E_n	5	4.50	1.35	0.68	0.41
VC	3	3.00	1.80	0.18	0.04
FC	50	20.00	12.00	8.40	2.52
EG'	15	10.50	6.30	5.04	3.53
J'	5	2.50	0.75	0.38	0.30
I_e		0.51	0.26	0.21	0.35

Procedure

The optimization process will consist of the following steps in a planning mode application:

1. Compile overall transportation demand data for the present and future period of interest
2. Create a GIS-based model of the transportation system, including highway, railway, and waterway networks and intermodal transfer stations.
3. Import the transportation model to a VITS model of the system.
4. Simulate the present system and demand in order to validate the simulation model and extract data for metrics.
5. Simulate the future demand and alternatives.
6. Use simulation results to calculate parameters used in the metrics.
7. Normalize the metrics and identify the best solution(s) among the alternatives simulated.
8. Evaluate the results to identify other possible solutions that offer improved outcomes and repeat steps 5-7.

7. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The objective of this work is to provide:

- A plan for collaborative intermodal transportation investment decision analysis tools for both traditional and nontraditional intermodal system improvements that will accommodate expected increases in Latin American trade shipments through northern Gulf of Mexico ports.
- A framework for choosing a good mix of intermodal alternatives so that public and private sector officials are able to collaboratively plan system upgrades at the state, sub-region, and regional level that serve the public interest.

The Latin America Trade and Transportation Study (LATTS) results showed that increased trade with Latin America will test the United States transportation network's ability to safely and economically transport freight. The Southeastern Transportation Alliance region's transportation system must become a more interconnected multimodal system than it is now in order to provide current as well as potential customers the freight mobility that is currently required and expected in future to enhance the region's competitiveness.

Transportation officials are faced with making decisions on which transportation modes will become critical points in the overall transportation system and where funds should be invested in order to maximize economic development and safety while minimizing costs and preserving environmental quality. They need additional tools to perform this task.

Each of the transportation modes – highway, rail, waterway, air, and pipeline -- has performance metrics specific to that mode and its stakeholders, but many of those metrics are not directly applicable to other modes. Fourteen proposed intermodal metrics in five categories – Mobility and Reliability, Safety, Environment, Cost Effectiveness, and Economic Growth – represent a start on development of a mutually acceptable metrics.

The manner in which people and freight move through a transportation network is influenced by many interdependencies. Simulation provides a means to model interdependences and variation and avoid many of the pitfalls that are often encountered in the start-up of a new system or the modification of an existing system. In a previous research project, the National Center for Intermodal Transportation developed the Virtual Intermodal Transportation Simulation (VITS), which simulates the movements of trucks, trains, barges, and ships on the transportation network as well as the transference of freight between the different modes. Addition of a port model to the VITS prototype has demonstrated the capability of the model to evaluate intermodal solutions.

Optimization provides a way to balance the competing needs of society in the planning process so that alternative mixes of intermodal transportation that best serve the public interest can be identified. This can be called optimization of alternatives; even though in the strictest sense optimization means that a given solution can be proved to be the best of all possible solutions.

The fourteen intermodal metrics provide a basis for establishing a ranking among alternative intermodal transportation network plans. A single measure, the intermodal efficiency index, is proposed, in which the metrics are non-dimensionalized and allowed to vary only between zero and one when comparing alternatives. The various stakeholders in transportation may value each of the metrics differently, so a weighting system is employed to allow each user or group of users to stress those metrics of primary interest. Different weights may produce dramatically different results, but the weights are legitimate subjects of negotiation and compromise among stakeholders when public decisions are made. An optimization procedure has been proposed to serve as a framework for making intermodal investment decisions in a collaborative manner.

This report provides the intended plan for a collaborative intermodal transportation investment decision analysis and the framework for choosing a good mix of intermodal alternatives.

Recommendations

The following are recommended:

- The intermodal metrics described here should be tested on highway, railway, waterway, and intermodal transfer station data to examine their effectiveness and identify data gaps.
- The VITS simulation should be expanded to allow simulation of the northern Gulf transportation system in Texas, Louisiana, Arkansas, Mississippi, Tennessee, Alabama, Georgia and Florida.
- Trial VITS simulations should be made to provide data for evaluation of the recommended intermodal metrics.
- Alternatives, including expanding highway, railway, waterway, and transfer station capacity should be examined on a regional basis to identify innovative solutions to the expected increase in Latin American trade.

APPENDIX: NOTATION

A_r – designated habitat destruction metric
AN – Number of trips per year
A_f – Designated habitat area fragmentation metric
ATC – Annual equivalent total cost in present dollars of construction and maintenance (dollars)
C – Design carrying capacity of a transportation link (variable units, but same as V)
$D_{i,j,n}$ – Property damage cost caused by accidents in trip (i,j,n) (dollars)
E_d – Air quality impacts metric (tons per ton-mile)
EG – Economic growth index denoting total economic growth per dollar of investment (percent per dollar)
E_h – Habitat impacts metric (tbd)
E_n – Noise impact metric (1/ton-mile)
E_w – Water quality impacts metric (tons per ton-mile)
FC – Facility cost per operation cost *TMR* or *PMR* (dollars per ton mile required or dollars per passenger mile required)
$f_{i,j,n}$ – Expected travel time for a specific trip n between origin and destination pair i and j (hours)
$F_{i,j,n}$ – Fatalities for specific trip n between each origin and destination
GC_p – Fuel consumption cost involved in trip (i,j,n) (dollars)
$H(L^{*})$ – Percentage of time threshold sound level is exceeded (as a function of traffic load)
H_m – Maximum sound level (decibels) produced by the primary transport mode
H_t – Threshold sound level considered a nuisance
i – Trip index denoting origin
$I_{i,j,n}$ – Number of injuries for a specific trip n between each origin and destination
J – Job improvement index It denotes number of job years created by transportation per dollar of investment
j – Trip index denoting destination
k – Index corresponding to a link in a transportation network
K – Number of links traveled in a trip between origin and destination
L – Community livability index It denotes the percent of people affected by transportation system
L^* – Traffic Load (no units) as given by $L^* = f^*(V/C)$ where $f^*()$ is a function to obtain the traffic load based on V/C ratio (volume over capacity ratio) which may be determined either by observation or by simulation.
LD – Daytime noise level (decibels)
LN – Nighttime noise level (decibels)
$l_{i,j}$ – Geographic distance between origin and destination (miles)
M – Mobility (hours per mile)
n – Index denoting a particular trip
N – The set of all trips
P – Pollutants index denoting tons of mobile source emissions per *TMR* or *PMR*
P_a – Number of people that are negatively affected by transportation systems
pa – Tons of air pollutants released in the trip (or link) per TMR

$p_{i,j,n}$ – Number of tons or passengers involved in trip *i,j,n*, where *i* is the origin, *j* is the destination, and *n* is the index of the trip with the same origin and destination

PMR – Passenger-miles required which is the multiplication of $p_{i,j,n}$ and $l_{i,j}$

$PO_{i,j,n}$ – Tons of mobile pollutants involved in trip *(i,j,n)* (tons)

P_e – Total number of people using the transportation system

pw – Tons of liquid and solid pollutants released per TMR

R – Reliability (no units)

R_u – Reliability due to unexpected travel delay (no units)

S_F –Number of fatalities per *TMR* or *PMR*

S_I –Nnumber of injuries per *TMR* or *PMR*

S_p – Property damage cost caused by accidents in trip *(i,j,n)* (dollars)

t – Subscript indicating metric applies to transfer terminals, such as ports

TEG – Total economic growth

TI – Total investment (dollars)

$T_{i,j,n}$ – Total travel time between each origin and destination for a specific trip *n* (hours) as given by $T_{i,j,n} = \sum_{k=1}^{K_{i,j,n}} T_k(L^*)$

TJ – Total created job years due to the transportation system

T_k – The traveling time on link *k* for the n^{th} trip between each origin and destination (hours)

TMR– Ton-Miles Required which is the multiplication of $p_{i,j,n}$ and $l_{i,j}$

V – Volume of traffic on a transportation link (variable units, but same as *C*)

$VA_{i,j,n}$ – Vehicle aging cost involved in trip *(i,j,n)* (dollars)

VC – Vehicle operation cost per *TMR* or *PMR* (dollars per ton mile required or dollars per passenger mile required)

$VI_{i,j,n}$ – Vehicle insurance cost involved in trip *(i,j,n)* (dollars)

$VM_{i,j,n}$ – Vehicle maintenance cost involved in trip *(i,j,n)* (dollars)

$VO_{i,j,n}$ – Other vehicle operation cost involved in trip *(i,j,n)* (dollars)

* – Superscript indicating normalized metric

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