GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: August 30, 1976

Project Title: ~~Devise~~ Analytical Procedures for Intercity Transportation and Development Planning

Project No: E-24-651

Project Director: Dr. Paul Jones

Sponsor: U. S. Department of Transportation, Washington, D. C.

Agreement Period: From 8/24/76 Until 8/23/77

Type Agreement: Contract No. DOT-OS-60512

Amount: $244,673 DOT
49,786 Total Cost Sharing (GIT $5,298 -- E-24-319)
$294,459 Total

Reports Required: Quarterly Progress; Final Report

Sponsor Contact Person (s):

Technical Matters

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Washington, D. C. 20590

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400 Seventh Street, S. W.
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202/426-9745

Defense Priority Rating:

Assigned to: Industrial and Systems Engineering (School/Laboratory)

COPIES TO:

- Project Director
- Division Chief (EES)
- School/Laboratory Director
- Dean/Director—EES
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- Project Code (GTRI)
- Other

Posted
[illegible]
[illegible]

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 2/17/78

Project Title: ~~Devise~~ Analytical Procedures for Intercity Transportation and Development Planning

Project No: E-24-651

Project Director: Dr. P.S. Jones

Sponsor: U.S. Department of Transportation; Washington, D.C. 20590

Effective Termination Date: 12/31/77

Clearance of Accounting Charges: 12/31/77

Grant/Contract Closeout Actions Remaining:

X Final Invoice and Closing Documents
_ Final Fiscal Report
X Final Report of Inventions
X Govt. Property Inventory & Related Certificate Submitted 16 Feb 78
_ Classified Material Certificate
_ Other ____________

Assigned to: Industrial and Systems Engineering (School/Laboratory)

COPIES TO:

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Project File (OCA)
Project Code (GTRI)
Other ____________

CA—4 (3/76)

E-24-651

SCHOOL OF INDUSTRIAL AND SYSTEMS ENGINEERING

Atlanta, Georgia 30332 R. N. Lehrer, Director (404) 894-2300

November 22, 1976

Dr. Byron Nupp, Assistant Director
Office of Transportation Systems Analysis
and Information
Office of the Secretary of Transportation
Washington, D.C. 20590

Subject: First Quarterly Progress Report Contract DOT-OS-60512

Dear Dr. Nupp:

This letter constitutes a report of progress during the first quarter's execution of contract DOT-OS-60512, entitled "Analytical Procedures for the Study of a Specific Multimodal Transportation Corridor."

First quarter progress has in general been good. However, the entire technical effort has been impeded by the delay in granting federal approval of subcontracts with the nine participating universities. Necessary travel has not been performed because personal expenses could not be reimbursed. In addition, a great deal of time has been spent attempting to explain the delay to school administrators. It is hoped that this vexing problem will soon be resolved.

Specific technical progress is described below in terms of tasks and activities that were identified in the management plan. As set forth in that plan, eleven events are scheduled to occur during the first quarter which ends at work day 52, when measuring from September 10, 1976. These events require the completion of eleven activities. Three more activities are optional.

Task 1. Identify Legislative Constraints

This task has been launched by Dr. Hille. Preliminary state reconaissance has been performed. A procedure has been developed and considerable data have been collected. Progress has been impeded by the need to travel to Washington to interview knowledgable individuals and to research federal documents. This trip has been postponed until after the subcontracts are executed.

Activity 1-1, reconnaissance is complete. Activity 1-2, prepare preliminary catagories, is also complete. Activity 1-3, check catagories, is partly complete.

Some of the slack in Task 1 has been used. However, the task is well within its schedule constraints.

Task 2A. Compile Transportation Data

Under the leadership of Dr. Holloway, this task has been launched and is progressing satisfactorily. The reconnaissance is complete. We believe that we are thoroughly familiar with the data that are available. The magnetic tape containing commodity flow data for 20 commodity groups between BEA zones has been received and analyzed.

After careful review of the commodity data, we have concluded that we need to express commodity flow in terms of 50 commodity groups. A tentative procedure has been developed that

a. Augments the BEA tape with fresh fruit and vegetable movements derived from USDA unload reports

b. Expands the 20 BEA commodity groups using a 1972 Census of Manufacturers tape that has been ordered but not received.

c. Develops origin and destination data for the 50 commodity groups using a combination of the BEA tape and industry profile data.

The data collection plan is complete except for railroad, pipeline and electric power data. Reconnaissance for these latter activities is complete but data needs have not yet been formalized. Thus activities 2A-1 and 2A-2 are complete. Activity 2A-3 is almost complete and 2A-4 is underway.

Progress on this task has been impeded by the lack of subcontracts. Once subcontracts are execute, we expect to catch up promptly.

Task 2B. Preliminary Economic Analysis

Under the leadership of Dr. Smith and Dr. Spraggins, this task is well underway. The work is on schedule. Economic data needs have been identified. Industry profiles have been undertaken for each of the 50 industry groups. Good progress has been made. Activities 2B-1, 2B-2 and 2B-3 are essentially complete and activity 2B-4 is nearly complete.

Preliminary study of econometric models is also underway. These developments are being carried out in parallel with the transportation modeling to insure compatability. Work to date is encouraging but no final decisions have been made. Activity 2B-6 is complete. Activity 2B-7 is underway.

Task 2C, Transportation Network

This task is also progressing well under the direction of Dr. Lipinski. Several alternative approaches to network modeling have been explored. It appears likely that the transportation network will have variable zone sizes. The zones in the Multi-State Corridor will be multi-county and will consist of Area Planning and Development Center or equivalent size. Adjacent to the corridor, zones will be BEA sized.

More distant zones will be states or clusters of states. The final zone configuration has not yet been selected. However, all of the necessary data have been assembled.

Preliminary evaluation criteria have been assembled and analyzed. A tentative evaluation procedure has been selected, subject to confirmation at the Guidance and Control Committee meeting in December.

Activities 2C-1, and 2C-2 are essentially complete. Activity 2C-3 is very nearly complete activity 2C-4 on time.

Task 2D. Preliminary Transportation Analysis

Good progress has been made on Task 2D. The modeling issues and requirements have been identified, completing activities 2D-1 and 2D-2. Alternative models are being developed. One workable scheme has been devised to date.

Other Tasks

Tasks 3, 4 and 5 have not been started yet. Task 6 is underway. A temporary library site has been secured at Georgia Tech. No catalogueing scheme has been adopted. Most project data are in the hands of personnel at participating universities.

Summary

The project is moving ahead essentially on schedule. Delays due to contractural difficulties will soon be cleared up when subcontracts have been executed. We hope that this report adequately conveys our achievements to date. If you have need of additional information, please let me know.

Sincerely,

Paul S. Jones

/lf

SCHOOL OF INDUSTRIAL AND SYSTEMS ENGINEERING

Atlanta, Georgia 30332 R. N. Lehrer, Director (404) 894-2300

February 25, 1977

Dr. Byron Nupp, Assistant Director
Office of Transportation Systems
Analysis and Information
Office of the Secretary of Transportation
Washington, D. C. 20590

Subject: Second Quarterly Progress Report, Contract DOT-05-60512

Dear Dr. Nupp:

This letter describes progress made during the Second Quarter's effort on Contract DOT-05-60512, entitled, "Analytical Procedures for the Study of a Specific Multimodal Transportation Corridor."

Subcontracts with the nine participating universities were executed on December 13, 1976. Much of the time lost awaiting formal agreements has been made up. We hope that most of the balance of the lost time will be made up during the next quarter.

Specific technical progress is described below by task and activity. As of February 23, 1977, 117 working days have elapsed since the management plan was prepared (September 10, 1976). Eight events were scheduled for the second quarter.

Task 1. Identify Legislative Constraints

Progress on this task was impeded by the delay in executing the subcontracts. However, considerable slack is available in the schedule and work is now proceeding well. Tasks 1-1, 1-2 and 1-3 are complete. At present, the research is dealing with intergovernmental agreements and governmental private agreements which are involved in the establishment of transportation corridor projects. Highway statutes delegate the authority to establish, regulate, maintain and vacate such transportation corridors to specific agencies so there is no doubt about responsibility for establishing and maintaining the system. These agreements are preliminary to project finance, land acquisition, letting bids for construction, etc.

Task 2-A. Compile Transportation Data

This task is almost complete. Some data are still missing because of subcontractural delays. Additional data will be needed from time to time as the research proceeds. The cooperation of state officials and federal agencies has been excellent. Data reduction and summarization is underway. Preparation of the task report has begun. Activities 2-A4, 2-A5 and 2-A6 are nearing completion. Those portions necessary to proceed from event T have been completed. Activity 2-A7 is underway.

Task 2-B. Preliminary Economic Analysis

This task is complete except for a few straggling details and the preparation of the draft report. Activities 2-B4, 2-B5, 2-B6, 2-B7 and 2-B8 are complete. The industry profiles are complete, with a few minor exceptions. The economic model has been selected and has been described in a working paper. Work on the draft report, activity 2-B9, is in progress.

Task 2-C. Transportation Network

This task, also, is very near completion. Transportation zones have been selected. Highway, rail and water arcs have been identified and described. Network data are being coded for easy computer access.

Data have been collected on pipelines and on electric power high voltage networks. These facilities will not be subjected to the same type of analysis as the other transportation modes.

Activities 2-C3 and 2-C4 are complete. The draft report, activity 2-C5 is underway.

Task 2-D. Preliminary Transportation Analysis

A method has been devised for use in the transportation analysis. The essential features have been worked out. Some problems remain, but they can be accommodated. Some key features, notably market penetration, mode split and arc capacitation, will require work during the second contract year. These features will be included in the analysis but the key relationships will require further work.

Activity 2-D4, Nominate Preliminary Evaluation Criteria, is complete. Several potentially interesting transportation alternatives (Activity 2-D5) have been nominated. Others are being studied. The draft report has been started.

Task 3. Techniques for Developing Economic Opportunities

Portions of this task are complete. Data needs (Activity 3-1) have been identified and much of the data have been collected. The economic model (Activity 3-3) has been formulated, but specific input data (3-4) have not been prepared. However, transportation input data (3-5) are almost complete. This task is receiving careful attention because of its key role and its critical timing.

Task 4. Measures for Comparing Alternative Mixes of Transportation Services

This task is proceeding well. Activities 4-1 and 4-2 are complete. Preliminary criteria have been selected and evaluated. Final criteria selection (4-3) will take place at the March meeting of the Guidance and Control Committee. Combination methods have been explored. A method will be selected when the final criteria have been selected.

Task 5. Formulate Preliminary Analytical Framework

This task is well under way. The key modeling issues (5-1) have been resolved. Model requirements (5-2) have been established. Other modeling efforts have been reviewed, analyzed and compared (5-3, 5-4, 5-5). Finally, a model framework has been prepared. This work is well ahead of schedule. In as much as activities 5-1, 5-2, 5-3 and 5-4 lie on the critical path, fifteen days time has been made up. Tasks 3-6, 3-8, 3-9, 3-10 and 3-11 now constitute the critical path.

Events

Events R, T, U, W, X, Y, AB, AG and AL were accomplished during this quarter.

Summary

Although progress has been uneven, the project can be considered to be on schedule. Task 3 is now the critical task and will receive direct attention and support throughout the next quarter.

Respectfully submitted,

Paul S. Jones

jc

E-24-651

GEORGIA INSTITUTE OF TECHNOLOGY

SCHOOL OF INDUSTRIAL AND SYSTEMS ENGINEERING

Atlanta, Georgia 30332 R. N. Lehrer, Director (404) 894-2300

May 23, 1977

Dr. Byron Nupp, Assistant Director
Office of Transportation Systems
Analysis and Information
Office of the Secretary of Transportation
Washington, D. C. 20590

Dear Dr. Nupp:

The purpose of this letter is to describe progress during the Third Quarter of Contract DOT-05-60512, entitled, "Analytical Procedures for the Study of a Specific Multimodal Transportation Corridor."

Progress continues to be good. However, it was deemed advisable to request a two month, no-cost extension to the project for the following reasons:

1. It is much more efficient to complete the analytical framework before preparing data for the Northern Mississippi test.

2. Faculty time is available during the summer in greater proportion than during the school year. It is advantageous to use this time.

3. Excellent progress is being made on the analytical method. It is advantageous to carry this work further than wad intitially planned.

Although formal approval has not yet been received, we have informal information that the new schedule is acceptable. The scheduled dates for the deliverable items are tentatively revised to the following:

Task 1 Report	July 23, 1977
Task 2 Report	May 15, 1977
Task 3 Report	August 23, 1977
Task 4 Report	July 23, 1977
Task 5 Report	August 23, 1977
Preliminary Draft of Final Report	August 23, 1977
List of Library Publications	October 23, 1977
Final Report	October 23, 1977

Sepcific technical progress is described below by task and activity. As of May 20, 1977, 180 working days have elapsed since the management plan was prepared (September 10, 1976). Eight events have been reached during the third quarter.

Task 1. Identify Legislative Constraints

Task 1 was accelerated during the third quarter and showed substantial progress. State data were collected on legislative and administrative constraints. These data are being analyzed and compiled. Task 1-4 is complete and Task 1-5 is underway.

Task 2. Initial Transportation Guidelines

This task is nearly complete. All of the analytical work has been accomplished. The draft report is substantially complete. Significant work was performed in revising and finalizing the network configuration and in completing the industry profiles. Perliminary work is complete on modal split and market share analyses; however, additional work will be performed as part of Task 5.

Task 3. Techniques for Developing Economic Opportunities

All preparatory work has been completed in anticipation of the Northern Mississippi Test. Activities 3-2 (General Data Collection), 3-3 (Econometric Model), and 3-5 (Transportation Data) are complete. The collection of detailed economic data (activity 3-4) has been delayed until the analytical procedure is more dompletely defined. The work will resume on June 1.

Task 4. Measures for Comparing Mixes of Transportation Services

This work has proceeded as far as it can before the Northern Mississippi test is conducted. Activities 4-3 (Criteria Selection), 4-4 (Combination Techniques), and 4-5 (Combination Method) are essentially complete. Draft material (4-7) has been prepared on work to date.

Task 5. Formulate Preliminary Analytical Framework

This task is proceeding extremely well and continues to be ahead of schedule. Activity 5-6 (Evaluate Alternatives) is complete and the specification of the final model is in process. The network model is being programmed. We hope to be able to exercise this model on Northern Mississippi test data.

The mode split and market share formulations remain a vexing problem. Regression results based on the Commodity Flow data are far from acceptable, but they are comparable to those reported by other investigators. Substantial problems exist with the Commodity Flow data. In addition, shipment size and non-homogeneity of commodities contribute to our problems. Cost and shipping time data also contain inconsistencies. At this time, we have expended all of the effort that we can afford on these subjects. We plan to select the best representations that we have and proceed with the work.

Events

Events V, Z, AA, AC, AD, AF, AH, and AJ were accomplished during this quarter.

Summary

Project activity is well within the revised schedule. Task three remains the critical task. It will be the subject of most summer activity. Although many new problems have arisen, we remain optimistic about the quality of our product.

Respectfully Submitted,

Paul S. Jones

PSJ:erm

E-24-651

SCHOOL OF INDUSTRIAL AND SYSTEMS ENGINEERING

Atlanta, Georgia 30332 R. N. Lehrer, Director (404) 894-2300

August 23, 1977

Dr. Byron Nupp, Assistant Director
Office of Transportation Systems
Analysis and Information
Office of the Secretary of Transportation
Washington, D. C. 20590

SUBJECT: Fourth Quarterly Progress Report, Contract DOT-05-60512

Dear Dr. Nupp:

The purpose of this letter is to report progress on Contract DOT-05-60512 that occurred during the fourth quarter of work that extended from 24 May through 23 August.

The summer months have been a period of intense activity with excellent progress on many tasks.

A set of sequential dependencies, that was generally anticipated, has caused some delay. The chain of events goes something like this. Detailed employment data were needed to complete the breakdown of the CTS commodity flow data into the zones selected for the Multi-State Corridor. The commodity flow data were needed to identify services and markets for the commodities to be used in the Northern Mississippi test. Production cost data were needed for each source in order to develop the market share model. Finally, the market share model is needed before new opportunities can be explored for northern Mississippi. The sequence is complete to the development of the market share relationships. That work is underway with early completion expected.

With the dependancies of the above series of activities, the first year's work was not completed by 23 August as planned. We are now expecting the analytical work to be completed by 23 September, with the draft final report to be submitted by 30 September.

Specific progress on individual tasks is outlined briefly below.

Task 1. Identify Legislative Constraints

Task 1 is complete and the report was submitted on 23 July.

Task 2. Initial Transportation Guidelines

Task 2 is complete. The Task 2 report has been drafted and is being typed. It will be submitted on 9 September.

Task 3. Techniques for Developing Economic Opportunities

Task 3 lies on the critical path. Key data have been collected. The computer runs will be made as soon as the market share work is complete. Further analysis will follow the computer runs. We expect this task to be completed by 23 September, with the Task report to be submitted on 30 September.

Task 4. Measures for Comparing Mixes of Transportation Services

Task 4 is complete except for applying the evaluation procedure to the results of the Northern Mississippi test. The Task 4 report is largely complete and will be submitted on 16 September.

Task 5. Formulate Preliminary Analytical Framework

Task 5 is largely complete. Some work on market share remains. The Task 5 report has been written and it is now being typed. It will be submitted on 9 September.

Events

Events AE, AK, AI, AL, AN and AO were accomplished this quarter. Eight events remain.

Summary

Progress has been good, but some delays have been encountered. We do not anticipate further delays. Completion of the final report draft by 30 September seems reasonable. It may be desirable to extend the contract to allow time for a thorough DOT review of the Final Report. However, to maintain effective use of the project staff, we request that the second year's work be scheduled to start on 1 October.

Respectfully submitted,

Paul S. Jones

jc

SCHOOL OF INDUSTRIAL AND SYSTEMS ENGINEERING

GEORGIA INSTITUTE
OF TECHNOLOGY
ATLANTA, GEORGIA 30332

PROCEDURES FOR MULTI-STATE,
MULTI-MODE CORRIDOR ANALYSIS:
TASK 2: ANALYTICAL GUIDELINES

by
Paul S. Jones

School of Industrial and Systems Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332

Prepared for

DEPARTMENT OF TRANSPORTATION
Office of the Secretary
Washington, D. C. 20590

July 1977

PREFACE

This report describes Task 2 of the project entitled "Analytical Procedures for the Study of a Specific Multimodal Transportation Corridor." In this task, many of the essential features of multimode corridor analysis were formulated. Key data were collected and preliminary analyses were conducted. The work of Task 2 is summarized and the more important achievements are presented.

The research is sponsored by the Office of Transportation Systems Analysis and Information of the Office of the Secretary of the U. S. Department of Transportation. Dr. Byron Nupp is Contracting Officer's Technical Representative.

The work has been performed by a consortium of nine universities under the direction of Dr. Paul S. Jones of the Georgia Institute of Technology. Participating universities include the University of Alabama, Arkansas State University, Auburn University, Memphis State University, Mississippi State University, the University of Missouri, the University of North Florida, and Tennessee Technological University. Principal faculty participants in Task 2 include Dr. Frank M. Holloway of Tennessee Tech, Dr. H. Barry Spraggins of North Florida, Dr. Martin E. Lipinski and Dr. Subbarayan Prasanna of Memphis State, and Dr. Gunter Sharp of Georgia Tech. Major contributions were also made by the following graduate students: Mr. Michael A. Mullens, Mr. Wade Morgan, and Mr. H. C. David Yu.

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I INTRODUCTION

The research reported here represents a new approach to intercity transportation planning. The initial effort has focused on freight transportation. Later extensions are expected to passenger transportation. The present approach views intercity freight transportation services as tools for stimulating and supporting economic development. The economic development of interest is the creation of new production facilities in locations that do not have similar facilities today. In this context, the research deals with basic production -- that which is largely exported from the producing area. The transportation facilities and services of interest are those that will bring about new circumstances with respect to transportation cost, access, or quality of service that are sufficiently different that they will provide the key increment that makes new production facilities feasible. The essence of the research is the determination of quantitative relationships between (1) new transportation facilities and services, and (2) the new production facilities that are made possible by these transportation services.

That there is a relationship between transportation services and economic development has been known for a long time. For centuries, major production facilities have been located where good transportation is available. New transportation services of many different kinds have stimulated new development. One need only look at the Interstate and Defense Highway System to be assured that there is an important relationship between the two. However, there has never been a satisfactory quantitative method developed that can predict the introduction of a specific new transportation service. Such a predictor would be a valuable aid in identifying high potential transportation projects. If one could measure expected development in quantitative terms, that factor could make a large contribution to the expected benefits from a transportation project. In fact, expected development may be the major benefit that accrues to non-highway transportation projects. Several investigators [1,2,3]* have developed models that relate land use or other economic indicators to the general quality of transportation. Harris [1] uses an input-output model to measure the relative value of different highway systems. He expresses the quality

*Numbers in parenthesis refer to references listed at the end of the report.

of transportation service in terms of costs between origin and destination points. Routing is prescribed as part of the cost determination and only a single transportation mode is treated. Polenski [2] has used input-output models for regional planning and has contributed much to the state of that art. Floyd [3] has used input-output analysis on a regional basis to measure the impact of transportation on land use. This work is also limited to one mode and present technology. Past work is useful because it deals with both passenger and freight transportation and also with basic and non-basic (local) impacts of transportation. However, past work fails to answer specific development questions in sufficient detail to provide effective planning assistance.

Multi-State Transportation System

The analytical work presented here focuses on a single setting -- the Multi-State Transportation System, which encompasses a strip of land approximately 100 miles wide and 1200 miles long extending from Brunswick, Georgia to Kansas City. Planning for the Multi-State System is vested in 7 states, many planning districts , many municipalities, and a large number of private citizen groups. Planning is coordinated by an advisory board where members are listed in Table 1. Using state and Federal support, a parametric study [4] and a highway feasibility study [5] have been prepared and a multi mode feasibility study [6] is underway.

The Multi-State System area, which is illustrated in Figure 1, is of particular interest to this research for the following reasons:

1. It is a linear area or corridor which permits consideration to be restricted to simple networks of new transportation facilities.
2. It is largely undeveloped, simplifying the problems of economic modeling.
3. Transportation services at present are limited, creating substantive opportunities for improvement.
4. It lies in a region of high development potential in which sound early guidance can lead to large future benefits.
5. Sufficient past work has been done to simplify the data collection process.
6. The Multi-State Board provides outstanding support in all phases of the research.

The Multi-State Corridor contains four major metropolitan areas -- Jacksonville, Birmingham, Memphis, and Kansas City -- and a handful of cities with

TABLE 1
THE MULTI-STATE TRANSPORTATION
SYSTEM ADVISORY BOARD

Elton B. Stephens, Chairman
Kermit B. Blaney, Executive Director

ALABAMA
Hon. George Wallace, Governor
Hon. Ray Bass, Highway Director
Hon. David Vann, Mayor, Birmingham
Mr. Lyman Mason, Vice Chairman
Mayor Jack M. Brown
Mr. William C. Davis, Jr.
Senior Vice Chairman
Councilman Don A. Hawkins
Senator George D. H. McMillan, Jr.
Mr. Elton B. Stephens, Chairman
Mr. Sim S. Wilbanks

ARKANSAS
Hon. David Pryor, Governor
Hon. Henry Gray, Highway Director
Mr. Ralph McDonald, Vice Chairman
Mr. Frank Carlisle, Jr.
Mr. Jimmy Driftwood
Mr. J. E. Dunlap
Mr. Randall W. Ishmael
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FLORIDA
Hon. Reubin Askew, Governor
Hon. Tom Webb, Jr., Secretary, DOT
Hon. Hans G. Tanzler, Mayor,
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Mr. Tom V. Schifanella,
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Mr. William M. Godfrey
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Mr. Edward A. Mueller
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Councilman Victor F. Swyden,
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Mr. Robert Hunter
Mr. George Innes
Councilman David D. James
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TENNESSEE
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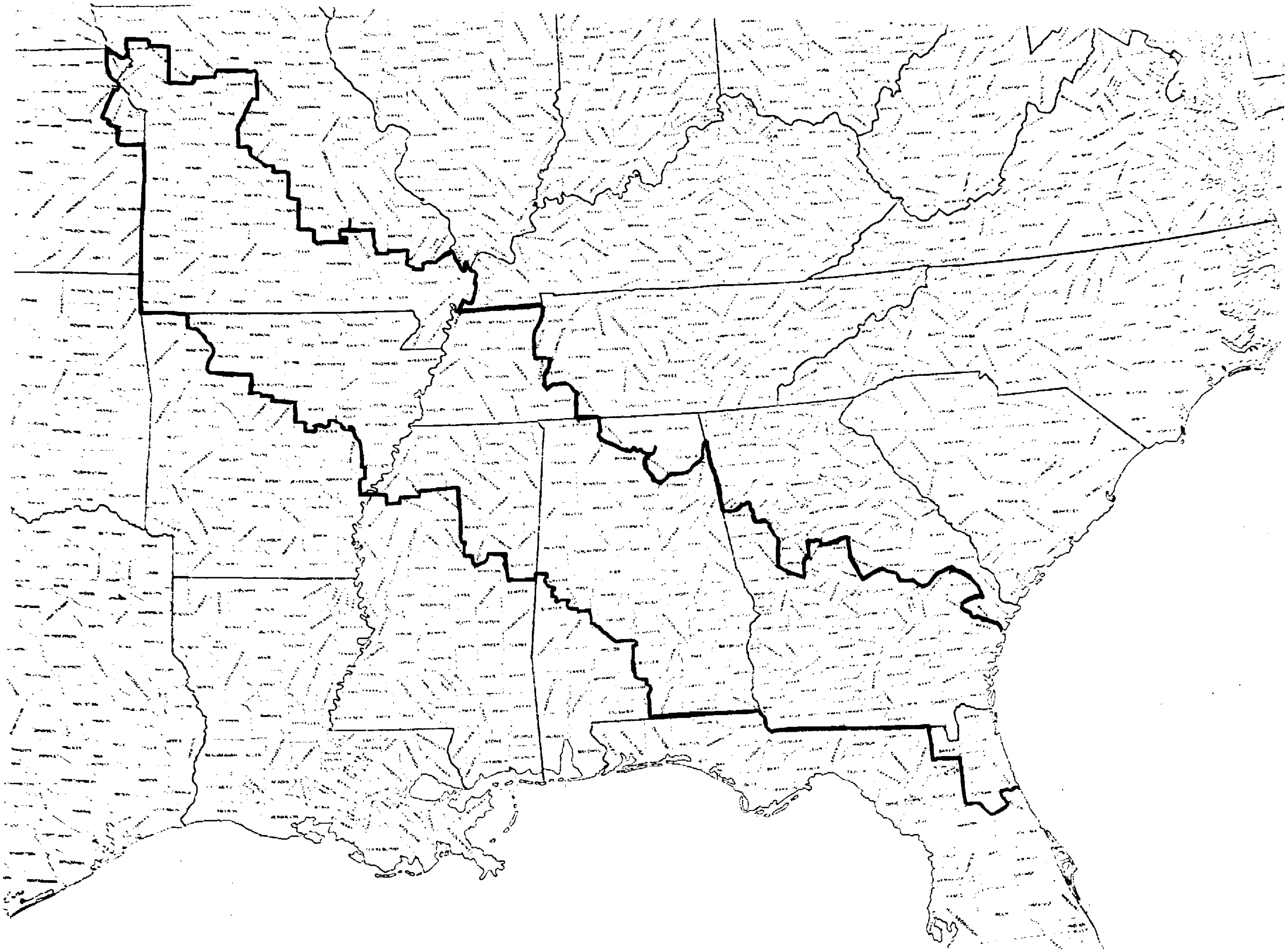
Hon. Wyeth Chandler, Mayor, Memphis
Hon. Roy Nixon, Mayor, Shelby County
DOT Commissioner Eddie Shaw, Vice Chairman
Mr. George Dando
Mr. Frank C. Holloman, Senior Vice Chairman
Mr. George Houston
Mr. Frank Palumbo
Mr. Jack Ramsay
Mr. Bruce C. Taylor

FIGURE 1
MULTI-STATE SYSTEM AREA



populations greater than 100,000 people (e.g., Columbus, Georgia, Montgomery, Alabama, and Springfield, Missouri). For the most part, the area is rural. A large fraction of the population is engaged in marginal agriculture. The rural populations have the lowest per capita income of any part of the United States. The corridor has some natural resources, notably coal, iron ore, and timber. It also has abundant water resources.

There has been some development in the Multi-State Corridor. Just to the north, under the stiumulus of the space program, Huntsville, Alabama has blossomed from an agricultural marketing center to a major research and engineering center. New facilities -- principally textile -- have been located in rural areas to take advantage of low wage rates and abundant unskilled labor.

The Multi-State Corridor is an ideal setting for new multi-modal development. New transportation facilities can be built without the citizen protests that accompany most major projects in urban and industrialized areas. Economic development is desperately needed to improve the lives of an impoverished population. The terrain is gentle, having few major geographic obstacles. It includes the base of the Appalachian chain and the eastern Ozarks. In addition, the predominantly rural corridor provides an opportunity to test whether substantial populations can be supported in rural areas without the necessity of migrating to major urban areas and contributing to a worsening of urban problems.

Traffic volumes in the Multi-State Corridor are not high. No interstate highway runs the length of the Corridor although a number cross it. Longitudinal roads are of moderate to poor quality. A main line of the Frisco Railroad traverses the area from Kansas City to Birmingham and a secondary main line of the Seaborad Coast Line Railroad continues to Jacksonville. Through freight service is available. The area is crossed by the major waterways of the Southeast including the Chattahoochee/Apalachicola Rivers, the Tennessee-Tombigbee project, the Tennessee River, the Mississippi River, and the Missouri River. Ocean port facilities are located at Columbus, Georgia, Birmingham, and Decatur, Alabama, Memphis, and Kansas City.

Scope

The process of selecting and locating transportation facilities and services and thereafter planning industrial development along transportation routes is an extremely complex one. In particular, the knowledge, effort, and expense to perform specific location studies suggests that one should not launch into detailed planning without a high probability of success. What is apparently called for is a screening process by which the problem can be viewed in several levels of detail, with each level narrowing the scope of study for successive work.

This research is viewed as the first of a succession of screening steps. The product of this work is an analytical method that can identify potentially attractive transportation development opportunities in terms of the industrial development that each can stimulate. The transportation services are identified in terms of mode, capacity, and approximate route. Details concerning alignment, design, points of ingress and egress and specific technology are left for later study. Development opportunities are described in terms of industry group, approximate location, approximate markets, and approximate size. Details concerning specific products and activities, raw materials, specific location, and corporate ownership are left to others.

The research is concerned only with basic industry -- that is new facilities that will produce goods or services that are largely exported from the producing area to national markets. The total market for each industry group is assumed to remain fixed with respect to size and location. Thus, new facilities built in the Multi-State Corridor must compete with existing facilities for existing markets. Market competition among competing suppliers is conducted on the basis of cost. Product quality is assumed to be equal. This assumption, in effect, treats new facilities as though they are branch plants for which higher management has the authority to allocate production on the basis of cost.

Secondary, nonbasic, or multiplier effects of new facilities are not considered at this time nor are the development of new market demands induced by the establishment of new facilities. Although both issues are of immense importance to the development of the Multi-State Corridor, consideration of these issues is postponed to a later date.

Consideration is given only to freight transportation. Although passenger transportation is an important part of highway use, it is not studied at this time. By omitting passenger transportation, it has also been necessary to omit tourism from the candidate developments. Tourism has great potential in the Multi-State Corridor, particularly along the Georgia and Florida coasts and in the Ozark Mountains. It fully warrants later consideration.

The industrial markets used to test new development opportunities are restricted to the 48 contguous to the United States. Alaska, Hawaii, and

Puerto Rico are grosely lumped with overseas markets for the purposes of the present work. At a later time, overseas and export opportunities will be examined.

Many alternative transportation services can be identified. It is expected that several of these will be attractive from different view points. The alternative services will be assembled into programs, each of which represents a complete transportation strategy for the Multi-State area. Programs will be evaluated and compared in terms of complex criteria that include traffic volume, economic development, user benefits, employment, potential profit, and others. Specific environmental and public acceptance issues will not be addressed at this level of analysis.

Task 2

Task two is a preparatory step in the multi-mode investigation. Its specific objectives are to:

A. Review and compile data on transportation and industrial development,
B. Identify key industry descriptors and cluster industries into groups for analysis,
C. Develop a structure of geographic zones suitable for the analysis and evaluation of transportation and industrial activities, including zones within the multimodal corridor and external zones, and
D. Perform preliminary transportation analysis which shall inlcude the establishment of information on a base transportation load reflecting present transportation activities and patterns of movement.

These objectives have been met in the manner described in this report.

II ANALYTICAL FRAMEWORK

The research is concerned with examining a very large number of potential transportation projects. These are combined into an even larger number of transportation programs, each of which will support different economic developments on a different time schedule. The analytical method focuses first on new transportation services and facilities and thereafter on the developmental and economic consequences of the new services and facilities.

In underdeveloped regions, the transportation planning process needs to focus on opportunities rather than on deficiencies. Present traffic levels are low because economic activity is limited and because highways, railroads, and waterways are often of secondary quality. In these regions, the patterns of economic activity cannot be predicted from past trends because past trends lead nowhere. If the region is to grow economically, new breakthroughs are needed. New industry must be established in locations that were not heretofor possible. Future growth depends on the ability to identify, locate, and exploit these new opportunities.

In this context, transportation facilities and services play the role of triggers to industrial and economic development. Lower cost or higher quality transportation services provide an incremental advantage that aids the marketability of products and services produced by a new enterprise. This incremental advantage can represent the difference between success and failure in launching the new enterprise.

The impact of new transportation services and facilities is not limited to new economic ventures. New transportation services will serve both new and existing industry and commerce. In some instances, the incremental advantage provided to a new enterprise will be more than offset by a similar or greater advantage realized by an existing enterprise. Thus, it is necessary to examine the complex impacts that a new transportation service can have on all conceivable industries in all locations.

The transportation routes of interest are not confined to the Multi-State Corridor. Because of the multi-modal focus of the work, many shipments can take advantage of the new facilities. Some traffic will both originate and terminate outside the corridor or both. To the extent that new highway and rail facilities tie into existing networks, traffic can take advantages of new high quality links for a variety of trips. Modal interchange terminals will be also considered so as to make maximum economic use of inter-modal combinations.

The Analytical Problem

The analytical problem is to jointly identify a set of potential transportation services and facilities and the development opportunities that will result from their construction and operation.

It is made up of two distinct parts (see Figure 2). In Part 1, the analytical framework is established and the necessary data are prepared. In Part 2, specific transportation improvement programs are postulated and their impacts are measured and evaluated.

The Analytical Framework

The analytical framework is expressed in terms of commodity flow between pairs of network zones over existing transportation routes.

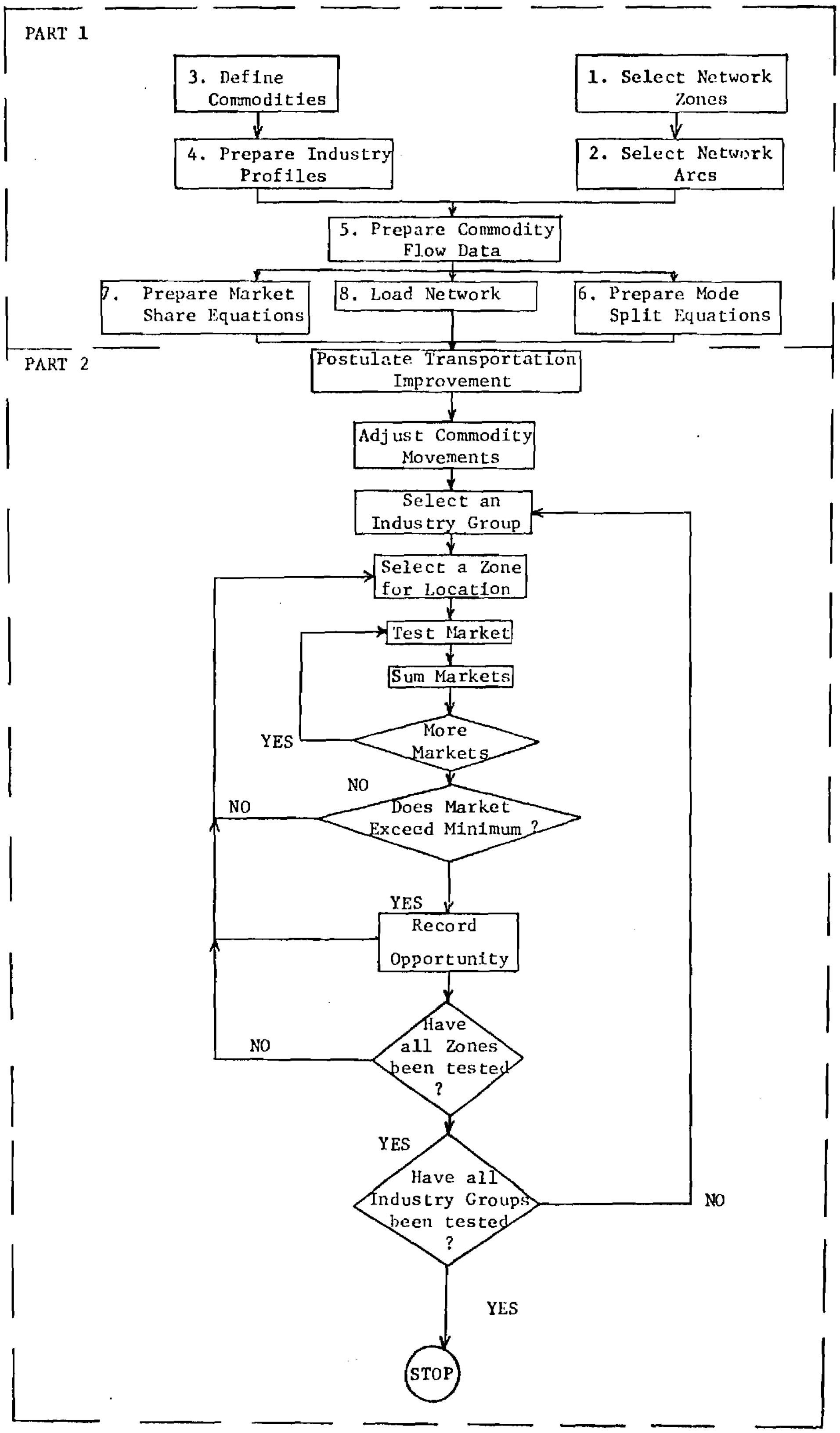
Network Zones

Network zones are identifiable areas where principle commodity movements originate or terminate. A variable zone size structure is used to provide detailed analysis of the Multi-State Corridor without burdening the analysis with an excessive number of zones. Zones within the corridor are small and reflect areas where new development might occur. External zones are larger because they are of interest only as markets, as sources of raw material, or as sources of competing production. As zones become remote from the corridor, they become very large because precise locations have less significance to corridor activity.

Each zone designation consists of a boundary and a representative city or centroid. All zones include an integer number of counties. Within the corridor, zones include about ten counties and generally conform to the districts that have been formed for comprehensive planning, e.g., Area Planning and Development Commissions in Georgia. Adjacent to the corridor, zones consists of the input-output sectors developed by the Office of Business Economics (BEA*) that include twenty to thirty counties. The choice of BEAs was based on their individual homogeneity and the availability of commodity flow data. The major disadvantage of BEAs is that many cross state boundaries. As zones become more remote from the corriodr, BEAs are combined for form large zones. In all, there are 120 zones in the network. A zone centroid is generally the largest city in

*Basic Ecnomic Area

FIGURE 2
ANALYTICAL PROCEDURE



a zone. Where the choice of a centroid is not obvious, locations of major transportation routes are taken into account.

Network Arcs

Network zones are connected by arcs that represent the different transportation facilities that are available. Separate arcs have been identified for highway, rail, and water modes. Additional arcs can be added for postulated new facilities. Arc impedences reflect travel time, cost, and travel time variability.

Network arcs constitute the major routes for each mode over which interzone traffic is carried. Intrazone traffic is not included in the analysis. Arc designations are related to zone size. Arcs connecting the small zones in the Mutli-State Corridor consist of almost all intercity cargo routes. As zones get larger, more intercity routes are omitted because they are not carrying significant amounts of interzonal traffic. For example, the highway network includes Interstate, Federal Aid Primary, and some state routes between the small corridor zones. In contrast, the network arcs between large zones have few routes that are not Interstate Highways. Similarly, the rail network contains most through routes within the corridor, but only principle routes outside. The water network contains major intra and inter-coastal services as well as all inland waterways with seven foot channel depth or more.

Network arcs are described in terms of length, capacity, mean speed, or travel time and travel time variability. Where two or more routes are combined in a single arc, length and speed are determined for the higher quality route. The second route serves as additional capacity when the higher quality route became congested.

Commodities

Commodities are amalgamations of the products of more or less homogeneous groups of industries. Each group is identified in terms of the Standard Industrial Classification (SIC) Codes. Fifty-three different commodity/industry groups have been selected for analysis. This number represents a compromise between a desire for simplicity and the need to recognize some of the important differences within two digit SIC classifications. The intention was to select industries that can be represented as a single mean, whose products have similar market and transportation characteristics and whose industrial facilities are comparable.

An industrial profile was prepared for each commodity. The profile describes the industry that produces the commodity in terms of raw material quantities, direct labor hours, indirect labor cost, energy cost, tax cost, and capital investment. Material costs are location sensitive as is direct labor cost. Mean wage rate helps to identify labor skill requirements. Indirect labor is assumed to be a function of industry organization and overhead structure and is made up of a fixed charge plus a charge that is proportional to output. Energy cost is location sensitive. Capital investment is independent of location. Taxes and transportation depend on location. Transportation modal choice is intended to be commodity specific but independent of specific origins or destinations except as they influence the characteristics of the available transportation services. Market mechanisms consist of price elasticity of demand estimators that relate market share to price.

For each industry, major production and market areas are identified by zone from commodity flow data. These data, as modified, give origins and destinations by zone for each commodity group. To simplify the analysis, zones that account for very small amounts of production or consumption are omitted from the detailed investigations.

Commodity Flow Data

Commodity flow data always pose a problem Although many pieces of commodity flow data are available, assembling the complete fabric is almost impossible. Three principle data sources were used: NTP Commodity Flow Projections, largely based on the 1972 Census Commodity Transportation Survey, or (CTS Data) [9], the Census of Transportation [10], and the Census of Manufacturers [11]. The NTP data as compiled by U. S. DOT were the principle source. These data are more complete than other sources and provide BEA to BEA movements. However, they are divided into only 20 commodity groups which mask many potential development opportunities in the Multi-State Corridor. Both Census sources are available in finer commodity detail. However, both suffer from disclosure problems.

Considerable effort has been expended in using Census and other data to break down the NTP data into 53 commodity groups and to further divide them into the smaller corridor zones. The process is described in some detail in Chapter IV. The modified commodity flow data are loaded onto the network to provide the structure against which new opportunities are measured. This structure includes the locations of the major producing facilities in each commodity/industry group. It also includes the markets served by each facility and the commodity flow between producers and markets. Costs are calculated for each production facility. These costs are combined with the transportation cost over the most favorable route to yield an estimated cost at each market for each facility.

The Investigation of New Opportunities

Once the analytical framework is complete, the analysis focuses on identifying promising programs of transportation facilities and services in terms of their stimulus to economic development. The work begins by postulating and describing a set of new transportation services that has promise for supporting economic development in the Multi-State Corridor. Then the analysis focuses on testing those economic development opportunities.

The objective function combines the amount of labor employed in the Multi-State Corridor, the gross product of the corridor industry, and the transportation cost savings achieved in U.S. markets as a whole. Attractive development programs will show high values for the objective function. The research will find a good solution by comparing alternaive transportation programs. It does not necessarily lead to an optimal value.

The analysis is of necessity money based. To be successful, a new facility must be able to produce and deliver its products to a sufficient number of markets at a cost that is comparable to the costs of other facilities with which it must compete. The costs of delivering competitive products to a market place include the costs of (1) raw materials, (2) direct labor, (3) indirect labor, (4) energy, (5) taxes, (6) capital, and (7) transportation. The final measure of economic viability for a new industrial facility is whether it can compete in a sufficient number of markets to support a financially viable facility size.

When testing new facility types and locations, to identify development opportunities, the raw material costs, labor rates, energy costs, and taxes are characteristics of the elected locations. Transportation costs depend on sources of raw materials, on the locations of markets to be served, and on the amount and quantity of the services available between the new facility and its potential markets. Transportation cost and service are subject to change by the construction and operations of new transportation facilities and services or by using advantageous intermodal transfers.

The analysis proceeds in the orderly fashion illustrated in Figure 2. When the transportation improvements have been postulated, the first step is to adjust the routing of the commodity movements in the base commodity flow so that they can take advantage of the new transportation facilitieis and services. Next, an industry/commodity group is selected for analysis. A zone is picked, and production costs are calculated for that zone. Next, transportation costs are calculated from the new facility to existing markets for the products. Market costs for the new facility are set equal to production costs plus transportation costs. A market share is calculated for each market on the basis of relative costs. All market shares are summed. If the aggregation of the market shares is greater than the minimum sized facility for that industry, then a development opportunity has been identified. It is catalogued by zone, industry, and potential size. If the sum of the estimated market shares is too small, no opportunity has been found. In either case, the analysis proceeds to the next zone for which it tests the same industry.

When all zones have been tested, the one that can support the largest industry is selected. It is possible to fix one industry location and test for additional opportunities for the same industry. The analysis then proceeds in a similar fashion to test the balance of the industry/commodity groups. The product of the analysis is a set of opportunities with at least one potential location identified for each.

The incremental gross product and the incremental employment are calculated by zone for the potential new development and for the corridor as a whole. Total transportation costs are also calculated for all commodity movements and transportation savings brought about by the new transportation developments are recorded.

Summary

The following chapters describe the different components of the analytical method in greater detail. Chapter III describes the development of the zone structure. Chapter IV discusses the data manipulations that were used to prepare the commodity flow data. Chapter V presents the development of the industry profiles which are summarized in Appendix B. Chapter VI describes the selection of the network arcs which are listed in Appendix C. Finally, Chapter VII gives a brief discussion of the network analysis which will be presented in more detail in a later report.

III TRANSPORTATION ZONES

Because of the close relationship between transportation zones and commodity flow data, the zones and data sources were developed together. However, it is convenient to present the zone structure first because of its influence on the manipulations needed to develop the commodity flow data base.

A transportation zone structure was sought that would be detailed enough to reflect local movements within the Multi-State Corridor and yet general enough to retain analytical tractability. Some investigators, notably Harris [1], have worked with county sized zones. With more than 3000 counties in the continental United States, this degree of detail presents formidable data and analytical problems. Harris has been able to investigate only a limited number of transportation alternatives because of the time and expense associated with each investigation. Many investigators have used state sized zones. This size, while convenient from a data viewpoint, would have little value within the Multi-State Corridor because of its grossness. State data also introduce difficulties because of the large number of major production centers that straddle state boundaries -- e.g., New York, Philadelphia, Chicago, St. Louis.

Variable Zone Size

To achieve detail within the Multi-State Corridor without assuming too heavy a burden outside the corridor, a variable zone size structure was selected. Variable zone size structures have been used in a number of investigations, particularly state transportation plans (e.g., 7, 8) where gateways for entry to and exit from the state are more important than precise relationships among origins and destinations. These studies focus on present commodity movements and future movements that are based on a continuation of present relationships. Under these restricted circumstances, it is likely that the variable zone structures do not distort the analysis so as to lead to erroneous conclusions. However, no proof has been presented.

In the present research, the zone size, composition, and representation play key roles in identifying economic development opportunities for the Multi-State Corridor. Each zone is described in terms of its area and its nodal point or centroid. The centorid represents its zone in the following important ways:

1. Production Costs -- labor, material, energy and tax costs -- represent

costs throughout the zone.

2. Transportation costs and service to and from the zone are adequately represented by transportation costs and service to and from the centroid.
3. Intermode transfers are allowed to occur only at zone centroids.
4. All transportation arcs are represented by routes that originate and terminate at zone centroids.
5. Intra-zone movements are neglected as having no bearing on development opportunities.

These conditions do not appear to be unduly burdensome for small zones that contain one dominant urban center. However, small zones that have several candidate centroids and large zones with considerable rural area or with a varied urban development can present serious problems. No suitable proof is available to allay fears. The following discussion is merely intended to make a case for the reasonableness of the approach.

The first point concerning production costs requires either a homogeneity throughout the zone or a strong dominance by the centroid. It can be argued that on balance, the type or variation that occurs favors the acceptance of centroid costs as representative of either a large or a non-homogeneous zone. Some cost elements -- e.g., labor and taxes -- will be cheaper in rural or low density areas than they are in adjacent urban areas. Other costs -- e.g., transportation for raw materials -- are just as often higher in rural or low density areas. On balance, in today's industrial environment, urban costs are comparable with rural costs. If this were not so, firms would not continue to locate in urban areas in preference to rural areas. In fact, a major goal of this research is to identify the circumstances under which more industry will choose to locate in small cities or rural areas. Furthermore, the volume of activity in urbanized areas is sufficiently greater than that in surrounding rural areas to dominate the rural activity. Thus, if a single urban centroid exists, it will likely dominate a zone, and it is not unreasonable to represent the zone with the characteristics of the urban center. If several urban centers exist they should each be examined and the one selected for centroid that most closely approaches the mean characteristics.

Common carrier operations focus on terminals that are generally located in or near shipping centers. Long distance shipments are brought to the terminals for redirection to particular consignees. Thus, costs increase and service decreases as the distance from the terminal increases. This suggests that node centroids represent transportation costs and service only to the extent that the centroid dominates commerce in the zone. This situation is mitigated by the structure of private truck, barge, and bulk rail operations for which distance is the major determinant of cost and service. Under these circumstances, it can be argued that the zone centroid represents the zone if it is near the geometric centroid of commercial activity in the zone.

The requirements that all intermodal transfers take place at zone centroids and that transportation arcs terminate at centroids present three types of problems. The first is the requirement that modal routes intersect at or near zone centroids. For zones dominated by a single metropolitan area, this is not a problem. However, the centroid of small corridor zones may be foci of highway or rail or water activity, but not all three. The problem is particularly severe with regard to the inland waterways which intersect other modes only at major ports. Some accomodation is needed. The second problem concerns distant points for which large zones are desired. Transportation routes need to be somewhat distorted to preserve the essence of intermodal transfer opportunities that occur far outside of zone centroids. The third problem concerns the arid regions of the west that have sparse populations and sparse transportation networks. In a number of instances, no single location exists that serves as a transportation focus and as a center of intermodal transfers.

Intra-zone shipments pose an even more difficult problem. In small zones, intra-zone shipments may amount to little more than local drayage -- commerce between firms that are close together. While many of these movements represent important shipments from producers to customers they are often based on relationships that require close proximity. Participation in these exchanges of goods is not likely to be available to new establishments in the Multi-State Corridor and hence the intra-zonal movements can be neglected. In the larger, more distant zones, intra-zone shipments can be several hundred miles long. However, these large zones are sufficiently remote from the Corridor that transport distances from Corridor facilities would be extremely long, suggesting doubtful opportunities for new Corridor developments. A more likely eventuality is that a new Corridor facility would compete with an existing facility in a distant zone for a market in a third location. In this instance, the size of the distant zone may not pose a serious problem.

The selection of variable zone sizes undoubtedly introduces some errors. The size of these errors is not known at this time. It is reasonable to expect that the errors are no larger than the irreducible data errors, and are therefore acceptable. However, the final resolution of this problems must await a later point in the research.

Building Blocks

A review of available data reveals that a large number of different territorial subdivisions have been made for the continental United States. These have been used for regulation, rate making, data collection, evaluation, and a variety of other purposes by a alrge number of different organizations. Several have resulted from different organizations seeking geographical divisions that are smaller than states but larger than counties. Two of these are of particular interest. The U. S. DOT has done considerable work in terms of a set of 440 Transportation Zones. They have defined transportation networks for the different modes and they have collected a good bit of data on transportation facilities. Regrettably, no commodity flow data have been collected for these zones.

The Office of Business Economics of the Department of commerece has done considerable ecnomic analysis in terms of a set of 171 Basic Economic Areas (BEAs). In addition, U. S. DOT has prepared a comprehensive set of commodity flow data for the BEAs. On careful study, it appeared easier to translate facility data from Transportation Zones to BEAs than to translate commodity flow data from BEAs to the Transportation Zones. Therefore, the BEA was selected as the basic building block outside the Multi-State Corridor.

BEAs are too large for use within the Mutli-State Corridor. Each BEA contains about thirty counties. In all, the Corridor would contain only 12 BEA sized zones. This level of detail was judged unsatisfactory and a smaller building block was sought for use in the Corridor. The most suitable building block found was the Planning and Development District (PDD) which is comprised of about ten counties. PDDs have been designated by all Corridor states. In addition, data have been collected and local transportation studies have been performed by almost all PDDs within the Corridor.

Zone Selection Criteria

The selected buidling blocks -- BEAs and PDDs -- largely determine the zones in and near the Multi-State Corridor. Corridor zones are PDDs and the and the zones close around the Corridor are BEAs. However, this selection omits three-quarters of the nation for which zones larger than a BEA are desired. To define these larger zones, a basis is needed for combining BEAs in a manner likely to yield a set of zones that can support the analysis of the Corridor's commercial relationships with the nation.

Several criteria were selected to guide and evaluate the different combinations of BEAs:

1. Each zone should have a dominant urban centroid.
2. Each zone should have homogeneous economic activity.
3. Each zone centroid should be served by the transportation modes that serve the zone.
4. Each zone centroid should contain a major terminal for at least one transportation mode.
5. Each zone should have a major direction of access from each of the Corridor zones.

The first two criteria can be expressed quantiatively in terms of population and industry activity. The last three are expressed qualitatively, using transportation system maps and transportation data as principle sources.

Zone Selection

The zone selection process began with the designation of the PDDs within the Multi-State Corridor. The PDD boundaries do not match either the designated Multi-State Corridor Boundaries or the BEA boundaries. Thus, a uniform transition from PDDs to BEAs is not possible. The transition problem was resolved in two ways. First, the Multi-State Corridor boundary was adjusted to include an integral number of PDDs. The team felt that a larger number of small corridor zones is preferable to a too early transition to BEA-sized zones.

The interface between PDDs and BEAs contained some counties that were excluded from a selected PDD and the adjacent BEA and other counties that were included in both a PDD and the adjacent BEA. Extra counties were accomodated in one of three ways:

1. The county was added to the nearest PDD,
2. The county was added to the nearest BEA, or
3. The county was combined with other adjacent extra counties to form a sub-BEA sized zone.

Counties claimed by both PDD and BEA were awarded to the BEA if they fell outside the Multi-State Corridor jurisdiction. This action tended to preserve BEA integrity which was desirable for purposes of preparing commodity flow data. Counties that fell inside the Multi-State Corridor were awarded to the nearest PDD to preserve the small zone size nature of the Corridor. The resolution process produced a few small zones outside the Corridor, but in general, the structure conformed to the guidelines that were established for the variable zone sizes.

The next step in the zone selection was to develop the external zones from the BEA building blocks. The zones immediately around the Corridor were BEA sized or BEAs augmented with miscellaneous counties. The balance of the zones are made up of two or more BEAs. Candidate combination schemes were prepared to suit different selection criteria.

The first trial was based on the first two criteria -- dominant urban centroid and homogeneous economic activity. This effort sought to combine BEAs that shared common principle industries and that could focus on a single centroid Data on the value of shipments for the three largest commodity/industry groups were prepared for each BEA from the OBERS data for 1972 [12]. Adjacent BEAs were compared in terms of both the ranking and the size of their top three industries. Where two of the three industries agreed, a good match was found. Where only one agreed, but it was large, or where major industries were related, an acceptable match was found. This procedure was followed to identify a set of relatively homogeneous zones.

A modification was prepared to the first set of zones that reflects the major crop regions of the midwester and western states. Data on Water Resource Regions, grain districts, and timber districts were used to modify the midwestern and western zones. In most cases, proposed changes did not upset industry balances for industries that were very large.

The second trial was based on the third, fourth, and fifth criteria -- modal transportation routes, transportation terminals, and access from the Multi-State Corridor. The first step was to prepare maps of the major modal transportation routes. The highway map consisted of the Interstate and Defense Highway System augmented by a few federal aid primary routes where the interstate system did not fit the BEA structure very well. The railroad map contained the class A Mainlines as designated by the U. S. DOT, augmented with potential

Class A mainlines and a few Class B mainlines to round out a balanced network [13]. The waterway map included all of the inland waterways maintained by the Corps of Engineers together with coastal and intercoastal routes. In this trial, nodal cities were identified first in terms of their impacts on the transportation networks. Zones were collected around the nodal cities in a manner that generally reflected the market areas served by each city.

The two alternative approaches proceeded independently to complete zone designations for the 80 zones external to the Corridor. The two results were then compared. Twenty-one of the zones were identical. Differences among the balance were quite varied but many differences represented a choice between adding a BEA to one zone or another. These differences were resolved in conference to the satisfaction of all. The resulting zone map is shown in Figure 3. Zone centroids are listed in Table 2. Appendix A contains a complete list of the network zones, including the BEAs and/or counties included in each. This structure has been used throughout the balance of the analysis.

FIGURE 3
TRANSPORTATION ZONES

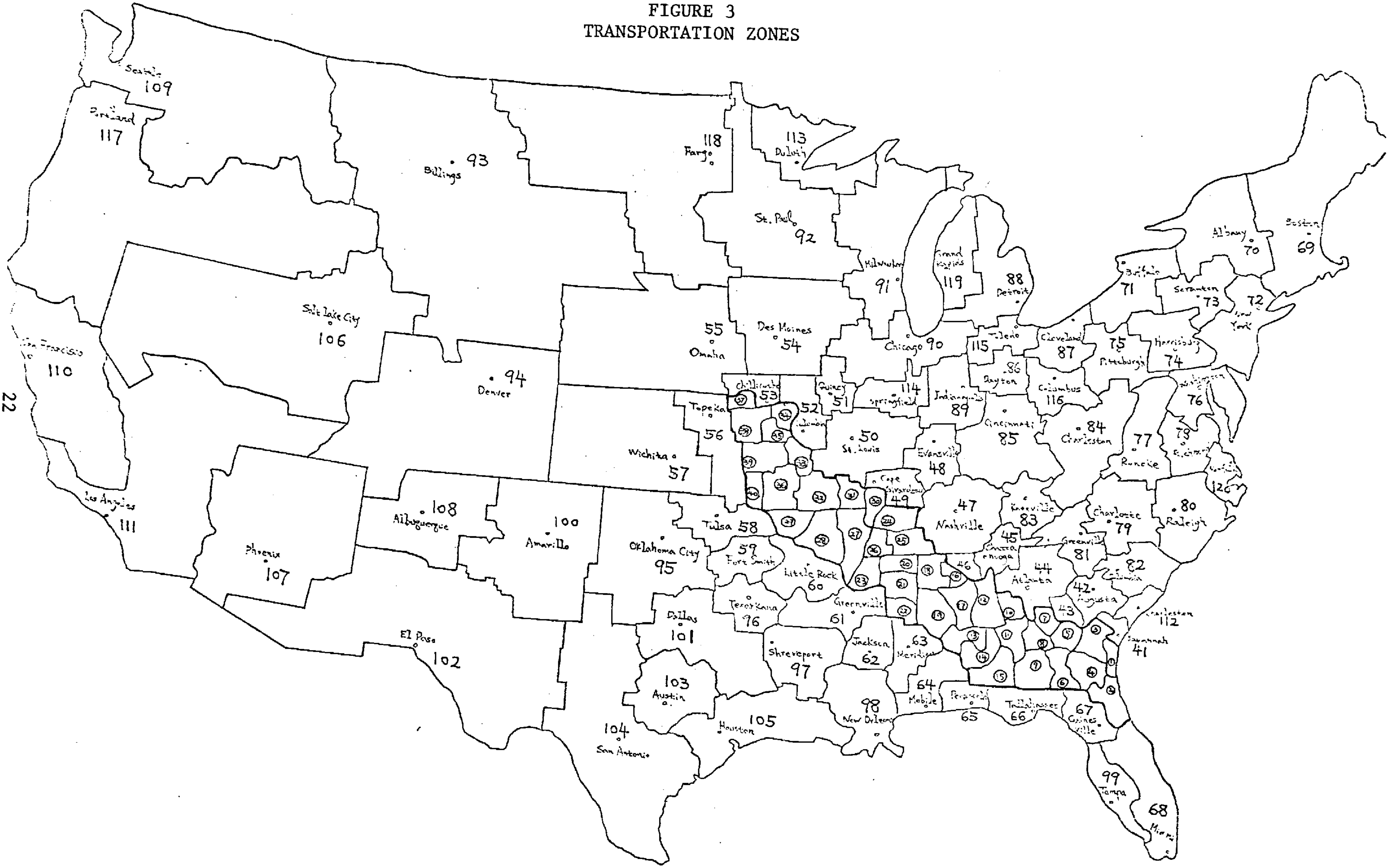


TABLE 2
TRANSPORTATION ZONE CENTROIDS

Multi-State Corridor Zones | External Zones

1.	Brunswick, Ga.	41.	Savannah, Ga.	81.	Greenville, SC
2.	Jacksonville, Fl.	42.	Augusta, Ga.	82.	Columbia, SC
3.	Statesboro, Ga.	43.	Milledgeville, Ga.	83.	Knoxville, Tn.
4.	Waycross, Ga.	44.	Atlanta, Ga.	84.	Charleston, WV
5.	Dublin, Ga.	45.	Chattanooga, Tn.	85.	Cincinnati, Oh.
6.	Valdosta, Ga.	46.	Huntsville, Al.	86.	Dayton, Oh.
7.	Macon, Ga.	47.	Nashville, Tn.	87.	Cleveland, Oh.
8.	Cordele, Ga.	48.	Evansville, In.	88.	Detroit, Mi.
9.	Albany, Ga.	49.	Cape Girardeau Mo.	89.	Indianapolis, In.
10.	LaGrange, Ga.	50.	St. Louis, Mo.	90.	Chicago, Il.
11.	Columbus, Ga.	51.	Quincy, Il.	91.	Milwaukee, Wi.
12.	Anniston, Al.	52.	Columbia, Mo.	92.	St. Paul, Mn.
13.	Montgomery, Al.	53.	Chillacothe, Mo.	93.	Billings, Mt.
14.	Troy, Al.	54.	Des Moines, Ia.	94.	Denver, Co.
15.	Dothan, Al.	55.	Omaha, Ne.	95.	Oklahoma City, Ok.
16.	Decatur, Al.	56.	Topeka, Ks.	96.	Texarkana, Tx.
17.	Birmingham, Al.	57.	Wichita, Ks.	97.	Shreveport, La.
18.	Florence, Al.	58.	Tulsa, Ok.	98.	New Orleans, La.
19.	Tuscaloosa, Al.	59.	Ft. Smith, Ak.	99.	Tampa, Fl.
20.	Corinth, Ms.	60.	Little Rock, Ak.	100.	Amarillo, Tx.
21.	Tupelo, Ms.	61.	Greenville, Ms.	101.	Dallas, Tx.
22.	Columbus, Ms.	62.	Jackson, Ms.	102.	El Paso, Tx.
23.	Clarksdale, Ms.	63.	Meridian, Ms.	103.	Austin, Tx.
24.	Dyersburg, Tn.	64.	Mobile, Al.	104.	San Antonio, Tx.
25.	Jackson, Tn.	65.	Pensacola, Fl.	105.	Houston, Tx.
26.	Memphis, Tn.	66.	Tallahassee, Fl.	106.	Salt Lake City, Ut.
27.	Jonesboro, Ak.	67.	Gainesville, Fl.	107.	Phoenix, Ar.
28.	Searcy, Ak.	68.	Miami, Fl.	108.	Albuquerque, NM
29.	Harrison, Ak.	69.	Boston, Ma.	109.	Seattle, Wa.
30.	Sikeston, Mo.	70.	Albany, NY	110.	San Francisco, Ca.
31.	Poplar Bluff, Mo.	71.	Buffalo, NY	111.	Los Angeles, Ca.
32.	West Plains, Mo.	72.	New York, NY	112.	Charleston, SC
33.	Lebanon, Mo.	73.	Scranton, Pa.	113.	Duluth, Mn.
34.	Marshall, Mo.	74.	Harrisburg, Pa.	114.	Springfield, Il.
35.	Sedalia, Mo.	75.	Pittsburgh, Pa.	115.	Toledo, Oh.
36.	Springfield, Mo.	76.	Washington, D. C.	116.	Columbus, Oh.
37.	St. Joseph, Mo.	77.	Roanoke, Va.	117.	Portland, Or.
38.	Kansas City, Mo.	78.	Richmond, Va.	118.	Fargo, ND
39.	Nevada, Mo.	79.	Charlotte, NC	119.	Grand Rapids, Mi.
40.	Joplin, Mo.	80.	Raleigh, NC	120.	Norfolk, Va.

IV COMMODITY FLOW DATA

Commodity flow data that describe the present movements of goods in commerce from producers to major markets are a key ingredient in the analysis of development opportunities. Unfortunately, accurate commodity flow data are not available in the form needed for analysis. This shortcoming is due to differences in the reporting requirements made of the different transportation modes, differences in the purposes of data collection efforts, omissions necessitated by disclosure regulations, and simply to the errors and omissions attendant to any massive data collection effort.

By far the best data available are the commodity flows for movements by rail. All railroads are common carriers and all commodity movements by rail are subject to regulation by the Interstate Commerce Commission (ICC). Furthermore, a one percent sample is taken each year of all carload rail shipments. For each waybill in this sample, data are recorded on commodity, origin station, destination station, shipment size, car type, milage, short line milage,* and revenue. Although the sample is but a small fraction of the shipments, it gives a good representation of moderate and high volume commodity movements between major terminals. Recent unpublished research by Day and Zimmerman and the University of California suggests that when treated in three year combinations the waybill sample does give a statistically reliable, railroad specific representation of commodity movements for two digit STCC** groupings.

Commodity movements by highway are much more difficult to estimate because of differences in regulations, less detail in reporting requirements, and the large number of non-regulated and private truckers. Truckers that generate substantial commodity movements can be generally divided into five categories:

1. Common carriers operating over prescribed routes in prescribed territories and subject to ICC regulations,
2. Common carriers hauling exempt commodities*** for back haul,
3. Contract (or irregular route) carriers acting as shipper's agents who carry goods that are subject to only limited regulations, with or without back hauls of exempt commodities,

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*Shortline milage is the length of the shortest possible rail route between origin and destination.

**Standard Transportation Commodity code.

***Exempt from ICC regulations; principally unprocessed agricultural products

4. Private truckers moving their own goods or exempt commodities* anywhere without restriction or regulation, and
5. Individual truckers or firms that move only exempt commodities without restriction or regulation.

A majority of all highway shipments are handled by private truckers who are not obliged to report on their activity except as they may be requested to make periodic inputs to the Census of Transportation surveys. In addition, all short hauls within designated terminals are free from regulations and reporting.

Even the reports of regulated motor common carriers are less detailed than are the railroad reports. Typically, highway carriers report only tonnage originated by commodity classification. They do not give geographical movement or shipment size data.

Data on commodity movements by water are subject to many of the same difficulties experienced with highway movements where private carriage also predominates. Many manufacturing firms operate tow boats and barges to carry their own products and supplies. The vast Great Lakes ore movements are almost entirely in private hands that are free from reporting requirements. Some companies also operate coastal and intercoastal steamship services. Common carriers by water that operate in inland waterways or in coastwise or intercoastal trade are subject to ICC regulations. However, like highway carriers they report only tons originated and carried by commodity.

The Corps of Engineers keeps some data on port and waterway activity. How-However, these data do not include origin to destination movements, nor are uniform data kept for all ports and waterways.

The commodity data problem has been recognized for a long time. In 1963, the Bureau of the Census undertook the first Census of Transportation. This survey and analysis has been repeated at five year intervals since. Manufacturers and producers are requested to provide data on a sample of individual shipments. including commodity, origin, destination, carrier mode, shipment size, route, and revenue where appropriate. These data are combined by geographical location industry group, and other measures and summarized in a variety of useful documents. The detailed data are subjected to disclosure protection before publication. Thus, geographical jurisdictions with three or fewer producers or consumers are eliminated from the published data. Disclosure problems are avoided by preparing larger amalgamations in terms of geographical area and

*Exempt from ICC regulations; principally unprocessed agricultural products.

commodity grouping. The fine grain data omit many shipments and therfore do not adequately represent small areas such as counties or specific commodities to the three or four digit STCC level.

If one amalgamates both by geography and commodity, completeness is achieved at the expense of detail. Some compromise is clearly indicated. The research team chose to use geographical amalgamations with commodity detail. This compromise did not give complete coverage but it provided a useful building block.

The Census of Transportation has focused on intercity movements and therefore has excluded shipments from its sample that travel less than 25 miles. This convention in no way affects the validity of the sample, but it does prevent reconciliation between the Census of Transportation and the Census of Manufacturers. In 1978, the Census of Transportation will sample from all shipping distances and it will reconcile commodity movements against the Census of Manufacturers. This step will be difficult but it will greatly enhance the value of both censuses.

The last source that was extensively used in compiling commodity flow data was the Census of Manufacturers. This five year census is both larger and older than the Census of Tansportation. It produces production data by county, SMSA, or larger areas by five digit SIC code. A large amount of useful information is collected, including employement data, wage and salary data, raw material cost, value added, and many other useful tidbits. Unfortunately, data for small geographical divisons suffer from disclosure problems and have limited usefulness. Statewide data are generally complete and reliable.

NTP Data

Assembling the available data into a reliable set of zone to zone movements for transportation analysis is an immense task. Fortunately, the Department of Transportation, through its Transportation System Center (TSC) in Cambridge, Mass. has undertaken this formidable task, and has made substantial progress. By combining the 1972 Census Commodity Transportation Survey with a special study of bulk commodity movements, TSC has produced what is likely the most comprehensive set of commodity flow data available for the United States. This work is adequately described in Reference 9. We will summarize those steps that have greatest significance to the Multi-State research.

TSC organized commodity movements into BEA zones of origin and destination. Use of the OBERS divisions in combination with the use of only 20 commodity classes, provided the amalgamation needed to circumvent disclosure problems and to fit available data sources. Table 3 lists the NTP commodity groupings together with the principle sources of each group: the CTS survey or the special bulk commodity study.

The major omission from the NTP data is movements of unprocessed agricultural products, except field crops. These data were omitted because of the extreme difficulty in identifying nation-wide commodity flows with reasonably uniform accuracy. Comparisons with Census of Transportation and Census of Manufacturers data suggest that the NTP set is remarkably complete. However, no specific check was made for completeness. We judged the data adequate to demonstrate the analytical method -- our first year objective.

The NTP data were made available to the project team on a magnetic tape that contains commodity by NTP group, origin zone, destination zone, mode split, and transportation cost for each mode. The specific fields on the tape are listed in Table 4. These data constitute the starting commodity flow data for all of the first year's analysis.

Commodity Groupings

The 20 groups used in the NTP data have some important shortcomings from the viewpoint of multi-mode transportation planning. Several industries of great importance to the Southeast have been included in the single miscellaneous category. These include tobacco, rubber and plastics, leather and stone, clay and glass. Lumber and wood have been combined with furniture and fixtures. Printing and publishing have been omitted, and all chemicals have been grouped together. In addition, metal working industries appear as only 3 categories -- fabricated metal products, non-electrical machinery, and electrical machinery. It is desirable to present a finer breakdown of these industries so that more specific industrial development data can be investigated.

In selecting the commodity breakdown to be used, the desire for greater detail was balanced against available data and the need to expand the 20 commodity NTP data set. There was also a strong desire to provide detail for those industry areas likely to be attracted to the Multi-State Corridor. Attractive industries could not be identified with any certainty at this early date, but attention was given to industries with relatively high labor input,

TABLE 3
NTP COMMODITY GROUPINGS

Commodity No.	Name	STCC Codes	Source
1	Field Crops	011	B
2	Forestry & Fishery Products	08,09	B
3	Coal	11	B
4	Crude Petroleum	13	B
5	Metallic Ores	10	B
6	Non-Metallic Minerals	14	B
7	Food & Kindred Products	20	C
8	Textile Mill Prod. & Apparel	22,23	C
9	Mfgr. Not Otherwise Identified	*	C
10	Chemical & Allied Products	28	B,C
11	Lumber & Furniture	24,25	C
12	Machinery (Except Electrical)	35	C
13	Electrical Machinery	36	C
14	Transportation Equipment	37	C
16	Paper & Allied Products	26	C
17	Petroleum & Coal Products	29	B,C
18	Primary Metal Products	33	C
19	Fabricated Metal Products	34	C
20	Miscellaneous Products	21,30,31,32,38,39	C

B = Bulk Survey

C = Census Data

* = This commodity group contains an amalgamation of all of the manufacturers that were removed from other groups to avoid disclosure.

TABLE 4
NTP MAGNETIC TAPE DATA FIELDS

Data Field	Description	Format
1-2	Year Code	I2
3-4	Commodity Number (Table 3)	I2
5-7	Origin BEA Code	I3
8-10	Destination BEA Code	I3
11	Transport Mode Code	I1
	1 = Rail	
	2 = Motor Carrier	
	3 = Private Truck	
	4 = Water	
	5 = Pipeline	
	6 = Air Freight	
12-21	Annual Commodity Flow (tons)	I10
22-27	Shipping Cost ($/ton)	F6.2
28-33	Time Value ($/ton/day)	F6.2
34-39	Time in Transit (days)	F6.2
40-51	"K" Value for Mode Split	E12.7
For a Mode Split Alternative:		
52-57	New Shipping Cost ($/ton)	F6.2
58-63	New Time Value ($/ton/day)	F6.2
64-69	New Time in Transit (days)	F6.2
70-79	Calculated Commodity Flow (tons)	I10

low to moderate capital investment needs and to industries that draw on resources known to be available in the Corridor area. After much consideration the team elected to expand the following areas beyond the two digit code:

10 Metal Mining,

20 Food & Kindred Products,

28 Chemicals & Allied Products,

30 Rubber & Miscellaneous Plastic Products,

32 Stone, Clay, Glass, & Concrete Products,

33 Primary Metal Industries,

34 Fabricated Metal Products except Machinery & Transportation Equipment,

36 Electrical & Electronic Machinery, Equipment, & Supplies, and

37 Transportation Equipment.

All other commodities were treated in terms of the two digit SIC (or STCC) commodity codes. This, itself represented some expansion of the NTP data.

Particular care was given to the selection of industry/commodity groups because each one is treated like a homogeneous industry for purposes of identifying economic development opportunities. Industry characteristics are discussed in Chapter V. The final list of 53 commodity/industry groups is presented in Table 5.

Commodity Flow Data Preparation

A commodity flow set was prepared from the data resources at hand to give zone to zone origin to destination movements for the zones illustrated in Figure 3 and the commodities listed in Table 5.

The NTP data were the source of zone to zone movement information. These data were adjusted using other data sources, to yield the desired form and detail. The principle source used for the adjustment was a magnetic tape of the 1972 Census of Transportation giving state to state movements of commodities to four digit detail. These data were exapnded where important disclosure omissions were observed and they were supplemented with demographic and employment data as required. The principle manipulations and data used to perform these manipulations are:

TABLE 5

COMMODITY/INDUSTRY GROUPS SELECTED FOR ANALYSIS

NO.	DESCRIPTION	SIC CODES
011	Grain	011
013	Field Crops	013,016,018,019
021	Livestock	021
024	Dairy	024
025	Poultry & Eggs	025
080	Forestry	08
090	Commercial Fishing	09
101	Iron Ore	101
102	Non Ferrous Ores	102,103,104,105, 106,108
110	Coal	11,12
130	Oil& Gas Extraction	13
140	Non-Metallic Minerals	14
201	Meat	201
202	Dairy Products	202
203	Canned & Preserved Food	203
204	Grain Products	204
205	Bakery Products	205
206	Confectionary	206
207	Fats & Oils	207
208	Beverages	208
209	Misc Food	209
210	Tobacco	21
220	Textile Mill Products	22
230	Apparel	23
240	Lumber & Wood	24
250	Furniture & Fixtures	25
260	Paper	26
270	Printing & Publishing	27
281	Industrial Inorganic Chemicals	281

NO.	DESCRIPTION	SIC.CODES
282	Plastics	282
283	Drugs	283
284	Soap	284
285	Paint	285
286	Industrial Organic Chemicals	286
287	Agricultural Chemicals	287
289	Miscellaneous Chemicals	289
290	Petroleum Refining	29
301	Tires & Tubes	301
302	Rubber & Plastic Products	302,308,304,306 307
310	Leather & Leather Products	31
324	Cement	324
321	Stone,Clay,Glass&Concrete Prod.	321,322,323,325 326,327,328,329
331	Iron & Steel	331,332
333	Non Ferrous Metals	333,334,335,336 339
341	Metal Cans & Shipping Containers	341
342	Fabricated Metal Products	342,343,344,345, 346,347,348,349
350	Machinery, Except Electrical	35
362	Electrical Industrial Apparatus	362
361	Electrical Machinery	361,363,364,365, 366,367,369
371	Motor Vehicles & M.V. Equip.	371
372	Transportation Equipment	372,373,374,375, 376,379
380	Measuring Instruments	38
390	Miscellaneous Manufacturing	39

1. Expand the NTP data from 20 commodities to 53 commodities using Census of Transportation data,
2. Compress the NTP data from BEA to BEA to zone to zone format for all zones containing more than one BEA, and
3. Expand the NTP data from BEA to BEA to zone to zone format for Multi-State Corridor zones, that are smaller than BEAs, using employment data by industry and other demographic data.

It is comvenient to divide the manipulation into three categories for descriptive puroses.

Category I: Products for Which NTP Commodities are used Intact (110, 130, 140, 290, 350)

This category is the most straightforward.

1. NTP commodity flow data were compressed to zonal data for the large multi-BEA zones. Other data were kept in BEA form. Thus

$$f^m_{ij\ell} = \sum_{L=1}^{Q} \sum_{J=1}^{K} d^m_{iJL}$$

where:

$f_{ij\ell}$ is the movement of commodity i from zone j to zone ℓ via mode m where j and ℓ are zones of the network,

d^m_{iJL} is the reported commodity movement from BEA zone J to BEA zone L via mode m, where zone J is part of zone j and zone L is part of zone ℓ

Q is the number of BEA zones in zone ℓ, and

K is the number of BEA zones in zone j.

2. Production in zones smaller than a BEA was estimated from employment data. The number of persons in each zone j that are employed by industry i was estimated using state directories of manufacturers, state labor department data, and other sources for the seven corridor states:

$$e_{ij} = \frac{E_{ij}}{\sum_{j=1}^{J} E_{ij}}$$

where:

e_{ij} is the fraction of industry i workers in BEA zone J that work in zone j,

E_{ij} is the number of employees in industry i in node j, and

J is the number of zones in the BEA that contains zone j.

3. Production reported for each BEA was allocated to the smaller zones comprising the BEA on the basis of the employment fractions developed in step 2.

$$\hat{P}_{ij} = e_{ij}P_{iJ}$$

where:

$\hat{P}_{ij}$ is the estimated production of commodity i in zone j,

P_{ij} is the reported production of commodity i in BEA zone J based on tons of commodity i originating in zone J.

4. Markets for commodities produced in sub-BEA zones was divided exactly as was production

$$d_{ij\ell} = e_{ij}d_{iJ\ell}$$

where:

$d_{iJ\ell}$ is the movement from BEA zone J to market ℓ

5. Markets in zones smaller than a BEA were allocated on the basis of population:

$$d_{ij\ell} = \frac{P_\ell}{P_L}d_{ijL}$$

where:

P_ℓ is the population of zone ℓ,

P_L is the population of zone L, and

d_{ijL} is the movement of commodity i from j to BEA L.

Steps 2 through 5 were repeated for all zones that are smaller than a BEA. Where small zones cross BEA boundaries, the calculations are based on a large zone, J or L, that is made up of two BEAs. The result of the analysis is a complete origin-destination matrix for each commodity i.

Category II: Commodities That are Part of Large NTP Groupings (201-209, 210, 220, 230, 240, 250, 260, 270, 281-289, 301, 302, 310, 321, 324, 331, 333, 341, 361, 371, 380, 390)

The second category is the largest category. It is somewhat more complex. than Category I because the NTP commodity flow groupings are sufficiently large to contain commodities with very different flow paaterns. For example, NTP category 5 contains all metalic ores. However, iron ore and bauxite have very different movement patterns. The NTP commodity flow data are revised to fit the network using additional data sources, principally the state to state Census of Transportation that reports four digit SIC commodities. By this procedure, BEA commodity flow data first are compressed for all multi-BEA zones, as for Category I.

Next, NTP commodity flow data are disaggregated into smaller classes using fractions developed from the Census of Transportation state to state data.

$$f^m_{ij\ell} = a^m_{iJL} \cdot d^m_{Ij\ell}$$

where:

$f^m_{ij\ell}$ is the movement of commodity i fron zone j to zone ℓ via mode m (j, ℓ, are BEA sized zones or multiple BEA sized zones),

$d^m_{Ij\ell}$ is flow of CTS commodity class I from zone j to zone ℓ via mode m as determined in Step 1, and

a^m_{iJL} is the fraction of CTS commodity class I moving from state J to state L via mode m that is represented by commodity i.

In this case, commodity i is a subclass of NTP commodity I, States J and L are selected to be those that most nearly approximate the economic behavior of zones j and ℓ. Thus

$$a^m_{iJL} = F^m_{iJL} \Big/ \sum_{k \varepsilon C_I} F^m_{kJL}$$

where:

F^m_{iJL} is the movement of commodity i from state J to state L via mode m, and

C_I is the set of commodities comprising NTP class I.

When the BEA commodities are allocated to the smaller commodity groups as outlined above, some BEA origins and destinations are divided among the smaller zones in and about the Multi-State Corridor. This was accomplished by the same procedrue outlined for Category I.

Category III: Commodities that are Part of Larger NTP Groups for Which Census Data are not Available (011, 013, 080, 090)

Of the four commodities in the category, three -- grain (011), field crops (013), and forestry (080) -- are of great interest to the Multi-State Corridor. Each commodity is combined with one other commodity in the NTP commodity flow data. The task is to separate the two NTP commodity groups into four in as realistic a manner as possible. This was accomplished by selecting one commodity and subtracting it from the total. The computational steps were as follows:

1. Compress BEA commodity flow data to conform to the large zones.

$$d_{ij\ell} = \sum_{q=1}^{Q} \sum_{k=1}^{K} d_{ij_{k\ell q}}$$

2. The originations were divided by sampling county data in each zone. A sample of five to ten counties was selected for each zone. In no case did sample size exceed 50 percent of the counties in the zone. For each county in the sample, state and federal agricultural data were used to estimate production for grain and field crops. Data were converted to tons and a ratio was computed.

$$g_{ij} = \frac{P_{ij}}{\sum_i P_{ij}}$$

where:

g_{ij} is the fraction of commodity i produced in zone j, and

P_{ij} is the production of commodity i in the sample counties of zone j.

Factors g_{ij} were computed for each zone.

3. Destinations focused on the commodity group whose market was easiest to identify. Thus in BEA group 1 (grain and field crops), the destination analysis focused on field crops (cotton, tobacco, sugar, potatoes). For BEA group 2, the destination analysis focused on forest products.

The destination analysis made use of the raw material data developed as part of the industry profiles. Industries were identified that have substantial raw material requirements from the commodities under study. Tons of raw material per ton of output were calculated for each industry. Using these factors, raw material destinations were calculated from industry outputs.

$$\delta_{i\ell} = \sum_{t} \gamma_{ti} P_{t\ell}$$

where:

$\delta_{i\ell}$ is the amount of commodity i that terminates in zone ℓ,

γ_{ti} is the ratio of raw material i to the production of commodity t, and

$P_{t\ell}$ is the output of industry t in zone ℓ. This value is equal to the originations of commodity t.

The $\gamma_{ti}P_{t\ell}$ products were summed over all industries.

4. Origin to destination flows were estimated by means of a simple gravity model:

$$d_{ij\ell} = \frac{g_{ij} P_{Ij} \delta_{i\ell}}{\Delta^{\beta}_{j\ell}}$$

where:

$d_{ij\ell}$ is the amount of commodity i that moves from zone j to zone ℓ,

$\Delta_{j\ell}$ is the network distance from zone j to zone ℓ, and

β is a coefficient.

The above steps produce commodity flow estimates for field crops and forest products. Estimates for grain are obtained by subtracting field crop estimates from NTP Commodity 1. Estimates for commercial fishing are obtained by subtracting forest products from NTP Commodity 2.

V INDUSTRY PROFILES

If a new facility in the Multi-State Corridor is to be successful, it must be able to market is products at a profit. The essence of this research is to determine the circumstances under which new facilities can be successful and to determine the contribution that transportation improvements can make to their success.

Market research, development planning, and other techniques have been devised to predict future economic change. Regrettably, past work fails to meet the needs of Multi-State development planning for one of two reasons -- either it is too narrow, of it is too broad. Market research is conducted for narrow industry segments -- generally specific products, often with particular brand identification -- always much narrower than the 53 commodity groups under study. In addition, the normal sequence of interviews and surveys is much too detailed a procedure to follow for 53 different commodity groups.

Development planning tends to lean heavily on the experience of the past and to deal with very broad industry sectors. The OBERS projections of future industrial growth by BEA represent the better and more comprehensive development planning work. However, this work has no mechanism with which to quantitatively measure the impacts of radical changes such as might be brought about by new transportation services.

In a similar manner, other approaches to development planning are set aside one by one. It remains for this research to devise a new procedure that can be used to identify and measure new opportunities. The new procedure is based on two key premises:

1. A new facility cannot effectively compete in an existing market unless it has at least a marginal advantage over some firms already supplying to that market, and
2. To succeed, a new facility must be able to compete successfully in at least one existing market.

The first premise introduces the concepts of market advantage and market share that are developed below. The second premise is the basis for disregarding local demands that are induced by new facilities. This and other local impacts are important, but they could not be adequately explored during the first year of research. They will be the focus of future work.

Market Advantage

The success of a new facility will depend on its ability to compete effectively with other facilities that produce the same or similar products for the same market or markets. To compete effectively in a market, the new facility needs some sort of marginal market advantage over one or more of the other facilities that supply the market. This marginal advantage can be in the form of production cost, customer service, product quality or some combination of the three. Each of these three parameters of market advantage has several dimensions. Thus production cost includes raw material cost, direct labor cost, indirect labor cost, energy cost, capital cost, and tax cost. These are all costs that are associated with producing a product at a specific location. Customer service includes delivery cost, delivery time, delivery dependability, maintenance support, spare parts support, and other activities that facilitate a customer's use of a product. Customer service concerns serving a particular market from a particular facility location.

Product quality includes design, material, workmanship, quality control, and other design and manufacturing related factors. The product quality criterion is not considered in this analysis because of the complexity and uncertainty of making useful comparisons. Instead, we have assumed that all competing facilities can produce products of comparable quality.

Production Cost

The cost of producing commodity i at a facility located at j is calculated as follows:

$$c_{ij} = \sum_{k=1}^{6} c_{ijk}$$

where:

c_{ij} is the unit of cost to produce i at location j, and

c_{ijk} is the unit cost of component k for product i at location j.

There are six cost components: raw material, direct labor, indirect labor, energy, capital, and tax.

Production costs depend on facility size, as well as component costs. However, size in turn depends on the number of markets that the facility can serve and on its market share in each. For purposes of the anlysis, a minimum attractive size was developed for each inudstry type. Costs were developed on the basis of this minimum facility size. To be considered feasible, a new facility must have market opportunities that are large enought to absorb the output of a minimum sized facility. If the market opportunities exceed the minimum, a larger facility could be built which could realize even larger cost advantages. To limit the complexity of the analytical process, additional cost advantages are not calculated.

Customer Service

Customer service is of a locational character. Its value depends on the specific commodity under study, on the specific location of the producing facility, and on the specific location of the market being tested. It includes some factors that are costable, others that are quantifiable, and still others that are not quantifiable. For the present research, a somewhat simplified approach has been followed to generate a dollar valued result. By this procedure, only three factors are considered: transportation cost, delivery time, and delivery dependability. All of these factors are influenced by the transportation mode selected and by the route chosen. The general form of the expression is

$$m_{ij\ell} = c_{ij} + \min_m \{t^m_{ij\ell} + f_{1i}\tau^m_{ij\ell} + f_{2i}\sigma^{2m}_{ij\ell}\}$$

where:

$m_{ij\ell}$ is the unit cost at market ℓ of product i when manufactured at location j,

$t^m_{ij\ell}$ is the unit transportation cost of product i moving from j to ℓ via mode and route m,

f_{1i} is the value of a unit of travel time to commodity i,

$\tau^m_{ij\ell}$ is the travel time for coomodity i from j to ℓ via mode and route m,

f_{2i} is the value of service dependability for commodity i, and

$\sigma^m_{ij\ell}$ is the measure of service dependability for commodity i from j to ℓ via m (equal to the standard deviation of delivery time).

Values of the coefficients f_{1i} and f_{2i} are taken from the results of the mode split analysis. These carry the implicit assumption that utility to the consignee is the same as utility to the shipper. The values of $t^m_{ij\ell}$, $\tau^m_{ij\ell}$ and $\sigma^m_{ij\ell}$ depend on the commodity i and the transportation mode and route m. They constitute the utility measure of the mode and route m. In addition to cost, time, and time

TABLE 6
MANUFACTURING INDUSTRY COST
DATA

Item	Description	Units
1.	Number of Companies	
2.	Number of Establishments	
3.	Establishments > 20 Emp.	
4.	Employees	Thousand
5.	Payroll	$Million
6.	Production Workers	Thousand
7.	Man-Hours--Production	Millions
8.	Wages	$Million
9.	Wage Rate	$/Man Hr.
10.	Value Added by Mfgr.	$Million
11.	Cost of Materials	$Million
12.	Cost of Goods Produced	$Million
13.	Beginning Inventory (12-31-71)	$Million
14.	Ending Inventory (12-31-72)	$Million
15.	Correction	$Million
16.	Cost of Goods Sold	$Million
17.	Value of Shipments	$Million
18.	Difference	$Million
19.	Capital Expenditures	$Million
20.	Structures & Additions	$Million
21.	Machy. & Equipment	$Million
22.	Gross Value of Fixed Assets	$Million
23.	Materials & Supplies	$Million
24.	Fuel & Energy	$Million
25.	Fuel & Energy	Bil. BTU
26.	Resale	$Million
27.	Contract	$Million

variability, utility could include volume and shipment size and may later be modified to reflect the level of traffic between j and ℓ.

Marginal Advantage

The marginal advantage that a new facility enjoys over another facility in a particular market, ℓ, is determined by comparing the sum of the first facility's production cost and customer service cost with a similar sum for the second facility. The expression for marginal advantage is:

$$\Delta m^{p}_{ij\ell} = \{c_{ij} + m_{ij\ell}\} - c_{ip} - m_{ip\ell}$$

where:

$\Delta m^{p}_{ij\ell}$ is the marginal advantage of a facility producing product i at location j and marketing it in market ℓ in competition with a producer at location p.

Other terms are previously defined.

The extent to which the new facility participates in the market at ℓ depends on values $\Delta m^{p}_{ij\ell}$, as reflected in a market share relationship.

Industry Cost Data

Each industry is presumed to be made up of facilities of varying size that each produce the common, homogeneous commodity that represents the group. Each manufacturing industry group (SIC 200+) is described in general terms in the Census of Manufacturers. These general data are modified and used to describe the characteristics of the industry.

Cost data were collected to satisfy the production cost equation. Census of Manufacturers data were extracted to complete the form illustrated in Table 6. Items 1 through 11 were taken directly from the census. Item 12 is the sum of material costs (item 11) and value added by manufacturing (item 10). When adjusted for the change of inventory, this should approximate the cost of goods sold. The reconciliations (item 18) were generally quite good. Some discrepencies were noted in industries where unit inventory values fluctuate (e.g., tobacco and plastic products). Resale income (item 26) came from sale of materials rather than products and contract input (item 27) was work on products performed by non-employees. In general, the data presented a reasonably credible picture of its industry.

Raw material data were also collected for each industry group from the census of manufacturers. Commodity groups that comprise more than ten percent of the total material purchases were identified as principle raw materials and the quantity used was noted. Raw material values were listed in the Census for all commodities, however, weights were not always included. Mean unit prices were difficult to find because of the breadth of the commodity groups. A number of different courses were used. Where no independent data could be found, Robert's [14] figures were used.

Mean facility characteristics were calculated for each industry group by dividing group totals by the number of establishments. The characteristics of interest included annual cost of goods sold, number of employees, direct labor cost, indirect labor cost, average wage rate, energy quantity, energy cost, and capital investment. These data are listed in Appendix B for all of the manufacturing industry groups.

We also sought a basis for estimating minimum attractive facility size for a Multi-State Corridor installation. The minimum facility size varies widely from industry to industry and is not readily discernible from published data. Many small facilities belong to private companies that are not obliged to publish financial data. For most industries, only three items of size information were available from the Census of Manufacturers: (1) the number of establishments, (2) the number of establishments with 20 or more employees, and (3) the total number of employees. These bits of information immediately give an impression of the number of small firms in each industry group. As might be expected, facilities with fewer than 20 employees predominate in some industry groups and are a factor in all industry groups.

Most indutries are characterized by a small number of large establishments that dominate the industry together with a very large number of small firms that play much less significant roles. The firms with 20 and fewer employees undoubtedly fall into the latter category in each case. To be attractive, a new establishment in the Multi-State Corridor need not become a dominant producer, but it does need to be large enough to have an impact on national markets.

A rationale was developed for identifying a minimum attractive facilty size based on the desire for a large if not a dominant facility size. If one were to rank in order all the establishments in increasing order of size as measured by the number of employees, the functional relationship can be approximated by the negative exponential density function:

$$f(w) = \lambda e^{-\lambda w}$$

where:

$f(w)$ is the number of firms with w employees, and

λ is the single parameter of the relationship.

The mean value of this function is $1/\lambda$. Thus the parameter λ can be determined from the mean facility size. If one assumes that the largest n facilities dominate the market, then a minimum attractive facility size might be the lower bound of the n largest facilities. Thus

$$\int_{w}^{\infty} \lambda e^{-\lambda w} dw = n$$

$$\text{or } e^{-\lambda w} = n$$

If n is set equal to 20 percent of the facilities, then

$$\dot{w} = 1.61/\lambda$$

Using this as a first approximation of the desired minimum facility size, the size was calculated for each of the 41 manufacturing industry/commodity groups as listed in Table 7 using constant output per direct labor employee. The characteristics of the different industries are presented in Appendix B. Data include major components and principal raw material needs.

Market Share

The existence of a positive $\Delta m_{ij\ell}^{p}$ does not assure that a new facility at j can displace the producer at p from the market at ℓ. In fact, the new facility may not capture as much of the market as the facility at p. However, the existence of a positive $\Delta m_{ij\ell}^{p}$ suggests that there is a strong likelihood that a new facility at j can capture some of the market at ℓ from the producer at p. The question to be addressed here is the size of the market share that a new facility might capture.

TABLE 7
MINIMUM FACILITY SIZE

Industry Group	Name	Employees	Capital Investment ($ Thousand)	Annual Cost of Goods Sold ($ Thousands)
201	Meat	111	851	12,416
202	Dairy	66	961	7,611
203	Preserved	147	16,917	7,745
204	Grain	58	1,475	7,385
205	Bakery	104	952	4,300
206	Confectionary	138	2,657	922
207	Fats & Oils	75	2,306	14,511
208	Beverages	94	2,273	8,322
209	Misc. Food	52	690	3,731
210	Tobacco	392	4,894	35,265
220	Textile	215	1,790	6,750
230	Apparel	90	155	1,925
240	Lumber	33	175	1,235
250	Furniture	81	2,310	2,300
260	Paper	169	4,530	8,277
270	Printing	40	355	1,432
281	Inorganic Chem.	153	4,002	11,398
282	Plastics	566	16,258	39,505
283	Drugs	203	4,589	16,636
284	Soap	70	832	7,408
285	Paint & Misc.	57	486	3,942
286	Organic Chem.	266	21,347	27,386
287	Ag. Chem.	63	782	6,277
290	Petroleum Ref.	111	8,954	26,750
301	Tires	839	19,427	49,619
302	Rubber & Plastic	91	607	2,786
310	Leather	137	139	3,027
321	Stone & Glass	60	851	2,157
324	Cement	244	27,056	15,624
331	Steel	525	17,990	25,350
333	Non Fe. Metals	135	3,491	9,631
341	Cans	229	4,615	15,676
342	Fab. Metal Prod.	79	518	2,921
350	Machy exc. Elec.	67	662	2,756
358	Refrig. Machy.	180	264	9,077
361	Elec. Machy.	220	1,773	8,339
362	Elec. Apparatus	200	2,039	6,576
371	Motor Vehicles	384	5,092	32,630
372	Trans. Equip.	271	1,553	11,097
380	Meas. Inst.	122	991	5,015
390	Misc. Mfg.	47	250	1,428

The size of the new facility's market share will depend on the nature of the industry i, the corporate affiliation of the new facility, and on the competition within the industry. The nature of the industry is described by the Census data; notably:

1. The number of different firms that produce the commodity,
2. The ease with which new firms can enter the market in terms of capital requirements, raw materials, and market competition, and
3. Market growth opportunities based on historical trends.

The corporate affiliation of the new facility influences the ease with which the new facility's products will find a place in a particular market, and the amount of price competition that might occur. There are two extreme situations that illustrate what might occur.

1. The new facility may be built as a branch by a company that operates similar plants at other locations. In this case, the company can assign part of its existing market to the new plant. Such assignments are often made strictly on the basis of cost. The introduction of the new plant will change the company's assignment of production to different facilities, and it will change the assignment of markets to facilities. The presence of the new facility is not likely to change marketing practices or prices, although the introduction of a new facility may be tied to growth aspirations by which a company seeks a larger share in some markets.
2. A new facility may be built by a new company or by an existing company that is seeking to enter a new market through the new facility. In this situation the new facility will seek a position in markets where the company does not have one. Any of several lines of competitive strategy can be followed. Counter moves will be made by firms now filling the sought-after markets. Market entry may be difficult or impossible, depending on the resources behind the new venture and those behind competing firms.

Any successful development program will include new facilities that fall into both categories, as well as between them. However, the affiliation issue addresses who should build a new facility, not whether one should be built. Inasmuch as this research does not address the question of "built by whom?" we will assume that all new plants fall into the first affiliation category.

The "branch plant" assumption allows the analysis to avoid the issue of price competition for market entry, but it does not assure that each market will be served exclusively by the facilities that can offer the lowest cost deliveries to the market. Rather, each market will likely be served by two or more competing firms that may each ship from more than one facility.

Market competition is assumed in each market area. The nature of the competition depends on the nature of the commodity, the number of suppliers, and other factors. Competition is assessed independently for each commodity/industry group. However, all commodity assessments share two assumptions:

1. Each new facility will represent a small enough addition to industry capacity, that no large scale market impacts will occur.
2. New firms will have adequate financial resources to combat local destructive price competition if it should occur, so that steady state market shares can be reached.

On the basis of these assumptions, market price is assumed to be sufficiently stable to validate the cost analysis.

Market share is calculated from the following expressions:

$$s_{ij\ell} = f_i\{\Delta m^p_{ij\ell}\} \qquad p = 1, 2, \ldots.$$

where:

$s_{ij\ell}$ is the fraction of market ℓ for commodity i that is filled by the facility at j.

$f_i\{\ \}$ is a function of the commodity category.

Values for the functions will be developed from an examination of present shipping patterns as revealed in the commodity flow data.* These will be expressed as commodity zone of origin, zone of destination, transport mode split, and annual volume in tons. We will begin by extracting all commodity movements from the commodity flow data that exceed about one-third percent of the total movement. The origins of these movements are considered to be the locations of major producers and the destinations are the major markets.

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*This work has not been completed as of this writing. Results will be included in a later report.

Production costs will be estimated for each originating zone using the data of Appendix B as a starting point. The Appendix B data give nationwide averages for labor rates, material costs, energy costs, and taxes. Each of these factors is locationally sensitive and will be corrected to suit the conditions in the particular zone. Local wage rates are obtained from Labor Department sources, energy costs are obtained from ERDA sources, and taxes are obtained from local government sources.

Raw material prices are more difficult to determine. Bulk products of agriculture and mines have market determined prices. Producers of these materials typically receive the market price less transportation charges. Raw material prices for these commodities are estimated at the producing area, subtracting transportation costs from existing market prices to yield a set of estimated raw material source prices. Raw material costs at the different commodity producing zones are thereafter compiled by adding transportation costs to estimated raw material source prices. Manufactuered raw material prices are equal to the production cost as estimated here plus transportation costs.

Once production costs have been estimated for each producing zone of the commodity under study, market costs are estimated for each market that is now supplied from a producing zone by adding transportation costs to production costs. Where more than one transport mode is used, more than one market price will be developed. The result of this work will be a set of market costs for each major market, with a volume associated with each cost. These constitute the raw data for the market share analysis.

Market share as a function of marginal advantage will be determine by regression analysis for each commodity group. We hope that a single functional relation can be determined for each commodity, however, market specific determination cannot be ruled out at this time.

Potential market share for a new facility located in the Multi-State Corridor will be estimated for each market by comparing the price at which the new facility can deliver to the market with the prices at which those zones now serving the market can deliver to it. When all existing markets have been tested, the total output of a new facility will be

$$P_{ij} = \sum_{\ell>0} f_i \{\Delta m_{ip\ell}\} M_{i\ell}$$

where:

P_{ij} is the total output of a new facility at j that produces commodity i,

$M_{i\ell}$ is the total market at ℓ for product i.

It this output, P_{ij}, exceeds the minimum attractive facility size as identified in Table 7. then a development opportuntiy has been identified. If P_{ij} is less than the minimum attractive facility size, an opportunity has not been identified. In either case, the search continues with other zones and other commodities until all potential opportunities have been explored.

VI BASIC TRANSPORTATION NETWORK

The basic transportation network consists of the 120 zone centroids (nodes) and a set of arcs connecting pairs of nodes that represent the existing transportation routes and services. The basic network was developed for one mode at a time--highway, rail and water--and it will be described in terms of that development. However, to achieve network simplicity, the different modes have been combined. Thus, each network arc is described in terms of:

1. Terminal nodes,
2. The transportation modes serving the arc, and
3. Utility measures--cost, time and time variability--for each mode, that describe impedences to the flow of one ton of traffic

Network nodes provide for origination, termination, mode transfer and passage without mode change. Each modal activity is associated with characteristic impedences to flow. Each impedence includes cost, time, and time variability.

Each individual commodity/industry group has a factor that modifies tranportation impedence to take into account density, perishability and other commodity specific characteristics. This factor is applied uniformly to all areas and nodes.

Detailed network descriptions are presented in Appendix C for each of the three modes studied to date.

Highway Network

The highway network, illustrated in Figure 4, is made up of the principal freight supporting intercity routes that connect the different zones. The method of selecting highway arcs depended on the sizes of the zones connected. Two different approaches warrent discussion: (1) Corridor and adjacent arcs; and (2) remote arcs.

Corridor Arcs

The internodal distances between Multi-State Corridor nodes are on the order of 50 to 75 miles. Nodal cities are served by Federal Aid Primary, Secondary, state and county roads, but not generally by interstate highways. Many of the existing highways are not of sufficiently high quality to support significant truck traffic.

The quest for appropriate highway arcs began with state traffic density maps. In some instances these maps also contained truck traffic counts. A

FIGURE 4
HIGHWAY NETWORK

set of candidate arcs was selected from these maps on the basis of alignment and traffic volume. Alignment posed the greatest problem because of the number of highways serving communities that are not network nodes. In some instances, nodal areas were enlarged to include principal highways that do not specifically pass through nodal cities. The product of this initial quest was a set of probable truck routes connecting adjacent nodes and a few routes that connect non-adjacent nodes but that could not be construed as passing through any intermediate node. Each route was described in terms of one or more highway designations. In some instances, a route was made up of as many as three different highway numbers that jointly provide a path between the two nodes. In other instances, two or more parallel routes were identified.

State transportation officials reviewed all of the candidate routes. They suggested dropping some, adding others and modifying still more. Where two or more parallel routes were available, a preferred route was selected. The preferred route became the basic highway arc. All arc descriptions apply to this route. In cases where additional parallel routes are available, they are added to the arc description as extra lanes. The presumption is that as the basic arc becomes congested with traffic, the point will be reached where the cost and travel time on the basic route will deteriorate to the level of the parallel route. At this time, the uncongested parallel route will be preferable to the congested basic route because it will have less travel time variability. Thus the parallel routes will offer additional capacity for congestion relief. In these cases, the additional route description are included in Appendix C.

Non-Corridor Arcs

Non-Corridor arcs in the seven corridor states were developed in the same manner described for corridor arcs. However, arcs serving the more remote zones were developed in a different way. Long distance intercity movements take place predominantly on the Interstate and Defense Highway Network. Therefore, interstate routes formed the backbone of the remote highway network. Care was taken to include all interstate routes on the highway network. These were augmented with principal Federal Aid Primary routes where suitable interstate routes were not available.

The rationale behind using a network made up almost exclusively of interstate routes is as follows. Interstate routes are the highest quality intercity routes available and are preferred by truckers even at the cost of reasonable detours. Short distance intercity movements, within zones resemble Corridor intercity movements and use a variety of routes, including interstate routes. In as much as intrazone movements are excluded from the model. Interstate routes will support the predominant intrazone traffic.

Utility Measures

Utility measures for the highway arcs--cost, transport time, and transport time variability--were calculated from a variety of sources. Final values represent the best data that could be found. However, improvements could be made in individual values.

Transportation costs, expressed as cost per ton mile, were taken from the Whitten equations [17]. If:

LHM^n_{ij} = total line haul costs/ton of commodity n moving from zone i to zone j,

Then:

$$LHM^n_{ij} = \sum_{e \varepsilon E_M} p^{en} \sum_{g \varepsilon MCCA} \sum_{c \varepsilon C_M} d^{gc}_{ij} \cdot ML^{ec}_g \cdot I^n$$

Where:

E_M = set of trailer types,

p^{en} = fraction of commodity n using trailer type e,

MCCA = set of motor carrier cost areas,

C_M = set of highway classifications,

d^{gc}_{ij} = distance on arc i,j in MCCA g on highway class c,

ML^{ec}_g = highway line haul cost/ton mile for any commodity using trailer type e, highway class c in MCCA g, and

I^n = density multiplier for commodity n.

Three trailer types were used--van, refrigerated and tank. Cost areas are those established by the ICC for analyzing motor carrier costs [19]. Three highway classifications were used--interstate, federal aid primary and all other.

Costs per ton mile, ML^{ec}_g were calculated for each condition that occurs on a highway arc. These in turn can be extended as indicated in the equation to yield arc costs. Where an arc crosses a cost area boundary and where an arc is composed of more than one highway classification, weighted averages are prepared to represent arc costs.

Highway travel times were determined from estimated truck speed for each arc. Highway speeds are highly variable among arcs depending on grades, curves, lane width and other factors. Interstate highways generally provide for the highest speeds. Trucks can operate over almost all routes at the national speed limit of 55 miles per hour. In fact, in private conversations, common carrier truckers have admitted to keeping schedules that require drivers to consistently exceed the speed limit. Nonetheless, a speed of 55 mph has been used for all interstate highways. This speed includes rest and fuel stops. Speeds on lower quality routes were estimated with help from state highway officials who were asked to estimate travel times for the different routes comprising network arcs. Where expert estimates were not available, a speed of 40 mph was assigned to high quality roads through relatively level terrain and a speed of 30 mph was assigned to other routes.

Travel time variability comes from delays and from conditions that prevent the attainment of estimated speeds. Thus almost all variations result in longer than expected travel times. Excessive delays result from accidents, mechanical problems, undue driver fatigue or driver dalliance. Most such delays are of a short duration, rarely exceeding four hours.* If one considers that the likelihood of a delay is uniformly distributed over a trip, then the travel time variability is a function of trip time or trip distance. If:

LHV^n_{ij} = highway time variance in transporting commodity n from i to j

Then:

$$LHV^n_{ij} = \sum_{c \in C_M} k_c \cdot d^c_{ij} \cdot I^n$$

Where:

k_c = delay factor for highway classification c, and

d^c_{ij} = distance between i and j on highway category c.

No differentiation was made among trailer types when calculating travel time variability.

*Serious accidents generally destroy the cargo and are not counted as delays.

Loading and unloading times depend on commodity, trailer type, facility size, loading crew size, location and other factors. Times were estimated on the basis of commodity, trailer type and location only. Thus if:

LM_i^n = loading time per trailer for commodity n at zone i,

Then:

$$LM_i^n = \sum_{e \varepsilon E_M} p^{en} \cdot LM_i^{en}$$

Where:

LM_i^{en} = loading time per trailer for commodity n in trailer type e at zone i.

Loading time variability was also based on commodity and trailer type.

VM_i^n = loading time variation per trailer for commodity n at zone i.

$$VM_i^n = \sum_{e \varepsilon E_M} p^{en} \cdot VM_i^{en}$$

Where:

VM_i^{en} = loading time variation per trailer for commodity n in trailer type e at zone i.

Arc Lengths

Arc lengths were expressed in terms of the basic arcs, using state maps and atlases as principal sources of highway distances.

Highway Nodes

Highway nodes have impedence values that reflect the time and cost associated with loading and unloading trucks at the originating and terminating nodes. No impedence is assessed against trucks that are passing through a node while enroute to another node.

Loading and unloading costs were also based on thw Whitten equations. If:

LM_i^n = loading cost per ton for commodity n at zone i,

Then:

$$LM_i^n = \sum_{e \varepsilon E_M} p^{en} \cdot p_1^{en} \cdot MT_{g(i)}^e \cdot I^n$$

Where:

p_1^{en} = fraction of terminal cost for commodity n, trailer type e attributable to loading, and

$MT_{g(i)}^{e}$ = terminal cost per ton for any commodity using trailer type e in the MCCA associated with zone i.

Similarly, for unloading if:

UM_i^n = unloading cost per ton for commodity n at zone i,

Then:

$$UM_i^n = \sum_{e \varepsilon E_M} p^{en} (1 - p_1^{en}) MT_{g(i)}^{e} \cdot I^n$$

Lacking knowledge of p_1^{en}, we assumed that for all trailer types exactly half of the terminal expense is attributable to loading and half to unloading.

Rail Network

The rail network illustrated in Figure 5 and specified in Appendix C was developed in a manner similar to the highway network, but using different sources of data. Two classes of arcs--Corridor and non-Corridor-- were identified and developed by different methods. Nodal delays occasioned by switching movements play a key role in determining rail transportation times and time variations, and require careful attention when defining the network.

Corridor Arcs

Almost all intercity rail lines within the Multi-State Corridor have been identified as potential rail arcs. This has been done even though some lines are little used and of poor quality. The logic behind this step is that it is easier and cheaper to rehabilitate an existing rail line than to build a new one. Thus even a poor quality line represents a potential focus for future development should a future demand for rail service arise.

Branch lines were excluded because they serve only local traffic. By concentrating zone activities at the zone centroid, branch line originations and terminations are modeled as though they take place at the centroid.

The large number of rail lines in the Multi-State Corridor mode arc designations difficult. A practice was followed similar to that used in the highway network analysis. Each centroid was assigned an area that represents a notional terminal, encompassing rail lines that do not directly enter the centroid city proper. Network arcs were then selected from among the rail lines connecting the enlarged nodal areas.

FIGURE 5
RAIL NETWORK

Rail line quality was estimated from the zone maps prepared by the Federal Railroad Administration [18]. These maps show type of signaling and traffic volume on all rail lines. Line quality is generally reflected by traffic volume. Very low levels of traffic suggest a line of poor or marginal quality.

The selected arcs were checked against state rail plans, where available, and they were reviewed with a few railroad managements. Although the review was not complete, it did confirm the approach used.

In a number of instances, two or more parallel routes were identified. The highest quality route was selected as the basic arc. The additional routes were recorded to act as additional capacity in the event that the basic route becomes congested.

The ownership of different lines was recorded. To the extent possible, arcs were selected so that each arc is owned by a single railroad, or by two railroads known to cooperate. Interchange between railroads was restricted to nodes.

Non-Corridor Arcs

Non-Corridor arcs were developed from the FRA zone maps on the basis of traffic volume. For these arcs--like the non-Corridor highway arcs--we sought principal traffic carrying routes. We began by plotting all rail lines that carry traffic level 4 (5 to 9.9 million tons per year). If one uses an average train weight of about 4,000 gross tons, then level 4 represents about 4 to 7 trains per day. Main lines and prncipal secondary lines can be expected to support this level of traffic.

The level 4 route network provided most of the desired arcs. These needed to be augmented in the west with level 3 routes in order to complete paths from zone to zone. As with the corridor zones, some latitude was taken with the true routes of the lines. For example, the main line of the Union Pacific goes from Omaha to Ogden, Utah. Ogden was combined with Salt Lake City. Furthermore, although the line passes through Cheyenne, Wyoming, it was routed through Denver for analytical purposes.

Parallel routes and ownership were treated as for Corridor arcs. Because non-Corridor arcs are much longer, exclusive ownership was sometimes difficult to achieve. In these instances, the best available compromise was sought.

Utility Measures

Utility measures were developed for the rail arcs from secondary sources including time tables, speed estimates, opinion and published data. The values used in the analysis are reasonably representative, but they do not accurately reflect present operating practices in many instances.

Transportation cost per ton mile for each arc was calculated using the Whitten equations, which are somewhat more detailed for rail than for highway. If:

LHR^n_{ij} = line haul cost per ton of commodity n moving by rail from zone i to zone j

Then:

$$LHR^n_{ij} = \sum_{e \varepsilon E_R} p^{en} \sum_{g \varepsilon RCCA} \sum_{c \varepsilon C_R} d^{gc}_{ij} \left(\frac{M^{ec}_g}{q^{en}} + L^{ec}_g + k^{ec}_g \right)$$

Where:

E_R = the set of rail car types,

p^{en} = fraction of commodity n using car type e,

RCCA = the set of rail carrier cost areas [19],

C_r = the set of rail line classifications,

d^{gc}_{ij} = length of arc i,j in RCCA g on rail line classification c

M^{ec}_g = variable line haul cost per car-mile in RCCA g, line class c, car type e,

q^{en}_{ec} = tons per car of commodity n in car type e,

L^{ec}_g = variable line haul cost per ton mile in RCCA g, line class c, car type e, and

k^{ec}_g = fixed line haul cost per ton mile in RCCA g, line class c, car type e.

Rail line haul costs were also calculated for the different conditions by computer. Weighted averages were calculated for arcs crossing RCCA boundaries and for arcs containing end to end connections of different rail line classifications. Data for the different terms are contained in Whitten's report [17] or were taken from ICC or FRA publications.

Rail travel times were drawn from several sources. Schedule times for merchandise freight trains traveling over the designated arcs were used when available. Other travel times were estimated on the basis of number of tracks, signalling, line quality and terrain. For example, at one extreme merchandise trains traveling over first class single track lines under Centralized Traffic Control (CTC) through relatively flat country can maintain speeds of 35 to 40 miles per hour, if there are no intermediate switching movements. Intermediate switching is not an issue on short movements in and around the Multi-State corridor, but it is elsewhere. At the other extreme, way switching trains traveling over secondary main lines between Corridor nodes that have automatic block signalling and gentle terrain average only about 11 miles per hour. A variety of intermediate situations exist.

Line haul rail travel time variations are occasioned by routine delays in dispatching trains, variations in train weight and power, delayed meetings and accidents. These occasions all tend to increase travel time. With the exception of major derailments, they can be measured in hours per arc. They are expressed as a function of geography and rail line classification. If:

LVR_{ij} = line haul variability for a train moving from i to j

Then:

$$LVR_{ij} = \sum_{g \in RCCA} \sum_{c \in C_R} d^{gc}_{ij} \, LVR^{gc}_{ij}$$

Where:

LVR^{gc}_{ij} = travel time variation for rail line class c in RCCA g with grade and signal attributes from i to j.

Arc Lengths

Arc lengths were taken from railroad time tables giving mile posts, the FRA railroad zone maps [18] and from the Rand McNally Railroad Atlas [21].

Rail Nodes

Terminals and classification yards play a key role in the operation of railroads. Each individual railroad operates its yards and terminals in a manner that minimizes cost while facilitating the movement of traffic. The American railroads do not operate yards at all of the nodes of the transportation network, nor does the network have a node at each yard. Thus, some accomodation has been necessary.

Within the corridor, it has been possible to associate major yards with specific nodes without much difficulty. Thus the Seaboard Coast Line's new yard at Waycross, Georgia is easily located at the Waycross node. Major switching activities at Birmingham, Memphis, and Kansas City are properly located at these nodes.

Outside the Corridor, more accommodation has been needed. Major Norfolk and Western, Richmond, Fredericksburg and Potomac and SCL yards in the Richmond-Petersburg area have been concentrated at Richmond. Conrail's large Conway yard has been combined with other yards at Pittsburgh. As zones get larger, more displacement is needed. Conrail's Elkhart yard is shifted to Chicago, Southern Pacific's Roseville yard is shifted to San Francisco and so forth. Every effort has been made to preserve essential rail functions despite the necessary adjustments.

Classification functions were assigned to the yards at each node. Terminal switching occurs at every node and is an essential part of freight originations and terminations. The complexity of the terminal switching depends on the amount of activity at the node. Classification of through traffic occurs at several levels. In some yards minimum classification occurs when cuts of cars are transferred between local and through trains. In major classification yards, all arriving trains are broken up and their cars sorted into a variety of outbound destinations. At gateways two or more railroads interchange traffic. At its worst, this may involve two or more complete classifications* plus local movements between inbound and outbound yards.

Two types of rail node costs are identified--terminal costs and classification costs. In loading and unloading costs, let:

LR_i^n = total loading costs per ton of commodity n at zone i

Then:

$$LR_i^n = \sum_{e \varepsilon E_R} p_1^{en} \cdot \frac{F_{g(i)}^e}{q^{en}} + (p_2^{e,n} \cdot T_{g(i)}^e + p_3^{en} \cdot J_{g(i)}^{en} + b^n B^n)$$

*A terminal and switching company may also handle the traffic.

Where:

p_1^{en} = fraction of variable terminal car cost for commodity n, car type e attributable to loading,

$F_{g(i)}^{e}$ = variable terminal car cost per car of type e in RCCA associated with zone i,

p_2^{en} = fraction of variable terminal cost for commodity n, car type e, in RCCA associated with zone i,

p_3^{en} = fraction of fixed terminal cost for commodity n, car type e attributable to loading,

$J_{g(i)}^{e}$ = fixed terminal cost per ton of any commodity, car type e, in RCCA associated with zone i,

b^n = fraction of loss and damage claims for commodity n attributable to loading, and

B^n = loss and damage per ton of commodity n.

By this formulation, loading costs depend only on location as determined by the RCCA and commodity. Unloading costs are similar. If:

UR_i^n = unloading cost per ton of commodity n at zone i

Then:

$$UR_i^n = \sum_{e \varepsilon E_R} p^{en} \left[(1-p_1^{en}) \frac{F_{g(i)}^{e}}{q^{en}} + (1-p_2^{en})\, T_{g(i)}^{e} + (1-p_3^{en})\, J_{g(i)}^{e} + (1-b^n)\, B^n\right]$$

Classification costs are more zone specific. Thus, if:

CR_i^n = classification cost per ton for commodity n at zone i

Then:

$$CR_i^n = \sum_{e \varepsilon E_R} p^{en} \left(\frac{CL_{g(i)}^{e}}{q^{en}} + CF_{g(i)}^{e} \right)$$

Where:

$CL_{g(i)}^{e}$ = classification cost per car of type e at zone i, and

$CF_{g(i)}^{n}$ = fixed classification cost per ton of commodity n at zone i

The cost per car depends on the type of yard activity and the operations associated with each car classification. The fixed cost per ton depends on the capital investment and the level of classification yard use. If sufficiently detailed data were available, each zone could be given a unique value of $CL^{e}_{g(i)}$ and $CF^{n}_{g(i)}$. However, for present purposes only four levels of activity have been identified and associated with the different zones.

Terminal and yard time is even more difficult to establish than cost. Time spent in terminals in support of loading and unloading is heavily location dependent. It varies with the nature, amount and scheduling of way switcher and yard switcher crews and equipment. Pick up and set off times can vary from an hour or less to several days. Four categories of pick up and set off activity have been identified and associated with the different zones.

Classification time also varies widely. Some railroads follow the policy of dispatching trains on time regardless of the number of cars available for them. Other railroads hold trains for traffic accumulation or until particular inbound trains have been classified. A car late in arriving may have to wait a day or longer under the first policy, while under the second, the delay would only be a few hours. Classification times have been associated with the level of classification activity at each yard. Thus, if:

CRT_i = classification time per car at zone i

Then:

$$CTR_i = CL_{g(i)} \cdot CT$$

Where:

CT = normalized classification time per car.

Terminal and yard time variation is based on the likelihood of missing an outbound train, requiring classified services or requiring repair. Values are based on the quality of inbound and outbound rail service as an indicator of train frequency. Thus, where only daily outbound service is available, the variation in terminal and yard time comes in increments of one day, and the standard deviation is set equal to one day. Where more frequent service is available, the standard deviation is appropriately reduced.

Water Network

The waterway network was selected to include all major domestic waterways within the continental United States. This includes facilities to support both barge and ship traffic. Barge movements occur throughout the inland waterways, on the intercoastal waterway system, on the Great Lakes and across open seas. Ship movements are limited to those waterways that can accommodate ships of commercial draft. For the purposes of the first year's work, the movement categories are artificially restricted. Barge movements are considered only on waterways with channel depths less than 30 feet. All deep water movements are assumed to occur in ships. This is not an unreasonable decision because bulk commodities in coastwise trade are often towed in old ship hulls whose operating characteristics, except speed, resemble small bulk carriers.

Inland Waterways

All inland waterways with channel depths of seven feet or greater are included in the water network. Only those waterways that occur within large zones are omitted, e.g., the Columbia River and the Sacramento-San Joaquin Rivers. The network includes the Hudson River - New York State Barge Canal, the Savannah River, the Apalachicola/Chattahoochee River, the Alabama River, the Tennessee-Tombigbee project and the Mississippi River system including the Mississippi, Missouri, Arkansas, Illinois, Ohio, Kanawha, Cumberland and Tennessee Rivers and the Chicago Canal. Terminal points of each river are indicated in Figure 6.

It was difficult to fit the inland waterways into the zone structure, particularly in the case of the Mississippi River System. Major river ports were generally network nodes. However, several Corridor cities selected as nodes do not lie on the river, but the river flows through their zone and has port facilities within it. To provide realistic commodity flows, the water arcs were directed to some of these non-port nodes. In this fashion, the Mississippi River arcs pass through Jackson, Greenville, and Clarkdale, Mississippi and Dyersburg, Tennessee. Of these, all are within 15 miles of the river except Jackson, which is 45 miles from the river. However, for other reasons, Jackson was selected over Vicksburg as the zone centroid.

Deep Water Network

The deep water network includes the Great Lakes, the St. Lawrence Seaway, coast wise and intercoastal service. The Great Lakes - St. Lawrence Seaway system can accommodate ships up to 27 ft. draft. The coastwise and intercoastal

FIGURE 6
WATER NETWORK

traffic has been limited to the same ship size in order to include the Cape Cod Canal, the Delaware Maryland Canal and the Port of Brunswick all with 30 ft. channel depths.

Although direct routes are available between each pair of coastal nodes, coastwise shipping is modeled like a linear network with intermediate nodes. This convention slightly increases distances for longer trips, but no impedance is imposed on through movements so that longer shipments do not suffer an additional port penalty.

Utility Measures

Accurate utility measures for water movements were difficult to obtain. After careful analysis, the Whitten equations [17] were rejected because water costs generated with them were not consistent with cost data used for highway and rail arcs. However, a good alternative was not easy to find. Common and contract carriers by water are regulated by the ICC and they are required to report their financial and operating performance to the ICC. Unfortunately, these regulated carriers are responsible for only a small fraction of the water movements. Most domestic marine traffic--including the vast Great Lakes ore movement and major traffic in coal, petroleum and chemicals--is in private hands. Private carriers are under no obligation to report their performance. They do periodically report via the Census of Transportation surveys in which they receive disclosure protection. Similarly, operators carrying exempt commodities--notably grain--are under no obligation to report to the ICC.

The Corps of Engineers has made a number of studies of traffic on rivers and in ports. A study now underway will attempt to specify travel time, loading and unloading time and cost for a variety of port to port movements. In the absence of these results, the project team had to make do with what was available. Available data included reports to the ICC by common and contract carriers, Census of Transportation data on movements between states and past reports by a variety of study groups.

Using all available data, an expression was developed for barge movement costs. If:

LHW^n_{ij} = line haul cost per ton to move commodity n by water carrier from i to j,

Then:

$$LHW_{ij}^{n} = \sum_{g\varepsilon WCCA} TW_{ij} \cdot WL_{g} \cdot I^{n}$$

Where:

$WCCA$ = set of water carrier cost areas that are based on draft and maximum tow size,

TW_{ij} = time in hours for a tow boat to travel from i to j, and

WL_{g} = cost per hour for tow and tow boat operation in area g.

Hourly costs, WL_g, are based on modern tow boats powered by 3,000 to 4,000 horsepower engines, pushing maximum tows made of jumbo barges. Because of data difficulties, specific distinctions were not made among barge types.

Great Lakes, coastwise and intercoastal water movement costs are calculated in a slightly different way.

$$LHW_{ij}^{n} = \sum_{e\varepsilon E_W} p^{en} \sum_{g\varepsilon WCCA} d_{ij}^{g} \cdot WL_{g}^{e} \cdot I_{n}$$

Where:

p^{en} = fraction of commodity n using shipping configuration e,

d_{ij}^{g} = distance between i and j in g, and

WL_{g}^{e} = cost per ton-mile for any commodity using configuration e in WCCA g.

Only two configurations were used in the first year's work, liner and container type ships. Additional variations such as large bulk ships can be added in the future.

Travel times were also elusive on the inland waterways because they are heavily influenced by current, number of locks, traffic level, water depth and other factors which vary widely through the year. An expression was ultimately developed that considers only distance, speed and number of locks.

$$TW_{ij} = d_{ij}/s_{ij} + aL_{ij}$$

Where:

d_{ij} = distance along the channel between i and j,

s_{ij} = mean speed from i to j,

L_{ij} = number of locks between i and j, and

a = constant

Mean values of speed were selected for the principal waterways where available. Otherwise an upstream speed of 5 mph and a downstream speed of 7 mph were used. Lock operating times were examined for a large number of different locks. The constant a represents a mean traverse time including entry, gate operation, lift and departure.

Travel times for Great Lakes, coastal and intercoastal movements were based on average over water speeds of 16 to 18 knots. Allowances for leaving and entering port were included in loading and unloading time so as not to prejudice the convention adopted for long journeys.

Travel time variability for movements on rivers and canals is heavily influenced by the number of locks traversed, because this is where most delays occur. Thus, if:

VW_{ij} = travel time variation for water movement from i to j,

Then:

$$VW_{ij} = \sum_{g \varepsilon WCCA} a_1^g L_{ij} + a_2^g d_{ij}$$

Where a_1 and a_2 are constants for WCCA g.

Travel time variability for Great Lakes, coastwise and intercoastal movement is largely a result of weather. The likelihood of a weather delay is a function of distance, area, time of year and other factors. However, a simple function of distance has been adopted for the first year's work.

Arc Length

Arc lengths for the different water arcs were taken from nautical charts, channel descriptions and published reports.

Water Nodes

Water node activities are restricted to loading and unloading. No terminal impedances are assigned to through traffic. If:

LW_i^n = loading cost per ton for commodity n at zone i,

Then:

$$LW_i^n = \sum_{e \varepsilon E_W} p^{en} \cdot p_1^{e,n} \cdot WT^e_{g(i)} \cdot I^n$$

Where:

$WT^e_{g(i)}$ = cost per ton of any commodity using water configuration e in WCCA g associated with zone i

In this case, three configurations are used--barge, container and liner vessel. The cost factor includes daily port costs for the vessel, stevedore and crew costs divided by mean loading or unloading activity. Similarly if:

UW^n_i = unloading cost per ton for commodity n at zone i,

Then:

$$UW^n_i = \sum_{e \epsilon E_W} P^{en} (1-P^{en}_1) \, WT^e_{g(i)} \cdot I^n$$

Loading and unloading times are based on average productivity and include an allowance for entering and leaving port. Loading and unloading time variation includes allowances for productivity differences, dock congestion, stevedore availability and berth availability. These variations are port specific depending on the port facilities and the expected level of activity.

Intermodal Transfers

Two forms of intermodal transfer are common today, water-highway and highway-rail. In addition, there is some water-rail activity. Intermodal transfers can be broadly classified as break bulk transfers and container transfers.

In a break-bulk transfer, the inbound carrier is completely unloaded, the cargo is sorted by outbound carrier and the outbound carriers are loaded. Cost and time requirements to perform this kind of a transfer are closely related to loading and unloading costs. Thus if:

TT^n_{XYi} = break-bulk terminal transfer costs per ton of commodity n from mode X to mode Y at zone i,

Then:

$$TT^n_{XYi} = 0.8 \, [LY^n_i + UX^n_i]$$

Where:

LY^n_i = cost per ton for loading commodity n into mode Y at i, and

UX^n_i = cost per ton for unloading commodity n from mode X at i.

The use of a factor of 0.8 reflects loading and unloading economies that can be achieved at a transfer terminal. No special equipment is generally used outside of general purpose material handling equipment and conveyors.

Container terminals require large capital investments in sophisticated special purpose equipment, like container cranes, and in general purpose equipment, like yard tractors and chassis. In addition, large land areas are required for storing empty and loaded containers. The cost of operating a container terminal depends very heavily on the use made of the terminal's capital assets. Thus, if:

TT'^{n}_{XYi} = container terminal transfer cost per ton of commodity n from mode X to mode Y at location i,

Then:

$$TT'^{n}_{XYi} = \left[\frac{TC_{XY}}{V_i} + TO'_{XYi} \right] I^n/q^n$$

Where:

TC_{XY} = the equivalent annual capital cost of a transfer terminal to interchange between modes X and Y,

V_i = expected number of containers per year to be transferred at i,

TO'_{XYi} = operating cost per container to transfer between modes X and Y at i,

q^n = tons of commodity n per container.

TC_{XY} is calculated with interest at 20 percent per annum. TO'_{XY} depends on the terminal facilities and on labor cost and efficiency at location i.

Transfer times are based on productivity data for the different terminal types. If:

TTT'^{n}_{XYi} = break-bulk terminal transfer time for commodity n between modes X and Y at i

Then:

$$TTT'^{n}_{XYi} = UX^n_i + LY^n_i + a_i$$

Where:

a = a constant to account for expected accumulation and delay times at i,

and if

TTT'^{n}_{XYi} = container terminal transfer time for commodity n between modes X and Y,

Then:

$$TT'^{n}_{XYi} = \frac{N_X C^i_X}{2} + \frac{N_Y C^i_Y}{2}$$

Where:

N_X = number of containers expected on carrier X

C^i_X = expected cycle time for unloading carrier X at i

N_Y = number of containers expected on carrier Y

C^i_Y = expected cycle time for loading carrier Y

Unload and load cycles are generally equal and may be simultaneous at a container terminal. A uniform distribution is assumed for container location in a shipment. Thus, a given container may be unloaded at any time during the unloading operations.

Transfer time variability depends on productivity variations, equipment delays, crew delays, and other factors. Delay factors have generally been expressed as a fraction of terminal time.

VII TRANSPORTATION MODELING

The six preceding chapters have described the methods used to prepare a data base for joint transportation and economic development planning. In this chapter we will describe the procedures that have been devised and are under development for measuring evaluating and comparing the impacts of different transportation improvement programs. Inasmuch as the work is not complete at this writing (July 1977) some of the techniques are still speculative. They will be described in greater detail in the Task 5 report, to be prepared later.

Four topics are treated in this chapter--modal split, network manipulations, transportation improvements, and evaluation. Each plays a key role in the analysis. Each is treated in a preliminary manner with a description of key issues and a method of approach that is being followed in ongoing work.

Modal Split

Freight mode split work to date has been of limited scope. Most describes historical experience in a manner that reduces to a mode specific representation [22,23]. By mode specific is meant an expression for approximating the modal share of a particular mode that depends on paramater values and coefficients that must be developed for that particular mode. Thus a model used to predict rail modal share can do that, and no more. This kind of model has no value in predicting the transportation share that a new service can attract from existing services, because the necessary relationships cannot be constructed on any historical base. What is needed is a mode abstract modal split model. This model would be able to predict each mode's transportation share in terms of that mode's attributes and a set of coefficients that apply to all modes. Without a mode abstract modal split model, the impact new transportation services cannot be predicted.

It is equally important to have a single modal split model that can apply to all origin-destination (O-D) pairs. Otherwise, direct application is questionable for new production facilities that are attempting to establish new movements.

Mode split is determined by the arc utilities of the shortest path available between origin and destination. It is desirable that the mode split use some additive combination of arc utilities so that the most desired path between origin and destination can be determined by a conventional shortest path procedure. The utilities need not be directly additive because the logarithms of multiplicative utilities can also be added.

Finally, the mode split model must be developed from available data. This is a severe restriction because of limitations such as those described in Chapter IV. This suggests that at this time we must settle for mode split results that are less than one might hope for. With the continuous development of improved commodity flow data this shortcoming should be lessened in the future.

Utility Parameters

Shippers select transportation modes for many different reasons. These include cost, delivery time, delivery dependability, transit damage, frequency and availability of service, claim settlement procedures, corporate reciprocity and others. A complete set of parameter values tends to be situation specific as well as very difficult to obtain. Lacking complete information and the resources to make use of it, a fall back position has been taken that uses only three utility parameters: cost, transit time and transit time variability (the variance of transit time). Sources of data for these parameters have been set forth in considerable detail in Chapter VI.

The selection of modal shares is highly commodity specific. Therefore, it will be necessary to seek a separate modal split model for each of the 53 commodity groups. The existence of a single model for each group depends on homogeniety within each group. Since this does not exist, there will of necessity be errors in the models.

Analytical Data

The modal split analysis will use the commodity flow data described in Chapter IV. These data contain modal shares of existing movements for rail, private and common carrier truck and water. Unfortunately the data are not uniformly consistent for all modes. Careful examination of individual commodity records reveals that some movements known to be made by a particular mode are not included. Nonetheless, since no better data are available, we must make do as best we can. This requires careful review of all commodity flow data to be sure that questionable data are removed.

Model Form

The form of the desired modal split model is not known at this time. Five types are under investigation. These are:

Multiplicative:

$$F^n_{kij} = a_0 \, (C^n_{kij})^{a_1} \, (T^n_{kij})^{a_2} \, (V^n_{kij})^{a_3}$$

Where:

F_{kij} = flow of commodity n from i to j that travels via mode k,

C^n_{kij} = cost per ton to move commodity n from i to j via k,

T^n_{kij} = time required to move commodity n from i to j via k,

V^n_{kij} = time variance from commodity n moving from i to j via k, and

a_0, a_1, a_2, a_3 = constants

Impedance:

$$f^n_{kij} = \frac{\dfrac{1}{Z^n_{kij}}}{\sum_{m=1}^{M} \left[\dfrac{1}{Z^n_{mij}} \right]}$$

Where:

$Z^n_{kij} = a^n_{kij} \, [C^n_{kij} + b^a \, T^n_{kij} + v^n_{kij}]$,

f^n_{kij} = fraction of commodity n moving from i to j via k,

Z^n_{kij} = path impedance from i to j for commodity n via mode k, and

a^n_{kij}, b^a, v^a = constants

Linear:

$$f^n_{kij} = \frac{U^n_{kij}}{\sum_{m=1}^{m} U^n_{mij}}$$

Where:

$$U^n_{kij} = A_0 + a_1 C^n_{kij} + a_2 T^n_{kij} + a_3 V^n_{kij}, \text{ and}$$

U^n_{kij} = utility of mode k for commodity n from i to j.

Exponential:

$$f^n_{kij} = \frac{U^n_{kij}}{\sum_{m=1}^{M} U^n_{mij}}$$

Where:

$$U^n_{kij} = \exp\,(a_0 + a_1 C^n_{kij} + a_2 T^n_{kij} + a_3 V^n_{kij})$$

Modified Logit:

$$f^n_{kij} = \frac{U^n_{kij}}{\sum_{m=1}^{M} U^n_{mij}}$$

Where:

$$U^n_{kij} = \frac{\exp\,(a_0 + a_1 C^n_{kij} + a_2 T^n_{kij} + a_3 V^n_{kij})}{1\text{-}\exp\,(a_0 + a_1 C^n_{kij} + a_2 T^n_{kij} + a_3 V^n_{kij})}$$

Each of the models can be tested as presented above and in terms of a base mode, where for example:

$$\Delta C^n_{kij} = C^n_{kij} - C^n_{bij}$$

Where:

C^n_{bij} is the cost of the base mode and

ΔC^n_{kij} is the term that enters the modal split model.

Procedure

The following procedure will be followed to develop the model split models:

1. Extract the largest movements of commodity n from the commodity flow data (at least 40 movements).
2. Examine the data for credability based on intuitive grasp of mode split circumstances. Reject data outliers.
3. Conduct regression analyses of the data for the different models plus variations that may come to mind until acceptable results are achieved.

Past correlation work has not given good results. It is likely that the models produced will have shortcomings. These will be pursued as part of the second year's research.

Network Manipulations

Network manipulation procedures need to be devised that can (1) load the commodity flow data on the transportation network, following paths of lowest utility; (2) determine transportation costs from sources to markets for all commodities and add these to production costs; (3) seek out means to best use the multi-modal opportunities presented by new transportation facilities and services; and (4) provide evaluation measures for comparing alternative transportation programs.

The network task is greatly complicated by the need to manipulate large quantities of data. The network structure, with 120 nodes and 400 arcs is not, in itself, alarming, but when the problem is compounded by the need to deal with 53 different commodities, the data problem becomes formidable. A set of six interconnected computer programs is being designed. The function of each program is briefly outlined below.

Network Construction

Because of the mass of data, a special program is being written to combine the arcs of the different modes into a single network. This program will also calculate arc and node utility for each arc, node and commodity.

Trees

This program will find shortest path, single mode, routes for each mode pair and each commodity, taking into account transportation arc and node costs. To reduce calculation and data storage needs a composit set of trees that would apply to a large class of commodities is under investigation.

Cost Determination

This program will calculate production cost at each major source of each commodity. It will combine production cost with transportation cost equivalent (cost plus money equivalent of time and time variability) for the shortest route between producing facility and market to estimate the market costs of each facility at each market that it serves. These market costs are used to compute new market shares after the entire system has been perturbed by new production facilities and new transportation services.

Inter-Modal Trees

This program will search for mode interchange opportunities that will lead to improvements in transportation utility both inside and outside of the Multi-State Corridor. Paths under study will include loading, unloading and interchange costs as well as arc and node costs. The result of the analysis will be a new set of trees that will include both single mode and intermodal paths.

Traffic Assignment

A traffic assignment program will load all of the commodity flow on the network, calculating and following modal split decisions and using the intermodal trees. The result will be a fully loaded network that supports all of the base system commodity movements. No congestion effects will be considered at this time.

Cost Revisions

Traffic densities on different arcs and nodes will give rise to cost changes for those costs that are use dependent. A program will be written that edits the output of the traffic assignment program and updates the set of costs. If necessary, several iterations can be made with the program set to achieve stability. In view of the program complexities, we hope that no more than one or two iterations will be needed.

Transportation Improvements

An almost unlimited number of transportation improvements can be envisioned for the Multi-State Corridor. The problem of identifying promising improvements is a formidable one. At least two approaches are possible: (1) an intuitive or pragmatic approach; and (2) an analytical approach. The intuitive approach will be followed in the first year's work. The analytical approach will be pursued during the second year.

The intuitive approach consists of examining improvements that seem likely to provide valuable service. Sources for these improvements include long range state plans, the ideas of state highway engineers, railroad officials, Corps of Engineers planners and the output of early analysis. This approach has the advantage of dealing with relative reality. Improvements are postulated. Costs, times and time variabilities are estimated for the improved facilities. Then the utility of these new facilities is tested for the set of commodity movements. The intuitive approach has a high risk, because truly advantageous improvement programs can easily be overlooked.

The analytical approach requires the development of a heuristic procedure that can search for improvement opportunities. These opportunities will be described in terms of network parameters that may or may not be translatable into real counterparts. Because of the dimensionality of the problem, the required heuristic will likely be complex. Straightforward approaches, like sensitivity analysis, and statistical approaches simply require too many investigations to be practical.

As part of the first year's work, we will explore three types of improvements: (1) those which improve the accessability of the Northern Mississippi test area to the national transportation network; (2) modal improvements that extend the length of the Multi-State Corridor, and; (3) Intermodal transfer improvements. Improvements in local accessability will focus on the four Northern Mississippi zones. They will be devised with the cooperation of Mississippi highway officials, state officials concerned with railroad planning, and officials of railroads serving the area. No waterway improvements will be explored beyond the completion of the Tennessee-Tombigbee project. Rail and highway improoevements will be postulated for the length of the corridor. These will be represented as upgrading existing arcs to the highest quality for each mode. Intermodal transfer opportunities will be offered at all nodes serving the upgraded rail and highway arcs. These terminals will be patterned after the best of the existing container terminals.

The different improvements will be combined into several improvement programs. Each of these programs will be tested with the commodity movements. The different programs will be evaluated and compared.

Evaluation

It is a very complex task to determine whether a transportation improvement program is a good thing. There are many view points to consider and many affected groups whose voices will be heard. A large set of evaluation criteria is being prepared in an effort to encompass all of the different stakeholder views.

Five different areas are under investigation--economic, physical, fiscal, social and aesthetic. The principal issues in each area are summarized briefly below. A more detailed development will be presented in the Task 4 report.

Economic Issues

The economic issues concern the operators of transportation services, the operators of new production facilities, state and local government, and the public. The operators of transportation services will be concerned with the resources available to construct their facilities, the labor and management personnel available to man them, the level of use of their services, and their competitive climate. The operators of new production facilities have similar concerns, but their concerns focus on their business interests and are not the same as the transportation operator's interests. For example, both may compete for the same construction resources; one may bring in a labor union that has an impact on the other's labor supply. State and local governments are concerned with employment, tax base, property values, gross commercial sales and other measures of the area's prosperity. The public's view is both general and specific. Individuals are concerned about employment, income and life style. Collectively, the public is concerned about many of the same issues as government.

Physical Issues

Physical issues relate to the directly measurable results of the transportation and economic development projects. Use of resources, energy and land are key physical issues. The intensity of use of transportation facilities is an issue since it will have an impact on alternative uses of the same facilities.

Fiscal Issues

Fiscal issues concern the flow of money between the new facilities and the balance of the economy. The impacts of the new facilities on prices is also of major concern. Money benefits and costs accrue to widely different parties--some realize net benefits, others suffer net costs. A final accounting or benefit/cost will attempt to measure the joint impact on stakeholder groups.

Social Issues

Social issues include a broad range of non-economic concerns that are largely non-quantifiable. These range from land use and community form through quality of life and urban renewal opportunities to meeting community and Multi-State Corridor goals.

Aesthetic

Aesthetic issues concern changes in the appearance of the Northern Mississippi test area. These include noise, air quality, light, water quality and drainage, clutter, advertising and other factors that affect how individuals and groups view their communities. Aesthetic issues are closely bound in diverse sets of values. Although some aesthetic factors are quantifiable, individual reactions are highly subjective.

Procedure

Evaluation criteria have been postulated as part of the Task 4 effort. Units of measure are being selected for each. Limited discussions will be held with different stakeholder groups in Northern Mississippi to determine tentative weights for some of the criteria. An array of values will be prepared for the alternative transportation programs tested in Northern Mississippi. However, the development of a specific evaluation model will have to await the second year's research.

APPENDIX A
NETWORK ZONE DESCRIPTIONS

The zones in the Multi-State Transportation Network are comprised of three types:

1. Zones inside the Multi-State Corridor that are smaller than BEAs,
2. Zones outside the Multi-State Corridor whose boundaries do not follow BEA boundaries, and
3. Zones made up of integral numbers of Basic Economic Areas (BEAs).

Zone composition is described below for each category. Type one zones are described in terms of their included counties and their nodal cities. Type two zones are often associated with a BEA but they are described in terms of their included counties and their nodal city. Type three zones are described in terms of their included BEAs and their nodal cities.

CORRIDOR ZONES

Zone No.	Nodal City	APDC*	Included Counties
1.	Brunswick, Ga.	--------------	Liberty, Long, McIntosh, Glynn, Camden Co., Ga.
2.	Jacksonville, Fl.	APDC 1, Fl.	Baker, Clay, Duval, Nassau, Putnam, St. Johns
3.	Statesboro, Ga.	Southern	Appling, Bullock, Candler, Evans, Jeff Davis, Tattnall, Toombs, Wayne
4.	Waycross, Ga.	Slash Pine	Atkinson, Bacon, Brantley, Charlton, Clinch, Coffee, Pierce, Ware
5.	Dublin, Ga.	Heart of Ga.	Bleckley, Dodge, Laurens, Montgomery, Pulaski, Telfair, Treutlen, Wheeler, Wilcox
6.	Valdosta, Ga.	Coastal Plain	Ben Hill, Berrier, Brooks, Cook, Echols, Irwin, Lanier, Lowndes, Tift, Turner
7.	Macon, Ga.	Middle Ga.	Bibb, Crawford, Houston, Jones, Monroe, Peach, Twiggs
8.	Cordele, Ga.	Middle Flint	Crisp, Dooly, Marion, Macon, Schley, Sumter, Taylor, Webster,
9.	Albany, Ga.	S.W. Ga.	Baker, Calhoun, Colquitt, Decatur, Dougherty, Early, Grady, Lee, Miller, Mitchell, Seminole, Terrell, Thomas, Worth
10.	Lagrange, Ga.	Chattahoochee-Flint	Carroll, Coweta, Heard, Meriwether, Troup
11.	Columbus, Ga.	Lower Chattahoochee Valley APDC 10, Al.	Chattahoochee, Clay, Harris, Muscogee, Quitman, Randolph Stewart, Talbot, Ga., Lee, Russell, Al.
12.	Anniston, Al.	APDC-4	Calhoun, Chambers, Cherokee, Clay, Cleburne, Cosa, Etowah, Randolph, Talladega, Tallapoosa
13.	Montgomery, Al.	APDC-9+	Autauga, Dallas, Elmore, Montgomery, Perry
14.	Troy, Al.	APDC-5	Bullock, Butler, Crenshaw, Lowndes, Macon, Pike
15.	Dothan, Al.	APDC-7	Barbour, Coffee, Covington, Dade, Geneva, Henry, Houston
16.	Decatur, Al.	APDC-11	Cullman, Lawrence, Morgan
17.	Birmingham, Al.	APDC-1	Blount, Chilton, Jefferson, St. Clair, Shelby, Walker
18.	Florence, Al.	APDC-1	Colbert, Franklin, Lauderdale, Marion, Winston
19.	Tuscaloosa, Al.	APDC-2	Bibb, Greene, Fayette, Hale, Lamar, Pickens, Tuscaloosa
20.	Corinth, Ms.	N.E. Ms.	Alcorn, Benton, Marhsall, Prentiss, Tippah, Tishomingo

*Area Planning and Development Commission or equivalent comprehensive planning agency.

Zone No.	Nodal City	APDC*	Included Counties
21.	Tupelo, Ms.	3 Rivers	Calhoun, Chickasaw, Itawanba, Lafayette, Lee, Monroe, Pontotac, Union
22.	Columbus, Ms.	Golden Triangle	Clay, Choctaw, Lowndes, Noxubee, Ortibbeh, Webster
23.	Clarksdale, Ms.	No. Delta	Coahoma, DeSoto, Quitman, Panola, Tate, Tunica
24.	Dyersburg, Ten.	N.W. APDC-	Carroll, Crockett, Dyer, Gibson, Henry, Lake, Obion, Weakley
25.	Jackson, Tn.	SW APDC+	Chester, Decatur, Hardeman, Hardin, Haywood, Henderson, McNairy, Madison, Wayne
26.	Memphis, Tn.	Memphis Delta	Fayette, Lauderdale, Shelby, Tipton
27.	Jonesboro, Ak.	East	Clay, Craighead, Crittenden, Cross, Greene, Lawrence, Lee, Ms. Phillips, Poinsett, Randolph, St. Francis
28.	Searcy, Ak.	White River	Cleburne, Fulton, Independence, Izard, Jackson, Sharp, Stone, Van Buren, White, Woodruff
29.	Harrison, Ak.	--------	Baxter, Boone, Carroll, Marion, Newton, Searcy
30.	Sikeston, Mo.	Bootheel	Bunklin, Mississippi, New Madrid, Plemescot, Scott, Stoddard
31.	Poplar Bluff, Mo.	Ozark Foothills	Butler, Carter, Reynolds, Ripley, Wayne
32.	West Plains, Mo.	So. Cent. Ozark	Douglas, Howell, Oregon, Ozark, Shannon, Texas, Wright
33.	Lebanon, Mo.	Lake of the Ozarks	Camden, Laclede, Miller, Morgan, Pulaski
34.	Marshall, Mo.	Mo. Valley	Carroll, Chariton, Saline
35.	Sedalia, Mo.	Show-Me	Johnson, Lafayette, Pettis
36.	Springfield, Mo.	Lakes Country	Barry, Christian, Dade, Dallas, Greene, Lawrence, Polk, Stone, Taney, Webster
37.	St. Joseph, Mo.	Bi State	Andrew, Buchanon, Clinton, DeKalb, Mo., Doniphan, Ks.
38.	Kansas City, Mo.	Mid America Reg. Council	Cass, Clay, Jackson, Platte, Ray, Mo., Johnson, Leavenworth, Wyandatte, Ks.
39.	Nevada, Mo.	Kaysinger Basin	Bates, Benton, Cedar, Henry, Hickory, St. Clair, Vernon
40.	Joplin, Mo.	Ozark Gateway	Barton, Jasper, McDonald, Newton

2. NON BEA EXTERNAL ZONES

BEAs Disrupted: 33, 34, 40, 41, 42, 43, 44, 45, 46, 47, 111, 112, 114, 115, 116, 117

Zone No.	Nodal City	BEA	Included Counties
41	Savannah, Ga.		Bryan, Chatham, Effingham, Screven, Ga.; Jasper, S.C.
43	Milledgeville, Ga.		Oconee APDC, Ga: Baldwin, Hancock, Jasper, Putnam, Washington, Wilkerson
44	Atlanta, Ga.	BEA 44 minus:	Cleburne Co., Ala.; Carroll, Coweta Co., Ga.
46	Huntsville, Al.		Limestone, Madison, Marshall Co., Ala.; Lincoln, Franklin Co., Tenn.
49	Cape Girardeau, Mo.		Bolinger, Cape Girardeau, Mo.; Alexander, Hardin, Johnson, Massac, Pope, Pulaski, Union, Ill.; Ballard, Carlisle, Calloway, Fulton, Graves, Hickman, Livingston, Lyon, Marshall, McCracken, Ky.
50	St. Louis, Mo.	BEA 114 minus:	Laclede, Pulaski, Reynolds, Texas, Mo.
52	Columbia, Mo.	BEA 112 minus:	Putnam, Sullivan, Linn, Chariton, Morgan, Camden, Miller Co., Mo.
53	Chillicothe, Mo.		Northwest, Mo., Green Hills APCD, Mo., Atchison, Caldwell, Daviess, Gentry, Grundy, Harrison, Holt, Linn, Livingston, Mercer, Nodaway, Putnam, Sullivan, Worth

Zone No.	Nodal City	BEA	Included Counties
56	Topeka, Ks.		Allen, Anderson, Atchison, Bourbon, Brown, Cherokee, Craig, Crawford, Douglas, Franklin, Geary, Jackson, Jefferson, Labette, Linn, Lyon, Marshall, Miami, Montgomery, Nemaha, Neosho, Osage, Ottawa, Pottawatomie, Riley, Shawnee, Wabaunsee, Washington, Wilson, Woodson, Ks.
60	Little Rock, Ak.	BEA 117 minus:	White River APDC, Ak. (See zone 28 for omitted counties)
67	Gainesville, Fl.		Alachua, Bradford, Columbia, Dixie, Gilchrist, Hamilton, Lafayette, Levy, Marion, Sewannee, Union, Fl.

3. ZONES COMPRISED OF INTEGRAL BEAS

Zone No.	Nodal City	BEAs
42	Augusta, Ga.	32
45	Chattanooga, Tn.	48
47	Nashville, Tn.	49
48	Evansville, In.	55
51	Quincy, Il.	113
54	Des Moines, Ia.	80,81, 104, 105, 106
55	Omaha, Ne.	102, 103, 107,108
57	Wichita, Ks.	109, 110
58	Tulsa, Ok.	119
59	Ft. Smith, Ok.	118
61	Greenville, Ms.	134
62	Jackson, Ms.	135
63	Meridian, Ms.	136
64	Mobile, Al.	137
65	Pensacola, Fl.	39
66	Tallahassee, Fl.	38
68	Miami, Fl.	35, 36
69	Boston, Ma.	1, 2, 3, 4, 5
70	Albany, N.Y.	6, 7
71	Buffalo, N.Y.	8, 9, 10
72	New York, N.Y.	14, 15
73	Scranton, Pa.	12, 13
74	Harrisburg, Pa.	11, 16
75	Pittsburgh, Pa.	66, 67
76	Washington, D. C.	17, 18
77	Roanoke, Va.	19, 20
78	Richmond, Va.	21
79	Charlotte, N.C.	25, 26
80	Raleigh, N.C.	23, 24
81	Greenville, S.C.	27, 28
82	Columbia, S.C.	29, 30
83	Knoxville, Tn.	50
84	Charleston, W.V.	51, 52, 65
85	Cincinnati, Oh.	53, 54, 62
86	Dayton, Oh.	61, 63, 69
87	Cleveland, Oh.	68
88	Detroit, Mi.	71, 72, 74
89	Indianapolis, In.	56, 59, 60
90	Chicago, Il.	76, 77, 78, 79
91	Milwaukee, Wi.	82, 83, 84, 85, 86
92	St. Paul, Mn.	88, 89, 90, 91
93	Billings, Mn.	94, 95, 100, 101, 150
94	Denver, Co.	147, 148, 149
95	Oklahoma City, Ok.	120, 121
96	Texarkana, Tx.	131
97	Shreveport, La.	132, 133
98	New Orleans, La.	138
99	Tampa, Fl.	37
100	Amarillo, Tx.	122, 123

Zone No.	Nodal City	BEAs
101	Dallas, Tx.	127, 130
102	El Paso, Tx.	124, 145, 163
103	Austin, Tx.	128, 129
104	San Antonio, Tx.	125, 126, 142, 143, 144
105	Houston, Tx.	139, 140, 141
106	Salt Lake City, Ut.	151, 160
107	Phoenix, Ar.	162
108	Albuqurque, NM	146
109	Seattle, Wa.	153, 154, 155, 156
110	San Francisco, Ca.	166, 167, 168, 171
111	Los Angeles, Ca.	161, 164, 165
112	Charleston, S.C.	31
113	Duluth, Mn.	87
114	Springfield, Il.	57, 58
115	Toledo, Oh.	70, 75
116	Columbus, Oh.	65
117	Portland, Or.	152, 157, 158, 159, 169, 170
118	Fargo, ND	92, 93, 96, 97, 98, 99
119	Grand Rapids, Mi.	73
120	Norfolk, Va.	22

APPENDIX B

MANUFACTURING INDUSTRY PROFILES

COMMODITY GROUP

	201	202	203	204	205	206	207
Industry Data							
No. of Companies	3,944	3,557	1,923	2,223	3,044	1,043	595
No. of Establishments	4,437	4,590	2,557	3,080	3,633	1,249	861
Establishments with > 20 Empl.	1,882	2,067	1,389	1,093	1,551	584	458
Cost of Materials, $Million	26,623	12,284	6,939	8,504	3,357	4,161	5,681
Value Added, $Million	4,961	4,054	4,514	3,699	4,537	2,473	1,292
Value of Shipments, $Million	31,478	16,312	11,479	12,162	7,896	6,620	6,910
Mean Establishment							
Annual Cost of Goods Sold, $Thousands	7,095	3,552	4,503	3,928	2,171	530	7,973
Tons Shpped/Year	7,109	2,200	13,010	20,458	650	1,227	39,865
Employees	69	41	91	36	65	86	47
Direct Labor, Man-Hours	114,199	41,111	149,433	54,838	78,365	139,632	74,913
Indirect Labor, $Thousands	142	188	138	112	250	180	146
Capital Investment, $Thousands	608	608	12,227	1,010	633	1,904	1,608
Energy Consumption, Thou. KWH	8,857		12,124	13,864		30,984	7,549
Raw Materials							
Class/Annual Tons	021/6,206 025/2,724 201/1,162	024/204 202/879	013/10,864 341/	011/ 207/3,642	204/1,760	013/37,191 017/ 230 206/ 2,307	013-9/31,347 207/ 255
Min. Economic New Facility							
Employees	111	66	147	58	104	138	75
Annual Cost of Goods Sold, $Thousands	12,416	7,611	7,745	7,385	4,300	922	14,511
Capital Investment, $Thousands	851	961	16,917	1,475	952	2,657	2,306
Direct Labor, Man Hours	200,000	88,000	257,000	103,000	155,000	243,000	136,000

	COMMODITY GROUP						
	208	209	210	220	230	240	250
Industry Data							
No. of Companies	2,980	3,486	177	5,611	21,949	31,935	8,482
No. of Establishments	3,624	4,153	272	7,203	24,438	33,948	9,232
Establishments with > 20 Empl.	1,993	1,309	154	4,505	12,226	6,867	3,646
Cost of Materials, $Million	7,292	4,955	2,941	16,505	14,532	13,593	5,328
Value Added, $Million	6,689	3,397	2,637	11,718	13,488	10,309	6,090
Value of Shipments, $Million	13,869	8,336	5,920	28,072	27,809	23,816	11,309
Mean Establishment							
Annual Cost of Goods Sold, $Thousands	3,835	1,995	20,744	3,945	1,136	700	1,237
Tons Shipped/Year	13,599	2,934	5,346	1,672	238	3,500	611
Employees	59	32	244	132	36	20	46
Direct Labor, Man-Hours	59,078	43,992	392,647	239,622	88,432	34,391	81,846
Indirect Labor, $Thousands	299	91	372	173	72	31	95
Capital Investment, $Thousands	1,430	474	3,558	1,295	113	124	1,560
Energy Consumption, Thou. KWH	9,603	11,461	20,221	10,209	747	596	763
Raw Materials							
Class/Annual Tons	208/506	209/722 091/269	013-9/1,324 21/3,538	202/617 282/408	220/388	240/	220/ 6 240/662 285/ 2 331/233 333/ 9 340/ 94
Min. Economic New Facility							
Employees	94	52	392	215	90	33	81
Annual Cost of Goods Sold, $Thousands	8,322	3,731	35,265	6,750	1,925	1,235	2,300
Capital Investment, $Thousands	2,273	690	4,894	1,790	155	175	2,310
Direct Labor, Man Hours	128,000	82,000	667,000	410,000	150,000	61,000	157,000

COMMODITY GROUPS

	260	270	281	282	283	284	285,9
Industry Data							
No. of Companies	3,956	39,894	345	265	922	2,308	3,361
No. of Establishments	6,038	42,102	1,049	461	1,078	2,573	4,204
Establishments with > 20 Empl.	3,956	8,618	510	364	425	732	1,462
Cost of Materials, $Million	15,241	10,043	2,779	4,855	1,972	3,630	4,141
Value Added, $Million	13,064	20,197	3,343	4,935	6,131	6,201	3,994
Value of Shipments, $Million	28,262	30,132	6,133	9,746	8,019	9.778	8,090
Mean Establishment							
Annual Cost of Goods Sold, $Thousands	4,677	716	5,845	21,239	7,427	3,704	1,923
Tons Shipped/Year	14,616	133	47,910	52,833	1,386	4,431	3,216
Employees	105	25	95	351	126	43	35
Direct Labor, Man-Hours	172,325	28,043	121,830	512,360	122,727	53,712	42,269
Indirect Labor, $Thousands	277	104	427	1,308	770	194	174
Capital Investment, $Thousands	3,215	234	2,680	11,286	2,827	549	316
Energy Consumption, Thou. KWH	63,829	714	652,526		18,089	6,063	9,562
Raw Materials							
Class/Annual Tons	240/29,184	260/518	102/12,097		203/	207/218	207/ 38
	260/12,295	289/ 8	140/ 4,426			281/819	281/345
		390/ 2	281/ 3,883			284/204	282/169
			331/ 425				286/149
							287/ 76
Min. Economic New Facility							
Employees	169	40	153	566	203	70	57
Annual Cost of Goods Sold, $Thousands	8,277	1,432	11,398	39,505	16,636	7,408	3,942
Capital Investment, $Thousands	4,530	355	4,002	16,258	4,589	832	486
Direct Labor, Man Hours	305,000	56,000	238,000	953,000	275,000	107,000	87,000

COMMODITY GROUP

	286	287	290	301	302	310	321
Industry Data							
No. of Companies	557	795	1,236	136	7,799	2,699	13,170
No. of Establishments	827	1,233	2,016	206	9,031	3,201	15,817
Establishments with > 20 Empl.	454	484	720	126	4,062	1,657	5,130
Cost of Materials, $Million	5,515	2,194	22,763	2,745	6,721	2,895	8,407
Value Added, $Million	6,073	1,737	5,793	3,071	7,583	2,917	11,433
Value of Shipments, $Million	11,605	3,929	28,695	5,747	15,177	5,770	19,746
Mean Establishment							
Annual Cost of Goods Sold, $Thousands	14,044	3,186	14,229	27,876	1,565	1,791	1,247
Tons Shipped/Year	36,958	17,700	309,326	27,655	1,252	381	6,928
Employees	165	39	69	522	57	85	38
Direct Labor, Man-Hours	214,994	51,663	99,454	819,903	88,513	155,920	59,955
Indirect Labor, $Thousands	818	152	284	1,485	139	112	91
Capital Investment, $Thousands	14,287	521	6,141	13,724	430	101	612
Energy Consumption, Thou. KWH	398,065	3,032	231,597	115,049	1,988	3,061	15,660
Raw Materials							
Class/Annual Tons	140/848	140/47,194	130/370,238	220/1,651	281/ 46	201/205	140/19,319
	281/6,534	281/ 1,125	140/ 25,681	281/1,292	282/654	310/ 26	281/ 221
	287/1,396	287/ 4,930	290/ 4,815	282/3,971	286/ 39		282/ 7
	290/19,451		321/ 1,355	286/10,458	289/ 22		324/ 579
				289/4,340	302/ 66		331/ 1
				302/1,448	321/ 8		
				331/589			
Min. Economic New Facility							
Employees	266	63	111	839	91	137	60
Annual Cost of Goods Sold, $Thousands	27,386	6,277	26,750	49,619	2,786	3,027	2,157
Capital Investment, $Thousands	21,347	782	8,954	19,427	607	139	851
Direct Labor, Man Hours	419,000	102,000	187,000	1,459,000	157,000	264,000	104,000

	COMMODITY GROUP						
	324	331	333	341	342	360	358
Industry Data							
No. of Companies	75	1,855	3,745	223	26,150	36,519	1,566
No. of Establishments	198	2,370	4,422	553	28,972	39,023	1,769
Establishments with 20 Empl.	171	1,746	2,155	408	11,168	9,796	803
Cost of Materials, $Million	655	19,232	16,477	2,985	22,212	24,744	4,460
Value Added, $Million	1,153	15,597	7,661	2,005	24,941	33,136	4,427
Value of Shipments, $Million	1,791	34,366	24,064	4,972	46,767	57,110	8,711
Mean Establishment							
Annual Cost of Goods Sold, $Thousands	9,031	14,486	5,441	9,114	1,614	1,466	4,933
Tons Shipped/Year	301,033	53,257	7,216	7,495	1,232	374	1,259
Employees	152	326	84	142	49	42	112
Direct Labor, Man-Hours	251,010	527,764	135,504	253,888	74,634	57,786	160,147
Indirect Labor, $Thousands	374	830	226	284	142	167	369
Capital Investment, $Thousands	19,353	12,867	3,476	3,334	363	454	183
Energy Consumption, Thou. KWH	678,788	207,511	50,905	4,521	2,668	600	6,670
Raw Materials							
Class/Annual Tons	140/ 260/	101/556,744 102/ 335 110/ 36,157 140/ 3,567 321/ 15,333 331/ 14,135 333/ 295	102/1,911 140/ 27 281/1,796 282/ 261 331/ 8 335/2,308	331/12,200 333/ 932	282/ 2 331/1,283 333/ 69 342/ 4	110/ 4 331/297 342/ 17	331/1,307 333/ 12 342/ 14
Min. Economic New Facility							
Employees	244	525	135	229	79	67	180
Annual Cost of Goods Sold, $Thousands	15,624	25,350	9,631	15,676	2,921	2,756	9,077
Capital Investment, $Thousands	27,056	17,990	3,491	4,615	518	662	264
Direct Labor, Man-Hours	434,000	924,000	240,000	437,000	135,000	108,000	295,000

	COMMODITY GROUP					
	361	362	371	372	380	390
Industry Data						
No. of Companies	8,742	1,289	2,817	4,731	5,269	14,560
No. of Establishments	10,763	1,511	3,391	5,411	5,987	15,188
Establishments with > 20 Empl.	5,016	720	1,547	2,071	2,070	3,755
Cost of Materials, $Million	21,046	2,270	42,125	13,643	5,071	5,559
Value Added, $Million	27,359	3,224	22,056	17,743	10,584	6,777
Value of Shipments, $Million	48,021	5,412	63,921	30,784	15,566	12,186
Mean Establishment						
Annual Cost of Goods Sold, $Thousands	4,459	3,574	18,753	5,691	2,585	802
Tons Shipped/Year	1,188	1,366	11,407	10,911	239	295
Employees	137	125	238	169	76	29
Direct Labor, Man-Hours	186,324	178,425	408,994	210,774	95,140	43,554
Indirect Labor, $Thousands	534	418	602	922	344	72
Capital Investment, $Thousands	1,216	1,413	3,651	1,039	66	177
Energy Consumption, Thous. KWH	4,996	9,464	21,587	7,577	336	1,211
Raw Materials Class/Annual Tons	282/ 39 331/342 340/ 2	282/ 6 331/1007 333/ 482 342/ 2	282/ 331/4,592 333/ 843 342/ 486	331/818 333/945 342/ 34	207/ 1 331/25 333/18	282/25 310/ 1 333/36 333/ 2
Min. Economic New Facility						
Employees	220	200	384	271	122	47
Annual Cost of Goods Sold, $Thousands	8,339	6,576	32,630	11,097	5,015	1,428
Capital Investment, $Thousands	1,773	2,039	5,092	1,553	991	250
Direct Labor, Man-Hours	349,000	328,000	712,000	411,000	185,000	78,000

APPENDIX C
NETWORK ARC DESCRIPTIONS

This Appendix contains a detailed description of each two way arc in the transportation network. Separate tables and a separate format are presented for highway rail and water arcs.

Highway Arcs

Seven items of information are presented for each highway arc. They are:

Column 1. Arc number,

Column 2. Originating network node number*,

Column 3. Terminating network node number,

Column 4. Distance in miles between the two nodes,

Column 5. Travel time in minutes for a truck to move from node to node,

Column 6. Number of lanes of traffic in both directions, and

Column 7. The route designations for the highways comprising the arc

I = Interstate

US = Federal aid primary or secondary

S = State

Rail Arcs

The seven items of information that describe each rail arc are different from those used to describe highway arcs. Rail arc descriptors are:

Column 1. Arc number,

Column 2. Origin node,

Column 3. Terminating node,

Column 4. Arc length in miles,

Column 5. Average speed made good by the highest class freight train normally traversing the arc,

Column 6. Arc capacity in trains per day in both directions. This includes the capacity of all parallel routes considered part of the same arc.

Column 7. Railroad Company(s) owning the lines comprising the arc.

1. Atchison, Topeka & Santa Fe
2. Atlanta and West Point
3. Burlington Northern
4. Bessemer and Lake Erie

*Flow can move in both directions between the pair of nodes designated origin and destination.

5. Baltimore & Ohio/Chesapeake & Ohio
6. Conrail
7. Chicago & North Western
8. Chicago, Rock Island & Pacific
9. Denver & Rio Grande Western
10. Detroit, Toledo & Ironton
11. Florida East Coast
12. Georgia
13. Illinois Central Gulf
14. Kansas City Southern
15. Louisiana & Arkansas
16. Louisville & Nashville
17. Milwaukee
18. Missouri-Kansas-Texas
19. Missouri Pacific
20. Norfolk & Western
21. Penn Central (other than Conrail lines)
22. Richmond, Fredericksburg & Potomac
23. Seaboard Coast Line
24. Southern
25. Soo Line
26. Southern Pacific
27. St. Louis-San Francisco
28. St. Louis Southwestern
29. Texas & Pacific
30. Union Pacific
31. Western Railway of Alabama
32. Western Pacific

All rail arcs are capable of carrying two way traffic.

Water Arcs

The eight water arc descriptors are:

Column 1. Arc number,

Column 2. Origin node,

Column 3. Destination node,

Column 4. Arc length in miles,

Column 5. Down stream speed in miles per hour,

Column 6. Number of locks along the arc --

a-1 entry designates an ocean arc with no locks,

Column 7. Channel depth in fee, a-1 entry designates an ocean arc.

Column 8. Waterway system

1. Alabama River
2. Arkansas River
3. Atlantic Coastwise
4. Black Warrior River
5. Chattahoochee River
6. Cumberland River
7. Great Lakes Waterway
8. Gulf Coastwise
9. Hudson River
10. Illinois River
11. Kanawha River
12. Mississippi River
13. Missouri River
14. N.Y. State Barge Canal
15. Ohio River
16. Pacific Coastwise
17. Savannah River
18. Tennessee River
19. Tennessee-Tombigbee Waterway

Water arcs also support two way traffic.

HIGHWAY ARCS

Arc	Orig.	Dest.	Dist.	Time	La. Routes
1	1	2	68	74	4 I-95
2	1	4	49	65	2US-84
3	1	41	70	76	4 I-95
4	2	66	163	177	4 I-10
5	2	67	49	53	4US301 S-24
6	2	68	349	379	4 I-95
7	3	4	108	144	2US-25US-82
8	3	5	72	96	2US-80
9	3	8	130	170	2 I-16 US-1US280
10	3	41	53	58	4 I-16
11	3	42	47	63	2US-25
12	4	2	78	104	2US-23
13	4	6	61	81	2US-84
14	4	8	111	139	2US-82 I-75
15	4	9	113	151	2US-82
16	4	41	94	120	2US-82 I-95
17	5	1	146	195	2US441US341
18	5	4	121	153	2 I-16 US-1
19	5	7	52	57	4 I-16
20	5	8	92	123	2US441US280
21	5	42	85	113	2US319 US-1
22	5	43	47	63	2US441
23	6	2	75	82	4 I-75 I-10
24	6	8	88	96	4 I-75
25	6	9	89	107	2 I-75US-82
26	6	66	71	82	2US-84US221 I-10
27	6	67	93	101	4 I-75
28	7	43	31	46	2 S-49
29	7	44	78	85	4 I-75
30	8	7	56	61	4 I-75
31	8	11	87	116	2US280
32	9	8	34	51	2S-257
33	9	11	77	104	2US-82 S-55US280
34	9	66	98	131	2US-19US319
35	10	44	49	53	4 I-85
36	11	7	98	131	2US-80
37	11	10	50	54	4I-185
38	12	10	69	95	2US431S-244
39	12	13	88	96	2US231
40	12	17	61	66	4 I-20
41	12	44	86	93	4 I-20
42	12	45	111	129	2US431 I-59
43	12	46	98	131	2US431
44	13	9	150	200	2US-82
45	13	10	88	96	4 I-85
46	13	11	86	100	2 I-85US280
47	13	14	44	48	4US231
48	13	17	94	102	4 I-65
49	13	19	105	140	2US-82
50	13	63	153	204	2US-80
51	13	64	179	195	4 I-65
52	13	65	154	187	2 I-65US-31US-29
53	14	64	159	185	2US-29 S-10 I-65
54	14	65	162	216	2US-29
55	15	9	82	122	2 S-62
56	15	11	105	140	2US431
57	15	14	56	61	4US231
58	15	65	141	161	2US231 I-10
59	15	66	101	117	2US231 I-10
60	16	18	41	45	4US-72
61	16	46	23	25	4US-72
62	16	47	116	126	4 I-65
63	17	11	148	197	2US280
64	17	16	81	88	4 I-65
65	17	19	56	61	4 I-59
66	17	21	165	220	2US-78
67	17	45	150	163	4 I-59
68	18	20	54	72	2US-43US-72
69	18	22	127	169	2US-43US-78 S-12
70	18	47	104	131	2US-43 I-65
71	19	18	116	155	2US-43
72	19	22	61	81	2US-82
73	19	63	75	82	4 I-59
74	19	64	197	262	2US-43
75	20	25	54	72	2US-45
76	20	26	94	125	2US-72
77	21	20	50	67	2US-45
78	21	23	110	164	2 S-6
79	21	26	97	129	2US-78
80	21	62	215	263	2 S-6 I-55
81	22	21	68	91	2US-45
82	22	23	165	220	2US-82US49E
83	22	61	160	213	2US-82
84	22	62	168	203	2US-82 I-55
85	22	63	89	118	2US-45
86	23	26	78	104	2US-61
87	23	28	136	181	2US-61US-49 S-1 S-64
88	23	60	140	173	2US-61US-49 I-40

Arc.	Orig.	Dest.	Dist.	Time	La. Routes
89	23	61	70	93	2US-61
90	23	62	186	217	2 S-6 I-55
91	24	27	100	121	2I-155 I-55 S-18
92	24	30	78	85	4I-155 I-55
93	24	48	203	232	2US-51FTNFKTFKWYFFKWY
94	25	24	41	61	2 S-20
95	25	47	150	163	4 U-40
96	25	48	235	271	2 I-40 S-13
97	26	24	74	80	4US-51
98	26	25	75	82	4 I-40
99	26	27	65	81	2 I-55US-63
100	26	28	92	123	2US-64
101	26	30	145	157	4 I-55
102	26	60	138	150	4 I-40
103	27	28	79	105	2 S-39US-64US-67
104	27	29	166	221	2US-63US-62
105	27	30	120	149	2 S-18 I-55
106	27	31	91	121	2US-63US-67
107	27	32	104	139	2US-63
108	28	29	165	220	2US167US-64US-65
109	28	32	142	189	2US167US-63
110	28	60	43	47	4US-67
111	29	32	109	145	2US-62 S-5US-160
112	29	36	65	87	2US-65
113	29	40	148	197	2US-62US-71
114	29	58	186	248	2US-62 S-33
115	29	59	132	176	2US-62US-71
116	29	60	134	171	2US-65 I-40
117	30	31	47	63	2US-60
118	30	47	190	223	2US-60 I-24
119	30	48	227	267	2 I-57 S-13US-60
120	30	49	38	41	4 I-55
121	31	32	100	133	2US160
122	31	50	202	231	2US-60 I-55
123	32	33	111	148	2US-60 S-5
124	32	36	110	146	2US-60
125	32	50	210	254	2US-63 I-44
126	32	52	205	273	2US-63
127	33	35	99	132	2 S-64US-65
128	33	39	123	164	2 S-5US-54
129	33	49	181	230	2 I-44 S-8US-67US-72
130	33	50	165	179	4 I-44
131	33	52	151	187	2 I-44US-63
132	34	51	75	100	2 S-41US-24
133	34	52	61	69	2US-65 I-70
134	34	53	65	87	2US-65

Arc	Orig.	Dest.	Dist.	Time	La. Routes
135	35	34	24	32	2US-65
136	35	38	83	95	2US-65 I-70
137	35	52	68	78	2US-65 I-70
138	36	33	53	58	4 I-44
139	36	35	120	160	2US-65
140	36	39	91	121	2 S-13US-54
141	36	40	69	75	4 I-44
142	37	53	74	99	2US-36
143	37	54	181	204	2US-36 I-35
144	37	55	152	165	4 I-29
145	37	56	85	113	2US-59
146	38	34	76	85	2 I-70US-65
147	38	37	52	57	4 I-29
148	38	53	100	118	2I-35US-36
149	38	54	195	212	4 I-35
150	38	56	65	71	4 I-70
151	38	57	200	217	4 I-35
152	39	35	127	169	2US-54US-65
153	39	38	98	131	2US-71
154	39	57	170	226	2US-54
155	40	39	64	85	2US-71
156	40	57	218	279	2US166 I-35
157	40	58	95	103	4 I-44
158	40	59	149	199	2US-71
159	41	82	142	154	4 I-95 I-26
160	42	82	69	75	4 I-20
161	43	42	80	100	2 S-22 S-16US278 I-20
162	43	81	158	211	2US441
163	44	42	150	120	4 I-20
164	44	81	119	129	4 I-85
165	45	44	114	124	4 I-75
166	45	83	112	122	4 I-75
167	46	45	75	100	2US-72
168	47	45	128	139	4 I-24
169	47	46	187	209	2 I-65US-72
170	47	83	177	192	4 I-40
171	47	84	384	417	4 I-64
172	47	85	269	315	4 I-65 I-71
173	48	47	159	173	4US-41 I-24
174	48	84	392	426	4 I-64
175	48	85	224	243	4 I-64 I-71
176	49	47	171	194	2US-60 I-24
177	50	47	328	357	4 I-64 I-57 I-24
178	50	48	172	187	4 I-64
179	50	49	148	161	4 I-55
180	50	89	235	255	4 I-70

Arc	Orig.	Dest.	Dist.	Time	La. Routes
181	51	50	116	155	2US-61
182	51	52	119	159	2US-61US-54
183	52	50	106	115	4 I-70
184	53	51	130	172	2US-36US-61
185	53	54	149	171	2US-36 I-35
186	54	89	465	521	4 I-80 I-74
187	54	90	327	355	4 I-80
188	54	92	252	274	4 I-35
189	55	54	132	143	4 I-80
190	56	55	159	212	2US-75
191	57	56	127	138	4KTNPK
192	58	56	195	260	2US-75
193	59	58	117	127	4 I-40
194	59	101	243	264	4US-69 I-40
195	60	59	154	167	4 I-40
196	61	60	151	201	2US-65
197	62	61	120	113	2 I-20US-61
198	62	97	219	238	4 I-20
199	63	62	93	101	4 I-20
200	63	98	194	211	4 I-59
201	64	62	182	198	2US-49US-98
202	64	63	133	146	2US-45
203	64	98	144	157	4 I-10
204	65	64	62	67	4 I-10
205	66	65	186	202	4 I-10
206	67	66	133	145	4 I-75 I-10
207	68	99	268	291	4 I-75
208	70	69	163	177	4 I-90
209	71	70	283	308	4 I-90
210	71	73	246	330	4 I-90 I-81
211	72	69	206	224	4 I-84
212	72	70	154	167	4 I-87
213	72	74	180	196	4 I-78
214	72	76	233	253	4 I-95
215	73	70	173	188	4 I-81 I-88
216	73	72	138	150	4 I-84
217	74	71	278	365	4 2-79 I-90
218	74	73	118	128	4 I-81
219	74	75	189	205	4 I-76
220	75	71	216	236	4 I-79 I-90
221	76	74	107	116	4 I-83
222	76	75	221	240	4 I-76 I-70
223	76	84	344	374	4 I-81 I-64
224	77	74	289	314	4 I-81
225	77	76	225	245	4 I-81 I-66
226	77	78	164	180	4 I-64

Arc	Orig.	Dest.	Dist.	Time	La. Routes
227	78	76	106	115	4 I-95
228	79	77	189	205	4 I-77 I-81
229	79	80	167	182	4 I-85 I-40
230	80	77	163	177	4US220 I-85
231	80	78	173	188	4 I-85
232	81	42	104	139	2US-25
233	81	79	90	98	4 I-85
234	81	82	95	103	4 I-26
235	82	79	94	102	4 I-77
236	82	80	205	223	4 I-20 I-95
237	83	77	263	286	4 I-81
238	83	80	359	405	4 I-40
239	83	81	150	163	4 I-40 I-26
240	83	84	335	364	4 I-81 I-77
241	83	85	253	275	4 I-75
242	84	75	213	231	4 I-79
243	84	77	181	197	4 I-77 I-81
244	84	78	306	330	4 I-64
245	84	79	287	312	4 I-77
246	85	84	208	226	4 I-75 I-64
247	85	86	52	56	4 I-75
248	87	71	187	203	4 I-90
249	87	73	310	337	4 2-80 I-84
250	87	75	129	140	4I-80S
251	87	84	243	264	4 I-77
252	89	47	279	320	4 I-65
253	89	48	167	210	2 I-70US-41
254	89	85	106	115	4 I-74
255	89	86	107	116	4 I-70
256	90	48	296	322	4 I-57 I-64
257	90	49	376	409	4 I-57
258	90	51	308	363	2 I-55 S-125US-24
259	90	88	266	289	4 I-94
260	90	89	181	197	4 I-65
261	91	90	87	95	4 I-94
262	92	90	405	440	4 I-94 I-90
263	92	91	349	379	4 I-94
264	93	55	897	975	4 I-90 I-29
265	93	94	559	608	4 I-90 I-25
266	94	55	537	584	4I-80S I-80
267	94	56	540	587	4 I-70
268	94	57	509	553	4 I-70I-35W
269	94	100	423	510	2 I-25US-87
270	94	108	456	496	4 I-25
271	95	57	159	173	4 I-25
272	95	58	105	114	4 I-44

Arc	Orig.	Dest.	Dist.	Time	La. Routes
273	95	59	184	200	4 I-40
274	96	59	181	241	2US-71
275	96	60	140	152	4 I-20
276	96	61	206	275	2US-82
277	97	61	210	257	2 I-20US165US-82
278	97	96	70	76	4 I-71
279	98	62	178	293	4 I-55
280	98	97	313	396	2 I-10US-71
281	99	67	127	138	4 I-75
282	100	95	258	280	4 I-40
283	100	101	358	390	4US287
284	100	102	419	559	2US-70US-54
285	100	104	516	688	2US-87
286	101	95	206	224	4 I-35
287	101	96	175	190	4 I-30
288	101	97	185	201	4 I-20
289	102	101	620	674	4 I-20
290	102	104	574	624	4 I-10
291	103	97	309	388	2 I-35 S-31 I-20
292	103	101	193	210	4 I-35
293	103	105	164	201	2US183 I-10
294	104	103	77	83	4 I-35
295	104	105	197	214	4 I-10
296	105	97	234	262	2US-59US-79
297	105	98	356	387	4 I-10
298	105	101	243	264	4 I-45
299	106	93	551	654	4 I-15 I-90
300	106	94	504	548	4 I-80 I-25
301	106	117	780	848	4I-80N
302	107	108	432	490	4 I-17 I-40
303	107	102	443	482	4 I-10
304	108	100	284	308	4 I-40
305	108	102	266	289	4 I-25
306	109	93	845	918	4 I-90
307	109	106	871	947	4 I-90 I-82I-80N
308	110	106	752	817	4 I-80

Arc	Orig.	Dest.	Dist.	Time	La. Routes
309	110	111	379	412	4 I-5
310	111	94	1059	1151	4 I-15 I-70
311	111	106	715	777	4 I-15
312	111	107	389	423	4 I-10
313	112	41	106	115	2US-17 I-95
314	112	42	139	185	2US-78US-28
315	112	80	255	277	2US-52 I-95
316	112	82	113	123	4 I-26
317	113	92	153	166	4 I-35
318	113	118	251	334	2 US-2ST200ST-34US-10
319	114	50	100	109	4 I-55
320	114	51	127	169	4US-36
321	114	54	326	354	4 I-55 I-74 I-80
322	114	89	193	260	2US-36
323	114	90	189	205	4 I-55
324	115	86	155	168	4 I-75
325	115	87	111	120	4 I-90
326	115	88	61	66	4 I-75
327	115	89	219	245	4 I-69US-24
328	115	90	232	252	4I-90
329	115	116	133	180	2US-23
330	116	75	182	198	4 I-70
331	116	84	164	219	2US-33
332	116	85	108	117	4 I-71
333	116	86	65	71	4 I-70
334	116	87	139	151	4 I-71
335	117	119	172	187	4 I-5
336	117	110	640	695	4 I-5
337	118	92	234	254	4 I-94
338	118	93	611	664	4 I-94
339	119	88	147	160	4 I-96
340	119	89	241	321	4US131US-31
341	119	90	168	183	4I-196 I-94
342	120	78	90	98	4 I-64
343	120	80	168	225	2US-58 I-95

RAIL ARCS

Arc.	Orig.	Dest.	Dist.	Speed	Cap.	RRCo.				
345	1	2	87	35	40	23				
346	1	4	48	12	10	23				
347	1	7	176	12	10	23				
348	2	67	70	45	100	23				
349	2	68	366	45	40	11				
350	2	99	210	35	24	23				
351	3	6	181	12	10	24				
352	3	7	112	12	10	24				
353	3	42	54	12	10	24				
354	4	2	76	35	40	23				
355	4	6	61	12	10	23				
356	4	8	108	35	40	23				
357	4	9	112	12	10	23				
358	5	7	54	12	10	23				
359	6	2	110	28	24	24				
360	6	8	86	28	24	24				
361	6	15	134	12	10	23				
362	6	67	108	12	10	24				
363	7	8	62	28	24	24				
364	7	11	101	28	24	24				
365	7	43	33	12	10	12				
366	7	44	88	35	40	24	24			
367	8	9	36	12	10	24				
368	8	10	123	35	20	23				
369	8	11	95	12	10	23				
370	8	13	170	12	10	23				
371	8	41	168	12	10	23				
372	8	44	138	35	20	23				
373	9	7	106	28	24	24				
374	9	11	77	28	24	24				
375	9	15	72	12	10	24				
376	9	66	99	12	10	23				
377	10	12	114	35	40	23				
378	10	44	69	12	10	2				
379	11	17	171	28	24	24				
380	11	44	120	12	20	24	24			
381	11	66	163	12	10	23				
382	12	17	64	35	80	16	24(2)	23	24	23
383	12	44	99	35	40	24	24			
384	12	45	122	12	10	24				
385	13	10	104	12	10	31				
386	13	14	51	12	10	23				
387	13	17	97	35	40	16	24			
388	13	19	104	12	10	13				

Arc	Orig.	Dest.	Dist.	Speed	Cap.	RRCo.			
389	13	63	171	12	10	16			
390	13	64	178	35	40	16	24		
391	13	65	158	12	10	16			
392	14	11	84	12	10	24			
393	14	15	68	12	10	23			
394	16	17	85	35	40	16			
395	16	18	43	28	24	24			
396	16	46	24	28	24	24			
397	16	47	121	35	40	16	16		
398	17	18	129	12	10	24			
399	17	19	56	35	40	24	16		
400	17	20	148	28	24	13			
401	17	21	138	35	40	27			
402	17	22	118	12	10	24			
403	17	45	143	28	24	24			
404	18	20	54	28	24	24			
405	18	47	126	12	10	16			
406	19	22	60	12	10	13			
407	19	63	96	35	40	24			
408	20	21	50	12	20	13	13		
409	20	25	57	35	40	13			
410	20	26	94	28	24	24	13		
411	21	22	65	12	20	13	13		
412	21	63	104	35	40	27			
413	22	61	169	12	20	13	13		
414	22	63	99	12	20	13	13		
415	22	65	60	12	10	27			
416	23	26	76	12	20	13	13		
417	23	61	63	12	30	13	13	13	
418	24	49	124	35	80	13	13	13	13
419	25	24	48	28	24	13	13	13	
420	25	47	153	35	40	16	16		
421	26	24	78	28	24	13			
422	26	25	89	12	10	16			
423	26	60	135	28	24	28			
424	26	62	214	28	24	13			
425	27	26	68	35	40	27			
426	27	28	90	35	40	27	19		
427	27	31	82	35	40	19			
428	27	32	105	35	40	27			
429	27	96	304	35	40	28			
430	28	26	90	28	24	19			
431	28	60	51	35	40	19			
432	30	26	142	35	40	27			

Arc.	Orig.	Dest.	Dist.	Speed	Cap.	RRCo.		
433	30	49	29	35	80	28	27	
434	31	30	44	35	40	19		
435	31	50	130	35	40	19		
436	32	36	113	35	40	27		
437	33	50	182	35	40	27		
438	34	51	155	35	40	1		
439	34	52	55	35	40	19	20	13
440	35	52	60	28	48	18	19	8
441	36	33	57	35	40	27		
442	36	39	83	28	24	27		
443	36	40	65	35	40	27		
444	37	54	170	28	24	3	7	
445	37	55	127	12	10	3		
446	38	34	80	45	50	13	19	3,20, 1
447	38	35	94	28	24	19	8	
448	38	36	184	12	10	27		
449	38	37	60	35	80	3	19	
450	38	39	103	35	40	27	14	19
451	38	53	87	45	100	17	8	
452	38	56	65	35	72	30	1	
453	38	57	227	45	100	1		
454	38	58	195	28	72	18	1	19
455	39	35	92	12	10	18		
456	40	28	310	12	10	19		
457	40	39	63	35	40	27	14	19
458	40	58	115	35	40	27		
459	40	59	175	28	24	14	27	
460	41	1	78	35	40	23		
461	41	3	75	12	10	24		
462	41	4	97	35	40	23		
463	41	5	118	12	10	23		
464	41	80	361	35	40	23		
465	41	82	141	35	40	23		
466	42	43	93	12	5	12		
467	42	44	159	28	24	12		
468	42	81	128	12	10	23		
469	42	82	82	12	10	24		
470	44	45	136	35	80	16	16	24
471	45	46	98	28	24	16	24	
472	47	45	151	35	40	16		
473	47	48	160	35	40	16		
474	48	50	166	28	24	16		
475	48	90	289	35	40	16		
476	49	50	130	40	72	27	19	
477	51	50	129	28	24	3		
478	52	50	130	45	100	8,3.19,13,18 , 20		

Arc	Orig.	Dest.	Dist.	Speed	Cap.	RRCo.			
479	52	51	88	35	80	20	3		
480	53	37	75	28	24	3	1		
481	53	52	83	28	24	3	20		
482	53	54	161	28	24	8			
483	53	90	412	35	40	8			
484	54	55	135	35	192	7	17	8	3
485	55	93	896	12	10	3			
486	55	94	560	35	40	3	30		
487	56	57	160	28	24	8			
488	57	94	580	28	24	1			
489	57	100	348	28	48	1	8		
490	58	59	124	28	24	19			
491	58	95	119	28	24	27			
492	58	101	318	28	24	18			
493	59	60	160	28	24	19			
494	59	95	210	12	10	8			
495	59	96	190	35	40	14			
496	60	96	144	35	40	19			
497	60	98	484	35	40	19			
498	62	61	138	12	10	13	13		
499	62	63	97	12	20	13	13		
500	62	64	179	12	10	13			
501	62	98	183	35	72	13	13	13	
502	63	64	137	12	20	13	27		
503	63	98	202	28	24	24			
504	64	65	96	12	10	16			
505	64	98	140	35	40	16			
506	65	66	202	12	10	16			
507	66	67	160	12	10	23			
508	67	99	141	35	40	23			
509	69	70	201	35	112	6	6		
510	69	72	230	35	72	6			
511	70	71	298	45	100	6			
512	70	73	190	35	40	6			
513	71	87	184	45	100	20	21		
514	71	88	252	35	40	6			
515	72	70	142	35	112	6	6		
516	72	73	134	35	72	6			
517	72	74	183	35	144	6	6		
518	72	76	225	35	112	6	5		
519	73	71	262	35	40	6			
520	73	74	136	35	40	6			
521	73	75	310	12	10	6			
522	74	75	245	45	100	21			
523	74	76	112	35	72	6			
524	75	76	296	35	72	5			

Arc	Orig.	Dest.	Dist.	Speed	Cap.	RRCo.			
525	75	87	131	35	216	21	5	6	
526	75	116	191	35	72	21			
527	76	77	227	35	40	20			
528	76	78	117	45	200	24	22		
529	77	84	225	35	72	20			
530	78	77	174	35	80	20			
531	78	79	279	35	40	24			
532	78	80	159	35	40	23			
533	78	84	369	35	40	5			
534	79	80	156	35	40	23			
535	79	81	98	45	100	23	24		
536	80	41	375	35	40	23			
537	81	44	154	145	100	24	23		
538	82	79	108	28	24	24			
539	82	80	203	35	40	23			
540	82	81	111	12	20	24	23		
541	83	44	197	28	24	16			
542	83	45	111	35	80	24	24	16	
543	83	47	216	12	10	16	24		
544	83	79	269	28	24	24			
545	84	85	204	45	100	5			
546	85	48	229	28	48	16	24		
547	85	50	338	28	24	5			
548	85	83	292	35	80	24	16		
549	85	90	281	35	40	5			
550	86	85	55	45	100	21			
551	86	87	109	35	144	21	21		
552	86	90	248	35	40	5			
553	87	90	340	35	256	20	5	21	6
554	88	90	272	35	72	21	20		
555	89	47	298	12	10	6	16		
556	89	50	240	35	40	6			
557	89	85	109	35	40	5			
558	89	90	184	35	40	21	16		
559	89	114	197	35	40	20			
560	90	49	364	35	72	13			
561	90	50	284	35	40	33			
562	90	51	272	45	100	3	1		
563	90	54	358	35	184	7	17	8	3
564	90	91	86	45	100	7	7	17	
565	90	92	396	35	40	3			
566	92	91	327	45	72	25	17		
567	93	109	903	35	40	3	3	17	
568	94	106	570	35	112	9	30		
569	95	57	172	35	80	8	1		
570	95	100	274	12	10	8			
571	96	101	182	45	30	29	26		
572	96	103	460	28	24	19			
573	97	62	218	12	10	13			
574	97	96	73	28	24	14	26		
575	97	101	194	45	20	29			
576	97	105	232	35	40	26	14		
577	98	97	315	12	10	15			
578	98	105	363	12	10	26			
579	99	68	261	35	40	23			
580	100	108	374	35	40	1			
581	101	103	209	28	24	18			
582	101	105	264	35	40	1			
583	101	95	236	35	40	22	1		
584	102	100	446	28	24	26			
585	102	101	646	35	40	29			
586	102	104	610	35	40	26			
587	102	107	434	35	40	26			
588	102	108	255	28	24	1			
589	103	104	82	24	19				
590	105	103	174	35	40	1	26		
591	105	104	210	28	24	26			
592	106	110	821	35	72	26	32		
593	106	111	783	35	40	30			
594	107	111	425	35	112	1	26		
595	108	107	576	35	72	1			
596	110	117	742	35	40	26	32		
597	111	110	470	35	80	26	26	1	
598	112	41	111	35	40	23			
599	112	80	204	35	40	23			
600	112	82	129	12	10	24			
601	113	92	145	28	24	3			
602	114	50	99	35	72	13	13	20	
603	114	51	123	35	40	20			
604	114	90	185	35	40	13	13		
605	115	75	261	35	40	21			
606	115	86	160	35	40	5			
607	115	87	107	45	100	21			
608	115	88	56	35	184	10	21	20	
609	115	90	243	45	100	21			
610	115	116	135	45	100	20	21		
611	116	86	71	35	224	21	21	21	21
612	116	87	138	45	100	21			
613	116	84	204	45	100	20	5		
614	117	106	836	35	40	30			
615	117	109	183	45	100	3			
616	118	92	231	35	72	3	3		
617	118	93	640	35	40	3	3		
618	119	88	152	35	40	6			
619	119	90	184	35	40	6			
620	120	77	258	35	40	20			
621	120	78	109	45	100	6	20		

WATER ARCS

Arc	Orig.	Dest.	Dist.	Speed	Lock	Chan	Sys.
623	62	98	337	7	0	11	12
624	61	62	101	7	0	11	12
625	23	61	80	7	0	11	12
626	26	23	120	7	0	11	12
627	24	26	115	7	0	11	12
628	49	24	168	7	0	11	12
629	50	49	128	7	2	9	12
630	51	50	147	7	7	9	12
631	92	51	526	7	22	9	12
632	58	59	182	7	5		2
633	59	60	230	7	6		2
634	60	61	154	7	6		2
635	52	50	179	7	0	8	13
636	34	52	78	7	0	8	13
637	38	34	109	7	0	8	13
638	37	38	82	7	0	8	13
639	55	37	168	7	0	8	13
640	25	49	222	7	6	11	18
641	20	25	60	7	1	11	18
642	18	20	50	7	0	11	18
643	16	18	48	7	4	11	18
644	46	16	19	7	0	11	18
645	45	46	141	7	2	11	18
646	83	45	184	7	3	11	18
647	47	49	304	7	7	11	6
648	48	49	241	7	9	11	15
649	85	48	322	7	4	11	15
650	75	85	470	7	6	11	15
651	84	85	263	7	4		11
652	90	50	365	7	9		10
653	19	64	215	7	4		19
654	22	19	125	7	2		19
655	21	22	75	7	4		19
656	20	21	55	7	4		19
657	17	19	224	7	2		4
658	13	64	334	7	3		1
659	15	65	100	7	1		5
660	11	15	200	7	2		5
661	42	41	150	7	0		17
662	70	72	180	7	0	12	9
663	71	70	342	7	35	20	14
664	69	72	265	10	-1	-1	3
665	72	120	440	10	-1	-1	3
666	120	76	197	10	-1	-1	3
667	120	112	460	10	-1	-1	3
668	112	41	121	10	-1	-1	3
669	41	1	90	10	-1	-1	3
670	1	2	90	10	-1	-1	3
671	2	68	371	10	-1	-1	3
672	68	99	369	10	-1	-1	3
673	99	66	220	10	-1	-1	8
674	66	65	253	10	-1	-1	8
675	65	64	81	10	-1	-1	8
676	64	98	166	10	-1	-1	8
677	98	105	417	10	-1	-1	8
678	111	110	351	10	-1	-1	16
679	110	117	635	10	-1	-1	16
680	117	109	361	10	-1	-1	16
681	71	87	176	10	-1	-1	7
682	87	88	108	10	-1	-1	7
683	88	91	568	10	-1	-1	7
684	88	113	726	10	-1	-1	7
685	113	91	743	10	-1	-1	7
686	91	90	85	10	-1	-1	7
687	115	88	54	10	-1	-1	7
688	87	115	96	10	-1	-1	7
689	72	76	270	10	-1	-1	3

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PROCEDURES FOR
MULTI-STATE, MULTI-MODE CORRIDOR ANALYSIS:
TASK 5, MODEL FORMULATION

by

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DEPARTMENT OF TRANSPORTATION
Office of the Secretary
Washington, D. C. 20590

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PREFACE

This report describes Task 5 of the project entitled, "Analytical Procedures for the Study of a Specific Multimodal Transportation Corridor." In this task an analytical model was developed that describes the interrelationships between transportation services and economic development opportunities. A small-scale demonstration of the model is also presented. The work in Task 5 is based directly on Task 2, and the latter task report should be read first in order to gain a complete understanding of this report. The work of Task 5 is summarized and the more important achievements are presented.

The research is sponsored by the Office of Transportation Systems Analysis and Information of the Office of the Secretary of the U.S. Department of Transportation. Dr. Byron Nupp is Contracting Officer's Technical Representative.

The work has been performed by a consortium of nine universities under the direction of Dr. Paul S. Jones of the Georgia Institute of Technology. Participating universities include the University of Alabama, Arkansas State University, Auburn University, Memphis State University, Mississippi State University, the University of Missouri, the University of North Florida, and Tennessee Technological University. Principal faculty participants in Task 5 include Dr. Gunter P. Sharp of Georgia Tech, Dr. Frank M. Holloway of Tennessee Tech, Dr. H. Barry Spraggins of North Florida, Dr. Robert L. Vecellio of Auburn, Dr. Martin E. Lipinski of Memphis State, and Dr. J. William Rush of Mississippi State. Substantive contributions were also made by Mr. Michael A. Mullens and Mr. H. C. David Yu, graduate students at Georgia Tech.

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I. INTRODUCTION

The research reported here represents a new approach to intercity transportation planning. The initial effort has treated only freight transportation. The present approach views intercity freight transportation services as tools for stimulating and supporting economic development. The economic development of interest is the creation of new production facilities in locations that do not have similar facilities today. In this context, the research deals with basic production--that which is largely exported from the producing area. The transportation facilities and services of interest are those that will bring about new circumstances with respect to transportation cost, access, or quality of service that are sufficiently different that they will provide the key increment that makes new production facilities feasible. The essence of the research is the determination of quantitative relationships between (1) new transportation facilities and services, and (2) the new production facilities that are made possible by these transportation services.

That there is a relationship between transportation services and economic development is well known. For centuries, major production facilities have been located where good transportation is available. New transportation services of many different kinds have stimulated new development. One need only look at the Interstate and Defense Highway System to be assured that there is an important relationship between the two. However, there has never been a satisfactory quantitative method developed that can predict the economic impact resulting from the introduction of a specific new transportation service. Such a predictor would be a valuable aid in identifying high potential transportation projects. If one could measure expected development in quantitative terms, that factor could make a large contribution to the expected benefits that are attributed to a transportation project. In fact, expected development may be the major benefit that accrues to non-highway transportation projects. Several investigators [1,2,3]* have developed models that relate land use or other economic indicators to the general quality of transportation. Harris [1] uses an input-output model to measure the relative value of different highway systems. He expresses the quality of transportation service in terms of costs between origin and destination points. Routing is prescribed as part of the cost determination and only a single transportation mode is treated. Polenske [2] has used input-output models for regional planning and has contributed much to the state of that art. Floyd and Wendt [3] have used input-output analysis on a regional basis to measure the impact of transportation on land use. This work is also limited to one mode and present technology. Past work is useful because it deals with both passenger and freight transportation and also with basic and non-basic (local) impacts of transportation. However, past work fails to answer specific development questions in sufficient detail to provide effective planning assistance.

Multi-State Transportation System

The analytical work presented here focuses on a single setting--the Multi-State Transportation System, which encompasses a strip of land ap-

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*Numbers in parenthesis refer to references listed at the end of the report.

proximately 100 miles wide and 1200 miles long extending from Brunswick, Georgia to Kansas City. Planning for the Multi-State System is vested in 7 states, many planning districts, many municipalities, and a large number of private citizen groups. Planning is coordinated by an advisory board whose members are listed in Table 1. Using state and federal support, a parametric study [4], a highway feasibility study [5], and a multi-mode feasibility study [6] have been prepared.

The Multi-State System area, which is illustrated in Figure 1, is of particular interest to this research for the following reasons:

1. It is a linear area or corridor which permits consideration to be restricted to simple networks of new transportation facilities.
2. It is largely undeveloped, simplifying the problems of economic modeling.
3. Transportation services at present are limited, creating substantive opportunities for improvement.
4. It lies in a region of high development potential in which sound early guidance can lead to large future benefits.
5. Sufficient past work has been done to simplify the data collection process.
6. The Multi-State Board provides outstanding support in all phases of the research.

The Multi-State Corridor contains four major metropolitan areas--Jacksonville, Birmingham, Memphis, and Kansas City--and a handful of cities with populations greater than 100,000 people (e.g., Columbus, Georgia; Montgomery, Alabama; and Springfield, Missouri). For the most

TABLE 1
MULTI-STATE TRANSPORTATION SYSTEM
ADVISORY BOARD

Elton B. Stephens, Chairman
Kermit B. Blaney, Executive Director

ALABAMA

Hon. George Wallace, Governor
Hon. Ray Bass, Highway Director
Hon. David Vann, Mayor, Birmingham
Mr. Lyman Mason, Vice Chairman
Mayor Jack M. Brown
Mr. William C. Davis, Jr.
Senior Vice Chairman
Councilman Don A. Hawkins
Senator George D. H. McMillan, Jr.
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Mr. Sim S. Wilbanks

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Hon. Henry Gray, Highway Director
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Representative Jerry Wilburn

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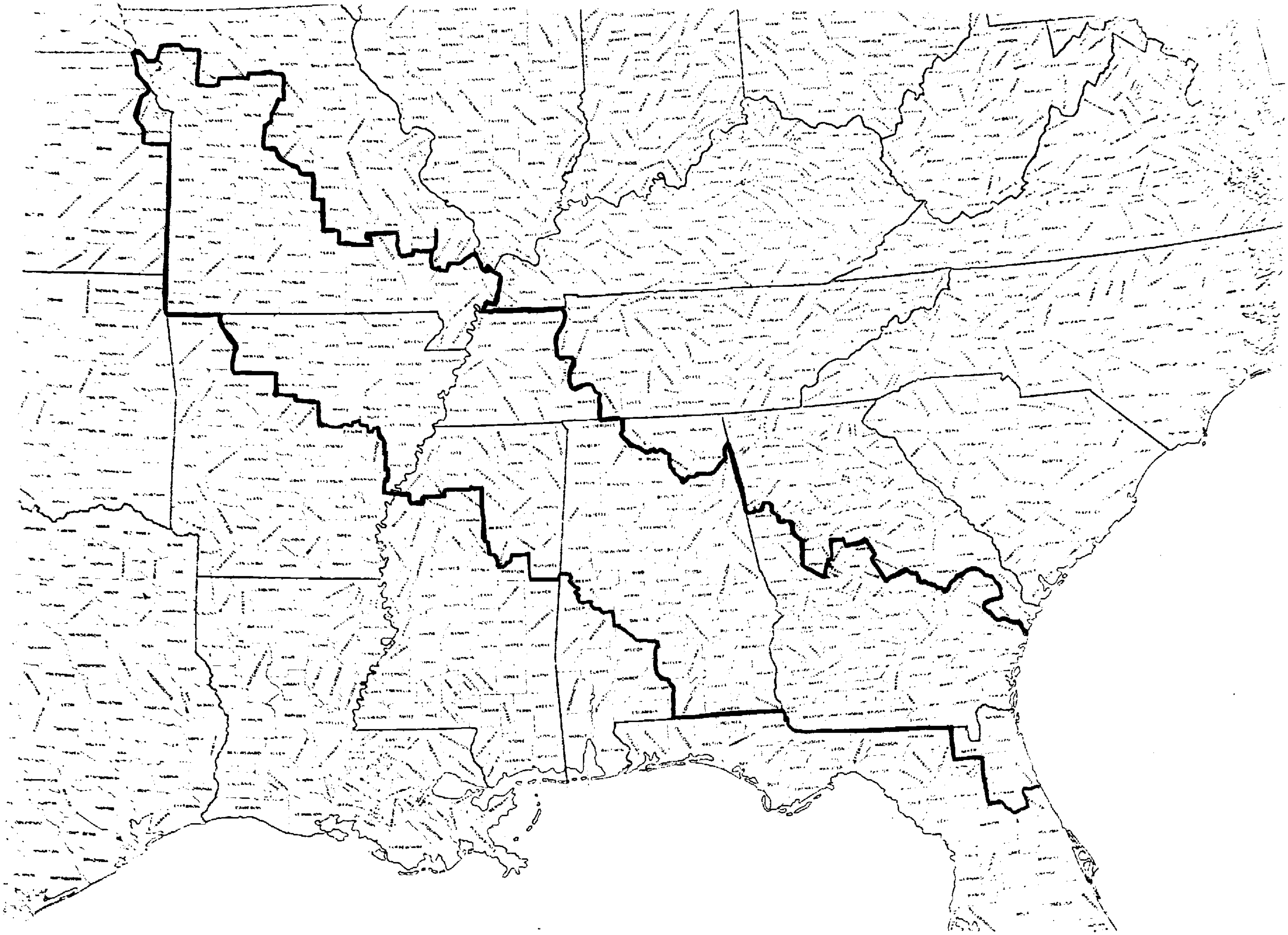
Hon. Jack Curtis, Chairman, Highway Commission
Hon. Charles Wheeler, Mayor, Kansas City
Councilman Victor F. Swyden, Vice Chairman
Mr. T. Dick Fleming
Mr. Robert Hunter
Mr. George Innes
Councilman David D. James
Mr. Max Norman
Mr. Willard Wilkinson

TENNESSEE

Hon. Ray Blanton, Governor
Hon. Wyeth Chandler, Mayor, Memphis
Hon. Roy Nixon, Mayor, Shelby County
DOT Commissioner Eddie Shaw, Vice Chairman
Mr. George Dando
Mr. Frank C. Holloman, Senior Vice Chairman
Mr. George Houston
Mr. Frank Palumbo
Mr. Jack Ramsay
Mr. Bruce C. Taylor

FIGURE 1
MULTI-STATE TRANSPORTATION SYSTEM AREA



part, the area is rural, and a large fraction of the population is engaged in marginal agriculture. These rural populations have the lowest per capita income of any part of the United States. The corridor has some natural resources, notably coal, iron ore, and timber, and also has abundant water resources.

There has been some development in the Multi-State Corridor. Just to the north, under the stimulus of the space program, Huntsville, Alabama has blossomed from an agricultural marketing center to a major research and engineering center. New facilities--principally textile--have been located in rural areas to take advantage of low wage rates and abundant unskilled labor.

The Multi-State Corridor is an ideal setting for new multi-modal development. New transportation facilities can be build without the citizen protests that accompany most major projects in urban and industrialized areas. Economic development is desperately needed to improve the lives of an impoverished population. The terrain is gentle, having few major geographic obstacles. It includes the base of the Appalachian chain and the eastern Ozarks. In addition, the predominantly rural corridor provides an opportunity to test whether substantial populations can be supported in rural areas without the necessity of migrating to major urban areas and contributing to a worsening of urban problems.

Traffic volumes in the Multi-State Corridor are not high. No interstate highway runs the length of the Corridor although a number cross it. Longitudinal roads are of moderate to poor quality. A main line of the Frisco Railroad traverses the area from Kansas City to Brimingham and a secondary main line of the Seaboard Coast Line Railroad continues to Jacksonville. Through freight service is available. The area is crossed by the major waterways of the Southeast, including the Chattahoochee/ Apalochicola Rivers, the Tennessee-Tombigbee project, the Tennessee River, the Mississippi River, and the Missouri River. Ocean port facilities are located at Brunswick and Jacksonville. Major river ports are located at Columbus, Georgia; Birmingha and Decatur, Alabama; Memphis; and Kansas City.

Scope

The process of selecting and locating transportation facilities and services and thereafter planning industrial development along transportation routes is an extremely complex one. In particular, the knowledge, effort, and expense to perform specific location studies suggests that one should not launch into detailed planning without a high probability of success. What is apparently called for is a screening process by which the problem can be viewed at several levels of detail, with each level narrowing the scope of study for successive work.

This research is viewed as the first of a succession of screening steps. The product of this work is an analytical method that can identify potentially attractive transportation development opportunities in terms of the industrial development that each can stimulate. The transportation services are identified in terms of mode, capacity, and approximate route. Details concerning alignment, design, points of ingress and egress and specific technology are left for later study. Development opportunities are described in terms of industry group, approximate location, approximate markets, and approximate size. Details concerning specific products and activities, raw materials, specific location, and corporate ownership are left to others.

The research is concerned only with basic industry--that is new facilities that will produce goods or services that are largely exported from the producing area to national markets. The total market for each industry group is assumed to remain fixed with respect to size and location. Thus, new facilities built in the Multi-State Corridor must compete with existing facilities for existing markets. Market competition among competing suppliers is conducted on the basis of cost, with product quality assumed to be equal. This assumption, in effect, treats new facilities as though they are branch plants for which higher management has the authority to allocate production on the basis of cost.

Secondary, nonbasic, or multiplier, effects of new facilities are not considered at this time nor are the development of new market demands induced by the establishment of new facilities. Although both issues are of immense importance to the development of the Multi-State Corridor, consideration of these issues is postponed to a later date.

Consideration is given only to freight transportation. Although passenger transportation is an important part of highway use, it is not studied at this time. By omitting passenger transportation, it has also been necessary to omit tourism from the candidate developments. Tourism has great potential in the Multi-State Corridor, particularly along the Georgia and Florida coasts and in the Ozark Mountains. It fully warrants later consideration.

The industrial markets used to test new development opportunities are restricted to the 48 contiguous United States. Alaska, Hawaii, and Puerto Rico are grossly lumped with overseas markets for the purposes of the present work. At a later time, overseas and export opportunities will be examined in more detail.

Many alternative transportation services are identified, and several of these will be attractive from different view points. The alternative services are assembled into programs, each of which represents a complete transportation strategy for the Multi-State area. Programs are evaluated and compared in terms of complex criteria that include traffic volume, economic development, user benefits, employment, potential profit, and others. Specific environmental and public acceptance issues are not addressed at this level of analysis.

Task 5

Task 5 deals with the formulation of the preliminary analytic model. Its specific objectives are the following:

a. Identify key modeling issues

b. Define model requirements

c. Formulate alternative models

d. Prepare evaluation criteria

e. Evaluate alternatives

f. Test the models in Northern Mississippi setting

The objectives have been met in the manner described in this report.

The presentation of the material is as follows:

Chapter II	Overview of the Model
Chapter III	Network Representation
Chapter IV	Transportation Cost Modeling
Chapter V	Mode Split Analysis
Chapter VI	Market Share Analysis
Chapter VII	Demonstration of the Model
Appendices	Computer Program Listings, Mode Split Results, Flow Assignment Algorithm

II. OVERVIEW OF THE MODEL

The purpose of the analytical model is to capture the esential interrelationships between transportation facilities and services and the economic development opportunities deriving therefrom. The model itself is contained within a larger analytical procedure consisting of a number of data gathering, computational, and model execution steps.

The first part of the procedure, model preparation, consists of eight principal steps: (1) identifying network zones, consisting of county groups, BEA (Basic Economic Area) sectors, and aggregations of BEA's; (2) identifying network arcs, consisting of Interstate, Federal aid primary and state highways, class I and class II rail lines, and navigable inland waterways; (3) defining 53 commodity groups based on SIC (Standard Industrial Classification); (4) establishing material inputs, labor, energy, and capital costs associated with each of the 53 groups; (5) preparing a 120 zone, 53 commodity flow table for the U.S.; (6) fitting abstract, mode split equations to the previous data; (7) fitting market share equations based on the distribution of delivered price for each commodity in each zone; (8) validating the combined process of steps 6 and 7.

The second part of the procedure consists of three steps: (1) Transportation improvements are postulated, based on apparent deficiencies, on specific development possibilities, and on intermodal service and new modes of transport; (2) existing freight movements are modified to take advantage of the improvements; (3) new industry development opportunities are tested. These three steps are combined into an interactive, iterative process.

Figure 2 shows a flow chart of the overall procedure. It is difficult to define precise system boundaries for the model, since it is so intricately related to the overall procedure. For classification purposes, however, the model may be defined as consisting of:

a. Network representation, contained within steps 1, 2, and 8

b. Transportation cost modeling, contained in step 2

c. Mode split analysis, step 6

d. Market share determination, step 7 and portions of Part 2

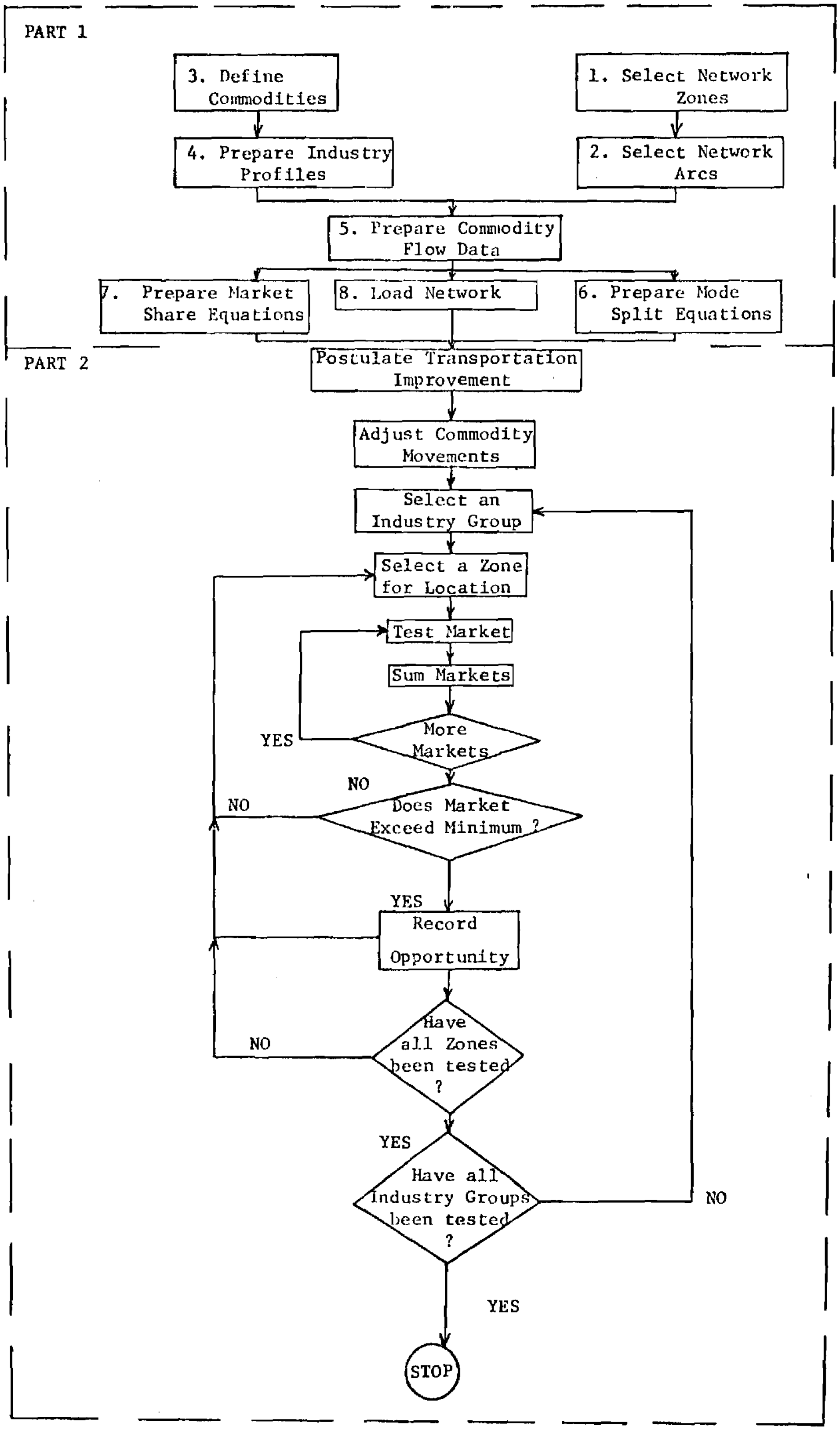
The Task 2 report contains a more complete description of steps 1, 2, 3, 4, and 5. Here follows a brief overview of the analytical procedure, including the model as defined above.

Establishment of Network Data

Network Zones

Each zone designation consists of a boundary and a representative city or centroid. All zones include an integer number of counties. Within the corridor, zones include about ten counties and generally conform to the districts that have been formed for comprehensive planning. Adjacent to the corridor, zones consist of the input-output sectors (BEA: Basic Economic Area) developed by the Office of Business Economics; each of these zones include twenty to thirty counties. The choice of BEA's was based on their individual homogeneity and the availability of commodity flow data. The major disadvantage of BEA's is that many cross state boundaries. As zones become more remote from the corridor, BEA's are combined to form large zones. In all, there are 120 zones in the network.

FIGURE 2
ANALYTICAL PROCEDURE



Zone centroids are generally the largest city in each zone, but, where the choice of a centroid is not obvious, locations of major transportation routes are taken into account.

Network Arcs

Network arcs constitute the major routes for each mode over which inter-zone traffic is carried (intrazone traffic is not included in the analysis). Arc selection was influenced by zone size: arcs connecting the small zones in the Multi-State corridor consist of almost all intercity cargo routes. As zones get larger, more intercity routes are omitted because they are not carrying significant interzonal traffic. For example, the highway network includes Interstate, Federal aid Primary and some state routes between the small corridor zones. In contrast, the network between large zones has few routes that are not Interstate Highways. Similarly, the rail network contains most through routes within the corridor, but only principal routes outside. The water network contains major intra and inter coastal services as well as all inland waterways with seven foot channel depth or more.

Network arcs are described in terms of length, capacity, and mean speed or travel time. Where two or more routes are combined in a single arc, length and speed are determined for the higher quality route. The second route would serve as additional capacity when the higher quality route becomes congested.

Existing Commodity Flows

Although many sources of freight commodity flow data are available, assembling the complete data base poses difficult problems. Three principal data sources were used: the NTP data [7]; the CTS (Census of Transportation) [8]; and the Census of Manufacturers [9]. These sources were augmented with additional data collected at the State and local levels. The NTP data are nearly complete and provide BEA to BEA movements for 20 commodity groups. The CTS data are available in finer commodity detail for state-to-state movements but suffer from disclosure problems. In addition, the Census of Transportation is incomplete and only sampled movements longer than 25 miles.

Considerable effort was expended in using Census and other data to break down the NTP data into 53 commodity groups and to further allocate flows to the smaller corridor zones. The complete process is described in the Task 2 report.

The resulting representations of existing commodity flows are important not only for characterizing the load on the network, but also for providing valuable information for market penetration analysis, as described later.

Transportation Cost Modeling

Transportation costs for the first year's work have been based largely on equations developed by H. O. Whitten [10]. These equations are based on ICC (Interstate Commerce Commission) data and reflect averages for line haul and loading-unloading over large geographical areas. The 20 commodities in [10] have been expanded to 53 by using national aggregate flow data for a finer commodity breakdown. Forwarding and transfer costs at terminals were estimated primarily from [11], and transportation times and time variances were estimated from other sources [12, 13, 14]. Chapter IV of this report contains a more complete description of the cost modeling.

Network Representation and Flow Assignment

Multi-Modal, Multi-Commodity Network

A network representation is achieved by designating flow variables

$f(i, j, m, k)$ = flow of commodity k by mode m on arc (i,j)

incurring cost variables on each arc of $c(i, j, m, k)$.

Transfer costs are represented for each node by a symmetric array

position	movement	position	movement
1,1	not used	2,3	highway-rail
1,2	load, highway	2,4	highway-water
1,3	load, rail	3,3	forward, rail
1,4	load, water	3,4	rail-water
2,2	forward, highway	4,4	forward, water

Flow Assignment

The costs on line haul arcs and the transfer costs at nodes are assumed to be additive for determining an overall cost for an origin-destination (O-D) path. Flow assignment is based on shortest paths determined by a Moore-type tree building algorithm developed specifically for this project. The network representation and flow assignment are presented in more detail in Chapter III.

It is assumed that transportation costs are unaffected by volume of freight traffic over the ranges of interest. This assumption is probably valid for the line haul arcs in the Multi-State Corridor. The second-year research effort will include the implementation of a congestion-effected multi-modal network assignment algorithm (Appendix A).

Mode Split

An abstract mode approach with a strict choice utility function is used in the mode split analysis. Specifically, a multinomial logit model was selected with the following path utility function:

$$U(\text{path}) = \exp(a_0 + a_1 C + a_2 T + a_3 V)$$

where

C = transportation cost

T = transportation time

V = transportation time variance

Chapter V describes this analysis in detail.

Economic Representation

Commodity Grouping

Commercial products were grouped into 53 industry/commodity groups, as shown in Table 2. This classification was a compromise: the NTP flow data are available for only a 20 commodity breakdown, and the more finely detailed CTS flow data suffer from severe data omissions (30% at our level of analysis).

Each commodity group is assumed to produce a relatively homogeneous group of products. Furthermore, each potential new facility to be located will be assumed to produce a single commodity. During the second year there will be explored the implications of finer commodity breakdown.

TABLE 2
INDUSTRY/COMMODITY GROUPS

NO.	DESCRIPTION	SIC CODES
011	Grain	011
013	Field Crops	013,016,018,019
021	Livestock	021
024	Dairy	024
025	Poultry & Eggs	025
080	Forestry	08
090	Commercial Fishing	09
101	Iron Ore	101
102	Non Ferrous Ores	102,103,104,105, 106,108
110	Coal	11,12
130	Oil& Gas Extraction	13
140	Non-Metallic Minerals	14
201	Meat	201
202	Dairy Products	202
203	Canned & Preserved Food	203
204	Grain Products	204
205	Bakery Products	205
206	Confectionary	206
207	Fats & Oils	207
208	Beverages	208
209	Misc Food	209
210	Tobacco	21
220	Textile Mill Products	22
230	Apparel	23
240	Lumber & Wood	24
250	Furniture & Fixtures	25
260	Paper	26
270	Printing & Publishing	27
281	Industrial Inorganic Chemicals	281

NO.	DESCRIPTION	SIC. CODES
282	Plastics	282
283	Drugs	283
284	Soap	284
285	Paint	285
286	Industrial Organic Chemicals	286
287	Agricultural Chemicals	287
289	Miscellaneous Chemicals	289
290	Petroleum Refining	29
301	Tires & Tubes	301
302	Rubber & Plastic Products	302,308,304,306 307
310	Leather & Leather Products	31
324	Cement	324
321	Stone,Clay,Glass&Concrete Prod.	321,322,323,325 326,327,328,329
331	Iron & Steel	331,332
333	Non Ferrous Metals	333,334,335,336 339
341	Metal Cans & Shipping Containers	341
342	Fabricated Metal Products	342,343,344,345, 346,347,348,349
350	Machinery, Except Electrical	35
362	Electrical Industrial Apparatus	362
361	Electrical Machinery	361,363,364,365, 366,367,369
371	Motor Vehicles & M.V. Equip.	371
372	Transportation Equipment	372,373,374,375, 376,379
380	Measuring Instruments	38
390	Miscellaneous Manufacturing	39

Industry Structure Analysis

Each commodity group is treated as a homogeneous economic activity with common raw material needs, common labor, and common capital requirements. Production input factors were developed for each industry group based on national average data from the Census of Manufacturers [9]. Production costs are assumed to be linear with quantity produced, provided that volume exceeds a minimum specific to each industry.

The Task 2 report contains a more complete description of both the commodity groupings and the industry structure analysis. Also, Chapter VI of this report elaborates on how the production costs are actually computed.

Market Share Analysis

This analysis focuses on penetration of existing markets by new production facilities as a result of some marginal advantage. The marginal advantage, in turn, is based on production costs, delivery costs, delivery time, and time reliability. The latter factors are influenced by the transportation mode selected, and are therefore mode specific. Existing markets for new facilities are identified by examining the existing commodity flow data. Chapter VI discusses these points in detail.

Sequence of Computer Programs

The computations relating to the previous sections were performed primarily by computer programs written in FORTRAN IV for the Control Data Corporation CYBER 74 located at Georgia Tech. To achieve more computational efficiency the actual sequence of program execution differs somewhat from that of Figure 2, and is as follows:

1. Determine existing O-D commodity movements,
2. Input network data and cost data,
3. Construct network with dual-node numbering system and appropriate line haul and transfer arcs,
4. obtain shortest path trees for each origin,
5. Load existing commodity movements,
6. Obtain samples of existing movements,
7. Calibrate mode split parameters for selected commodities,
8. Determine material sources and costs for selected commodities,
9. Determine production costs for selected commodities, and
10. Determine market share for selected commodities purchased by potential new facilities.

The complete computer listings include more than 19 separate programs, many of which are input-output and bookkeeping routines necessitated by the sheer volume of data. These listings are included in Appendix E.

Once the complete program battery has been operated, there are a number of strategies available for iterating through changes. These computations refer to Part 2 of the analytical procedure shown in Figure 2. That flow diagram does not indicate the inevitable feedback resulting from changes.

The following computational sequence has been developed as offering a reasonable balance between computational efficiency and obsolescence of network data:

1. Postulate transportation service improvements,
2. Update network representation, skip to 4,

3. Obtain shortest path trees for each origin,
4. Obtain shortest path trees for test zones,
5. Determine material costs for selected commodities,
6. Determine production costs for selected commodities, and
7. Determine market share for selected commodities purchased by potential new facilities.

By skipping the time consuming step 3 for several iterations at a time, a far greater number of alternatives can be examined in the same computer time, since the other six steps are performed rapidly. The second-year effort will focus on this problem as well as identifying those existing commodity flows affected by network changes [15].

III. NETWORK REPRESENTATION

Alternative Forms of Network Representation

A multicommodity flow network can be used to represent the flow of each of 53 commodities on each transport link (arc). The flow variables are of the type

$$f(i, j, k) = \text{flow of commodity } k \text{ on arc } (i, j).$$

At each node there are constraints of the type

$$\sum_j f(i, j, k) - \sum_h f(h, i, k) = s(i, k).$$

The first summation represents all flow of commodity k away from node i, the second all flow of commodity k to node i. The difference must be equal to the outbound shipping demand for commodity k at node i. Transportation costs are represented for each arc (i, j) and for each commodity by the coefficients c(i, j, k).

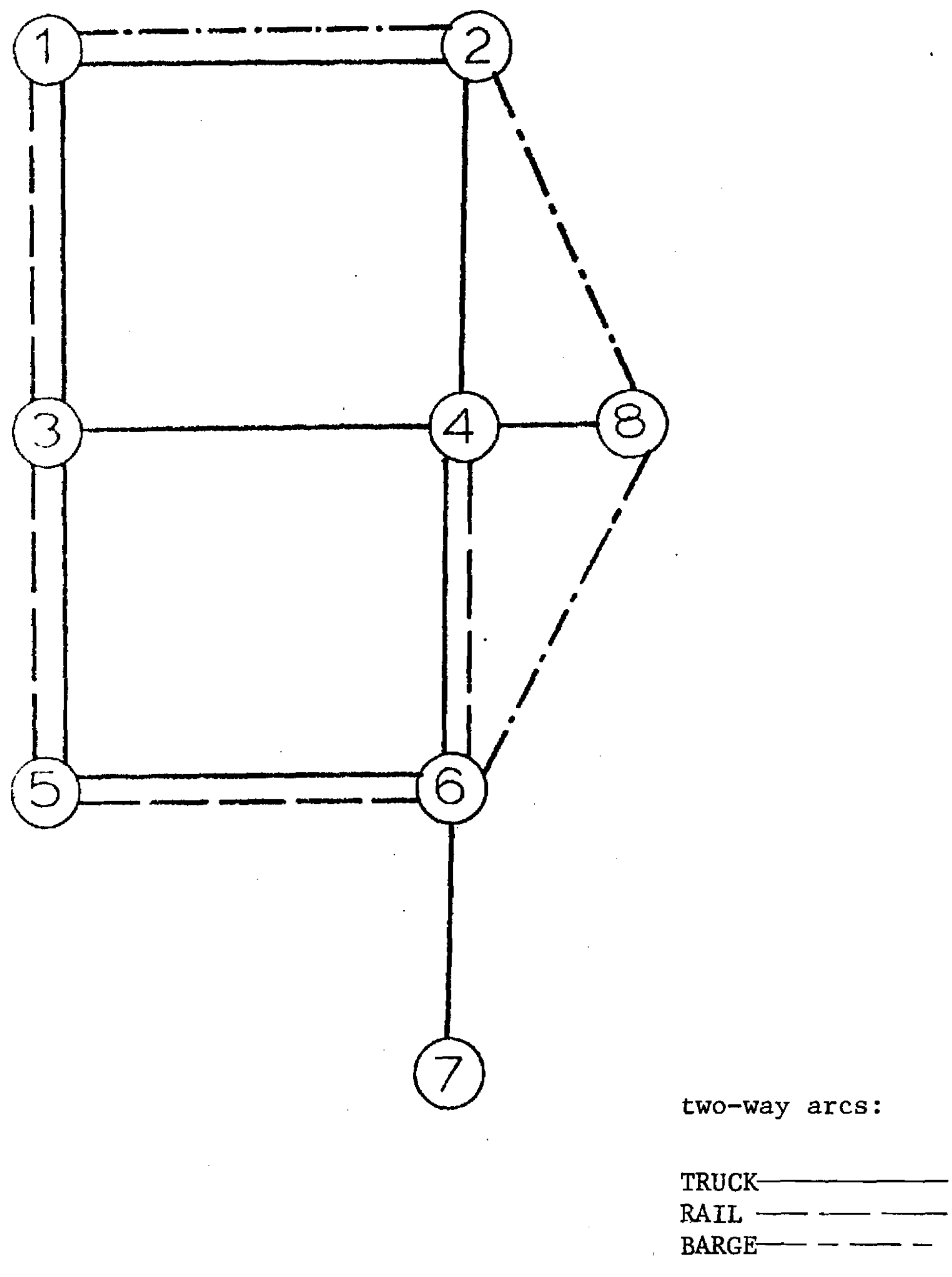
Within this general framework, three methods were examined for distinguishing between the different transportation modes, such as highway, rail, and water.

Expanded Network, Form 1

Using this method one represents each mode connecting two points by a separate arc with appropriate cost. Additional nodes and arcs are then inserted in the network to represent transfers between modes [16].

Figure 3 shows a small hypothetical example containing eight terminals and three modes. An expanded network is constructed according to the following rules:

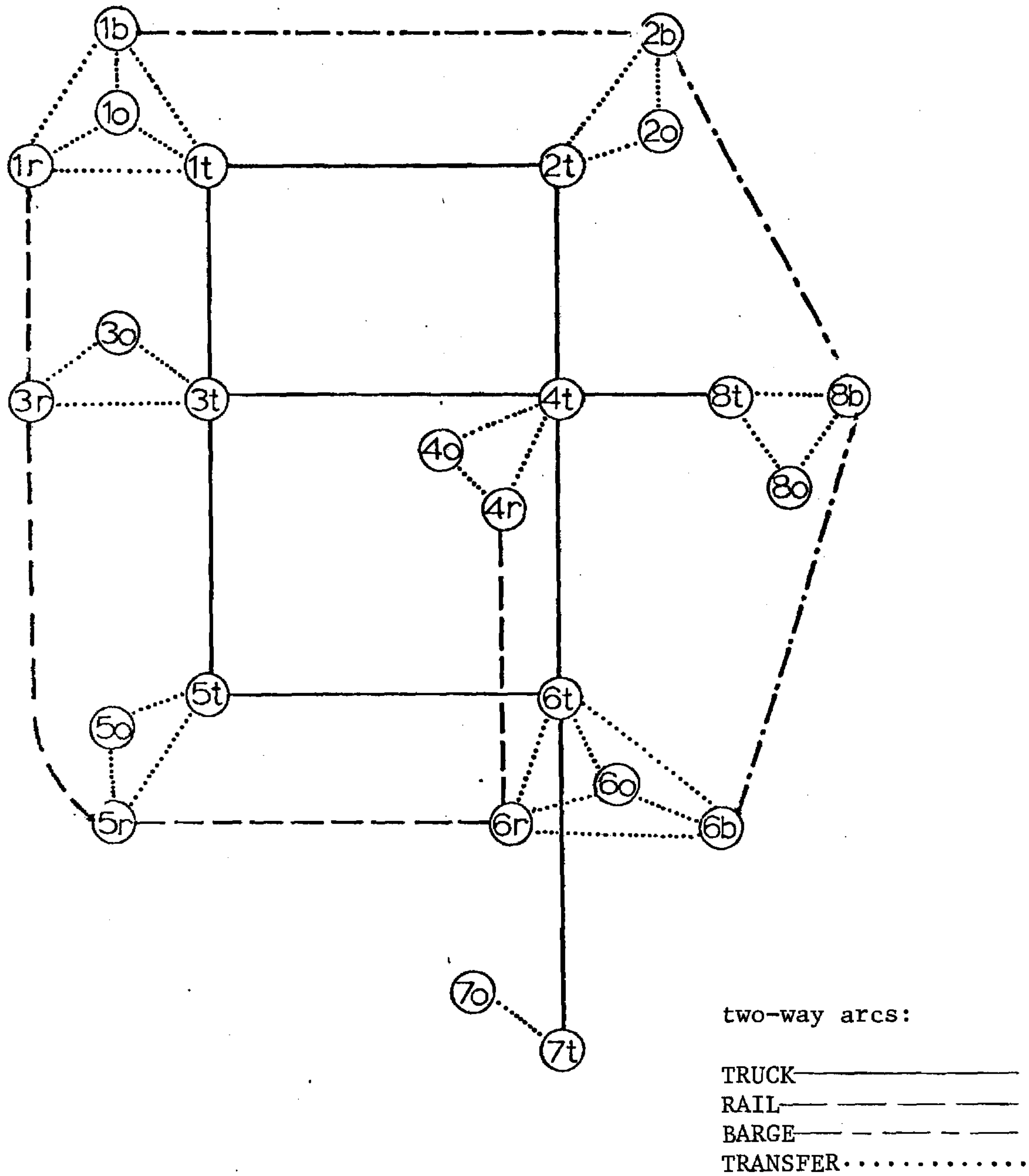
FIGURE 3
EXAMPLE OF TRANSPORT SYSTEM



1. For each terminal i served by mode r designate a node ir.
2. For each mode connect the nodes ir, jr, ... by arcs corresponding to the links in the original network. The unit shipping costs on each arc (ir,jr) correspond to the line haul costs of the original network. The capacities are likewise based on the original line haul capacities per mode.
3. For each terminal i of the original network designate an origin node io.
4. From each origin node io extend loading arcs to all nodes ir of the same original terminal number. The unit shipping costs for these arcs are based on unit loading costs. Capacity constraints may be assigned where appropriate, or they may be dealt with in step 7.
5. From each node ir extend an unloading arc to the corresponding origin node io, with appropriate unit shipping costs.
6. Where transfers are possible between modes r and s at terminal i, construct transfer arcs (ir,is) and (is,ir), with unit shipping costs based on thr transfer costs.
7. Assign aggregate capacity constraints to each set of arcs of the types (io,ir), (ir,io), (ir,is), and (is,ir) corresponding to a terminal.
8. Assign the original net shipping demands to the origin nodes io.

Applying these rules to the network in Figure 3 results in the expanded network of Figure 4, where each link represents two one-way arcs. The specific modal designations are no longer necessary since the arcs are associated with the proper costs and capacities.

FIGURE 4
EXPANDED NETWORK, FORM 1



The resulting network is much larger than the original one. If one had 120 nodes, 400 two-way arcs, and 3 modes originally, the expanded network could contain as many as 480 nodes and 1920 two-way arcs. There may also be difficulties in dealing with capacities when two or more modes share the same guideway or physical facility. Finally, transportation costs are represented in additive form, which may pose problems in structuring rates.

There are two advantages to this method: first, simple and well-known solution techniques can be applied to the expanded network. Second, there exist algorithms for determining the value of the transfer facilities [16].

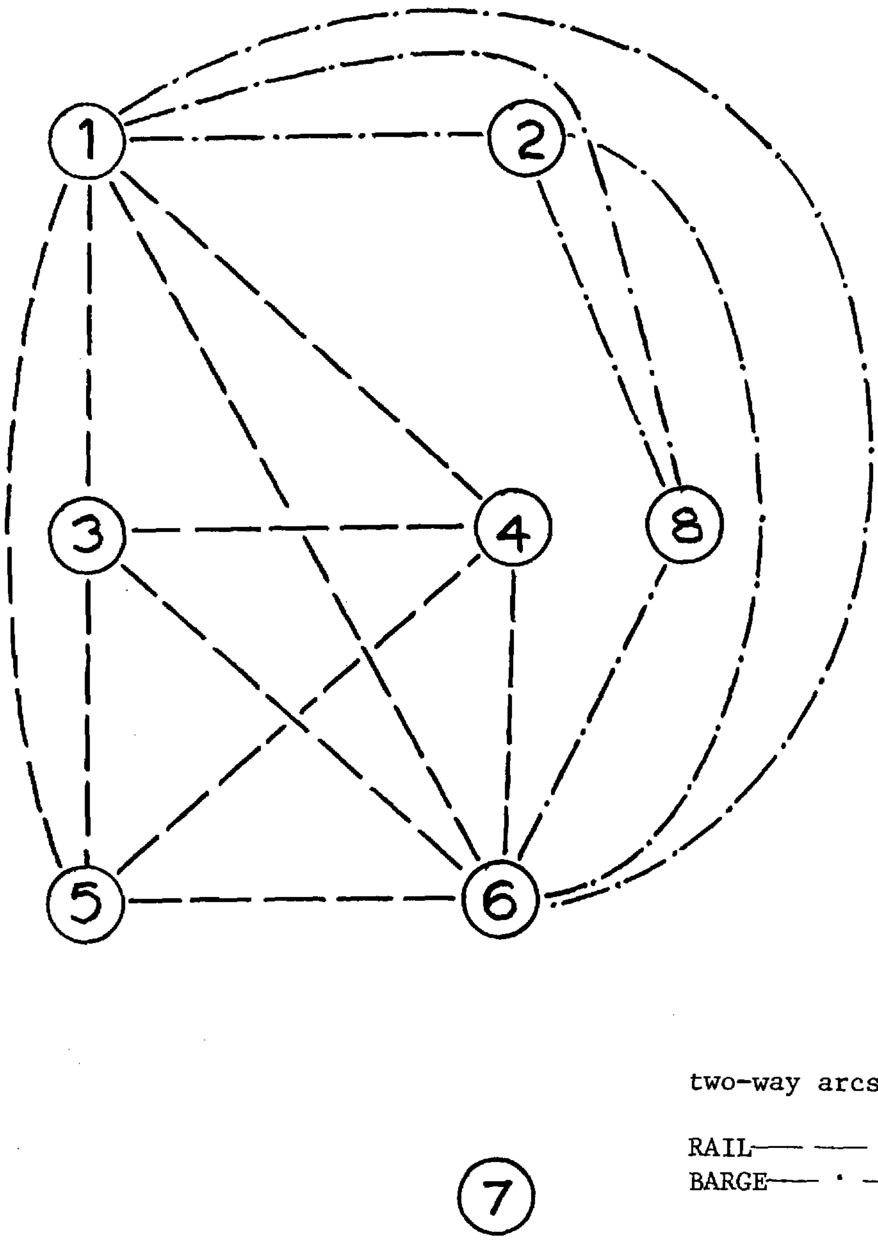
Expanded Network, Form 2

The second type of expanded network is constructed using the following principle:

> Each path between two nodes that can be followed on one mode without transfer or switching operations is represented by a unique arc [17].

Applying this principle to the network of Figure 3 again yields an expanded network as illustrated in Figure 5. Figure 5 contains only the two-way arcs corresponding to the rail and barge mode because inclusion of highway arcs in this illustration would make the network diagram too cluttered. By assigning the proper arc costs one can easily represent a greater variety of rate structures than with Form 1. Computation of shortest paths is performed with lists that replace the usual tree labels [17].

FIGURE 5
EXPANDED NETWORK, FORM 2
RAIL AND WATER ARCS ONLY



two-way arcs:

RAIL— — — —
BARGE— · — · —

One can easily see that for a network of 120 nodes the number of arcs can become disturbingly large. Also, if transfer costs are not additive in terms of loading and unloading costs, then additional dummy nodes and arcs must be inserted, as in Figure 4. This type of expanded network is more suited for modeling relatively small public transit systems, for which it was designed, than for modeling large freight transportation systems.

<u>Subscripted Flow Variables with Dual Node Numbers</u>

This method involves one additional subscript in the flow variables and in the cost coefficients:

$f(i, j, m, k)$ = flow of commodity k by mode m on arc (i, j)

$c(i, j, m, k)$ = corresponding cost coefficient

The node constraints become

$$\sum_j \sum_m f(i, j, m, k) - \sum_h \sum_m f(h, i, m, k) = s(i, k).$$

This approach involves some additional bookkeeping work in the computer program in order to keep track of mode transfer costs,

$t(i, m, n, k)$ = cost of transferring commodity k from mode m to mode n at node i.

For efficient implementation a dual node numbering system is used. Each node carries a two subscript designation, (i, i'), in which the i represents the node location and i' represents one of the following:

1	origination	2	destination
3	mode 1 (highway) inbound	4	mode 1 outbound
5	mode 2 (rail) inbound	6	mode 2 outbound
⋮		⋮	

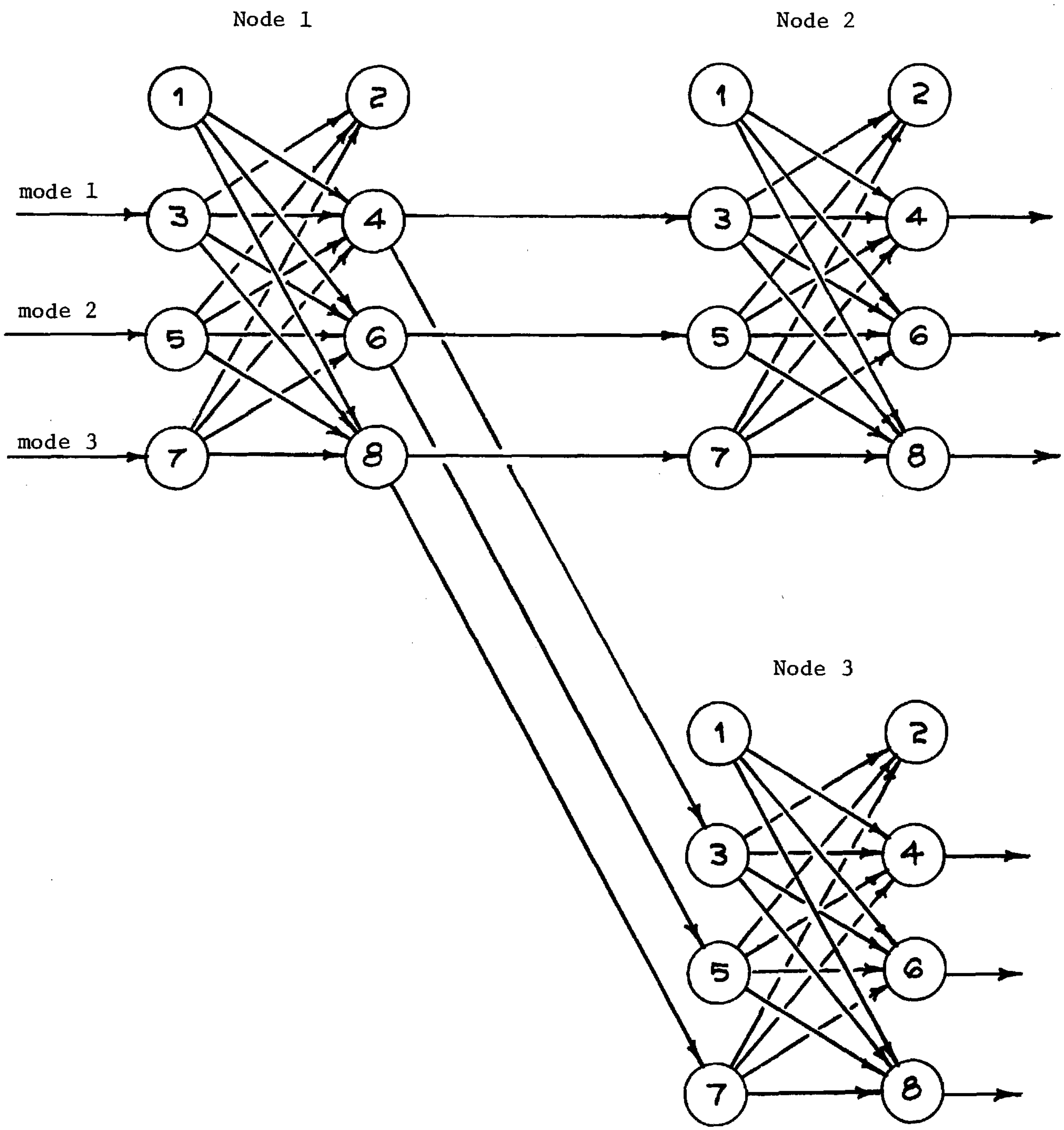
Line haul arcs always connect two nodes with consistent i' numbers. Transfers and forwarding at nodes can occur wherever costs are favorable. Figure 6 illustrates how this dual numbering system can represent an expanded network.

Transfer costs for each node are represented by a symmetric array:

position	movement	position	movement
1,1	not used	2,3	highway-rail
1,2	load, highway	2,4	highway-water
1,3	load, rail	3,3	forward, rail
1,4	load, water	3,4	rail-water
2,2	forward, highway	4,4	forward, water

This method of representing a multi-modal network is similar to the expanded network, form 1. In fact the only important difference is whether the last classification level (arc origin, arc destination, mode, commodity) is indexed by arc or by commodity. There are some important advantages to the dual numbering system, however. Since an input editor is not needed for building the expanded network, it is far easier to prepare the data, both for the initial network and for subsequent anterations. With the proper shortest path algorithm, it is easy to "turn off" one or two modes and thus determine single-mode or two-mode paths efficiently.

FIGURE 6
DUAL NODE NUMBERING SYSTEM,
ONE-WAY ARCS



Selection of Network Representation

The manipulative advantages of the subscripted flow variables with dual node numbers led to its adoption. The overriding factor was the need to obtain shortest path trees for each mode for each of 120 origin zones. The multi-modal shortest path algorithm, made this computation fast and convenient, with only one comprehensive set of input data needed. Furthermore, the same algorithm could be used for finding compound-mode journeys.

Other Conventions

All line haul arcs originate and terminate at a node representing a zone centroid. It is assumed that transportation costs and services to and from a zone are represented adequately by costs and services to and from the zone centroid. Similarly, intermode transfers can occur only at centroids. These assumptions could be easily changed, but they seemed appropriate for the first-year effort.

Intra-zone movements are not considered, since the focus of the research effort deals with identifying basic industries that can penetrate national markets.

Flow Assignment

Uncongested network assignment is achieved using a Moore-type tree building algorithm developed specifically for this project. The algorithm accepts as input the different arc costs by mode and the transfer costs at each node. It treats these costs as if it were dealing with an expanded network of form 1. The costs on line haul arcs and the node transfer costs are assumed to be additive for determining an overall cost for an O-D path.

The algorithm itself is an adaptation of a well-known procedure [19] to the dual node numbering system. It accepts as input the modes allowable in a particular run. Thus, it can be used for finding single mode paths as well as compound-mode paths. A program listing is contained in Appendix E. The use of the program is discussed further in Chapter V, Mode Split Analysis.

The assignment program assumes that transportation costs, times, and time variances are unaffected by the volume of freight traffic over the ranges of interest. This assumption is probably valid for the line haul arcs in the Multi-State Corridor. The additional flows generated on line haul arcs by products from new facilities are unlikely to change travel characteristics. In effect, one can then simply observe costs, times, and time variances and use these as values for assigning new flows in an uncongested network.

Congestion will most likely change, however, at the mode transfer terminals. The second-year research effort will examine this matter in detail. Based on queueing theory, one can develop typical average delay times as a function of flow through the terminal. Thus terminals can be represented as congestion-affected arcs. During the second-year effort we will program the congestion-affected multi-commodity flow assignment algorithm which has been developed already [18]. This algorithm is an extension of other, reasonably efficient assignment algorithms, and a working paper describing it is included in Appendix A.

IV. TRANSPORTATION COST MODELING

Development of Highway and Rail Costs

Highway and rail transportation costs have been developed from equations prepared by H. O. Whitten [10]. The equations are based on ICC (Interstate Commerce Commission) data and reflect averages for line haul and loading-unloading over large geographical areas. The 20 commodities have been expanded to 53 by using national aggregate flow data for a finer commodity breakdown, according to the procedures described below.

Highway

Line Haul Costs

Let

$LHM^{n}_{i,j}$ = total line haul costs/ton of commodity n moving by motor carrier between zones i and j

Then

$$LHM^{n}_{i,j} = \sum_{e \varepsilon E_M} p^{e,n} \sum_{g \varepsilon MCCA} d^{g}_{i,j} \cdot MLg^{e} \cdot I^{n}$$

Where

E_M = set of trailer types,

$p^{e,n}$ = fraction of commodity n motor traffic using trailer type e,

MCCA = set of motor carrier cost areas,

$d^{g}_{i,j}$ = distance on arc i,j in MCCA g, highway class c,

ML^{e}_{g} = total line haul cost/ton-mile of any commodity using, trailer type e, in MCCA g, and

I^{n} = density multiplier for commodity n.

Here $E_M = \{\text{van, tank-hopper, refrigerator}\}$. The $p^{e,n}$ were estimated based on national aggregate statistics [8], and are shown in Table 3. The motor carrier cost areas are defined by Whitten and shown in Figure 7. The revenue density multipliers are also based on an expansion of Whitten's 20 commodities into 53, and are shown in Table 4. The $d^g_{i,j}$ are obtained from the physical characteristics of the arc and the rate district containing it. Costs are given for van by Whitten, and following his suggestions, tanker costs were established at 200% of van cost and refrigerator truck at 110% of van cost.

Loading and Unloading Costs

Let

LM^n_i = total loading cost/ton for commodity at zone i

Then

$$LM^n_i = \sum_{e \varepsilon E_M} p^{e,n} \cdot p^{e,n}_1 \cdot MT^e_{g(i)} \cdot I^n$$

Where

$p^{e,n}_1$ = fraction of total terminal cost for commodity n, trailer type e, attributable to loading, and

$MT^e_{g(i)}$ = total terminal cost/ton of any commodity using trailer type e in MCCA g associated with zone i.

For lack of better data, we assumed that loading costs equal unloading costs and hence $p^{e,n}_1 = 0.5$. Costs for van loading are given by Whitten and the same percentages are applied for tanker and refrigerator trailer loading.

TABLE 3
COMMODITY SHIPMENTS BY MOTOR CARRIER

	Fraction by Trailer Type				Fraction by Trailer Type		
COMMODITY	VAN	TANKER	REFRIG.	COMMODITY	VAN	TANKER	REFRIG.
011 Grain	0.67	0.27	0.06	281 Inorg. Chem.	0.32	0.68	0
013 Field crops	1.0	0	0	282 Plastics	0.84	0.16	0
021 Livestock	1.0	0	0	283 Drugs	1.0	0	0
024 Dairy	0	1.0	0	284 Soap	0.96	0.04	0
025 Poultry & Eggs	0.4	0	0.6	285 Paint	0.6	0.4	0
080 Forrestry	1.0	0	0	286 Org. Chem.	0.32	0.68	0
090 Comm. Fish	0	0	1.0	287 Ag. Chem.	0.07	0.93	0
101 Iron ore	0	1.0	0	289 Misc. Chem.	0.65	0.35	0
102 Non-Fe. ore	0	1.0	0	290 Petr. Ref.	0.15	0.85	0
110 Coal	0	1.0	0	301 Tires	1.0	0	0
130 Oil & Gas	0	1.0	0	302 Rubber & Pl.	1.0	0	0
140 Non-Metal Min.	0.05	0.95	0	310 Leather	1.0	0	0
201 Meat	0.4	0.4	0.2	321 Stone C. & Gl.	0.25	0.75	0
202 Dairy Prod.	0.4	0	0.6	324 Cement	0.79	0.21	0
203 Pres. Foods	1.0	0	0	331 Iron & Steel	0.16	0.84	0
204 Grain Prod.	1.0	0	0	333 Non-Fe Metal	0.86	0.14	0
205 Bakery Prod.	1.0	0	0	341 Metal Cans	1.0	0	0
206 Confectionary	0.85	0.15	0	342 Fab. Metal Pr.	0.23	0.77	0
207 Fats & Oils	0.5	0.5	0	350 Machy. Ex. Elec.	0.7	0.3	0
208 Beverages	1.0	0	0	361 Elec. Mach.	1.0	0	0
209 Misc. Food	1.0	0	0	362 Elec. App.	1.0	0	0
210 Tobacco	1.0	0	0	371 Motor Veh.	1.0	0	0
220 Textile Mill Pr.	1.0	0	0	372 Trans. Equip.	0.95	0.05	0
230 Apparel	1.0	0	0	380 Meas. Inst.	1.0	0	0
240 Lumber	0.59	0.41	0	390 Misc. Mfg.	1.0	0	0
250 Furniture	1.0	0	0				
260 Paper	1.0	0	0				
270 Print & Pub	1.0	0	0				

FIGURE 7
MOTOR CARRIER COST AREAS

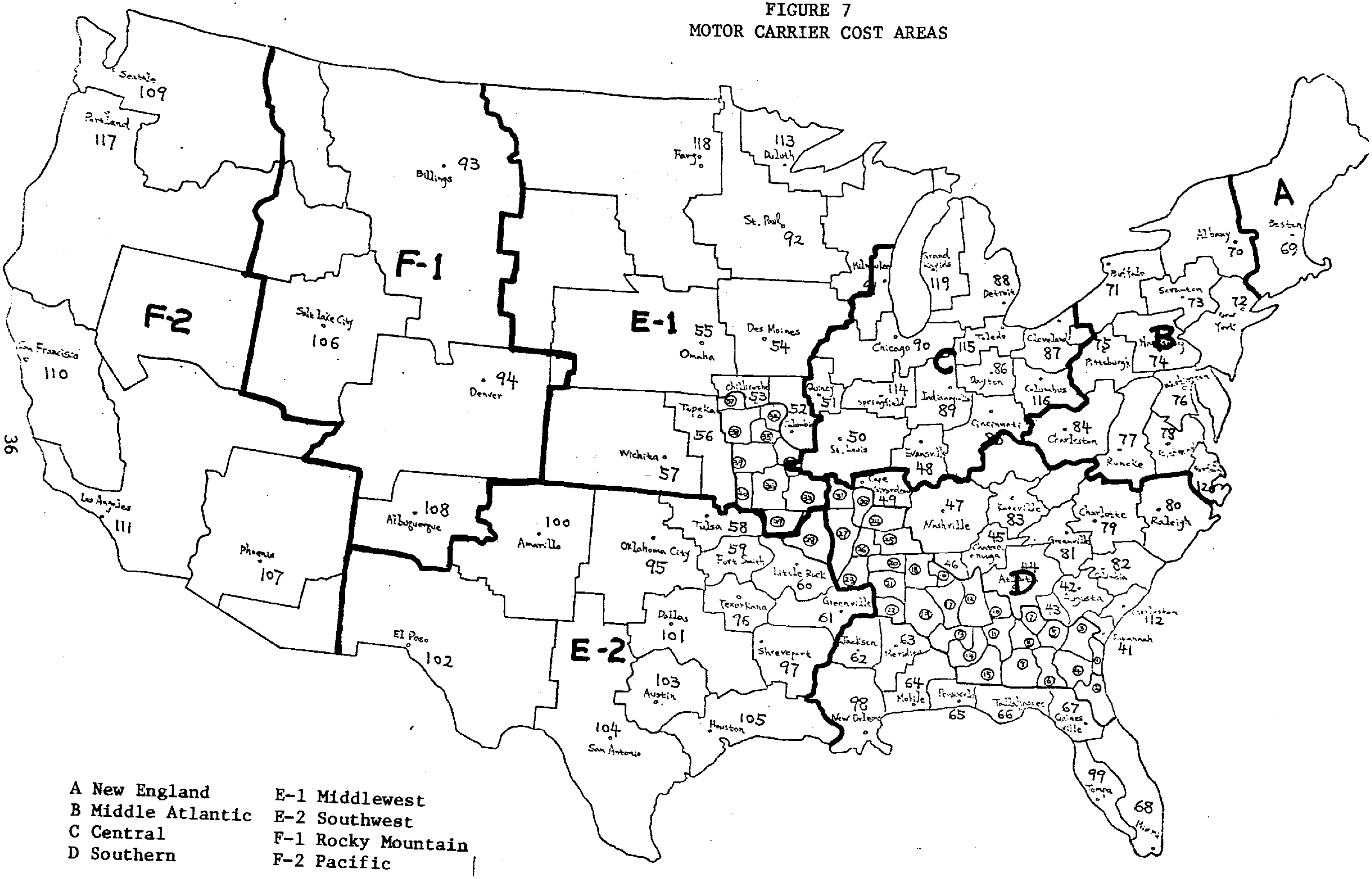


TABLE 4
MOTOR CARRIER REVENUE DENSITY FACTORS

Commodity	Factor	Commodity	Factor
1 Grain	1.0	31 Drugs	1.0
2 Field Crops	1.0	32 Soap	1.0
3 Livestock	1.6	33 Paint	1.0
4 Dairy	1.0	34 Ind. Org. Chem.	1.0
5 Poultry & Eggs	2.7	35 Agric. Chem.	1.0
6 Forrestry	1.0	36 Misc. Chem.	1.0
7 Comm. Fishing	1.0	37 Petrol. Ref.	1.0
8 Iron Ore	1.0	38 Tires & Tubes	1.5
9 Non Ferr. Ores	1.0	39 Rubber & Plastic Prod.	1.6
10 Coal	1.0	40 Leather	1.6
11 Extraction Oils & Gas	1.0	41 Cement	1.0
12 Non-metal Min.	1.0	42 Stone, Clay, Concrete Prod.	1.0
13 Meat	1.0	43 Iron & Steel	1.0
14 Dairy Prod.	1.0	44 Non Ferrous Metals	1.0
15 Canned & Pres. Food	1.0	45 Metal Cans, etc.	2.9
16 Grain Prod.	1.0	46 Fabricated Metal Prod.	1.0
17 Bakery	1.5	47 Machinery Exc. Elect.	1.1
18 Confections	1.0	48 Elect. Ind. App.	1.1
19 Fats & Oils	1.0	49 Elect. Machinery	1.6
20 Beverages	1.0	50 Motor Veh. & Equip.	2.7
21 Misc. Food	1.0	51 Transp. Equip.	2.7
22 Tobacco	1.6	52 Measuring Insts.	1.1
23 Textile	1.1	53 Misc. Mfg.	1.3
24 Apparel	2.6		
25 Lumber & Wood	1.0		
26 Furnit. & Fixt.	2.0		
27 Paper	1.0		
28 Print & Publish	1.0		
29 Ind. Inorg. Chem.	1.0		
30 Plastics	1.0		

Rail

Line Haul Costs

Let:

$LHR^{n}_{i,j}$ = total line haul costs/ton of commodity n moving by rail between zones i and j

Then:

$$LHR^{n}_{i,j} = \sum_{e \varepsilon E_R} p^{e,n} \sum_{g \varepsilon RCCA} d^{g}_{i,j} \left(\frac{M^{e}_{g}}{q^{e,n}} + L^{e}_{g} + K^{e}_{g} \right)$$

Where:

E_R = set of rail car types,

$p^{e,n}$ = fraction of commodity n rail traffic using car type e,

RCCA = set of rail carrier cost areas,

$d^{g}_{i,j}$ = distance on arc i,j in RCCA g,

M^{e}_{g} = variable line haul car cost/car-mile in RCCA g, car type e,

$q^{e,n}$ = tons of commodity n/car of type e,

L^{e}_{g} = variable line haul costs/ton-mile in kCCA g, car type e, and

K^{e}_{g} = fixed line haul cost/ton-mile in kCCA g, car type e.

The values for $p^{e,n}$ and $q^{e,n}$ are given in Table 5.

Loading and Unloading Costs

Let:

LR^{n}_{i} = total loading cost/ton of commodity n at zone i

Then:

TABLE 5
PERCENT OF COMMODITY MOVEMENT BY RAIL CAR TYPE,
TONS OF COMMODITY PER CAR TYPE

Com-modity	Desc.	Box		Tank Hopper		Refrig.		Flat		TOFC	
		%	q	%	q	%	q	%	q	%	q
1	Grain	66	53	27	48	6	24	---	--	1	27
2	Field Crops	100	39	--	--	--	--	--	--	--	--
3	Livestock	100	25	--	--	--	--	--	--	--	--
4	Dairy	--	--	100	57	--	--	--	--	--	--
5	Poultry & Eggs	40	25	--	--	60	25	--	--	--	--
6	Forrestry	--	--	--	--	--	--	100	44	--	--
7	Comm. Fishing	--	--	--	--	100	49	--	--	--	--
8	Iron Ore	--	--	100	78	--	--	--	--	--	--
9	Non Ferr. Ores	--	--	100	88	--	--	--	--	--	--
10	Coal	--	--	100	81	--	--	--	--	--	--
11	Extraction Oils & Gas	--	--	100	77	--	--	--	--	--	--
12	Non-Metal Min.	5	51	95	73	--	--	--	--	--	--
13	Meat	25	40	25	40	13	40	--	--	37	40
14	Dairy Prod.	40	42	--	--	60	42	--	--	--	--
15	Canned & Pres. F.	100	45	--	--	--	--	--	--	--	--
16	Grain Prod.	100	41	--	--	--	--	--	--	--	--
17	Bakery	17	17	--	--	--	--	--	--	83	17
18	Confections	85	61	15	61	--	--	--	--	--	--
19	Fats & Oils	50	66	50	66	--	--	--	--	--	--
20	Beverages	85	49	--	--	--	--	--	--	15	49
21	Misc. Food	85	51	--	--	--	--	--	--	15	51
22	Tobacco	88	32	--	--	--	--	--	--	12	32
23	Textile	100	20	--	--	--	--	--	--	--	--
24	Apparel	100	20	--	--	--	--	--	--	--	--
25	Lumber & W	42	52	41	47	--	--	17	52	--	--
26	Furnit. & Fixt.	95	9	--	--	--	--	--	--	5	9
27	Paper	95	41	--	--	--	--	2	41	3	41
28	Print & Publish	80	29	--	--	--	--	--	--	20	29
29	Ind. Inorg. Chem.	31	72	68	72	--	--	--	--	1	30
30	Plastics	80	72	16	72	--	--	--	--	4	30

TABLE 5, CONTINUED

Commodity	Desc.	Box %	Box q	Hopper %	Hopper q	Refrig. %	Refrig. q	Flat %	Flat q	TOFC %	TOFC q
31	Drugs	100	32	--	--	--	--	--	--	--	--
32	Soap	60	33	4	33	--	--	--	--	36	23
33	Paint	60	50	40	50	--	--	--	--	--	--
34	Ind. Org. Chem.	31	71	68	71	--	--	--	--	1	30
35	Agric. Chem.	7	68	93	68	--	--	--	--	--	--
36	Misc. Chem.	62	55	35	55	--	--	--	--	3	27
37	Petrol. Ref.	14	35	85	56	--	--	--	--	1	25
38	Tires & Tubes	100	20	--	--	--	--	--	--	--	--
39	Rubber & Plastic Prod.	100	21	--	--	--	--	--	--	--	--
40	Leather	80	20	--	--	--	--	--	--	20	20
41	Cement	25	73	75	73	--	--	--	--	--	--
42	Stone, Clay, Concrete P.	65	54	21	54	--	--	14	54	--	--
43	Iron & Steel	8	62	84	62	--	--	8	62	--	--
44	Non Ferrous Metals	80	59	14	59	--	--	6	59	--	--
45	Metal Cans, etc.	95	12	--	--	--	--	5	12	--	--
46	Fabricated Metal Pr.	14	37	77	37	--	--	9	37	--	--
47	Machinery Exc. Elec.	32	23	30	23	--	--	38	23	--	--
48	Elect. Ind. App.	92	47	--	--	--	--	8	47	--	--
49	Elect. Machin.	92	14	--	--	--	--	8	14	--	--
50	Motor Veh. & Equip.	59	23	--	--	--	--	41	23	--	--
51	Transp. Equip.	5	26	--	--	--	--	95	26	--	--
52	Measuring Insts.	97	21	--	--	--	--	--	--	3	16
53	Misc. Mfg.	100	15	--	--	--	--	--	--	--	--

$$LR_i^n = \sum_{e \epsilon E_R} p^{e,n} \left(p_1^{e,n} \cdot \frac{F_{g(i)}^e}{q^{e,n}} + p_2^{e,n} \cdot T_{g(i)}^e + p_3^{e,n} \cdot J_{g(i)}^e + b^n B^n \right)$$

Where:

$p_1^{e,n}$ = fraction of variable terminal arc cost for commodity n, car type e, attributable to loading,

$F_{g(i)}^e$ = variable terminal car cost/car of type e in RCCA associated with zone i,

$p_2^{e,n}$ = fraction of variable terminal cost for commodity n, car type e, attributable to loading,

$T_{g(i)}^e$ = variable terminal cost/ton of any commodity, car type e, in RCCA associated with zone i,

$p_g^{e,n}$ = fraction of fixed terminal cost for commodity n, car type e, attributable to loading,

$J_{g(i)}^e$ = fixed terminal cost/ton of any commodity, car type e, in RCCA associated with zone i,

b^n = fraction of loss and damage claims for commodity n attributable to loading, and

B^n = loss and damage claims/ton of commodity n.

As in the case with highway calculations, loading costs are set equal to unloading costs, with $p_1^{e,n}$, $p_2^{e,n}$, and $p_3^{e,n}$ all equal to 0.5.

Development of Waterway Costs

The waterway costs included in the Whitten data [10] were rejected because they did not appear to be consistant with the cost data presented for the rail and highway modes. However, the development of a more representative set of water cost data is a formidable undertaking.

Common and contract carriers by water, who are required to submit financial and operating data to the ICC, represent a small minority of the waterborne traffic. Most waterborne traffic is carried by private operators, or consists of exempt commodities--notably grain [30].

In the past, the Corps of Engineers has collected limited cost data from private operators. Corps analysts are now in the process of developing cost and operational data that will include trip time, commodity specific loading, unloading and transport costs. In the absence of this work, a fairly simple approach was taken to waterway costs. Two categories of shipments were recognized--inland waterway (barge) and coastwise and intercoastal. Some overlap occurs between these categories in as much as there are substantial large shipments along the intercoastal waterway, on the Great Lakes and between major ocean ports. Nonetheless, for the time being, these barge movements were overlooked. In the future, it may be appropriate to define two or more water modes to tak care of these differences.

Inland Waterways

Movements on inland waterways are largely made in terms of multi-barge tows. The size of tow depends on channel depth, turning radius and lock size. Transit speeds are influenced by current (which is variable) and by delays at locks and at terminals. In addition, to lock operating times, tow boats frequently queue up at locks and boats with very large tows may have to break them up. To reflect the different delays, a travel time expression was developed:

$$TW_{ij} = d_{ij}/s_{ij} + aL_{ij}$$

where TW_{ij} = time in hours for a tow boat to travel from i to j

d_{ij} = distance between i and j

s_{ij} = mean speed from i to j ($S_{jiL} \neq S_{ij}$)

L_{ij} = number of locks between i and j

a = constant based on analysis of a large number of lock operating cycles and traffic congestion situations

If: LHW^n_{ij} = total line haul cost/ton of commodity n moving by water carrier between zones i and j,

Then:

$$LHW^n_{ij} = \sum_{g \varepsilon WCCA} TW_{ij} \cdot WL_g \cdot I^n$$

Where:

WCCA = set of water carrier cost areas--largely a function of draft and maximum tow size,

WL_g = cost per hour for tow and tow boat operation in area g, and

I^n = density commodity multiplier for commodity n.

Coastwise and Intercoastal

The cost of coastwise and intercoastal movements depends on the size of the ship, its speed and its operating costs. Modest ship sizes were adopted to permit use of the Cape Cod Canal, the Delaware and Maryland Canal and Brunswick Harbor all of which are limited to less than 30-foot draft ships. The cost equation used for these water movements has the now familiar form:

$$LHW^n_{ij} = \sum_{e \varepsilon E_W} P^{e,n} \sum_{g \varepsilon WCCA} d^g_{ij} \cdot WL^e_g \cdot I_n$$

Where:

$p^{e,n}$ = fraction of commodity n using shipping configuration e. Only two configurations were used in the first year's work--container and liner type ships,

d_{ij}^{g} = distance between i and j in WCCA g, and

WL_{g}^{e} = cost per ton-mile for any commodity using configuration e in WCCA g.

Loading and Unloading Costs

Loading and unloading costs for water movements are calculated in the same fashion used for other modes. Let:

LW_{i}^{n} = total loading cost/ton for commodity n at zone i

Then:

$$LW_{i}^{n} = \sum_{e\varepsilon E_M} p^{e,n} \cdot p_{1}^{e,n} \cdot WT_{g(i)}^{e} \cdot I^{n}$$

Where:

$p_{1}^{e,n}$ = fraction of total terminal cost for commodity n, ship configuration e, attributable to loading, and

$WT_{g(i)}^{e}$ = total terminal cost/ton for any commodity using ship configuration e in WCCA g associated with zone i.

Once again we assumed that loading and unloading costs are equal.

Transfer Costs

The loading and unloading costs for highway, rail, and waterway modes represent elements (1,3) and (2,1), (1,3) and (3,1), and (1,4) and (4,1), respectively of the transfer cost array.

Forwarding costs were estimated based on a previous Federal Railroad Administration study [11]. These represent situations where the cargo stays on the same mode but incurs a cost because of change of carrier or railroad yard classification. Times and time variances for such forwarding activities were based on other DOT studies [12,13,14]. No forwarding costs are incurred by the highway and water modes. Costs of intermediate stops are charged as loading or unloading costs for the originating or terminating traffic.

Data on transfer costs between modes were drawn from the same references; however, they are not very definitive. Therefore, a simple convention has been adopted for the present work. Two types of mode transfers are recognized: (1) a break-bulk transfer in which the inbound carrier is unloaded and the cargo is transferred to the outbound carrier which is loaded; and (2) a container transfer in which the container is transferred between modes.

Break bulk terminal operations are closely akin to loading and unloading. Data sources on truck and marine terminal operations suggest that transfer costs are approximately equal to 80 percent of the unloading and loading costs. Thus if:

$TT^{n}_{X,Y,i}$ = Break-bulk terminal transfer cost per ton for commodity n from mode X to mode Y at location i

Then:

$$TT^n_{X,Y,i} = 0.8[LY^n_i + (1-p^{e,n}_1)\ LX^n_i]$$

Where:

LY^n_i = cost per ton for loading commodity n into mode Y at i, and

$(1-p^{e,n}_1)LX^n_i$ = cost per ton for unloading commodity n from mode X at i.

Container terminal operations require only the mechanical unloading of a container from the inbound mode and its loading aboard the outbound mode. The cost of container transfer is heavily influenced by the productivity of the mechanical transfer equipment, because the dominant cost is the capital cost of equipment. Thus if:

$TT'^n_{X,Y,i}$ = container terminal transfer cost per ton for commodity n from mode X to mode Y at location i,

Then:

$$TT'^n_{X,Y,i} = \left[\frac{TC_{X,Y}}{V_i} + TO^i_{X,Y}\right] I^n/q^n$$

Where:

$TC_{X,Y}$ = the equivalent annual capital cost of a transfer terminal to interchange between modes X and Y,

V_i = expected containers per year to be transferred at i,

$TO^i_{x,y}$ = operating cost per container to transfer between modes x and y at i, and

I_n = density multiplier for commodity n.

Values of $TC_{X,Y}$ and $TO_{X,Y}$ are as follows:

	$TC_{x,y}$	$TO^{i}_{x,y}$	Capacity Container Per Year
Highway-rail	$ 50,000	$1.50	200,000
Highway-water	1,000,000	2.50	400,000
Rail-water	1,200,000	3.00	400,000

$TC_{X,Y}$ is calculated with interest at 20 percent per annum. Values of $TO^{i}_{X,Y}$ are in dollars per ton for a 20 ton container load.

Compact Representation of Transportation Costs

The research team understood clearly that the transportation costs being used during the first-year research effort left much to be desired. Specifically, the costs were based largely on secondary sources which determined costs from summary financial statistics and allocated fixed costs by somewhat arbitrary methods. At the same time the need was recognized to determine O-D distances for each of 53 commodities for the 120 zone network.

In order to generate all the O-D network distances for just one commodity required the generation of 360 trees, one for each of three modes for each of the 120 origin nodes. This computation consumed about 15 minutes of computer time, including the CPU time required to write the trees onto magnetic tape. If separate trees had to be constructed for each commodity, the computer time would quickly become excessive. On the other hand, if one set of trees could be used for all 53 commodities, the resulting commodity paths might not be the true shortest paths.

Accordingly, the line haul arc costs were formulated in the following form:

$$t(i,j,m,k) = t(i,j,m) \times S(m,k)$$

where:

$t(i,j,m)$ = an average cost for transporting goods from node i to node j by mode m

$s(m,k)$ = a commodity specific factor that applies to all arcs of a given mode

An analysis was made of the line haul costs determined by the formulas developed for the different modes. Surprisingly, the commodity specific factors were remarkably consistent throughout the different geographic regions. A similar analysis was made of the Whitten based loading and unloading costs. There resulted again failry consistent commodity specific factors.

However, the commodity factors for line haul and loading-unloading were not the same. Upon closer examination, there appeared to be a monotonic relationship between the two sets of factors: the highest factor for line haul was also highest for loading-unloading, the lowest factors in both cases were for the same commodity, etc.

Accordingly, it was conjectured, but not proven, that a shortest path consisting of line haul arcs and transfer movements for a hypothetical average commodity would be a true shortest path for any of the 53 commodities, but that the length of the path could not be determined with only one commodity-specific factor. The multi-modal shortest path algorithm was subsequently revised to optimize the overall path length for the "average" commodity but to keep track separately of the line haul portion and the transfer portion. The "true" commodity specific path length for the resulting path was then obtained by multiplying the line haul portion and the transfer portion by the commodity-specific line-haul cost factor and transfer cost factor, respectively. Further compaction resulted when the geographic area cost factors were multiplied by the true arc lengths to achieve modified arc lengths.

The net effect of all the computations described in this chapter was to take the original, Whitten based, formula of

$$LHM^{n}_{i,j} = \sum_{e \varepsilon E_M} P^{e,n} \sum_{g \varepsilon MCCA} d^{g}_{i,j} \times ML^{e}_{g} \times I^{n}$$

and convert it to one of

$$LHM^{n}_{i,j} = (\text{modified arc length}) \times (\text{average cost}) \times (\text{commodity factor})$$

With the analogous simplification of transfer costs, the overall effect was the elimination of the need for commodity-specific trees and a great simplification of subsequent analysis.

V. MODE SPLIT ANALYSIS

Problem Setting

The research effort required the use of a freight modal split model to predict flows of up to 53 commodities in a network of 120 zones containing highway, rail, and waterway arcs, arcs representing new freight transportation modes, and mode combinations that include transfer between modes at one or more nodes. A variety of reasons justify the modal split approach, as opposed to finding the one best travel path for each shipment. Among these reasons are:

1. Aggregation of commodities. The SIC code goes to a 7-digit level, and these classes have been aggregated into 53 commodity groups based on homogeneity of production and transportation requirements. The individual differences that exist among the sub-classes within each of the 53 groups imply that there is no one best travel path for each of the 53.
2. Aggregation of decision makers. Even if one could deal with a finer classification scheme, different firms producing the same product will have different transportation requirements.
3. Aggregation over time. The flow data used are representative of annual shipments. A firm producing a product will have different transportation requirements throughout the year, depending on time and buyers.

Model Requirements

The requirements discussed below are those desired in an ideal model for use in the Multi-State Corridor study.

Abstract Mode Representation

Since one of the specific objectives of the study is to examine new means of transporting freight and new inter-modal service, an abstract mode approach is essential. Such an approach characterizes a mode by such factors as shipping time, cost, reliability, damage, etc. Any new mode or compound-mode journey would be characterized by these same factors and then compared with the existing modes in the model.

Ease of Calibration

Any model to be used should be amenable to standard regression techniques that are robust and efficient with respect to computer time. In order to have confidence in the model, a good fit must be produced for each commodity so that the model can predict accurately the flows on new modes and between new O-D pairs.

Irrelevance of Independent Alternatives

This concept deals with the change in the proportion of flow between two modes by changes in a third mode. Basically, if a third mode were to be improved, one would expect flow on the other two modes to be reduced, but the proportion of flows between the first two modes would be unchanged.

Additive Linear Arc Utility

In order to find the compound-mode journey with greatest utility in a network, one would prefer to have trip utility equal to the sum of the respective arc utilities. Then, one can use a shortest path algorithm to find the best path; otherwise, some less efficient enumeration scheme would have to be used. Actually, all that is needed is that trip utility be uniquely transformable into additive linear arc characteristics, such as time, cost, reliability, and damage.

Survey of Existing Models

A review of the literature indicates that very little work has been performed on freight modal split as compared to passenger flows and particularly urban transit mode split. The only type of model that has been calibrated for forecasting purposes is the multiplicative model described below. All of the models presented here recognize the need to distinguish among commodity types based on such factors as freight rates by the different modes, dollar value per ton, and susceptibility to damage, spoilage, and theft.

Multiplicative Demand, Abstract Mode Model

This theoretically significant model was first presented by Baumol & Quandt in 1966 [20]. It is formulated to predict both total demand between an origin-distribution (O-D) pair and the respective modal shares. The multiplicative version [21] is as follows:

$$T_{kij} = a_0 \, P_i^{a_1} \, P_j^{a_2} \, Y_i^{a_3} \, Y_j^{a_4} \, M_i^{a_5} \, M_j^{a_6} \, N_{ij}^{a_7} \, f_1(T) \, f_2(C) \, f_3(D)$$

where:

$$f_1(T) = T_{bij}^{b_0} \, T_{kij}^{b_1}$$

$$f_2(C) = C_{bij}^{d_0} \, C_{kij}^{d_1}$$

$$f_3(D) = D_{bij}^{e_0} \, D_{kij}^{e_1}$$

T_{kij} = demand from i to j by mode k

P_i, P_j = populations of zones i,j

Y_i, Y_j = mean incomes of zones i,j

M_i, M_j = institutional and manufacturing characteristics of zones i,j

N_{ij} = number of modes serving i to j

T_{bij} = best travel time from i to j

T_{kij} = relative travel time from i to j by mode k

C_{bij} = best (lowest) cost from i to j

C_{kij} = relative cost from i to j by mode k

D_{bij} = best frequency of service from i to j

D_{kij} = relative frequency of service from i to j by mode k

$a_0, a_1, \ldots, a_7, b_0, b_1, d_0, d_1, e_0, e_1$ = coefficients, usually obtained by regression

Given the populations, incomes, and institutional characteristics, the model reduces to

$$T_{kij} = a_0 \, N_{ij}^{a_7} \, f_1(T) \, f_2(C)$$

with the constraint that the total flow between i and j is equal to 100%. For a specific commodity p the model becomes

$$T_{pkij} = a_{po} \, N_{ij}^{a_{p7}} \, f_{p1}(T) \, f_{p2}(C)$$

with the constraint that total flow of p between i and j is 100%.

This type of model has several important advantages. It is an abstract mode approach, where a mode is described by its characteristics, rather than by its name. This allows the user to examine new modes by specifying travel time and cost. If these two items do not characterize a mode adequately, then other factors must be put into the equation, such as delivery time variance. There are certain difficulties that arise when new modes, or new compound-mode paths, are considered and the total flow between i and j remains the same. These problems relate to the effect of shifting flows by considering new modes. However, this problem occurs with all the modeling approaches discussed, not only this particular one. The model uses relative time and cost advantage of one mode against another. Thus, only one regression equation is needed for each mode (each commodity effectively constitutes a separate calibration problem). The use of absolute values instead of relative values would necessitate an equation for virtually each O-D pair.

The general model is linear in the logarithms, and thus linear regression techniques can be easily used to estimate the coefficients. The reduced problems have the additive constraint and cannot be transformed into a linear form. Linear regression techniques can still be used but they require some adaptation to deal with the constraint. The above type of model has been calibrated in a variety of settings [21, 22], but none of these applications provide directly usable results for the Multi-State corridor study.

Impedance Model

An example of the impedance model is the National Transportation Plan (NTP) modal split model [23]. The model uses an analogy to Kirchoff's law from electrical networks.

$$T_{p1ij} Z_{p1ij} = T_{p2ij} Z_{p2ij} = \ldots = T_{pnij} Z_{pnij} = A_{pij}$$

where A_{pij} is the basic attractiveness between i and j for commodity p, analogous to the electrical potential.

The total flow is then

$$\sum_{m=1}^{n} T_{pmij} = A_{pij} \left[\frac{1}{Z_{p1ij}} + \frac{1}{Z_{p2ij}} + \ldots + \frac{1}{Z_{pmij}} \right]$$

and the model share is

$$f_{pkij} = \frac{T_{pkij}}{\sum_{m=1}^{n} T_{pmij}} = \frac{\frac{1}{Z_{pkij}}}{\sum_{m=1}^{n} \left[\frac{1}{Z_{pmij}} \right]}$$

The impedance for commodity p is defined as

$$Z_{pkij} = a_{pkij} \left[b_p T_{pkij} + C_{pkij} \right]$$

where:

T_{pkij} = the time in transit for a unit of commodity p moving by mode k from i to j

C_{pkij} = the cost of moving a unit of commodity p by mode k from i to j

a_{pkij}, b_p = coefficients; b_p is usually given as the time value of commodity p, and a_{pkij} is usually found by regression.

The actual NTP model also considers time, in annual periods. The model has been calibrated for the 20-commodity, 173-BEA zone data set.

Since the a_{pkij} are specified for each O-D pair, and only for 20 commodities, those results would not be particularly useful to the corridor study. Furthermore, new modes cannot be represented, nor can existing modes operating between new O-D pairs.

Other Functional Forms

A great variety of functional forms have been used for passenger modal split models [24], and these same forms can be adapted to freight flows. All of them determine some type of modal attractiveness or utility U_{pkij} for commodity p by mode k between i and j and then allocate modal share based on a strict choice utility function,

$$f_{pkij} = \frac{U_{pkij}}{\sum_{m=1}^{n} U_{pmij}}$$

Additive Linear Form

This form expresses mode utility as

$$U_{pkij} = a_0 + a_1 C_{pkij} + a_2 T_{pkij}$$

where C_{pkij} and T_{pkij} are cost and time respectively. Here the a_0 would be positive and the a_1 and a_2 negative.

This form certainly would be easy to calibrate, but the equation may not yield a very good fit, even with the addition of other terms for abstract mode characteristics, such as frequency of service and delivery time variability. One important advantage of the form is that it allows one to find good compound-mode journeys. If one knows the time and cost characteristics of each line haul arc and each transfer arc in an expanded network, then a shortest path algorithm can be used to find the best compound mode journey, that is, the one with the greatest value of U_{pkij}. This process is illustrated with Figure 8.

Each arc in the diagram has characteristic $W = -a_1 C_{pkij} - a_2 T_{pkij} - a_3 V_{pkij}$, and a loading arc has a_0 added to its W value. A shortest path can be found through the network, using W's for arc length. This path will then maximize trip utility between i and j for the additive linear case.

Exponential Form

Sometimes called the logit form, this form expresses mode utility as

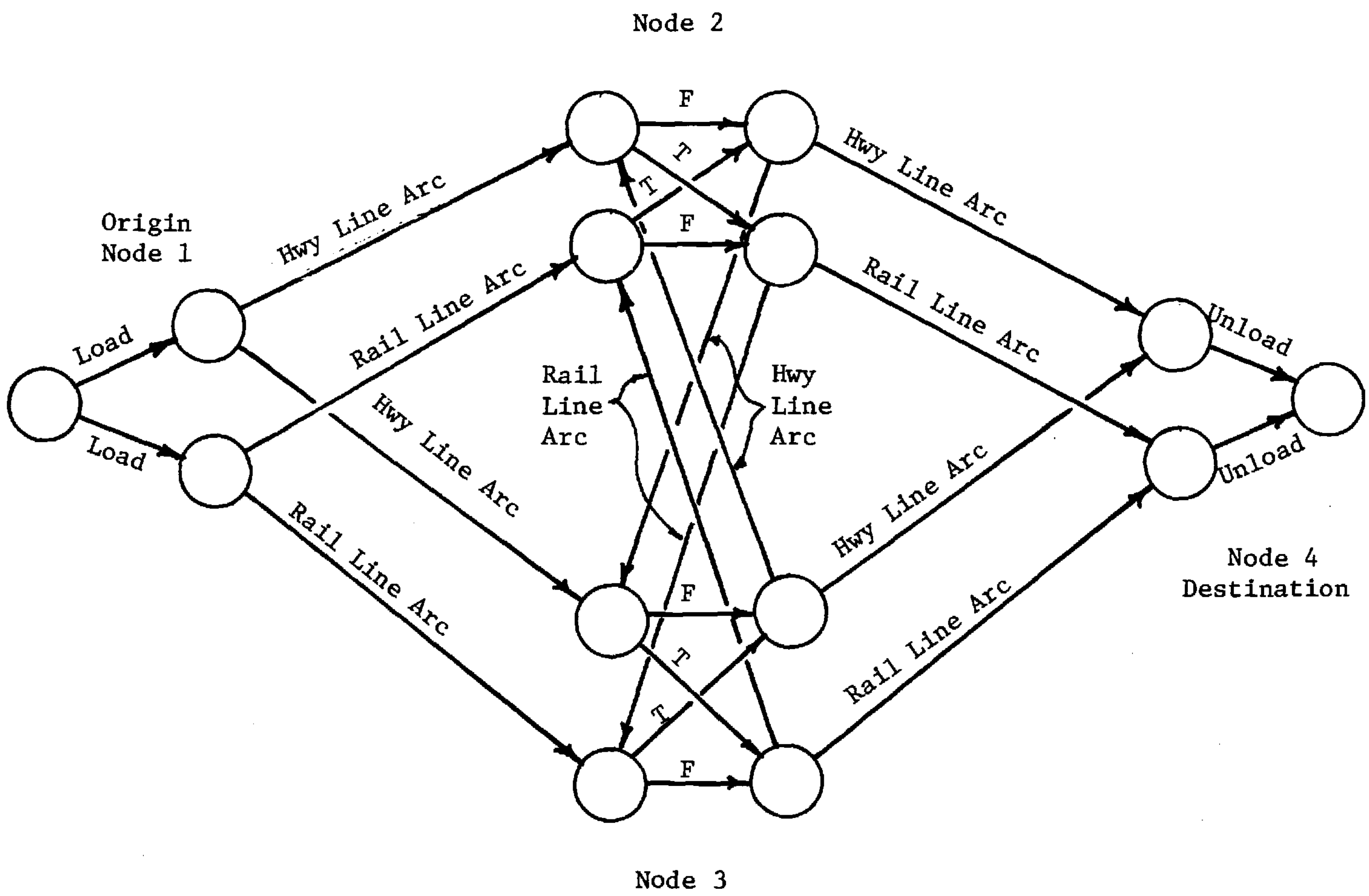
$$U_{pkij} = \exp(a_0 + a_1 C_{pkij} + a_2 T_{pkij})$$

Again, the a_0 term is positive and the a_1 and a_2 terms negative. This form would probably give a better regression fit than the strict linear form. A typical regression equation is:

$$\begin{aligned}
& f_{pkij} \exp(a_0 + a_1 C_{p1ij} + a_2 T_{p1ij}) \\
+\ & f_{pkij} \exp(a_0 + a_1 C_{p2ij} + a_2 T_{p2ij}) \\
& \vdots \\
+\ & f_{pkij} \exp(a_0 + a_1 C_{pnij} + a_2 T_{pnij}) \\
=\ & \exp(a_0 + a_1 C_{pkij} + a_2 T_{pkij})
\end{aligned}$$

FIGURE 8
FINDING THE BEST COMPOUND-MODE JOURNEY

F: Forwarding arc
T: Transfer arc



where the f_{pkij} is the actual fraction observed and the a's are the coefficients to be estimated.

Alternatively, one can compare the flows of each mode with a base mode:

$$\frac{f_{pkij}}{f_{bkij}} = \exp\ (a_1(C_{pkij} - C_{bkij}) + a_2(T_{pkij} - T_{bkij}))$$

This procedure allows one to use linear regression but the range of observations of the dependent variable may exceed 1.0, causing the regression program to give excessive weight to those observations. Also, there is the bias introduced by the log transformation of the data.

Since the exponential function is a monotonic transformation of the real numbers, one can find the best compound-mode journey by using a shortest path algorithm, as described for the additive linear form. Minimizing $(a_{0p} + a_{1p}\ C_{pkij} + a_{2p}\ H_{pkij})$ will result in minimizing the exponential form.

Modified Logit Form

Here the utility of a mode is given by

$$U_{pkij} = \frac{\exp(a_0 + a_1\ C_{pkij} + a_2\ T_{pkij})}{1 - \exp(a_0 + a_1\ C_{pkij} + a_2\ T_{pkij})}$$

This formulation is applied only to non-base modes. The utility for the base mode is defined to be 1.0. For example, if the base mode is highway, then a rail path utility can be defined as

$$U_{rkij} = \frac{\exp(a_0 + a_1(C_{rkij} - C_{hkij}) + a_2(T_{rkij} - T_{hkij}))}{1 - \exp(a_0 + a_1(C_{rkij} - C_{hkij}) + a_2(T_{rkij} - T_{hkij}))}$$

where subscripts r and h refer to rail and highway, respectively. For consistency,

$$U_{hkij} = \frac{\exp(a_0)}{1 - \exp(a_0)}$$

which implies that $a_0 = \log(0.5)$.

Discussion

In this section an attempt is made to synthesize the requirements with the capabilities of the models described above and to justify the selection of two models for testing.

Abstract Mode Representation and Mode Characteristics

The first selection criterion relates to abstract mode representation. This factor hardly seems to be an issue as there is no way a mode specific model can predict flows on new modes. Related to this is the requirement that coefficients be independent of O-D pairs in order to be able to predict flows for new O-D pairs. It is desirable that the coefficients be independent of origin and destination, separately, so that flows may be predicted for new origins, or for new destinations. This requirement, however, can be relaxed to the case where the coefficients relate to geographic zones. Finally, each of the 53 commodity groups must have its own set of coefficients. These criteria eliminate the NTP impdeance model as previously used, because its coefficients are specific to O-D pairs, and the general multiplicative model, because of its generality.

In order for a mode abstract model to yield good results it must include more than time and cost. Shipper decisions on mode reflect a variety of transport characteristics, including but not limited to reliability, damage, theft, time of day, and ease of loading/unloading. These factors are difficult to quantify, and in order to obtain good regression fits it is most unusual to see a mode abstract model modified by seemingly innocuous coefficients that in effect render the model mode specific [22].

The factors selected for inclusion in the model are transportation cost C, transportation time T, and variance of transportation time V. These will explain adequately the existing modal split decisions represented in the data base, and they will exhaust the data available for the 53 commodity groups.

All of the above considerations imply that

$$U_{pkij} = f(C_{pkij}, T_{pkij}, V_{pkij})$$

and admits direct extensions of the additive linear form, the exponential form, and the modified logit form. One can also modify the multiplicative form and the impedance model to suit:

$$T_{pkij} = a_{p0}\, N_{ij}^{a_{p7}}\, T_{bij}^{b_{p0}}\, T_{kij}^{b_{p1}}\, C_{bij}^{d_{p0}}\, C_{kij}^{d_{p1}}\, V_{bij}^{e_{p0}}\, V_{kij}^{e_{p1}}$$

$$Z_{pkij} = a_{pk}\,(b_{pk}\, T_{pkij} + C_{pkij} + d_{pk}\, V_{pkij})$$

Calibration and Data Base

It is generally preferable to use linear regression techniques, all other factors being equal. In this respect the multiplicative model seems favored, as the other model amenable directly to linear regression, the additive linear form is not likely to yield good results. The effects of regression bias when using a base mode must be determined for each data set before reaching conclusions on the viability of that method.

There are two alternatives for calibrating nonlinear models. The first is to use successive linearization of the nonlinear models. Unless an existing program is obtained to perform this work, this method must be rejected because of the difficulty of preparing a program. The second alternative is to use a search technique, such as a grid-type search or a cyclic coordinate search [25]. A program to perform this is easy to prepare, and with only 3 or 4 variables for each commodity the calibrations are easy and efficient.

At this point the choice was among the multiplicative model with linear regression and the logit and modified logit models with either mode/base mode comparison or nonlinear search techniques. Accordingly, all three forms, along with some others, were regressed on sample data.

Results

After testing more than 15 different linear regression forms on sample data from two commodities, there emerged two forms as offering reasonably acceptable fits:

Form 1, Estimate each mode compared to the predominant, or base, mode for a commodity. For example, if base mode is highway,

regress: rail weight/highway weight, RW/HW

waterway weight/highway weight, BW/HW

Form 2, Estimate each mode compared to the sum of its share plus the share of the base mode.

With highway as a base mode,

regress: RW/(RW + HW)

BW/(BW + HW)

Form 1 can be derived from a path utility of

$$U(\text{path}) = \exp(a_1 C + a_2 T + a_3 V)$$

Form 2 can be derived from a path utility of

$$U(\text{path}) = \frac{\exp(A)}{1 - \exp(A)}$$

where

$$A = \log 0.5 + a_1(\text{mode cost-base mode cost})$$
$$+ a_2(\text{mode time-base mode time})$$
$$+ a_3(\text{mode time variance-base mode time variance})$$

In form 2 the bias from data points with small denominators, or sample observations of the dependent variable above 1.0, is effectively eliminated.

The bias introduced by log transformation of the data was eliminated by using a cyclic coordinate search procedure [25] to estimate the parameters a_1, a_2, and a_3 while minimizing the sum of errors squared for the untransformed data. The cyclic coordinate search works fairly well, reducing the true sum of squares by about 10% when initiated with the linear regression results.

Upon fitting the strict utility, multinomial logit modal split model, it was found that almost all predicted splits between the highway and rail modes lay in the interval [.4,.6]. Actual splits, however, ranged over the interval [.05,.95]. In order to disperse predicted splits beyond this initial interval, the following transformation of the predicted split was performed:

$$RS_M = \frac{F^{u,\sigma}\ (ES_M)}{\sum\limits_{n \epsilon M} F^{u,\sigma}(ES_n)}$$

Where:

RS_M = revised predicted share of mode M

ES_M = predicted share of mode M obtained from multinomial logit model

M = set of modes

F = cumulative normal distribution function with parameters u, σ

Modal split parameters were re-estimated to correspond to this revised form and are shown in Appendix B. As expected, predicted splits were dispersed, although improvement in fit has not been demonstrated.

Limiting the Number of Modes

Virtually no model exists that is unaffected by the consideration of additional paths, and it is unlikely that a straightforward model could be so developed. Consider, for example, a rail path serving a pair of modes, with U(rail) = 8 and U(highway) = 2. The typical modal share function would assign 8/10 of the shipping volume to rail and 2/10 to highway. Suppose another, less desirable rail path existed with U = 5. The act of admitting three paths now results in the first rail path receiving 8/15 of the flow, the second rail path 5/15, and the highway path 2/15. In all likelihood the second rail path would actually carry little or no flow. For single mode flows the question of admissible paths is usually resolved by selecting the best path for each mode. When compound-mode journeys are involved, however, the issue is not so clear.

To overcome these difficulties the number of paths will be limited as follows:

1. the best all-highway path
2. the best all-rail path
3. the best all-waterway path
4. the predominant waterway path with short highway or rail connecting arcs (used in case no path of type 3 exists, only)
5. an efficient highway-rail path
6. an efficient rail-waterway path
7. a new technology mode

The first three should provide no difficulty: the best highway path will be the least-time path, since time-related costs tend to dominate in the trucking industry. The best rail path will be the one with the lowest shipping costs, since those tend to dominate in the selection among rail paths. Last, there will usually be only one reasonable waterway path, if at all, serving any two nodes and it will be selected on the basis of shipping cost. This designation of a critical attribute for each mode, that is, an attribute used for path selection, simplifies the progress of building the shortest path trees for each mode. Of course, the other, non-critical attributes are carried along in the tree-building process. (Actually, the critical attribute for an "average commodity" is optimized, and then the line haul and transfer portions of each attribute, including the critical one, are carried along.)

Similarly, the fourth category would be selected on the basis of shipping costs, since anyone seriously considering a type-4 path would be concerned mainly about cost. Paths in category 7 would generally be unique, thus posing no problems in identifying them. Paths of types 5 and 6 are unlike the others, and the method for their selection is discussed next.

Identifying Compound-Mode Journeys

In those cases where the trip modal utility can be transformed uniquely to a function that is additive linearly in arc characteristics, the selection of compound-mode journeys can be achieved by a shortest path routine, as discussed earlier and shown in Figure 8. Such a scheme will work with the modified impedance form, the additive form, the exponential form, and the modified logit form. This method was employed in the demonstration of the model.

An alternative method is to use a heuristic procedure to find compound-mode paths. For example, to find a highway-rail path one might take the best rail path, say 1-2-3-4-5-6, and then try to attach highway paths between the origin and successive nodes on the rail path, thus forming

highway	rail
1-2	2-6
1-3	3-6
1-4	4-6
⋮	
4-6	1-4
5-6	1-5

These paths could then be easily evaluated and the one with the best utility selected for the modal share determination.

VI. MARKET SHARE ANALYSIS

The technique for evaluating and locating potential industrial facilities can best be described as a screening activity that involves successive testing of individual opportunities. The analytical structure is designed to reflect major production, transportation and marketing factors. This is viewed as a first step that logically precedes detailed studies of location, facility size, design and distribution.

The construction and operation of a new production facility that is located within an economic development area will have considerable impact on the local economy from which it draws employees, power, utilities and other essential commodities. Much has been written about local impacts including multiplier effects and other phenomena that extend beyond the immediate needs for production. However, the impacts of regional economic development also extend considerably beyond the local area.

Of principal importance are the market impacts of the new facility. Although some of the new facility's production may enter new markets, much of it will travel to markets that are already served by other facilities. Thus the new facility will upset existing patterns of product distribution, perhaps even on a national scale. A new facility of sufficient scope can influence market prices, raw material cost and overall product demand over a wide area. Until these impacts are recognized and evaluated, the feasibility of a new facility has not been fully demonstrated.

At this stage in the analysis it is not practical to attempt to deal with all of the market participation factors or with all of the market impacts. Rather, we have selected a relative simple cost based rationale for the initial investigation of market penetration. This convention considers production and transportation costs together with a quality of service factor as expressed in terms of delivery time and delivery time variability. By the adopted convention, to be successful, a new facility must be able to produce and deliver its products to a number of existing markets at a cost that is comparable to the costs by which marketing facilities serve the same markets.

The measure of economic viability selected for a new industrial facility is whether it can compete in a sufficient number of markets to support a financially viable facility size. When testing new facility types and locations, the raw material costs, labor rates, energy costs, and taxes are characteristics of the selected locations. Transportation costs depend on the sources of raw materials, on the locations of the markets to be served, and the amount and quantity of the services available between the new facility and its potential markets. Transportation cost and service are subject to change by the construction of new transportation assets by the creation of new transportation services, or by the facilitation of advantageous intermodal transfers. Market penetration and selling price are determined from the characteristics of existing commodity flows.

Commodity Production Costs by Zone

Industry Structure Analysis

As described in more detail in the Task 2 report, each of the 53 commodity groups is treated as a homogeneous product of an industry group whose components have common raw material needs, common labor, and common capital requirements. Production input factors were developed for each industry group based on national average data from the Census of Manufacturers [9]. Table 6 shows a typical profile for SIC classification 250, Furniture and Fixtures. The profile describes the industry that produces the commodity in terms of raw material quantities, direct labor hours, indirect labor cost, energy cost, tax cost, and capital investment. Material costs are location sensitive as is direct labor cost. Mean wage rate helps to identify labor skill requirements. Indirect labor is assumed to be a function of industry organization and overhead structure and is made up of a fixed charge plus a charge that is proportional to output. Energy cost is location sensitive, as are taxes and transportation. Capital investment, on the other hand, is assumed to be independent of location.

Production costs are modeled in a linear form:

$$P(i,k) = \sum_{q} (c(i,q))\ (a(k,q))$$

where:

$P(i,k)$ = production cost in zone i of commodity k,

$c(i,q)$ = unit cost of input factor q in zone i, and

$a(k,q)$ = input coefficient of factor q for production of commodity k.

The above equation is assumed to hold for a facility greater than a certain minimum size with an appropriate size determined for each industry.

TABLE 6
INDUSTRY PROFILE--250 FURNITURE & FIXTURES
1972

Industry Size: 8,482 Companies, 9,232 establishments
461,600 Employees

$11.4 Billion cost of goods sold

Mean Establishment Characteristics

Raw Material Needs	
207 Fats and Oils	17 tons
240 Lumber & Wood	662
220 Textile Mill Products	6
260 Paper	
285 Paint	2
302 Rubber & Plastic Products	
321 Stone, Clay & Glass Products	87
331 Iron & Steel	233
333 Non-Ferrous Metals	9
342 Fabricated Metal Products	94
Employees	
Direct	
Number	46
Man Hours	82,000/year
Hourly Wage	$3.08
Indirect Labor	$95,000/year
Energy	1.9 Billion BTU Equiv./year
Capital Investment	$1.56 Million
Annual Cost of Goods Sold	1.23 million

Minimum Size Facility: 81 direct employees
$2 million annual cost of goods sold

It is also assumed that the all zone-specific costs can be applied uniformly throughout the zone.

Determination of Unit Costs for Input Factors

The production cost factors for each of the 53 industry/commodity groups have been developed from existing industry wide data, with local corrections as available. The cost of input commodities or raw materials for each of the 53 industry/commodity groups are based on historical costs of the groups. Input commodities as reported in the Census of Manufacturers or other secondary source documents are divided into two types, manufactured items and mine, forest or agricultural commodities for which price is determined by a national or regional market. In the former case, average national costs are assumed, with no distinction by zone.

The latter group consists primarily of raw materials. For each of these materials a national market location is identified, and then sources are identified by examining the commodity movement data. The cost of material k in zone i is then determined by the following formula:

$$c_{ik} = \min_{j} (c_{jk} - t_{jo} + t_{ji})$$

where

c_{jk} is the cost of each source j,

t_{jo} is the transportation cost to the market located at o, and

t_{ji} is the transportation cost from source j to production zone i

In the above formula the transportation costs are calculated after mode splits are determined for each O-D pair involved.

Direct Labor

Direct labor cost is estimated for each commodity by using the industry profiles and zone-specific labor costs. The process requires two steps: (1) determine the relative labor skill level required by the industry; and (2) establish the cost of labor of the requisite skill level at each of the major producing zones. The major data sources to support labor cost determination are the industry profiles, the summaries of major commodity movements produced from the commodity flow tape, and wage statistics published by the U.S. Department of Labor (DOL).

Industry labor skill levels are determined by comparing the average direct labor wage for the industry with the DOL data for the major producing zones. Inasmuch as DOL data are presented by skill level--e.g. craft, operative, unskilled--rather than industry, it is first necessary to prepare a weighted wage spectrum for the major producing zones. Thus, if:

L_q^n = weighted hourly wage rate for skill n in zones producing commodity q,

Then:

$$L_q^n = \sum_{i \varepsilon E_n} W_i^n \ell_{iq}$$

where:

W_i^n = fraction of commodity n produced in zone i, and

ℓ_{iq} = wage rate for skill q in zone i

when L_q^n have been determined for all skill categories, then the mean wage rate for industry n can be placed in the spectrum of skills. An average skill is then selected for industry n and local wage rates in each producing zone i are the wage rates associated with the selected skill.

Energy Costs

Energy costs are obtained for each type of energy generally used in each zone from Federal Energy Administration reports [26]. These are then combined in the proportions used by each industry to generate zone-specific equivalent KW-hour costs for each commodity.

Capital and Taxes

An annual capital cost recovery factor of 0.15 is used for all industries, assuming a discount rate of 8% and a recovery period of 10 years [27]. Commodity specific factors can be obtained from more detailed industrial profile analysis, as is anticipated for the second-year research effort. Similarly, building cost indexes could be used to adjust for location so that capital investment need not be applied uniformly for all zones.

Taxes are computed according to the following concept: Total business taxes per capita were obtained for each state from Tax Institute of America [28] data. These figures are taken as a proxy measure of the sum of property taxes, sales taxes on input commodities, and state and municipal corporate income taxes. Next the specific taxes are computed for each commodity in a specific zone, using zone-specific tax data [29] and industry profile data about capital investment, input commodities, sales, and profit. The taxes for other zones are then computed using the ratios of the total business taxes per capita for the respective states.

The second-year research effort will focus on obtaining more detailed data, both for industries and for zones, for this procedure.

Matrix Iterative Procedure

One of the elements of the second-year research effort will be a matrix iterative procedure for determining commodity production costs by zone. This method is outlined broadly by the following steps:

1. Begin with national average costs c_{ik},
2. Adjust the c_{ik} by zone-specific direct labor, energy, and capital costs,
3. Adjust the c_{ik} by zone-specific taxes,
4. Identify sources of input commodities for existing facilities by observing the commodity movement data. For new facilities find the best source.
5. Update the c_{ik} based on the input commodity costs determined in step 4. Return to step 3.

Customer Service Parameter

The customer service parameter includes three factors: transportation cost, delivery time, and delivery time dependability. All of these factors are influenced by the transportation mode selected, and are therefore mode specific. The general form of the expression is:

$$g_{ij\ell} = \sum_m f_m(C + a_2\, T/a_1 + a_3\, V/a_1)$$

where:

$g_{ij\ell}$ = the customer service parameter for commodity i produced in zone j and delivered to zone ℓ,

m = mode,

f_m = the modal share by mode m,

C = transportation cost,

T = transportation time, and

V = transportation time variance.

The parameters a_1, a_2, and a_3 are the same as those used in the mode split function for the particular commodity. Time and time variance are normalized to costs so that transport disutility can be added directly to production cost c_{ij}. The implicit assumption in this method is that buyers of commodity j would have the same trade-offs among delivery cost, time, and time variance as producers and shippers. Since the mode split function parameters express these trade-offs (by taking ratios a_2/a_1 and a_3/a_1), one can use these same parameters to obtain a dollar valued result as perceived by the buyers.

Market Share

The market share that a new facility can expect to achieve in an existing market depends on how its combination of production cost and transportation cost and service equivalents (customer service parameters) compares with similar costs of other producers serving the same market. The size of the share is based on a comparison between the cost and service estimated for the new facility and the cost and service determinations for the lowest cost facility now serving the market. If the proposed new facility enjoys a cost and service advantage over all other facilities that serve the market, the new facility is assured a reasonable share of the market; however, the new facility is not likely to capture all of the market. However, if the new facility does not enjoy an advantage over any of the other procedures, the new facility is not likely to attract a very large share of the market.

Market Share Function

The estimated size of a new facility's market share depends on the nature of the industry/commodity group as well as on cost and service relationships. Agriculture, forest and mineral product markets are close to perfectly elastic. Thus, a new entry must meet the existing market price in order to supply any product to the market at all. Markets for manufactured goods exhibit different amounts of elasticity. The price-market share relationship for each commodity group will be estimated from a regression analysis of existing market patterns. These have the general form:

$$MS^{i}_{j\ell} = f[(c_{ij} + g_{ij\ell}) - (c_{ik} + g_{jk\ell})]$$

Where:

$MS^{i}_{j\ell}$ = market share in zone ℓ enjoyed by a producer of commodity i in zone j,

C_{ij} = production cost of commodity i in zone j,

$g_{ij\ell}$ = customer service parameter for commodity i produced in zone j and shipped to zone ℓ,

k = producer with the lowest delivered cost to market ℓ, and

$c_{ij} + g_{ij\ell}$ = market cost for product i at market ℓ for a producer at j.

The functional relationship is known to be non-linear for all commodities except those enjoying perfect competition. In the absence of brand identification, quality considerations and other non-costable criteria, market share generally declines with an increasing penalty above the lowest cost supplier. The exact functional form for market share has not been developed at this writing. The regression analysis is still underway.

The market share relationship will be based on the behavior of the largest volume shipments. These shipments are identified by scanning all movements for each commodity and extracting only those larger than a threshold value--generally about 0.3 percent of the total commodity movements. The 20 to 50 selected large volume movements for each commodity account for about half of the total volume and represent a workable set of suppliers. Production costs are calculated for each of the selected producers and customer service costs are determined for each major movement. Inasmuch as many commodities move by more than one mode, there are multiple customer service costs for these movements.

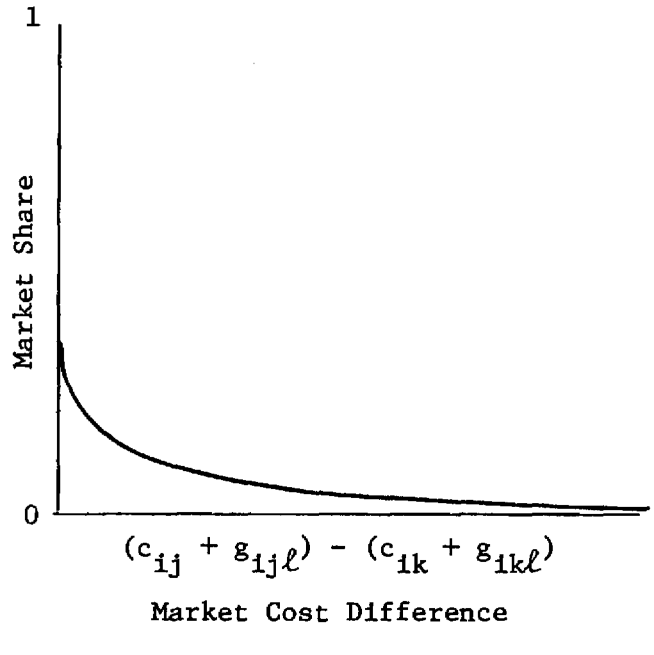
Market costs are determined for each producer--market pair by adding production and customer service costs. Suppliers to a given market are ranked in order of increasing market costs and market shares are calculated for each supplier.

$$MS^{i}_{j\ell} = \sum_{j \varepsilon J} V_{ij\ell}/MV_{i\ell}$$

where:

J = the set of major producers identified from the truncation of the commodity flow data,

FIGURE 9
MARKET SHARE FUNCTIONAL RELATIONSHIP



k = producer with the lowest market cost

$V_{ij\ell}$ = volume of commodity i supplied to market ℓ by producers in zone j, and

$MV_{i\ell}$ = total volume for commodity i in zone ℓ.

The largest market share is fixed as the share enjoyed by the lowest cost producer, thus establishing the y-axis intercept of the market share function (Figure 9). The most likely functional form is exponential or hyper-exponential form in which

$$MS^{i}_{j\ell} = a_o \exp a_1[(c_{ij} + g_{ij\ell}) - (c_{ik} + g_{ik\ell})]$$

where a_o and a_1 are correlation coefficients. The total market share for the major movements is constrained to equal the same total that was recorded when the movements were extracted from the commodity flow data. Thus:

$$\sum_{j\epsilon J} MS^{i}_{j\ell} = \sum_{j\epsilon J} V_{ij\ell}/MV_{i\ell}$$

Market Share of a New Facility

If a new facility can supply commodity i to an existing market at ℓ, the new facility will upset the balance among the suppliers to that market. Two situations can accompany the entry of the new facility:

1. It will have a market cost that is lower than the present lowest market cost, or
2. It will have a market cost that is higher than the present lowest market cost, but the new facility will be competitive with other suppliers.

In the first instance, the new facility will displace the lowest cost producer and all previous producers will lose market share at the expense of the new facility.

In the second instance, the new facility will displace higher cost suppliers, but it will not upset those that supply the market at lower cost. This is accomplished by establishing a market share for each effected producer from the market share function and dividing the market left over from the uneffected suppliers in terms of the calculated market shares, or

$$MS'^{i}_{j\ell} = MS^{i}_{j\ell} \; \frac{\sum\limits_{j \varepsilon J} MS^{i}_{j\ell} - \sum\limits_{j \varepsilon J_1} MS^{i}_{j\ell}}{\sum\limits_{p \varepsilon P} MS^{i}_{p\ell}}$$

Where:

$MS'^{i}_{j\ell}$ = revised market share in zone ℓ enjoyed by a producer of commodity i in zone j,

J_1 = set of major producers with market costs lower than those of the new facility, and

P = set of major producers with market costs higher than those of the new facility.

VII. DEMONSTRATING THE MODEL

The analytical model, contained within the overall analytical procedure, will be demonstrated, as part of the first year's work, using a small sample of potential applications to four zones in Northern Mississippi. Inasmuch as this test has not yet been completed, results cannot be described at this time. However, it may be useful to consider the magnitude of the test as determined by the data requirements and the planned analysis. Test results will be described in the final report for the first year's work. The results of this demonstration should in no way be interpreted as supporting conclusions of any sort. The first-year research effort has concentrated on developing analytical tools, and for this purpose the data gathered is representative but not accurate. In many cases sample data are used where an actual application would involve analyzing the complete set of data.

Zones

Four zones were selected for potential new facility locations:

Zone Number	Centroid Name	Area
20	Corinth	Northeastern Mississippi APDC
21	Tupelo	Three Rivers APDC, Mississippi
22	Columbus	Golden Triangle APDC minus Winston County, Mississippi
23	Clarksdale	North Delta APDC minus Tallahatchie County, Mississippi

Industries

Eight industry-commodity classifications were selected for testing:

220 Textile Mill Products

230 Apparel

240 Lumber & Wood

250 Furniture & Fixtures

287 Agricultural Chemicals

302 Rubber & Plastic Products

350 Machinery, Except Electrical

361 Electrical Machinery

The industry profiles for each of these are included in Appendix C.

Material Sources

The following material inputs were associated with national commodity markets and a limited number of sources:

logs

lumber

non-ferrous metals

potash

fiberglass

coal

For each of these the best delivered price to each production zone was then determined.

Cost Modeling and Assignment of Existing Flows

The procedure described in Section IV was followed in developing costs, times, and time variances for line haul arcs and transfers at nodes. Subsequently, shortest path trees were constructed for each origin, for each mode. The existing commodity O-D movement data, described in Section II and in greater detail in the Task 2 Report, were then used to assign freight flows to the network, thus establishing a base load on arcs and nodes. This assignment was performed according to the mode designated for each data point.

Determination of Mode Split Parameters

Sample flow data were prepared for each of the eight commodities under consideration, and for those commodities containing necessary input materials. These flow data were used to perform the mode split parameter calibration. The exponential (logit) form was fitted using first linear regression and then the cyclic coordinate search. The results of this gression equation coefficients are presented in Appendix B.

Determination of Commodity Production Costs by Zone

The procedures described in Section VI were used to generate commodity production costs for 14 to 27 existing zones, depending on the commodity. These existing production zones were the high volume origins selected from the commodity movement data. Production costs were also determined for each of the four test zones for each test industry/commodity group.

Delivered Cost Computation

The same sample production data were reordered for each commodity by destination zone. After determining the customer service parameters, the delivered "cost" was computed for each data point:

$$d_{ij\ell} = e_{ij} + C + a_2T/a_1 + a_3V/a_1$$

Where:

$d_{ij\ell}$ = the delivered "cost" in zone ℓ of commodity i produced in zone j,

c_{ij} = production cost for commodity i in zone j,

C = transportation cost from j to ℓ,

T = transportation time from j to ℓ,

V = transportation time variance from j to ℓ, and

a_1, a_2, a_3 = mode split parameters obtained previously.

Here the transportation cost, time, and attributes refer to the particular mode associated with each data point.

Market Share Analysis

Market share regression analysis is being conducted for each of the eight test commodities. Efforts are being made to develop a location abstract relationship for each commodity.

Transportation Alternatives

Three types of transportation alternatives will be explored. The first type consists of local highway and rail improvements in the Northern Mississippi test area. The nature of these improvements is set forth in Table 7. The purpose of these improvements is to provide potential new facilities with higher quality access to existing transport networks.

The second category of transportation alternatives consists of Multi-State Corridor wide improvements. The first alternative studied is a set of highway improvements extending from Brunswick to Kansas City. By this alternative, existing highways would be straightened and upgraded to support truck speeds of 55 mph. The second alternative studied is

TABLE 7
LOCAL TRANSPORTATION IMPROVEMENTS IN
NORTHERN MISSISSIPPI

Highway, upgrade	
US 78	Memphis to Birmingham
US 72	Membphis to Decatur, Alabama
US 82	Columbus, Mississippi to Tuscaloosa, Alabama
US 45	Corinth to Tupelo, Mississippi
US 82	Columbus, Mississippi to junction with US 45
US 45	US 82 to Tupelo
US 45	Corinth, Mississippi to Jackson, Tennessee
US 43	Spruce Pine to Hamilton, Alabama
Rail, upgrade	
Sou and ICG	Memphis to Corinth
ICG	Corinth to Birmingham
ICG	Corinth to Tupelo
Sou	Corinth to Decatur
L&N	Memphis to Jackson, Tennessee

a set of railroad improvements that extend from Jacksonville to Kansas City. This alternative includes rail line improvements that will support average train speeds of 35 mph and also eliminate the more serious grades and curves.

The third category of alternatives focus on terminal activity as a means of testing intermodal transportation opportunities. In this alternative, all major mode transfer activities along the Corridor will exhibit the characteristics of container terminals. Thus transfer costs will be greatly reduced from break-bulk costs.

In all, four alternative transportation programs will be tested: (1) local improvements; (2) Corridor highway plus local improvements; (3) Corridor rail plus local improvements; and (4) Corridor highway, Corridor rail, local and terminal improvements.

Evaluation

The evaluation framework that is described in the Task 4 report will be tested on the results of the Northern Mississippi test. Measures for the criteria set will be prepared for each of the four transportation alternatives tested.

The principal evaluation criteria are listed in Table 8. These are broadly divided into three categories:

1. Factors relating to the transportation system and system performance,
2. Factors relating to economic opportunities, and

TABLE 8
EVALUATION CRITERIA

ECONOMICAL
- Public Revenue
- Tax Base Changes
- Industrial Development
- Personal Income
- Property Values
- Employment
- Construction
- Commercial Sales

PHYSICAL
- Level of Transportation Service
- Resource Use
- Energy Use
- Operations
- Right-of-Way
- Terminals

FISCAL
- Construction Cost
- Maintenance Cost
- Operating Costs
- User's Cost
- Administrative Cost
- Accident Cost
- Effectiveness/Cost

SOCIAL
- Land Use
- Community Form
- Quality of Life
- Political
- Population
- Urban Renewal
- Community Goals
- Corridor Goals
- Displacement
- National Defense

Aesthetic
- Right-of-Way
- Terminals
- Value System
- Noise
- Beauty
- Drainage
- Vibration
- Lighting
- Advertising

3. Social, political, aesthetic and other factors.

Ratings for the different factors will be taken from the analytical results and from the judgments of public officials in the Northern Mississippi area. No effort will be made to arrive at an overall rating at this time. Techniques for combining evaluation criteria will be studied as part of the second year's work.

APPENDIX A

EQUILIBRIUM TRAFFIC ASSIGNMENT FOR MULTICLASS-USER TRANSPORTATION NETWORKS

INTRODUCTION

In recent work LeBlanc [1,2] describes the use of the Frank-Wolfe algorithm in solving traffic assignment problems. One of the key features of that approach is the fact that finding a good feasible direction reduces to solving p uncapacitated single-commodity problems, where p is the number of destination nodes.

The above assignment problem assumes that for one class of users, such as automobile drivers, each member of the class has the same cost curve for any given arc. The "commodities" in such a problem are usually defined according to destination node, or origin node, or origin-destination pair.

When one deals with different socio-economic classes, or with automobile and truck drivers, or with freight commodities, the cost curves for the user classes will differ for any given arc. Dafermos [3,4] has developed a feasible directions technique for solving such multiclass-user networks, but the procedure has not been tested on large networks with many user classes.

This note combines the results of LeBlanc and Dafermos to extend the Frank-Wolfe algorithm to multiclass-user transportation networks.

Problem Statement

Consider a fixed network (N,A), where

N = the set of nodes from 1,...,n

A = the set of arcs (i,j)

H = the set of user classes from 1,...,c

S = the set of destination nodes from 1,...,s

x_{ij}^{hs} = the flow on arc (i,j) of class h destined for s

$x_{ij}^{h} = \sum_{s} x_{ij}^{hs}$, the flow on arc (i,j) of class h

$x_{ij} = \sum_{h} \sum_{s} x_{ij}^{hs}$, the flow on arc (i,j)

D(h,j,s) = outbound shipping demand of class h at node j destined for s

$t_{ij}^{h}(x_{ij}^{h}, x_{ij})$ = total travel cost to class h on arc (i,j) with class flow x_{ij}^{h} and total flow x_{ij} on arc (i,j). This function is assumed to be non-negative and monotonically increasing.

The equilibrium traffic assignment problem is to find flows x_{ij}^{hs} that satisfy the following conditions:

$$D(h, j, s) + \sum_{i} x_{ij}^{hs} = \sum_{k} x_{jk}^{hs}, \quad \text{for } j = 1,\ldots,n \tag{1}$$
$$s = 1,\ldots,p,\ j \neq s$$
$$h = 1,\ldots,c$$

$$x_{ij}^{hs} \geq 0 \quad \text{for all } (i,j), h,\ s \tag{2}$$

no traveler (shipper) can unilaterally improve his travel (shipping) cost by changing paths (3)

Condition (3) is usually referred to as Wardrop's first principle(5).

Procedure

Following the development by Dafermos (4), the total travel cost over an arc produced by a set of flows is

$$t_{ij}(x) = \sum_h t^h_{ij} \; (x^h_{ij}, x_{ij}) \tag{4}$$

and the total travel cost over the entire network is

$$t(x) = \sum_{ij} \; t_{ij}(x) = \sum_{ij} \; \sum_h t^h_{ij}(x^h_{ij}, x_{ij}) \tag{5}$$

The simplest nontrivial example of a travel cost function is probably a quadratic form:

$$t^h_{ij}(x^h_{ij}, x_{ij}) = b^h_{ij} \; x^h_{ij} \; x_{ij} + g^h_{ij} \; x^h_{ij} \tag{6}$$

where the b^h_{ij} and g^h_{ij} are nonnegative constants.

Assuming that there is complete interaction among all users of class h on arc (i,j), the share of the travel cost to each of these users will be

$$\bar{t}^h_{ij}(x^h_{ij}, x_{ij}) = \frac{t^h_{ij} \; (x^h_{ij} \; , x_{ij})}{x^h_{ij}} \tag{7}$$

A system-optimizing flow pattern is a set of x^{hs}_{ij} that satisfies (1) and (2) and minimizes the total travel cost (5). Dafermas (4) has shown that under suitable conditions, a user-optimizing flow pattern (the solution to the equilibrium traffic assignment problem) can be obtained by finding the system-optimizing flow pattern for the associated problem:

$$\text{Min} \quad t^*(x) = \sum_{ij} \; \sum_h f^h_{ij} \; (x^h_{ij}, x_{ij}) \tag{8}$$

subject to (1) and (2), where

$$f_{ij}^{h}(x_{ij}^{h}, x_{ij}) = \int_{0}^{x_{ij}^{h}} \bar{t}_{ij}^{h}(z_{ij}^{h}, x_{ij})\, dz_{ij}^{h} \tag{9}$$

$$= \int_{0}^{x_{ij}^{h}} \left[\frac{t_{ij}^{h}(z_{ij}^{h}, x_{ij})}{z_{ij}^{h}} \right] dz_{ij}^{h} \tag{10}$$

Frank - Wolfe Algorithm

The Frank-Wolfe (6) algorithm is designed for problems with nonlinear objective function t(x) and linear constraints. Briefly stated, the algorithm starts with a current feasible solution x, and then finds a good feasible direction by solving the linear programming problem:

$$\min_{y}\ t(x) + \nabla t(x) \cdot (y - x) \tag{11}$$

s.t. linear constraints of original problem.

With y* the optimum solution to (11), the direction is then

$$d^* = y^* - x \tag{12}$$

A one-dimensional search is performed on

$$t(x + vd^*) \quad \text{over} \quad 0 \leq v \leq 1 \tag{13}$$

The optimum v* is then used to obtain the new solution

$$x \leftarrow x + v^* d^*. \tag{14}$$

Procedure

The objective function (11) can be written as

$$\min_{y}\ \nabla t^*(x) \cdot y = \min_{y_{ij}^{h}} \sum_{ij} \sum_{h} \frac{\partial t^*(x)}{\partial x_{ij}^{h}}\, y_{ij}^{h} \tag{15}$$

where the index notation for y corresponds to that for x. Since we wish to determine the x_{ij}^{hs}, we modify (15) to become:

$$\underset{y_{ij}^{hs}}{\text{Min}} \quad \sum_{ij} \sum_{h} \sum_{s} \frac{\partial t^*(x)}{\partial x_{ij}^{hs}} \; y_{ij}^{hs} \tag{16}$$

Now

$$\frac{\partial t^*(x)}{\partial x_{ij}^{hs}} = \sum_{k=1}^{c} \left[\frac{\partial f_{ij}^{k}(x_{ij}^{k}, x_{ij})}{\partial x_{ij}^{hs}} \right] \tag{17}$$

A typical term in the summation in (17) can be expressed as

$$\frac{\partial f_{ij}^{k}}{\partial x_{ij}^{hs}} = \frac{\partial}{\partial x_{ij}^{k}} \int_{0}^{x_{ij}^{k}} \bar{t}_{ij}^{k}(z_{ij}^{k}, x_{ij}) dz_{ij}^{k} \; \frac{\partial x_{ij}^{k}}{\partial x_{ij}^{hs}}$$

$$+ \frac{\partial}{\partial x_{ij}} \int_{0}^{x_{ij}^{k}} \bar{t}_{ij}^{k}(z_{ij}^{k}, x_{ij}) \, dz_{ij}^{k} \; \frac{\partial x_{ij}}{\partial x_{ij}^{hs}} \tag{18}$$

There are two cases to consider:

case i: $k \neq h$.

$$\frac{\partial x_{ij}^{k}}{\partial x_{ij}^{hs}} = 0 \tag{19}$$

and

$$\frac{\partial x_{ij}}{\partial x_{ij}^{hs}} = 1 \tag{20}$$

Thus,

$$\frac{\partial f_{ij}^{k}(x_{ij}^{k}, x_{ij})}{\partial x_{ij}^{hs}} = \frac{\partial}{\partial x_{ij}} \int_{0}^{x_{ij}^{k}} \frac{t_{ij}^{k}(z_{ij}^{k}, x_{ij})}{z_{ij}^{k}} \, dz_{ij}^{k} \tag{21}$$

So long as the form of t_{ij}^{k} is a polynomial, there should be no difficulty in obtaining a convenient, closed form for (21), expressed as a function in x_{ik}^{k} and x_{ij}.

Case ii: $k = h$

$$\frac{\partial f_{ij}^{h}(x_{ij}^{h}, x_{ij})}{\partial x_{ij}^{hs}} = \frac{t_{ij}^{h}(x_{ij}^{h}, x_{ij})}{x_{ij}^{h}} + \frac{\partial}{\partial x_{ij}} \int_{0}^{x_{ij}^{h}} \frac{t_{ij}^{h}(z_{ij}^{h}, x_{ij})}{z_{ij}^{h}} \, dz_{ij}^{h} \quad (22)$$

The net result of all these manipulations is that the partial derivatives in the LP objective function (16), will be polynomials in terms of current values of x_{ij}^{hs} and x_{ij}. For convenience, we can define

$$c_{ij}^{h} = \frac{\partial t^{*}(x)}{\partial x_{ij}^{hs}} \quad (23)$$

for current values of x. Note that the values of c_{ij}^{h} are independent of the destination node s.

The procedure now follows LeBlanc. At any iteration

$$\min_{y_{ij}^{hs}} \sum_{ij} \sum_{h} \sum_{s} c_{ij}^{h} y_{ij}^{hs} \quad (24)$$

s.t. flow constraints (1) and nonnegativity (2).

Due to the structure of the flow constraints, solving (24) is equivalent to solving (c x s) single-commodity, single-destination network flow subproblems with no capacity constraints or congestion effects. The feasible solution y^* to (24) is then used to obtain a best feasible direction

$$d^* = y^* - x \tag{12}$$

A one-dimensional search follows, yielding the new solution vector x, and the next iteration begins with the evaluation of the new c_{ij}^h.

Computation Time

The network under consideration contains approximately 120 nodes, 100 destination nodes, 400 one-way arcs, and 20 user classes. It is anticipated that 10 iterations of the Frank-Wolfe algorithm will be required to obtain a good solution. At an estimated 30% density, each iteration will require 0.3 x 100 x 20 = 600 subproblem solutions. Assuming a labeling-type tree-building algorithm, the total solution time will be approximately 10 iterations x 600 x 0.25 sec = 25 minutes. Since the trees for different user classes may be similar, one may wish to investigate the use of other types of procedures for solving the subproblems.

References

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APPENDIX B
MODE SPLIT RESULTS

The results of the mode split analysis for the eight commodities/ industry groups that were examined in the Northern Mississippi test are listed below:

	Commodity	a_1	a_2	a_3
220	Textiles	-0.0107	-0.0000333	-0.000552
230	Apparel	-0.0010	0	-0.000562
240	Lumber	-0.0075	-0.0000416	-0.000008
250	Furniture	-0.0087	-0.0000833	-0.000166
287	Ag. Chemicals	-0.0072	-0.0000233	-0.000062
302	Plastic Products	-0.0045	-0.0000966	0
350	Machinery, Exc. Elec.	-0.0054	-0.0001500	0
361	Electircal Equip.	-0.0050	-0.0000500	-0.000160

The above coefficients are used in equations of the form

$$U(\text{path}) = \frac{\exp(A)}{1-\exp(A)}$$

Where:

$$\begin{aligned} A = \log 0.5 &+ a_1 \text{ (mode cost - base mode cost)} \\ &+ a_2 \text{ (mode time - base mode time)} \\ &+ a_3 \text{ (mode time variance - base mode time variance)} \end{aligned}$$

The path utilities, representing RW/(RW+HW) and BW/(BW+HW) were then subjected to the normal transformation and the sum of the mode shares was corrected to 1.0 to yield final mode share values for each mode.

APPENDIX C
INDUSTRY PROFILES

Industry profiles for the eight commodity groups to be used in the Northern Mississippi test are presented. These data were largely taken from the 1972 Census of Manufacturers. Additional data on unit values were prepared by the project team from a number of different sources. A detailed description of the development of the industry profiles is contained in the Task 2 report.

TABLE 10
INDUSTRY PROFILES

	COMMODITY GROUP							
	220 TEXTILE	230 APPAREL	240 LUMBER	250 FURNITURE	287 AG. CHEM.	300 PLASTIC	350 MACHINERY	360 ELEC. EQUIP.
Industry Data								
No. of Companies	5,611	21,949	31,935	8,482	795	7,799	36,519	8,742
No. of Establishments	7,203	24,438	33,948	9,232	1,233	9,031	39,023	10,763
Establishments with < 20 employees	4,505	12,226	6,867	3,646	484	4,062	9,796	5,016
Cost of Materials, $ Million	16,505	14,532	13,593	5,328	2,194	6,721	24,744	21,046
Value Added, $ Million	11,718	13,488	10,309	6,090	1,737	7,583	33,136	27,359
Value of Shipments, $ Million	28,072	27,809	23,816	11,309	3,929	15,177	57,110	48,021
Mean Establishment								
Annual Cost of Goods Sold $ Thousand	3,945	1,136	700	1,237	3,186	1,565	1,466	4,459
Tons Shipped	1,672	238	3,500	611	17,700	1,252	374	1,188
Employees	132	56	20	46	39	57	42	137
Direct Labor Man Hours	239,622	88,432	34,391	81,846	51,663	88,513	57,786	186,324
Indirect Labor, $ Thousand	173	72	31	95	152	139	167	534
Capital Investment, $ Thousand	1,295	113	124	1,560	521	430	454	1,216
Energy Consumption, Thousand kwh	10,208	746	599	763	3,032	1,987	600	4,997
Raw Materials Class/Annual Tons	220/617 282/408	220/388	240/	220/6 240/662 285/2 331/233 333/9 340/94	140/47,194 281/1,125 287/4,930	281/46 282/654 286/39 289/22 300/66 321/8	110/4 331/297 340/17	282/39 331/342 340/2
Minimum Economic New Facility								
Employees	215	90	33	81	63	91	67	220
Annual Cost of Goods Sold $ Thousand	6,750	1,925	1,235	2,300	6,277	2,786	2,756	8,339
Capital Investment $ Thousand	1,790	155	175	2,310	782	607	662	1,773
Direct Labor Man Hours	410,000	150,000	60,700	157,000	102,000	157,000	108,000	349,000

APPENDIX D
TRANSPORTATION COSTS
FOR COMMODITIES

Line haul and loading and unloading costs are presented in this appendix for the rail and highway modes. The material is divided into four tables whose contents are as follows:

1. Railroad line haul costs per ton mile by commodity for each of three rail carrier cost areas. The first 53 entries are ordered by commodity for RCCA-1; the next 53 for RCCA-2 and the final 53 for RCCA-3.
2. Railroad loading and unloading costs per ton. Each entry includes loading plus unloading cost. These costs are listed by commodity for each of the three RCCAs as above.
3. Highway Line haul costs per ton mile by commodity for each of the eight motor carrier cost areas. The first 53 entires are ordered by commodity for MCCA-1, etc.
4. Highway loading and unloading costs per ton. These are listed by commodity for each MCCA.

RAILROAD LINE HAUL COSTS -- DOLLARS PER TON MILE

.0127	.0133	.0176	.0118	.0219	.0140	.0155	.0102	.0097	.010
.0103	.0106	.0150	.0154	.0123	.0130	.0282	.0107	.0106	.01
.0119	.0154	.0205	.0205	.0124	.0391	.0131	.0167	.0105	.0104
.0150	.0178	.0121	.0105	.0108	.0118	.0124	.0205	.0198	.0216
.0103	.0116	.0113	.0110	.0306	.0150	.0203	.0122	.0272	.0197
.0195	.0201	.0254	.0102	.0107	.0139	.0095	.0169	.0110	.0121
.0083	.0079	.0081	.0083	.0085	.0122	.0121	.0099	.0104	.0233
.0087	.0086	.0099	.0097	.0123	.0161	.0161	.0099	.0303	.0105
.0134	.0085	.0085	.0119	.0145	.0097	.0085	.0087	.0095	.0099
.0161	.0156	.0172	.0084	.0094	.0091	.0089	.0237	.0118	.0158
.0098	.0211	.0154	.0151	.0159	.0198	.0107	.0110	.0143	.0102
.0180	.0114	.0130	.0089	.0094	.0087	.0089	.0091	.0129	.0128
.0103	.0108	.0246	.0091	.0091	.0103	.0101	.0128	.0166	.0166
.0104	.0312	.0109	.0139	.0090	.0088	.0123	.0152	.0102	.0090
.0093	.0100	.0106	.0166	.0160	.0178	.0089	.0098	.0097	.0092
.0244	.0127	.0166	.0101	.0217	.0159	.0156	.0164	.0204	

RAILROAD LOADING & UNLOADING COSTS -- DOLLARS PER TON

3.1118	3.9694	6.6905	2.6843	4.1794	3.4134	2.1742	2.0860	1.9078	2.0265
2.2763	2.2067	7.5860	3.1489	3.5357	3.7337	19.1913	2.9263	2.7651	4.1704
3.8947	7.9560	6.1807	6.1807	2.9430	16.4659	3.6521	6.8314	2.3647	3.3589
4.0667	8.2582	2.9137	2.3868	2.3871	3.0320	2.9712	6.8496	6.5915	8.4724
2.2618	2.7460	2.5338	2.5273	9.7305	4.0556	7.0952	4.8117	10.3201	9.8178
5.2701	6.3826	7.9477	2.0632	2.7591	4.9131	1.7333	2.6228	2.2399	1.3582
1.3378	1.2221	1.2987	1.5210	1.4115	5.7284	2.1423	2.4604	2.5728	13.0864
2.0727	1.9429	2.9411	2.7058	6.2484	4.0084	4.0084	1.9114	11.4729	2.4356
4.7649	1.5537	2.4762	2.6348	5.5224	1.8986	1.5677	1.5615	1.9903	1.9186
4.6773	4.5132	5.5657	1.4877	1.7946	1.6480	1.6485	6.2275	2.7106	5.0787
3.7678	7.2819	7.8417	3.4277	4.1490	5.1173	3.0218	3.8337	6.4225	2.6019
4.0384	3.2770	2.1946	2.0528	1.8898	1.9983	2.2414	2.1625	7.3669	3.1056
3.4314	3.6095	18.2312	2.8727	2.7168	4.0501	3.7830	7.7286	5.8206	5.8206
2.8441	15.4841	3.5195	6.5407	2.3204	3.3073	3.8793	7.8678	2.8203	2.3405
2.3355	2.9402	2.8687	6.4895	6.2533	8.0059	2.2237	2.6680	2.4676	2.4675
9.0583	3.8790	6.7593	4.7141	9.7557	9.4962	4.9720	6.0204	7.4341	

HIGHWAY LINE HAUL COSTS -- DOLLARS PER TON MILE

.1282	.1005	.1608	.2010	.2876	.1005	.1105	.2010	.2010	.2010
.2010	.1960	.1427	.1065	.1005	.1005	.1507	.1156	.1507	.1005
.1005	.1608	.1105	.2613	.1417	.2010	.1005	.1005	.1688	.1166
.1005	.1045	.1407	.1688	.1940	.1357	.1859	.1507	.1608	.1608
.1759	.1216	.1849	.1146	.2914	.1779	.1437	.1105	.1608	.2713
.2578	.1105	.1306	.0709	.0556	.0890	.1112	.1591	.0556	.0612
.1112	.1112	.1112	.1112	.1084	.0790	.0589	.0556	.0556	.0834
.0639	.0834	.0556	.0556	.0890	.0612	.1446	.0784	.1112	.0556
.0556	.0934	.0645	.0556	.0578	.0778	.0934	.1073	.0751	.1029
.0834	.0890	.0890	.0973	.0673	.1023	.0634	.1612	.0984	.0795
.0612	.0890	.1501	.1426	.0612	.0723	.0725	.0568	.0909	.1136
.1626	.0568	.0625	.1136	.1136	.1136	.1136	.1108	.0807	.0602
.0568	.0568	.0852	.0653	.0852	.0569	.0568	.0909	.0625	.1477
.0801	.1136	.0538	.0568	.0954	.0659	.0568	.0591	.0795	.0954
.1096	.0767	.1051	.0852	.0909	.0909	.0994	.0687	.1045	.0648
.1647	.1005	.0812	.0625	.0909	.1534	.1457	.0625	.0738	.0567
.0444	.0710	.0838	.1271	.0444	.0488	.0888	.0888	.0888	.0888
.0866	.0630	.0471	.0444	.0444	.0666	.0511	.0666	.0444	.0444
.0710	.0488	.1154	.0626	.0888	.0444	.0444	.0746	.0515	.0444
.0462	.0622	.0746	.0857	.0599	.0821	.0666	.0710	.0710	.0777
.0537	.0817	.0506	.1288	.0786	.0635	.0488	.0710	.1199	.1139
.0488	.0577	.0601	.0471	.0754	.0942	.1348	.0471	.0518	.0942
.0942	.0942	.0942	.0918	.0669	.0499	.0471	.0471	.0706	.0542
.0706	.0471	.0471	.0754	.0518	.1225	.0664	.0942	.0471	.0471
.0791	.0546	.0471	.0490	.0659	.0791	.0909	.0636	.0871	.0706
.0754	.0754	.0824	.0570	.0867	.0537	.1366	.0834	.0674	.0518
.0754	.1272	.1208	.0518	.0612	.0521	.0408	.0653	.0816	.1168
.0408	.0449	.0816	.0816	.0816	.0816	.0796	.0579	.0432	.0408
.0408	.0612	.0469	.0612	.0408	.0408	.0653	.0449	.1061	.0575
.0816	.0408	.0408	.0685	.0473	.0408	.0424	.0571	.0685	.0787
.0551	.0755	.0612	.0653	.0653	.0714	.0494	.0751	.0465	.1183
.0722	.0583	.0449	.0653	.1102	.1047	.0449	.0530	.0561	.0440
.0704	.0880	.1259	.0440	.0484	.0880	.0880	.0880	.0880	.0858
.0625	.0466	.0440	.0440	.0660	.0506	.0660	.0440	.0440	.0704
.0484	.1144	.0620	.0880	.0440	.0440	.0739	.0510	.0440	.0458
.0616	.0739	.0849	.0594	.0814	.0660	.0704	.0704	.0770	.0532
.0810	.0502	.1276	.0779	.0629	.0484	.0704	.1188	.1129	.0484
.0572	.0749	.0587	.0939	.1174	.1680	.0587	.0646	.1174	.1174
.1174	.1174	.1145	.0834	.0622	.0587	.0587	.0880	.0675	.0880
.0587	.0587	.0939	.0646	.1526	.0828	.1174	.0587	.0587	.0986
.0681	.0587	.0610	.0822	.0986	.1133	.0792	.1086	.0880	.0939
.0939	.1027	.0710	.1080	.0669	.1702	.1039	.0839	.0646	.0939
.1585	.1506	.0646	.0763	.0883	.0692	.1107	.1384	.1981	.0692
.0761	.1384	.1384	.1384	.1384	.1349	.0983	.0734	.0692	.0692
.1038	.0796	.1038	.0692	.0692	.1107	.0761	.1799	.0976	.1384
.0692	.0692	.1163	.0803	.0692	.0720	.0969	.1163	.1336	.0934
.1280	.1038	.1107	.1107	.1211	.0837	.1273	.0789	.2007	.1225
.0990	.0761	.1107	.1868	.1775	.0761	.0900	.0537	.0421	.0674
.0842	.1205	.0421	.0463	.0842	.0842	.0842	.0842	.0821	.0598
.0446	.0421	.0421	.0631	.0484	.0631	.0421	.0421	.0674	.0463
.1095	.0594	.0842	.0421	.0421	.0707	.0488	.0421	.0438	.0589
.0707	.0813	.0568	.0779	.0631	.0674	.0674	.0737	.0509	.0775
.0480	.1221	.0745	.0602	.0463	.0674	.1137	.1080	.0463	.0547
.0531	.0416	.0666	.0832	.1191	.0416	.0458	.0832	.0832	.0832
.0832	.0811	.0591	.0441	.0416	.0416	.0624	.0478	.0624	.0416
.0416	.0666	.0458	.1082	.0587	.0832	.0416	.0416	.0699	.0483
.0416	.0433	.0582	.0699	.0803	.0562	.0770	.0624	.0666	.0666
.0728	.0503	.0765	.0474	.1206	.0736	.0595	.0458	.0666	.1123
.1067	.0458	.0541	.0559	.0438	.0701	.0876	.1254	.0438	.0482
.0876	.0876	.0876	.0876	.0854	.0622	.0464	.0438	.0438	.0657
.0504	.0657	.0438	.0438	.0701	.0482	.1139	.0618	.0876	.0438

HIGHWAY LINE HAUL COSTS (CONT.)

.0438	.0736	.0508	.0438	.0456	.0613	.0736	.0845	.0591	.0810
.0657	.0701	.0701	.0766	.0530	.0806	.0499	.1270	.0775	.0626
.0482	.0701	.1183	.1123	.0482	.0569	.0467	.0366	.0586	.0732
.1047	.0366	.0403	.0732	.0732	.0732	.0732	.0714	.0520	.0388
.0366	.0366	.0549	.0421	.0549	.0366	.0366	.0586	.0403	.0952
.0516	.0732	.0366	.0366	.0615	.0425	.0366	.0381	.0512	.0615
.0706	.0494	.0677	.0549	.0586	.0586	.0640	.0443	.0673	.0417
.1061	.0648	.0523	.0403	.0586	.0988	.0939	.0403	.0476	.0664
.0520	.0832	.1040	.1488	.0520	.0572	.1040	.1040	.1040	.1040
.1014	.0738	.0551	.0520	.0520	.0780	.0598	.0780	.0520	.0520
.0832	.0572	.1352	.0733	.1040	.0520	.0520	.0874	.0603	.0520
.0541	.0728	.0874	.1004	.0702	.0962	.0780	.0832	.0832	.0910
.0629	.0957	.0593	.1508	.0920	.0744	.0572	.0832	.1404	.1334
.0572	.0676	.0584	.0458	.0733	.0916	.1311	.0458	.0504	.0916
.0916	.0916	.0916	.0893	.0650	.0485	.0458	.0458	.0687	.0527
.0687	.0458	.0458	.0733	.0504	.1191	.0646	.0916	.0458	.0458
.0769	.0531	.0458	.0476	.0641	.0769	.0884	.0618	.0847	.0687
.0733	.0733	.0801	.0554	.0843	.0522	.1328	.0811	.0655	.0504
.0733	.1237	.1175	.0504	.0595	.0623	.0488	.0781	.0976	.1397
.0488	.0537	.0976	.0976	.0976	.0976	.0952	.0693	.0517	.0488
.0488	.0732	.0561	.0732	.0488	.0488	.0781	.0537	.1269	.0688
.0976	.0488	.0488	.0820	.0566	.0488	.0508	.0683	.0820	.0942
.0659	.0903	.0732	.0781	.0781	.0854	.0590	.0898	.0556	.1415
.0864	.0698	.0537	.0781	.1318	.1252	.0537	.0634	.0544	.0426
.0682	.0952	.1219	.0426	.0469	.0852	.0852	.0852	.0852	.0831
.0605	.0452	.0426	.0426	.0639	.0490	.0639	.0426	.0426	.0682
.0469	.1108	.0601	.0852	.0426	.0426	.0716	.0494	.0426	.0443
.0596	.0716	.0822	.0575	.0788	.0639	.0682	.0682	.0745	.0515
.0784	.0486	.1235	.0754	.0609	.0469	.0682	.1150	.1093	.0469
.0554	.0561	.0440	.0704	.0880	.1259	.0440	.0484	.0880	.0880
.0880	.0880	.0858	.0625	.0466	.0440	.0440	.0660	.0506	.0660
.0440	.0440	.0704	.0484	.1144	.0620	.0880	.0440	.0440	.0739
.0510	.0440	.0458	.0616	.0739	.0849	.0594	.0814	.0660	.0704
.0704	.0770	.0532	.0810	.0502	.1276	.0779	.0629	.0484	.0704
.1188	.1129	.0484	.0572	.0582	.0456	.0730	.0912	.1305	.0456
.0502	.0912	.0912	.0912	.0912	.0889	.0648	.0483	.0456	.0456
.0684	.0524	.0684	.0456	.0456	.0730	.0502	.1186	.0643	.0912
.0456	.0456	.0766	.0529	.0456	.0474	.0638	.0766	.0880	.0616
.0844	.0684	.0730	.0730	.0798	.0552	.0839	.0520	.1322	.0807
.0652	.0502	.0730	.1231	.1170	.0502	.0593	.0541	.0424	.0678
.0848	.1213	.0424	.0466	.0848	.0848	.0848	.0848	.0827	.0602
.0449	.0424	.0424	.0636	.0488	.0636	.0424	.0424	.0678	.0466
.1102	.0598	.0848	.0424	.0424	.0712	.0492	.0424	.0441	.0594
.0712	.0818	.0572	.0784	.0636	.0678	.0678	.0742	.0513	.0780
.0483	.1230	.0750	.0606	.0466	.0678	.1145	.1088	.0466	.0551
.0675	.0529	.0846	.1058	.1514	.0529	.0582	.1058	.1058	.1058
.1058	.1032	.0751	.0561	.0529	.0529	.0793	.0608	.0793	.0529
.0529	.0846	.0582	.1375	.0746	.1058	.0529	.0529	.0889	.0614
.0529	.0550	.0741	.0889	.1021	.0714	.0979	.0793	.0846	.0846
.0926	.0640	.0973	.0603	.1534	.0936	.0756	.0582	.0846	.1428
.1357	.0582	.0688	.0635	.0498	.0797	.0996	.1425	.0498	.0548
.0996	.0996	.0996	.0996	.0971	.0707	.0528	.0498	.0498	.0747
.0573	.0747	.0498	.0498	.0797	.0548	.1295	.0702	.0996	.0498
.0498	.0837	.0578	.0498	.0518	.0697	.0837	.0961	.0672	.0921
.0747	.0797	.0797	.0871	.0603	.0916	.0568	.1444	.0881	.0712
.0548	.0797	.1345	.1277	.0548	.0647	.0656	.0514	.0822	.1028
.1471	.0514	.0565	.1028	.1028	.1028	.1028	.1002	.0730	.0545
.0514	.0514	.0771	.0591	.0771	.0514	.0514	.0822	.0565	.1336
.0725	.1028	.0514	.0514	.0864	.0596	.0514	.0535	.0720	.0864
.0992	.0694	.0951	.0771	.0822	.0822	.0899	.0622	.0946	.0586
.1491	.0910	.0735	.0565	.0822	.1388	.1318	.0565	.0668	

HIGHWAY LOADING & UNLOADING COSTS -- DOLLARS PER TON

5.9402	6.8200	10.9120	3.4100	19.5188	6.8200	7.5020	3.4100	3.4100	3.4100
3.4100	3.5805	5.5924	7.2292	6.8200	6.8200	10.2300	6.3085	5.1150	6.8200
6.8200	10.9120	7.5020	17.7320	5.4219	13.6400	6.8200	6.8200	4.5012	6.2744
6.8200	6.6836	5.4560	4.5012	3.6487	5.6265	3.9215	10.2300	10.9120	10.9120
4.2625	6.1039	3.9556	6.3426	19.7780	4.1943	6.3767	7.5020	10.9120	18.4140
17.4933	7.5020	8.6660	6.6893	7.6800	12.2880	3.8400	21.9801	7.6800	8.4480
3.8400	3.8400	3.8400	3.8400	4.0320	6.2976	8.1408	7.6800	7.6800	11.5200
7.1040	5.7600	7.6800	7.6800	12.2880	8.4480	19.9680	6.1056	15.3600	7.6800
7.6800	5.0688	7.0656	7.6800	7.5264	6.1440	5.0688	4.1088	6.3360	4.4160
11.5200	12.2880	12.2880	4.8000	6.8736	4.4544	7.1424	22.2720	4.7232	7.1808
8.4480	12.2880	20.7360	19.6992	8.4480	9.9840	8.1787	9.3900	15.0240	4.6950
26.8742	9.3900	10.3290	4.6950	4.6950	4.6950	4.6950	4.9297	7.6998	9.9534
9.3900	9.3900	14.0850	8.6857	7.0425	9.3900	9.3900	15.0240	10.3290	24.4140
7.4650	18.7800	9.3900	9.3900	6.1974	8.6388	9.3900	9.2022	7.5120	6.1974
5.0236	7.7467	5.3992	14.0850	15.0240	15.0240	5.8687	8.4040	5.4462	8.7327
27.2310	5.7749	8.7796	10.3290	15.0240	25.3530	24.0853	10.3290	12.2070	7.7867
8.9400	14.3040	4.4700	25.5863	8.9400	9.8340	4.4700	4.4700	4.4700	4.4700
4.6935	7.3308	9.4764	8.9400	8.9400	13.4100	8.2695	6.7050	8.9400	8.9400
14.3040	9.8340	23.2440	7.1073	17.8800	8.9400	8.9400	5.9004	8.2248	8.9400
8.7612	7.1520	5.9004	4.7829	7.3755	5.1405	13.4100	14.3040	14.3040	5.5875
8.0013	5.1852	8.3142	25.9260	5.4981	8.3589	9.8340	14.3040	24.1380	22.9311
9.8340	11.6220	9.1716	10.5300	16.8480	5.2650	30.1369	10.5300	11.5830	5.2650
5.2650	5.2650	5.2650	5.5282	8.6346	11.1618	10.5300	10.5300	15.7950	9.7402
7.8975	10.5300	10.5300	16.8480	11.5830	27.3780	8.3713	21.0600	10.5300	10.5300
6.9498	9.6876	10.5300	10.3194	8.4240	6.9498	5.6335	8.6872	6.0547	15.7950
16.8480	16.8480	6.5812	9.4243	6.1074	9.7929	30.5370	6.4759	9.8456	11.5830
16.8480	28.4310	27.0094	11.5830	13.6890	13.3873	15.3700	24.5920	7.6850	43.9889
15.3700	16.9070	7.6850	7.6850	7.6850	7.6850	8.0692	12.6034	16.2922	15.3700
15.3700	23.0550	14.2172	11.5275	15.3700	15.3700	24.5920	16.9070	39.9620	12.2191
30.7400	15.3700	15.3700	10.1442	14.1404	15.3700	15.0626	12.2960	10.1442	8.2229
12.6802	8.8377	23.0550	24.5920	24.5920	9.6062	13.7561	8.9146	14.2941	44.5730
9.4525	14.3710	16.9070	24.5920	41.4990	39.4240	16.9070	19.9810	9.6681	11.1000
17.7600	5.5500	31.7682	11.1000	12.2100	5.5500	5.5500	5.5500	5.5500	5.8275
9.1020	11.7660	11.1000	11.1000	16.6500	10.2675	8.3250	11.1000	11.1000	17.7600
12.2100	28.8600	8.8245	22.2000	11.1000	11.1000	7.3260	10.2120	11.1000	10.8780
8.8800	7.3260	5.9385	9.1575	6.3825	16.6500	17.7600	17.7600	6.9375	9.9345
6.4380	10.3230	32.1900	6.8265	10.3785	12.2100	17.7600	29.9700	28.4715	12.2100
14.4300	9.4678	10.8700	17.3920	5.4350	31.1099	10.8700	11.9570	5.4350	5.4350
5.4350	5.4350	5.7067	8.9134	11.5222	10.8700	10.8700	16.3050	10.0547	8.1525
10.8700	10.8700	17.3920	11.9570	28.2620	8.6416	21.7400	10.8700	10.8700	7.1742
10.0004	10.8700	10.6526	8.6760	7.1742	5.8154	8.9677	6.2502	16.3050	17.3920
17.3920	6.7937	9.7286	6.3046	10.1091	31.5230	6.6850	10.1635	11.9570	17.3920
29.3470	27.8815	11.9570	14.1310	8.4661	9.7200	15.5520	4.8600	27.8186	9.7200
10.6920	4.8600	4.8600	4.8600	4.8600	5.1030	7.9704	10.3032	9.7200	9.7200
14.5800	8.9910	7.2900	9.7200	9.7200	15.5520	10.6920	25.2720	7.7274	19.4400
9.7200	9.7200	6.4152	8.9424	9.7200	9.5256	7.7760	6.4152	5.2002	8.0190
5.5890	14.5800	15.5520	15.5520	6.0750	8.6994	5.6376	9.0396	28.1880	5.9778
9.0882	10.6920	15.5520	26.2440	24.9318	10.6920	12.6360	8.7361	10.0300	16.0480
5.0150	28.7059	10.0300	11.0330	5.0150	5.0150	5.0150	5.0150	5.2657	8.2246
10.6318	10.0300	10.0300	15.0450	9.2777	7.5225	10.0300	10.0300	16.0480	11.0330
26.0780	7.9738	20.0600	10.0300	10.0300	6.6198	9.2276	10.0300	9.8294	8.0240
6.6198	5.3660	8.2747	5.7672	15.0450	16.0480	16.0480	6.2687	8.9768	5.8174
9.3279	29.0870	6.1684	9.3780	11.0330	16.0480	27.0810	25.7269	11.0330	13.0390
13.9708	16.0400	25.6640	8.0200	45.9064	16.0400	17.6440	8.0200	8.0200	8.0200
8.0200	8.4210	13.1528	17.0024	16.0400	16.0400	24.0600	14.8370	12.0300	16.0400
16.0400	25.6640	17.6440	41.7040	12.7518	32.0800	16.0400	16.0400	10.5864	14.7568
16.0400	15.7192	12.8320	10.5864	8.5814	13.2330	9.2230	24.0600	25.6640	25.6640
10.0250	14.3558	9.3032	14.9172	46.5160	9.8646	14.9974	17.6440	25.6640	43.3080
41.1425	17.6440	20.8520	7.0638	8.1100	12.9760	4.0550	23.2108	8.1100	8.9210
4.0550	4.0550	4.0550	4.0550	4.2577	6.6502	8.5966	8.1100	8.1100	12.1650
7.5017	6.0825	8.1100	8.1100	12.9760	8.9210	21.0860	6.4474	16.2200	8.1100
8.1100	5.3526	7.4612	8.1100	7.9478	6.4880	5.3526	4.3388	6.6907	4.6632

12.1650	12.9760	12.9760	5.0687	7.2584	4.7038	7.5423	23.5190	4.9876	7.5828
8.9210	12.9760	21.8970	20.8021	8.9210	10.5430	7.4383	8.5400	13.6640	4.2700
24.4415	8.5400	9.3940	4.2700	4.2700	4.2700	4.2700	4.4835	7.0028	9.0524
8.5400	8.5400	12.8100	7.8995	6.4050	8.5400	8.5400	13.6640	9.3940	22.2040
6.7893	17.0800	8.5400	8.5400	5.6364	7.8568	8.5400	8.3692	6.8320	5.6364
4.5669	7.0455	4.9105	12.8100	13.6640	13.6640	5.3375	7.6433	4.9532	7.9422
24.7660	5.2521	7.9849	9.3940	13.6640	23.0580	21.9051	9.3940	11.1020	6.8635
7.8800	12.6080	3.9400	22.5526	7.8800	8.6680	3.9400	3.9400	3.9400	3.9400
4.1370	6.4616	8.3528	7.8800	7.8800	11.8200	7.2890	5.9100	7.8800	7.8800
12.6080	8.6680	20.1880	6.2646	15.7600	7.8800	7.8800	5.2008	7.2496	7.8800
7.7224	6.3040	5.2008	4.2158	6.5010	4.5310	11.8200	12.6080	12.6080	4.9250
7.0526	4.5704	7.3264	22.8520	4.8462	7.3678	8.6680	12.6080	21.2760	20.2122
8.6680	10.2440	7.2380	8.3100	13.2960	4.1550	23.7832	8.3100	9.1410	4.1550
4.1550	4.1550	4.1550	4.3627	6.8142	8.8086	8.3100	8.3100	12.4650	7.6867
6.2325	8.3100	8.3100	13.2960	9.1410	21.6060	6.6064	16.6200	8.3100	8.3100
5.4846	7.6452	8.3100	8.1438	6.6480	5.4846	4.4458	6.8557	4.7782	12.4650
13.2960	13.2960	5.1937	7.4374	4.8198	7.7283	24.0990	5.1106	7.7698	9.1410
13.2960	22.4370	21.3151	9.1410	10.8030	7.9871	9.1700	14.6720	4.5850	26.2445
9.1700	10.0870	4.5850	4.5850	4.5850	4.5850	4.8142	7.5194	9.7202	9.1700
9.1700	13.7550	8.4822	6.8775	9.1700	9.1700	14.6720	10.0870	23.8420	7.2901
18.3400	9.1700	9.1700	6.0522	8.4364	9.1700	8.9866	7.3360	6.0522	4.9059
7.5652	5.2727	13.7550	14.6720	14.6720	5.7312	8.2071	5.3186	8.5281	26.5930
5.6395	8.5739	10.0870	14.6720	24.7590	23.5210	10.0870	11.9210	8.6752	9.9600
15.9360	4.9800	28.5055	9.9600	10.9560	4.9800	4.9800	4.9800	4.9800	5.2290
8.1672	10.5576	9.9600	9.9600	14.9400	9.2130	7.4700	9.9600	9.9600	15.9360
10.9560	25.8960	7.9182	19.9200	9.9600	9.9600	6.5736	9.1632	9.9600	9.7608
7.9680	6.5736	5.3286	8.2170	5.7270	14.9400	15.9360	15.9360	6.2250	8.9142
5.7768	9.2628	28.8840	6.1254	9.3126	10.9560	15.9360	26.8920	25.5474	10.9560
12.9480	8.4835	9.7400	15.5840	4.8700	27.8759	9.7400	10.7140	4.8700	4.8700
4.8700	4.8700	5.1135	7.9868	10.3244	9.7400	9.7400	14.6100	9.0095	7.3050
9.7400	9.7400	15.5840	10.7140	25.3240	7.7433	19.4800	9.7400	9.7400	6.4284
8.9608	9.7400	9.5452	7.7920	6.4284	5.2109	8.0355	5.6005	14.6100	15.5840
15.5840	6.0875	8.7173	5.6492	9.0582	28.2460	5.9901	9.1069	10.7140	15.5840
26.2980	24.9831	10.7140	12.6620	10.7830	12.3800	19.8080	6.1900	35.4315	12.3800
13.6180	6.1900	6.1900	6.1900	6.1900	6.4995	10.1516	13.1228	12.3800	12.3800
18.5700	11.4515	9.2850	12.3800	12.3800	19.8080	13.6180	32.1880	9.8421	24.7600
12.3800	12.3800	8.1708	11.3896	12.3800	12.1324	9.9040	8.1708	6.6233	10.2135
7.1185	18.5700	19.8080	19.8080	7.7375	11.0801	7.1804	11.5134	35.9020	7.6137
11.5753	13.6180	19.8080	33.4260	31.7547	13.6180	16.0940	10.5914	12.1600	19.4560
6.0800	34.8019	12.1600	13.3760	6.0800	6.0800	6.0800	6.0800	6.3840	9.9712
12.8896	12.1600	12.1600	18.2400	11.2480	9.1200	12.1600	12.1600	19.4560	13.3760
31.6160	9.6672	24.3200	12.1600	12.1600	8.0256	11.1872	12.1600	11.9168	9.7280
8.0256	6.5056	10.0320	6.9920	18.2400	19.4560	19.4560	7.6000	10.8832	7.0528
11.3093	35.2640	7.4784	11.3696	13.3760	19.4560	32.8320	31.1904	13.3760	15.8080
11.2794	12.9500	20.7200	6.4750	37.0629	12.9500	14.2450	6.4750	6.4750	6.4750
6.4750	6.7987	10.6190	13.7270	12.9500	12.9500	19.4250	11.9787	9.7125	12.9500
12.9500	20.7200	14.2450	33.6700	10.2952	25.9000	12.9500	12.9500	8.5470	11.9140
12.9500	12.6910	10.3600	8.5470	6.9282	10.6837	7.4462	19.4250	20.7200	20.7200
8.0937	11.5902	7.5110	12.0435	37.5550	7.9642	12.1082	14.2450	20.7200	34.9650
33.2167	14.2450	16.8350	8.0132	9.2000	14.7200	4.6000	26.3304	9.2000	10.1200
4.6000	4.6000	4.6000	4.6000	4.8300	7.5440	9.7520	9.2000	9.2000	13.8000
8.5100	6.9000	9.2000	9.2000	14.7200	10.1200	23.9200	7.3140	18.4000	9.2000
9.2000	6.0720	8.4640	9.2000	9.0160	7.3600	6.0720	4.9220	7.5900	5.2900
13.8000	14.7200	14.7200	5.7500	8.2340	5.3360	8.5560	26.6800	5.6580	8.6020
10.1200	14.7200	24.8400	23.5980	10.1200	11.9600	8.9539	10.2800	16.4480	5.1400
29.4214	10.2800	11.3080	5.1400	5.1400	5.1400	5.1400	5.3970	8.4296	10.8968
10.2800	10.2800	15.4200	9.5090	7.7100	10.2800	10.2800	16.4480	11.3080	26.7280
8.1726	20.5600	10.2800	10.2800	6.7848	9.4576	10.2800	10.0744	8.2240	6.7848
5.4998	8.4810	5.9110	15.4200	16.4480	16.4480	6.4250	9.2006	5.9624	9.5604
29.8120	6.3222	9.6118	11.3080	16.4480	27.7560	26.3682	11.3080	13.3640	

APPENDIX E
PROGRAM LISTINGS

Each of the ten principal computer programs is summarized briefly below followed by a complete listing of seven of the programs.

ARCDEV

Program ARCDEV reads three sets of undirected arcs, one for each mode, along with the distance and speed associated with each arc. It constructs an ordered set of directed arcs (base arcs) along with the distance, time, and time variability associated with each mode on each base arc.

AINDUTI

Program AINDUTI reads the set of base arcs together with unit transport costs including line-haul, loading-unloading, forwarding, and intermodal transfer costs for each commodity, mode, and geographic region. From these, it develops an average cost (over all commodities) for each transport facility. It also develops commodity cost factors which can be used to translate these average costs into commodity specific costs.

MTREES

Program MTREES reads the average costs for all transport facilities and constructs three shortest path trees (one for each mode) for each node. It also stores the cost, time, and time variance associated with the shortest path between each O-D pair.

DETCIJ

Program DETCIJ estimates the cost of producing a commodity in each of its major production zones as well as in the four test zones. Cost includes the basic cost of raw materials, raw material transport cost, energy cost, labor cost, and cost of capital. Eight test commodities are considered. The program also estimates single mode transport costs between current and potential commodity production zones and their most important markets. These costs are "total" transportation costs in the sense that they include cost, time, and time variance weighted by their respective modal split parameters.

HIJK

Program HIJK estimates the delivered costs of each commodity at its most important markets. Costs from current production zones as well as the four test zones are computed. No intermodal transport is considered.

MMTREE

Program MMTREE estimates commodity specific "total" transport costs for all transport facilities including line haul arcs, loading-unloading terminals, intermodal transfer terminals, and forwarding terminals. For each of the eight test commodities it then constructs shortest "total" cost trees for each major production zone and each of the four test zones. It also stores the "total" cost associated with the shortes path between each relevant O-D pair.

MMSPLT

Program MMSPLT splits the total flow between each production zone-market zone pair identified by Program SEPFLOW. Flow is split among truck, rail, water, and the best multi-modal path (when it is distinct from a single modal path) through the use of a mode-abstract modal-split model.

MMLOAD

Program MMLOAD loads multi-modal flows of each of the eight test commodities onto the network. Flows in production tons and freight tons are given for each transport facility.

SLOAD

Program SLOAD loads single-mode flows for each of the eight test commodities onto the network. Output in same form as MMLOAD.

MMHIJK

Program MMHIJK estimates a revised delivered cost for commodities produced in each of the four test zones and delivered to each of the significant commodity markets. The revised cost is computed by allowing a portion of flow along the shortest multi-modal path.

PROGRAM ARCDEV

```
      PROGRAM INPUT1(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,TAPE2,T
     1APE3,TAPE4,TAPE7)
C*****PNTR(130)        POINTER TO FIRST ARC EMANATING FROM A NODE, IN AN
C                      ORDERED ARC LIST
C     NR               NUMBER OF NODES READ IN, LIMIT 130
C     NGA(130,3)       NODE GEOGRAPHIC AREA, RANGES 3,6,5
C     RCO(700)         ARC ORIGIN
C     RCD(700)         ARC DESTINATION
C     NARCSR           NUMBER OF ARCS READ IN, LIMIT 300
C     NARCSC           NUMBER OF ARCS CREATED, 2*NARCSR
C     NRRNAM           NUMBER OF RAILROAD NAMES
C     RRNAM(35)        RAILROAD NAME, ALPHAMERIC
C     NAMERD(5)        DUMMY VARIABLE
C     LHD(700,3)       LINE HAUL ARC DISTANCE
C     LHT( )           LINE HAUL ARC TIME
C     LHCAP( )         LINE HAUL ARC CAPACITY, LANES, CAPACITY
C     LHNAM(700,3,6)      LINE HAUL ARC NAME, FORMAT 6A5
C     RLHCTM(53,3) RAIL LINE HAUL COST PER TON MILE, FOR COMMODITY N
C                          AND GEOGRAPHIC AREA G
C     HLHCTM(53,23)HIGHWAY LINE HAUL COST...
C     RLDC(53,3)       RAIL LOADING COST PER TON,...
C     HLDC(53,23)      HIGHWAY LOADING COST PER TON,...
C     NNCR             NUMBER OF NODE CHARACTERISTICS READ IN, LIMIT 30
C     NC(130)          NODE CHARACTERISTIC, FOR INDEXING TRANSFER COSTS
C     LDT(30,3)        BASE LOADING TIME FOR HIGHWAY, RAIL, WATERWAY
C     LDC(30,3)        BASE LOADING COST...
C     LDTV(30,3)       BASE LOADING TIME VARIANCE...
C     TRC(30,6)        BASE TRANSFER COSTFOR H-H,H-R,H-W,R-R,R-W,W-W
C     TRT( )           BASE TRANSFER TIME...
C     TRTV( )          BASE TRANSFER TIME VARIANCE...
      INTEGER RCO(1000),RCD(1000),PNTR(130)
      DIMENSION NC(130),RC3(1000,3)
      DIMENSION RC1(1000,3),RC2(1000,3),TC1(50,4,4),TC2(50,4,4),
     &TC3(50,4,4)
      DIMENSION CLHCF(53,3),CLDCF(53,3)
      DIMENSION NGA(130,3)
          REAL LHD(1000,3),LHT(1000,3),LHV(1000,3)
      DIMENSION HLHCTM(53,23),HLDC(53,23),RLDC(53,3)
          DIMENSION WLDC(53),ALHCTM(3,8),ALDCT(3,8)
          REAL ITC(50,3),ITT(50,3),ITTV(50,3)
      REAL LDT(50,3),LDTV(50,3),LDC(50,3)
      DIMENSION RLHCTM(53,3),FR(4)
          INTEGER X(32),Y(32)
          DATA X/4*1,4*2,4*3,4*4,4*5,4*6,4*7,4*8/,
     1Y/12*1,4*2,16*3/
10    FORMAT(16I5)
20    FORMAT(I7,3X,A10)
30    FORMAT(5I5,6A5)
40    FORMAT(20X,F10.4)
50    FORMAT(40I2)
60    FORMAT(1H ,7A10)
70    FORMAT(1H ,18A5)
75    FORMAT(4I5,F10.4)
80    FORMAT(10F8.4)
85    FORMAT(8F10.4)
86    FORMAT(8F10.0)
90    FORMAT(8I10)
95    FORMAT(2I5,3F10.2)
C*****READ GEOGRAPHIC ZONE IDENTIFIERS, TECH PUNCHED CARDS, TAPE2
      READ(2,10)NR
      N31=NR*3+1
      DO 105 I=1,NR
105   READ(2,10)IA,(NGA(I,J),J=1,3)
      DO 106 I=1,NR
      IF(NGA(I,1).LE.0.OR.NGA(I,1).GT.8)NGA(I,1)=8
      IF(NGA(I,2).LE.0.OR.NGA(I,2).GT.3)NGA(I,2)=3
      IF(NGA(I,3).LE.0.OR.NGA(I,3).GT.5)NGA(I,3)=1
106   CONTINUE
          READ(2,10) NNCR
          READ(2,50)  (NC(I),I=1,NR)
C*****READ RCO,RCD,LHD,LHT,LHV,PNTR,NARCSC
          READ(1,10) NARCSC
          READ(1,95)  (RCO(I),RCD(I),(LHD(I,J),LHT(I,J),LHV(I,J),
     1J=1,3),I=1,NARCSC)
          READ(1,10)  (PNTR(I),I=1,NR)
```

```
C*****READ LINE HAUL COST PARAMETERS
      READ(3,80)XA
      READ(3,80)((RLHCTM(I,J),I=1,53),J=1,3)
      READ(3,80)XA
      READ(3,80)((HLHCTM(I,J),I=1,53),J=1,23)
      READ(3,80)XA
      READ(3,80)((RLDC(I,J),I=1,53),J=1,3)
      READ(3,80)XA
      READ(3,80)((HLDC(I,J),I=1,53),J=1,23)
             READ(3,80) XA
             READ(3,80) WLHCTM
             READ(3,80) XA
             READ(3,80) (WLDC(I),I=1,53)
C*****ESTIMATE THE AVERAGE LINE HAUL COST/TON-MILE
C     AND THE AVERAGE LOADING-UNLOADING COST/TON
C     FOR EACH MODE IN EACH REGION
C     NOTE:  WATER    /TON-HR.
C
C*****HW
             DO 100 I=1,3
             DO 110 J=1,8
             ALHCTM(I,J)=0.
             ALDCT(I,J)=0.
110   CONTINUE
100   CONTINUE
             DO 500 I=1,8
             DO 510 J=1,53
             ALHCTM(1,I)=ALHCTM(1,I)+HLHCTM(J,I)
             ALDCT(1,I)=ALDCT(1,I)+HLDC(J,I)
510   CONTINUE
             ALHCTM(1,I)=ALHCTM(1,I)/53.
             ALDCT(1,I)=ALDCT(1,I)/53.
500   CONTINUE
C
C*****RR
             DO 520 I=1,3
             DO 530 J=1,53
             ALHCTM(2,I)=ALHCTM(2,I)+RLHCTM(J,I)
             ALDCT(2,I)=ALDCT(2,I)+RLDC(J,I)
530   CONTINUE
             ALHCTM(2,I)=ALHCTM(2,I)/53.
             ALDCT(2,I)=ALDCT(2,I)/53.
520   CONTINUE
C
C*****WATER
             ALHCTM(3,1)=WLHCTM
             DO 550 J=1,53
             ALDCT(3,1)=ALDCT(3,1)+WLDC(J)
550   CONTINUE
             ALDCT(3,1)=ALDCT(3,1)/53.
C*****ESTIMATE COMMODITY LINE-HAUL AND LOADING
C     COST FACTORS FOR EACH MODE AND COMMODITY
             DO 551 I=1,53
             DO 552 J=1,3
             CLHCF(I,J)=0.


             CLDCF(I,J)=0.
552   CONTINUE
551   CONTINUE
             DO 560 I=1,53
C
C*****HWY
             DO 561 J=1,8
      CLHCF(I,1)=CLHCF(I,1)+HLHCTM(I,J)/ALHCTM(1,J)
             CLDCF(I,1)=CLDCF(I,1)+HLDC(I,J)/ALDCT(1,J)
561   CONTINUE
             CLHCF(I,1)=CLHCF(I,1)/8.
             CLDCF(I,1)=CLDCF(I,1)/8.
C
C*****RR
             DO 562 J=1,3
             CLHCF(I,2)=CLHCF(I,2)+RLHCTM(I,J)/ALHCTM(2,J)
             CLDCF(I,2)=CLDCF(I,2)+RLDC(I,J)/ALDCT(2,J)
562   CONTINUE
             CLHCF(I,2)=CLHCF(I,2)/3.
             CLDCF(I,2)=CLDCF(I,2)/3.
C
C*****WATER
             CLHCF(I,3)=1.
             CLDCF(I,3)=WLDC(I)/ALDCT(3,1)
560   CONTINUE
C*****CREATE LINE HAUL COSTS AND TRANSFER COSTS
      DO 44_ J=1,NARCSC
      IA=RCO(J)
      IB=RCD(J)
```

```
C*****HIGHWAY ARCS
      IC=NGA(IA,1)
      ID=NGA(IB,1)
      XE=(ALHCTM(1,IC)+ALHCTM(1,ID))/2
      RC1(J,1)=LHD(J,1)*XE
      RC2(J,1)=LHT(J,1)
        RC3(J,1)=LHV(J,1)
C****RAIL ARCS
      IC=NGA(IA,2)
      ID=NGA(IB,2)
      XE=(ALHCTM(2,IC)+ALHCTM(2,ID))/2
      RC1(J,2)=LHD(J,2)*XE
      RC2(J,2)=LHT(J,2)
        RC3(J,2)=LHV(J,2)
C*****WATERWAY ARCS
      RC1(J,3)=LHD(J,3)*WLHCTM
      RC2(J,3)=LHT(J,3)
        RC3(J,3)=LHV(J,3)
440   CONTINUE
C*****PREPARE LDC,LDT,LDTV,ITC,ITT,ITTV
          DO 231 I=1,NNCR
          DO 232 J=1,3
          LDC(I,J)=0.
          LDT(I,J)=0.
          LDTV(I,J)=0.
          ITC(I,J)=0.
          ITT(I,J)=0.
          ITTV(I,J)=0.
232   CONTINUE
231   CONTINUE
C
C*****HWY
          READ(4,80) TLT,TLV,TIC,TIT,TIV
          DO 233 I=1,NNCR
          J=X(I)
          LDC(I,1)=ALDCT(1,J)/2.



          LDT(I,1)=TLT
          LDTV(I,1)=TLV
          ITC(I,1)=TIC
          ITT(I,1)=TIT
          ITTV(I,1)=TIV
233   CONTINUE
C
C*****RAIL
          READ(4,80) RLT,RLV,(FR(I),I=1,4),BIRC,BIRT,BIRV
          DO 998 I=1,NNCR
          J=Y(I)
          LDC(I,2)=ALDCT(2,J)/2.
          LDT(I,2)=RLT
          LDTV(I,2)=RLV
998   CONTINUE
          DO 234 I=1,8
          DO 235 J=1,4
          I1=(I-1)*4+J
          ITC(I1,2)=BIRC*FR(J)
          ITT(I1,2)=BIRT*FR(J)
          ITTV(I1,2)=(BIRV*FR(J))**2
235   CONTINUE
234   CONTINUE
C
C*****WATER
          READ(4,80) WLT,WLV,WIC,WIT,WIV
          DO 236 I=1,NNCR
          LDC(I,3)=ALDCT(3,1)/2.
          LDT(I,3)=WLT
          LDTV(I,3)=WLV
          ITC(I,3)=WIC
          ITT(I,3)=WIT
          ITTV(I,3)=WIV
236   CONTINUE
      DO 430 J=1,NNCR
      TC1(J,1,1)=0.
      TC2(J,1,1)=0.
      TC3(J,1,1)=0.
      DO 420 K=1,3
      TC1(J,1,K+1)=LDC(J,K)
      TC1(J,K+1,1)=LDC(J,K)
      TC2(J,1,K+1)=LDT(J,K)
      TC2(J,K+1,1)=LDT(J,K)
      TC3(J,1,K+1)=LDTV(J,K)
420   TC3(J,K+1,1)=LDTV(J,K)
          DO 410 K=2,4
          DO 411 L=2,4
          TC1(J,K,L)=0.
          TC2(J,K,L)=0.
          TC3(J,K,L)=0.
411   CONTINUE
410   CONTINUE
```

```
          DO 412 K=1,3
          TC1(J,K+1,K+1)=ITC(J,K)
          TC2(J,K+1,K+1)=ITT(J,K)
          TC3(J,K+1,K+1)=ITTV(J,K)
412    CONTINUE
       DO 600 K=2,4
       DO 601 L=2,4
       IF(K.EQ.L) GO TO 601
       TC1(J,K,L)=(TC1(J,K,1)+TC1(J,1,L))*.8
       TC2(J,K,L)=(TC2(J,K,1)+TC2(J,1,L))*.8
       TC3(J,K,L)=(TC3(J,K,1)+TC3(J,1,L))*.8
601    CONTINUE
600    CONTINUE


430    CONTINUE
C*****WRITE RESULTS ON TAPE7
C*****WRITE INPUT DATA ON TAPE7
       IDUMV=90001
       WRITE(7,90)IDUMV
       WRITE(7,90)NR,NARCSC,NNCR,N31
       IDUMV=IDUMV+1
       WRITE(7,90)IDUMV
       WRITE(7,90)NC
       IDUMV=IDUMV+1
       WRITE(7,90)IDUMV
       WRITE(7,90)PNTR
       IDUMV=IDUMV+1
       WRITE(7,90)IDUMV
       WRITE(7,90)NCO
       IDUMV=IDUMV+1
       WRITE(7,90)IDUMV
       WRITE(7,90)FCD
       IDUMV=IDUMV+1
       WRITE(7,90)IDUMV
       WRITE(7,85)CLDCF
       IDUMV=IDUMV+1
       WRITE(7,90)IDUMV
       WRITE(7,65)CLHCF
       IDUMV=IDUMV+1
       WRITE(7,90)IDUMV
       WRITE(7,65)RC1
       IDUMV=IDUMV+1
       WRITE(7,90)IDUMV
       WRITE(7,85)RC2
          IDUMV=IDUMV+1
          WRITE(7,90) IDUMV
          WRITE(7,85) RC3
       IDUMV=IDUMV+1
       WRITE(7,90)IDUMV
       WRITE(7,85)TC1
       IDUMV=IDUMV+1
       WRITE(7,90)IDUMV
       WRITE(7,85)TC2
       IDUMV=IDUMV+1
       WRITE(7,90)IDUMV
       WRITE(7,85)TC3
       IDUMV=IDUMV+1
       WRITE(7,90)IDUMV
          WRITE(7,90) NGA
       ENDFILE 7
       STOP
       END
```

PROGRAM MTREES

```
      PROGRAM TREES(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7,TAPE8,
     &TAPE9)
      INTEGER RCO(1000),RCD(1000),PNTR(130)
      DIMENSION NC(130)
      DIMENSION RC1(1000,3),RC2(1000,3),TC1(50,4,4),TC2(50,4,4),
     &TC3(50,4,4),RC3(1000,3)
      INTEGER TRNO(391),TRNDJ(391),TRRC(391),LI(130,8)
      DIMENSION TLE(130,3),TLELH(130,3),TLETR(130,3)
      DIMENSION TRNDL(391,3),TRLHL(391,3),TRTRL(391,3)
      DIMENSION CLHCF(53,3),CLDCF(53,3)
      COMMON /B1/ PNTR,RCO,RCD,TRNO,TRNDJ,TRRC,TRNDL,NC,LI,TLE,TRLHL
      COMMON /B1/ TRTRL,TLELH,TLETR,TC3,RC3
10    FORMAT(16I5)
20    FORMAT(I7,3X,A10)
30    FORMAT(5I5,6A5)
40    FORMAT(23X,F10.4)
50    FORMAT(40I2)
60    FORMAT(1H ,7A10)
70    FORMAT(1H ,18A5)
75    FORMAT(4I5,F10.4)
80    FORMAT(10F8.4)
85    FORMAT(8F10.4)
86    FORMAT(9F10.0)
90    FORMAT(8I10)
C***** READ DATA FROM TAPE7
      READ(7,90)IDUMV
      READ(7,90)NR,NARCSC,NNCR,N31
      READ (7,90)IDUMV
      READ (7,90)NC
      READ (7,90)IDUMV
      READ (7,90)PNTR
      READ (7,90)IDUMV
      READ (7,90)RCO
      READ (7,90)IDUMV
      READ (7,90)RCD
      READ (7,90)IDUMV
      READ (7,85)CLDCF
      READ (7,90)IDUMV
      READ (7,85)CLHCF
      READ(7,90)IDUMV
      READ (7,85)RC1
      READ (7,90)IDUMV
      READ (7,85)RC2
            READ(7,90) IDUMV
            READ(7,85) RC3
      READ (7,90)IDUMV
      READ (7,85)TC1
      READ (7,90)IDUMV
      READ (7,85)TC2
      READ (7,90)IDUMV
      READ (7,85)TC3
C***** OBTAIN TREES FOR EACH ORIGIN, AND EACH MODE, EACH ORIGIN
C*****GENERATES ABOUT 14000 10-CHARACTER WORDS
      IDUMV=99003
         IT=8
      DO 500 NODE=1,NR
         IF(NODE.GT.92) IT=9
      INA=NODE
      MO=1
      CALL MMSPTC(NR,NARCSC,N31,INA,MO,RC2,RC1,TC2,TC1)
      DO 300 I=1,N31
      IV=TRNDL(I,1)
      TRNDL(I,1)=TRNDL(I,2)
      TRNDL(I,2)=IV
      IV=TRLHL(I,1)


      TRLHL(I,1)=TRLHL(I,2)
      TRLHL(I,2)=IV
      IV=TRTRL(I,1)
      TRTRL(I,1)=TRTRL(I,2)
300   TRTRL(I,2)=IV
      DO 310 I=1,NR
      IV=TLE(I,1)
      TLE(I,1)=TLE(I,2)
      TLE(I,2)=IV
      IV=TLELH(I,1)
      TLELH(I,1)=TLELH(I,2)
      TLELH(I,2)=IV
      IV=TLETR(I,1)
      TLETR(I,1)=TLETR(I,2)
310   TLETR(I,2)=IV
      IDUMV=IDUMV+8
      WRITE(IT,90)IDUMV
```

```
      DO 1081 J=1,N31
1081  WRITE(IT,90)TRND(J),TRNDJ(J),TRRC(J)
      WRITE(IT,90)IDUMV
      DO 1082 J=1,NR
1082  WRITE(IT,90)(LI(J,I),I=1,8)
      WRITE(IT,90)IDUMV
      DO 1083 J=1,NR
1083  WRITE(IT,96)(TLE(J,I),I=1,3),(TLELH(J,I),I=1,3),(TLETR(J,I),I=1,3)
      DO 400 MO=2,3
      CALL MMSPTC(NR,NARCSC,N31,INA,MO,RC1,RC2,TC1,TC2)
      IDUMV=IDUMV+1
      WRITE(IT,90)IDUMV
      DO 1084 J=1,N31
1084  WRITE(IT,90)TRND(J),TRNDJ(J),TRRC(J)
      WRITE(IT,90)IDUMV
      DO 1085 J=1,NR
1085  WRITE(IT,90)(LI(J,I),I=1,8)
      WRITE(IT,90)IDUMV
      DO 1086 J=1,NR
1086  WRITE(IT,96)(TLE(J,I),I=1,3),(TLELH(J,I),I=1,3),(TLETR(J,I),I=1,3)
400   CONTINUE
500   CONTINUE
      ENDFILE 8
         ENDFILE 9
      STOP
      END
      SUBROUTINE MMSPTC(N,NARCS,N31,INA,MO,RC1,RC2,TC1,TC2)
C*****MULTIMODAL SHORTEST PATH ROUTINE,USING MOORE TYPE TREE BUILDING
C*****PROGRAMMED BY G. SHARP,SCHOOL OF ISYE,GEORGIA TECH,APRIL 1977
C*****ARGUMENTS FOR SPECIFIC USE ARE
C           INA       START NODE
C           MO        MODE USED
C*****MODAL REPRESENTATION IS ACHIEVED BY (NODE,NODE MODIFIER):
C     MOD=1: SHIP,ORIGINATION    MOD=2: RECEIVE,DESTINATION
C     MOD=3: MODE 2 INBOUND      MOD=4: MODE 2 OUTBOUND
C     MOD=5: MODE 3 INBOUND      MOD=6: MODE 3 OUTBOUND  ETC.
C*****LINE HAUL ARCS ARE BETWEEN
C           (NODE,MOD=4,6,...) AND (NODE,MOD=3,5,...)
C     TRANSFER AND FORWARDING ARCS ARE BETWEEN
C           (NODE,MOD=3,5,...) AND (NODE,MOD=4,6,...)
C     LOADING ARCS ARE (NODE,MOD=1) TO (NODE,MOD=4,6,...)
C     UNLOADING ARCS ARE (NODE,MOD=3,5,...) TO (NODE,MOD=2)
C*****VARIABLE DIMENSION ARGUMENTS
C           N         NUMBER OF NODES (MODIFIERS SUPPRESSED)
C           NARCS     NUMBER OF LINE HAUL ARCS (MODES SUPPRESSED)
C           NNC       NUMBER OF NODE CHARACTERISTICS
C           NMD1      NUMBER OF MODES - 1
C           N31       N * 3  +  1


C*****INPUTTED DATA ARRAYS
C           PNTR(N)                    POINTER TO FIRST ARC FROM NODE
C                                      IN AN ORDERED ARC LIST
C           RCO(NARCS)                 ARC ORIGIN
C           RCD(NARCS)                 ARC DESTINATION
C           NC(N)                      NODE CHARACTERISTIC FOR TRANSFER COSTS
C           RC1(NARCS,NMD1)             ARC ATTRIBUTE USED FOR FINDING PATH:
C                                      RAIL: DISTANCE, ADJUSTED BY ZONE,CLASS
C                                      MOTOR: TIME
C                                      WATER: DISTANCE, ADJUSTED
C           RC2(NARCS,NMD1)            ARC ATTRIBUTE CARRIED ALONG IN ALG.
C                                      RAIL: TIME
C                                      MOTOR: DISTANCE, ADJUSTED
C                                      WATER: TIME
C           TC1(NNC,NMC,NMD)            NODE ATTRIBUTE USED FOR FINDING PATH:
C                                      RAIL: ADJ. COST CONVERTED TO DISTANCE
C                                      MOTOR: TIME
C                                      WATER: ADJ. COST CONVERTED TO DISTANCE
C           TC2( ),TC3( )              NODE ATTRIBUTES CARRIED ALONG IN ALG.
C                                      RAIL: TIME, TIME, VARIANCE
C                                      MOTOR: ADJ. COST CONV. TO DISTANCE,
C                                             TIME VARIANCE
C                                      WATER: TIME, TIME VARIANCE
C*****OUTPUTTED DATA ARRAYS
C           TRND(N*2*(NMD))            TREE NODE
C           TRNDJ( )                   TREE NODE MODIFIER
C           TRNDL( ,1)                 NODE LABEL FOR CRITICAL ATTRIBUTE
C           TRNDL( ,2),TRNDL( ,3)      NODE LABELS FOR OTHER ATTRIBUTES
C           TRRC( )                    ARC TO TREE NODE, NOTE CONVENTION
C                                      LINE HAUL: TRRC IS ARC NUMBER
C                                      TRANSFER : TRRC IS PREVIOUS TRNDJ
C           LI(N,NMD)                  POSITION IN TREE OF (NODE,MODIFIER)
C           TLE( ,1)                   VALUE OF CRITICAL ATTRIBUTE FROM
C                                      ORIGIN TO NODE
C           TLE( ,2),TLE( ,3)          VALUES OF OTHER ATTRIBUTES ...
```

```
C*****EXPLANATION OF OTHER VARIABLES
C             TRL      CURRENT TREE LENGTH
C             SCNR     CURRENT SCANNER POSITION
C             TEMPL    TEMPORARY LABEL
C             NP       NODE POSITION IN TREE (ARGUMENT FOR ARRAY)
C             NA       NODE FROM WHICH BRANCHING OCCURS
C             NAJ      NA MODIFIER
C             NB       NODE BEING CONSIDERED FOR LABELING
C             NBJ      NB MODIFIER
C*****DECLARATIONS
      INTEGER RCO(1000),RCD(1000),PNTR(130)
      DIMENSION NC(130)
      DIMENSION RC1(1000,3),RC2(1000,3),TC1(50,4,4),TC2(50,4,4),
     &TC3(50,4,4),RC3(1000,3)
      INTEGER TRND(391),TRNDJ(391),TRRC(391),LI(130,8)
      DIMENSION TLE(130,3),TLELH(130,3),TLETR(130,3)
      DIMENSION TRNDL(391,3),TRLHL(391,3),TRTRL(391,3)
      DIMENSION TEMPL(3),TL(6)
      INTEGER TRL,SCNR
      COMMON /B1/ PNTR,RCO,RCD,TRND,TRNDJ,TRRC,TRNDL,NC,LI,TLE,TRLHL
      COMMON /B1/ TRTRL,TLELH,TLETR,TC3,RC3
C*****ZERO OUT WORKING ARRAY
      DO 10 J=1,8
      DO 10 I=1,N
   10 LI(I,J)=0
C*****LABEL ORIGIN NODE
      TRL=1
      SCNR=1
      TRND(1)=INA
      TRNDJ(1)=1


      DO 5 I=1,3
      TRNDL(1,I)=0.
      TRLHL(1,I)=0.
5     TRTRL(1,I)=0.
      TRRC(1)=0
      LI(INA,1)=1
C*****INITIALIZE NA AND NAJ
      NA=INA
      NAJ=1
  100 IF(NAJ.EQ.2)GO TO 170
      IF(MOD(NAJ,2).EQ.0)GO TO 130
C*****CONSIDER TRANSFER ARC NOW
C*****CHECK FOR PERMANENT LABEL,TEMPORARY LABEL
      NBJ=MO*2+2
      IF(LI(NA,NBJ).LE.SCNR.AND.LI(NA,NBJ).NE.0)GO TO 105
C*****COMPARE TEMPORARY LABELS
      NCNA=NC(NA)
      NAM=(NAJ+1)/2
      NBM=MO + 1
      TEMPL(1)=TRNDL(SCNR,1)+TC1(NCNA,NAM,NBM)
      TEMPL(2)=TRNDL(SCNR,2)+TC2(NCNA,NAM,NBM)
      TEMPL(3)=TRNDL(SCNR,3)+TC3(NCNA,NAM,NBM)
      TL(4)=TRTRL(SCNR,1)+TC1(NCNA,NAM,NBM)
      TL(5)=TRTRL(SCNR,2)+TC2(NCNA,NAM,NBM)
      TL(6)=TRTRL(SCNR,3)+TC3(NCNA,NAN,NBM)
      DO 99 I=1,3
99    TL(I)=TRLHL(SCNR,I)
C*****BRANCHING IMPLIES NODE UNLABELED
      IF(LI(NA,NBJ).EQ.0)GO TO 120
      NP =LI(NA,NBJ)
C*****NEXT TWO BRANCHINGS IMPLY NEW LABEL DOMINATED
      IF(TEMPL(1).GT.TRNDL(NP,1))GO TO 105
      IF(TEMPL(1).EQ.TRNDL(NP,1).AND.NBM.NE.NAM)GO TO 105
C*****UPDATE TEMP LABEL NOW
      DO 111 I=1,3
      TRNDL(NP,I)=TEMPL(I)
      TRTRL(NP,I)=TL(3+I)
111   TRLHL(NP,I)=TL(I)
      TRRC(NP)=NAJ
      GO TO 105
C*****LABEL UNLABELED NODE
  120 TRL=TRL+1
      TRND(TRL)=NA
      TRNDJ(TRL)=NBJ
      DO 112 I=1,3
      TRNDL(TRL,I)=TEMPL(I)
      TRTRL(TRL,I)=TL(3+I)
112   TRLHL(TRL,I)=TL(I)
      TRRC(TRL)=NAJ
      LI(NA,NBJ)=TRL
  105 CONTINUE
C*****CONSIDER UNLOADING ARC NOW
C*****CHECK FOR PERMANENT LABEL,TEMPORARY LABEL
      NBJ=2
      IF(LI(NA,NBJ).LE.SCNR.AND.LI(NA,NBJ).NE.0)GO TO 110
```

```
C*****COMPARE TEMPORARY LABELS
      NBM=1
      TEMPL(1)=TRNDL(SCNR,1)+TC1(NCNA,NAM,NBM)
      TEMPL(2)=TRNDL(SCNR,2)+TC2(NCNA,NAM,NBM)
      TEMPL(3)=TRNDL(SCNR,3)+TC3(NCNA,NAM,NBM)
      TL(4)=TRTRL(SCNR,1)+TC1(NCNA,NAM,NBM)
      TL(5)=TRTRL(SCNR,2)+TC2(NCNA,NAM,NBM)
      TL(6)=TRTRL(SCNR,3)+TC3(NCNA,NAM,NBM)
      DO 98 I=1,3
98    TL(I)=TRLHL(SCNR,I)


C*****BRANCHING IMPLIES NODE UNLABELED
      IF(LI(NA,NBJ).EQ.0)GO TO 125
      NP =LI(NA,NBJ)
C*****NEXT TWO BRANCHINGS IMPLY NEW LABEL DOMINATED
      IF(TEMPL(1).GT.TRNDL(NP,1))GO TO 110
      IF(TEMPL(1).EQ.TRNDL(NP,1).AND.NBM.NE.NAM)GO TO 110
C*****UPDATE TEMP LABEL NOW
      DO 113 I=1,3
      TRNDL(NP,I)=TEMPL(I)
      TRLHL(NP,I)=TL(I)
113   TRTRL(NP,I)=TL(3+I)
      TRRC(NP)=NAJ
      GO TO 110
C*****LABEL UNLABELED NODE
  125 TRL=TRL+1
      TRND(TRL)=NA
      TRNDJ(TRL)=NBJ
      DO 114 I=1,3
      TRNDL(TRL,I)=TEMPL(I)
      TRLHL(TRL,I)=TL(I)
114   TRTRL(TRL,I)=TL(3+I)
      TRRC(TRL)=NAJ
      LI(NA,NBJ)=TRL
  110 CONTINUE
      GO TO 170
C*****CONSIDER LINE ARCS NOW
  130 IARC=PNTR(NA)
C*****IARC IS FIRST ARC IN LIST STARTING FROM NA
C*****NEXT  BRANCHING IMPLIES ALL ARCS FROM NA EXAMINED
  140 IF(RCO(IARC).NE.NA)GO TO 170
      NB=RCD(IARC)
C*****CHECK FOR PERMANENT,TEMPORARY LABEL
      NBJ=NAJ-1
      IF(LI(NB,NBJ).LE.SCNR.AND.LI(NB,NBJ).NE.0)GO TO 160
C*****COMPARE TEMPORARY LABELS
      NAM1=NAJ/2-1
      TEMPL(1)=TRNDL(SCNR,1)+RC1(IARC,NAM1)
      TEMPL(2)=TRNDL(SCNR,2)+RC2(IARC,NAM1)
      TEMPL(3)=TRNDL(SCNR,3)+RC3(IARC,NAM1)
      TL(1)=TRLHL(SCNR,1)+RC1(IARC,NAM1)
      TL(2)=TRLHL(SCNR,2)+RC2(IARC,NAM1)
      TL(3)=TRLHL(SCNR,3)+RC3(IARC,NAM1)
      DO 97 I=1,3
97    TL(3+I)=TRTRL(SCNR,I)
C*****BRANCHING IMPLIES NODE UNLABELED
      IF(LI(NB,NBJ).EQ.0)GO TO 150
C*****BRANCHING IMPLIES NEW LABEL DOMINATED
      NP =LI(NB,NBJ)
      IF(TEMPL(1).GE.TRNDL(NP,1))GO TO 160
C*****UPDATE TEMP LABEL NOW
      DO 115 I=1,3
      TRNDL(NP,I)=TEMPL(I)
      TRTRL(NP,I)=TL(3+I)
115   TRLHL(NP,I)=TL(I)
      TRRC(NP)=IARC
      GO TO 160
C*****LABEL UNLABELED NODE
  150 TRL=TRL+1
      TRND(TRL)=NB
      TRNDJ(TRL)=NBJ
      DO 116 I=1,3
      TRNDL(TRL,I)=TEMPL(I)
      TRTRL(TRL,I)=TL(3+I)
116   TRLHL(TRL,I)=TL(I)
      TRRC(TRL)=IARC


      LI(NB,NBJ)=TRL
  160 IARC=IARC+1
      IF(IARC.LE.NARCS)GO TO 140
C*****EXIT LABELING,BEGIN SHUFFLE
  170 CONTINUE
```

```
C*****BRANCHING IMPLIES     NO NEED TO SHUFFLE 0 OR 1 ARC
      NDIF=TRL-SCNR
      IF(NDIF.LE.1)GO TO 220
      L=SCNR+1
      LA=L+1
      DO 210 M=LA,TRL
      IF(TRNDL(L,1).LE.TRNDL(M,1))GO TO 210
      IVE=TRRC(L)
      TRRC(L)=TRRC(M)
      TRRC(M)=IVE
      DO 211 K=1,3
      XV=TRNDL(L,K)
      TRNDL(L,K)=TRNDL(M,K)
      TRNDL(M,K)=XV
      XV=TRLHL(L,K)
      TRLHL(L,K)=TRLHL(M,K)
      TRLHL(M,K)=XV
      XV=TRTRL(L,K)
      TRTRL(L,K)=TRTRL(M,K)
211   TRTRL(M,K)=XV
      IVE=TRND(L)
      IVF=TRNDJ(L)
      LI(IVE,IVF)=M
      IVG=TRND(M)
      IVH=TRNDJ(M)
      LI(IVG,IVH)=L
      TRND(L)=IVG
      TRNDJ(L)=IVH
      TRND(M)=IVE
      TRNDJ(M)=IVF
  210 CONTINUE
C*****BRANCHING MEANS  TREE FINISHED
  220 IF(NDIF.EQ.0)GO TO 400
C*****NOW   PLACE  NODE ON PERMANENT TREE
      SCNR=SCNR+1
      NA=TRND(SCNR)
      NAJ=TRNDJ(SCNR)
      GO TO 100
C*****BRANCHING:  GO BACK AND LABEL FROM NEWLY PLACED PERMANENT NODE
C*****PREPARE OUTPUT INFORMATION FOR COMPLETE TREE
  400 DO 410 L=1,N
      NP=LI(L,2)
      DO 411 K=1,3
      TLE(L,K)=TRNDL(NP,K)
      TLELH(L,K)=TRLHL(NP,K)
411   TLETR(L,K)=TRTRL(NP,K)
410   CONTINUE
  500 RETURN
      END
```

PROGRAM DETCIJ

```
          PROGRAM DETCIJ(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     &TAPE7,TAPE12,TAPE13,TAPE14,TAPE15,TAPE16)
          DIMENSION IFLWM(120,120),NOFLI(120),TLELH(120,3,3),
     &COMPTL(999,3,3),COMPTI(999,3,3),SPLITA(54,3),IPRZN(31,8),
     &NOPRZN(8),MDUMMY(31),COENGZ(31,3),COLABZ(31,8),MATMKT(10),
     &XINDPF(8,8,3),INDPF(8,8,2),COCAPZ(31,6),RMMKTP(5),MATCMC(10),
     &MATSOU(10,3),TRELC(3),CORMZ(11,31),CLHCF(53,3),CLDCF(53,3),
     &MINSIZ(8),UPATH(2),TLETR(120,3,3),CIJ(31,8),INDEST(120,8)
          DIMENSION CPT(8),IS(9),PAR(8),PARM(2),FRACT(3)
      DATA CPT/2360.,4778.,200.,2224.,180.,1250.,3918.,
     &3752./,PAR/.08,.162,.162,.12,.162,.162,.162,.162/
31    FORMAT(10X,I3,10X,I3,10X,I1,10X,F13.0)
90    FORMAT(8I10)
86    FORMAT(9F10.4)
85    FORMAT(8F10.4)
32    FORMAT(5I10)
33    FORMAT(5I10,F10.2)
34    FORMAT(4(I10,F10.2))
87    FORMAT(8F10.2)
99    FORMAT(8F10.7)
          DO 991 I=1,999
          DO 991 J=1,3
          DO 991 K=1,3
          COMPTL(I,J,K)=0.
991   COMPTI(I,J,K)=0.
          READ(15,90)(MDUMMY(I),I=1,8)
C     ZERO OUT FLOW INCIDENCE MATRIX
          DO 205 I=1,120
          DO 200 J=1,120
200   IFLWM(I,J)=0
205   NOFLI(I)=0
C     ESTABLISH FLOW INCIDENCE MATRIX
C     FLOWS TO MARKETS
      DO 850 I=1,8
      IC=0
      DO 860 J=1,I
      IC=IC+MDUMMY(J)
860   CONTINUE
      IS(I+1)=IC
850   CONTINUE
      IS(1)=0
      IR=IS(9)
          DO 210 I=1,IR
          READ(12,31)IA,IB
210   IFLWM(IA,IB)=1
          REWIND 12
C*****RAW MATERIAL MARKET, COM,CLASS., SOURCES
          DO 215 I=1,5
215   READ(15,33)MATMKT(I),MATCMC(I),(MATSOU(I,J),J=1,3),
     &RMMKTP(I)
          DO 214 I=1,5
          DO 213 J=1,3
          IC=MATSOU(I,J)
          IF(IC.EQ.0) GO TO 213
          IA=MATMKT(I)
          IFLWM(IC,IA)=1
213   CONTINUE
214   CONTINUE
          GO TO 720
730   CONTINUE
          DO 216 J=1,3
          IC=MATSOU(1,J)
          IF(IC.EQ.0)GO TO 216
      IR=IS(3)
          DO 217 N=1,IR
217   READ(12,31)IA
      IR=MDUMMY(3)+MDUMMY(4)
          DO 218 N=1,IR
          READ(12,31)IA
218   IFLWM(IC,IA)=1
          REWIND 12
216   CONTINUE
          DO 219 J=1,3
          IC=MATSOU(2,J)
          IF(IC.EQ.0)GO TO 219
      IR=IS(4)
          DO 221 N=1,IR
221   READ(12,31)IA
      IR=MDUMMY(4)
          DO 222 N=1,IR
          READ(12,31)IA
222   IFLWM(IC,IA)=1
          REWIND 12
219   CONTINUE
```

```
          DO 223 J=1,3
          IC=MATSOU(3,J)
          IF(IC.EQ.0)GO TO 223
      IR=IS(5)
          DO 224 N=1,IR
224       READ(12,31)IA
      IR=MDUMMY(5)
          DO 225 N=1,IR
          READ(12,31)IA
225   IFLWM(IC,IA)=1
          REWIND 12
223   CONTINUE
          DO 226 J=1,3
          IC=MATSOU(4,J)
          IF(IC.EQ.0)GO TO 226
      IR=IS(6)
          DO 700 N=1,IR
700   READ(12,31) IA
      IR=MDUMMY(6)
          DO 227 N=1,IR
          READ(12,31)IA
227   IFLWM(IC,IA)=1
          REWIND 12
226   CONTINUE
          DO 228 J=1,3
          IC=MATSOU(5,J)
          IF(IC.EQ.0)GO TO 228
      IR=IS(7)
          DO 710 N=1,IR
710   READ(12,31) IA
      IR=MDUMMY(7)
          DO 229 N=1,IR
          READ(12,31)IA
229   IFLWM(IC,IA)=1
          REWIND 12
228   CONTINUE
          DO 600 K=1,8
          DO 600 N=1,120
600   INDEST(N,K)=0
C*****DETERMINE DESTINATIONS
          DO 620 K=1,8
          NR=MDUMMY(K)
          DO 610 N=1,NR
          READ(12,31) IA,IB
610   INDEST(IB,K)=INDEST(IB,K)+1
620   CONTINUE


          REWIND 12
C*****SET UP LOOP FOR NEW FLOWS
          DO 640 K=1,3
          DO 640 L=1,4
          IA=NOPRZN(K)-4+L
          IB=IPRZN(IA,K)
          DO 630 N=1,120
          IF(INDEST(N,K).LE.5) GO TO 630
          IFLWM(IB,N)=1
630   CONTINUE
640   CONTINUE
C*****SET UP FLOWS FROM RAW MATERIAL SOURCES TO
C     NEW PRODUCTION SITES
          DO 930 I=21,23
          DO 940 J=1,5
          DO 950 K=1,3
          IA=MATSOU(J,K)
          IF(IA.NE.0) IFLWM(IA,I)=1
950   CONTINUE
940   CONTINUE
930   CONTINUE
          K=0
          DO 230 I=1,120
          DO 220 J=1,120
          IF(IFLWM(I,J).EQ.0)GO TO 220
          K=K+1
          IFLWM(I,J)=K
          NOFLI(I)=1
220   CONTINUE
230   CONTINUE
C*****READ TREE INFORMATION SELECTIVELY
          DO 300 I=1,120
          IFR=13
          IF(I.GE.83)IFR=14
          DO 254 M=1,3
          K=90000+I*10+M
          DO 255 NN=1,3
256   READ(IFR,90)IA
          IF(IA.NE.K)GO TO 256
255   CONTINUE
```

```
          DO 257 N=1,120
          READ(IFR,86)XA,XB,XC,(TLELH(N,L,M),L=1,3),(TLETR(N,L,M),
     &L=1,3)
257   CONTINUE
254   CONTINUE
C*****BRANCHING IMPLIES TREE NOT USED
          IF(NDFLI(I).EQ.0)GO TO 300
C*****NOW STORE RELEVANT INFORMATION IN COMPACT ARRAY
          DO 260 J=1,120
          IA=IFLWM(I,J)
          IF(IA.EQ.0)GO TO 260
          DO 265 M=1,3
          DO 265 L=1,3
          COMPTL(IA,L,M)=TLELH(J,L,M)
265   COMPTT(IA,L,M)=TLETR(J,L,M)
260   CONTINUE
300   CONTINUE
          GO TO 740
C*****READ MODE SPLIT PARAMETERS FORCOMMODITIES
720       DO 310 K=1,54
310   READ(15,99)(SPLITA(K,L),L=1,3)
C*****READ LIST OF PRODUCTION ZONES AND STORE
          DO 320 K=1,8
          DO 320 I=1,31
320   IPRZN(I,K)=0


          READ(15,90)NOPRZN
          DO 330 K=1,8
          M=NOPRZN(K)
          READ(15,90)(IPRZN(J,K),J=1,M)
330   CONTINUE
          GO TO 730
740   CONTINUE
C*****READ CLHCF,CLDCF
          READ(7,90)IA
          READ(7,90)IA
          READ(7,85)XA
311   READ(7,90)IA
          IF(IA.EQ.90000)GO TO 312
          GO TO 311
312   READ(7,85)CLDCF
          READ(7,85)XA
          READ(7,85)CLHCF
C*****READ ENERGY PRICES
          DO 350 K=1,8
          M=NOPRZN(K)
350   READ(15,87)(COENGZ(J,K),J=1,M)
C*****READ LABOR RATES
          DO 360 K=1,8
          M=NOPRZN(K)
360   READ(15,87)(COLABZ(J,K),J=1,M)
C*****READ CAPITAL COST RATES
          DO 365 K=1,8
          M=NOPRZN(K)
365   READ(15,87)(COCAPZ(J,K),J=1,M)
C*****READ INDUSTRY PROFILE
          DO 380 K=1,8
          DO 380 L=1,3
      READ(15,32)IA,IB,IC,(INOPF(K,L,J),J=1,2)
          XINOPF(K,L,1)=IA
          XINOPF(K,L,2)=IB
380       XINOPF(K,L,3)=IC
C*****DEVELOP PRODUCTION COSTS BY ZONE
          DO 500 K=1,8
          NZ=NOPRZN(K)
          DO 490 J=1,NZ
          JC=IPRZN(J,K)
C*****LOCATE RAW MATERIAL SOURCE, COST
          DO 480 L=1,3
          IF(INOPF(K,L,2).EQ.0)GO TO 480
              COMARM=1000.
          IA=INOPF(K,L,2)
          JB=MATCMC(IA)
          DO 470 I=1,3
          IF(MATSOU(IA,I).EQ.0)GO TO 470
          IB=MATSOU(IA,I)
          IC=MATMKT(IA)
          JA=IFLWM(IB,IC)
          DO 460 M=1,3
          TREEC(M)=COMPTL(JA,1,M)*CLHCF(JB,M)+COMPTT(JA,1,M)*CLDCF(JB,M)
      UTEST=SPLITA(JB,1)+TREEC(M)+COMPTL(JA,2,M)*SPLITA(JB,2)+
     &COMPTL(JA,3,M)*SPLITA(JB,3)+COMPTT(JA,2,M)*SPLITA(JB,2)
     &+COMPTT(JA,3,M)*SPLITA(JB,3)
      IF(UTEST.LT.-100.) GO TO 880
      UPATH(M)=(2.718)**(SPLITA(JB,1)*TREEC(M)+COMPTL(JA,2,M)*SPLITA
     &(JB,2)+COMPTL(JA,3,M)*SPLITA(JB,3)+COMPTT(JA,2,M)
     &*SPLITA(JB,2)+COMPTT(JA,3,M)*SPLITA(JB,3))
      GO TO 460
880   UPATH(M)=.0000000000000001
460   CONTINUE
```

```
      COSTA=0.
      DO 261 M=1,3
      PARM(1)=.5
      PARM(2)=PAR(K)
      ARG=UPATH(M)/(UPATH(1)+UPATH(2)+UPATH(3))
261   FRACT(M)=PNORM(ARG,PARM,IZZ)
      DO 828 M=1,3
828   COSTA=COSTA+TREEC(M)*FRACT(M)/(FRACT(1)+FRACT(2)+
     &FRACT(3))
      JA=IFLWM(IB,JC)
      DO 450 M=1,3
      TREEC(M)=COMPTL(JA,1,M)*CLHCF(JB,M)+COMPTT(JA,1,M)*CLDCF(JB,M)
      UTEST=SPLITA(JB,1)*TREEC(M)+COMPTL(JA,2,M)*SPLITA(JB,2)+
     &COMPTL(JA,3,M)*SPLITA(JB,3)+COMPTT(JA,2,M)*SPLITA(JB,2)
     &+COMPTT(JA,3,M)*SPLITA(JB,3)
      IF(UTEST.LE.-10..) GO TO 920
      UPATH(M)=(2.715)**(SPLITA(JB,1)*TREEC(M)+COMPTL(JA,2,M)*SPLITA
     &(JB,2)+COMPTL(JA,3,M)*SPLITA(JB,3)+COMPTT(JA,2,M)*SPLITA(JB,2)
     &+COMPTT(JA,3,M)*SPLITA(JB,3))
      GO TO 450
920   UPATH(M)=.000000000000001
450   CONTINUE
      COSTB=0.
      DO 251 M=1,3
      PARM(1)=.5
      PARM(2)=PAR(K)
      ARG=UPATH(M)/(UPATH(1)+UPATH(2)+UPATH(3))
251   FRACT(M)=PNORM(ARG,PARM,IZZ)
      DO 829 M=1,3
829   COSTB=COSTB+TREEC(M)*FRACT(M)/(FRACT(1)+FRACT(2)+FRACT(3))
      COSTC=RMMKTP(IA)-COSTA+COSTB
      IF(COSTC.LT.CORAWM)CORAWM=COSTC
      CORMZ(IA,J)=CORAWM
470   CONTINUE
480   CONTINUE
      CIJA=XINOPF(K,2,1)*COLABZ(J,K)*2000.+XINOPF(K,5,1)
     &+XINOPF(K,4,1)*COCAPZ(J,K)/100.+COENGZ(J,K)*XINOPF(K,6,1)
      DO 440 L=1,3
      IF(INOPF(K,L,2).EQ.0)GO TO 430
      IA=INOPF(K,L,2)
      CIJA=CIJA+XINOPF(K,L,2)*CORMZ(IA,J)
      GO TO 440
430   CIJA=CIJA+XINOPF(K,L,3)
440   CIJ(J,K)=CIJA/(XINOPF(K,1,1)/CPT(K))
490   CONTINUE
      MINSIZ(K)=XINOPF(K,8,1)
500   CONTINUE
C*****WRITE RESULTS
      WRITE(16,90)NOPRZN
      DO 510 K=1,9
      NZ=NOPRZN(K)
510   WRITE(16,34)(IPRZN(J,K),CIJ(J,K),J=1,NZ)
      WRITE(16,93)SPLITA
      WRITE(16,65)CLHCF
      WRITE(16,65)CLDCF
      WRITE(16,90)MINSIZ
      WRITE(16,90)IFLWM
      WRITE(16,67)COMPTL
      WRITE(16,67)COMPTT
      STOP
      END
```

PROGRAM HIJK

```
      PROGRAM HIJK(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     &TAPE12,TAPE16)
      REAL NFLU,NFLWCU,NFLCIJ,NFLWCIJ
      DIMENSION NOPRZ(8),IPRZN(31,8),CIJ(31,8),NOREC(8),NODEST(8),
     &INDEST(120,8),SPLITA(54,3),CLHCF(53,3),CLDCF(53,3),MINSIZ(8),
     &IFLWN(120,120),COMPIL(999,3,3),COMPIT(999,3,3),COENS(8,3),
     &NAS(220,8),NBS(220,8),MOS(220,8),FLS(220,8),FLSCIJ(220,8),
     &FLSU(220,8),FLSWCU(220,8),IPVPRZ(120,8),ICOMUL(8),NFLCIJ
     &(4,30,8),NFLU(4,30,8),NFLWCU(4,30,8),NFLNP(4,30,8),TREC(3),
     &UPATH(3),KCL(8),UTIST(3)
      DIMENSION PAR(9),PARM(2),ARG(3),FRACT(3)
      DATA NOREC/116,92,212,119,109,111,183,135/
      DATA PAR/.06,2.162,.12,4.102/
11    FORMAT(1H0,"INDZ EXCEEDED",3I5)
31    FORMAT(10X,I5,10X,I3,10X,I1,10X,F13.5)
32    FORMAT(5I10)
33    FORMAT(5I10,F10.2)
34    FORMAT((4(I10,F10.2)))
85    FORMAT(8F10.4)
86    FORMAT(9F10.4)
87    FORMAT(8F10.2)
90    FORMAT(3I10)
12    FORMAT(1H1,"EXISTING FLOWS    COM=  ",I2,"    DEST=   ",I4)
13    FORMAT(1H0," ORIG  MODE    TONS          CIJ     EXP ARG     HIJK",
     &6X,"CUM.TONS",/)
14    FORMAT(1H0,"CANNOT FIND NEW FLOW",3I5)
15    FORMAT(1H0,"COMPETING NEW FLOWS",/)
16    FORMAT(1H ,2I5,3F10.2)
17    FORMAT(1H ,I5,10X,3F10.2)
99    FORMAT(8F10.7)
C*****READ RESULTS FROM DETCIJ
      READ(16,90)NOPRZ
      DO 110 K=1,8
      NZ=NOPRZ(K)
110   READ(16,34)(IPRZN(J,K),CIJ(J,K),J=1,NZ)
      READ(16,99)SPLITA
      READ(16,85)CLHCF
      READ(16,85)CLDCF
      READ(16,90)MINSIZ
      READ(16,90)IFLWN
      READ(16,87)COMPIL
      READ(16,87)COMPIT
C*****READ OTHER DATA
      READ(5,87)SPLITF
      READ(5,90)KCL
      READ(5,87)COENS
      DO 120 K=1,8
      NR=NOREC(K)
      DO 130 N=1,NR
130   READ(12,31)NAS(N,K),NBS(N,K),MOS(N,K),FLS(N,K)
120   CONTINUE
      REWIND 12
      DO 135 K=1,8
      DO 135 N=1,120
135   INDEST(N,K)=0
C*****DETERMINE DESTINATIONS
      DO 140 K=1,8
      NR=NOREC(K)
      DO 150 N=1,NR
      READ(12,31)IA,IB
150   INDEST(IB,K)=INDEST(IB,K)+1
140   CONTINUE
      REWIND 12
      DO 160 K=1,8
160   NODEST(K)=0


      DO 170 K=1,8
      DO 180 N=1,120
      IA=0
      IF(INDEST(N,K).GT.0)IA=1
180   NODEST(K)=NODEST(K)+IA
170   CONTINUE
C*****SHUFFLE DESTINATIONS
      DO 190 K=1,8
      NRA=NOREC(K)
      NRA1=NRA-1
      DO 200 N=1,NRA1
      NRB=N+1
      DO 210 L=NRB,NRA
      IF(NBS(N,K).LE.NBS(L,K)) GO TO 210
```

```
      IA=NAS(L,K)
      NAS(L,K)=NAS(N,K)
      NAS(N,K)=IA
      IA=NBS(L,K)
      NBS(L,K)=NBS(N,K)
      NBS(N,K)=IA
      IA=MOS(L,K)
      MOS(L,K)=MOS(N,K)
      MOS(N,K)=IA
      XA=FLS(L,K)
      FLS(L,K)=FLS(N,K)
      FLS(N,K)=XA
210   CONTINUE
200   CONTINUE
190   CONTINUE
C*****DETERMINE REVERSE INDEX TO PROD. ZONES
      DO 220 K=1,3
      NZ=NOPRZ(K)
      DO 230 N=1,NZ
      IA=IPRZN(N,K)
230   IRVPRZ(IA,K)=N
220   CONTINUE
C*****COMPUTE DELIVERED COSTS, EXISTING FLOWS
      DO 250 K=1,3
      NR=NOREC(K)
      DO 240 N=1,NR
      IA=NAS(N,K)
      IB=NBS(N,K)
      IC=IRVPRZ(IA,K)
      FLSCIJ(N,K)=CIJ(IC,K)
      KA=KCL(K)
      M=MOS(N,K)
      JA=IFLWM(IA,IB)
      FLSU(N,K)=SPLITA(KA,1)*(COMPTL(JA,1,M)*CLHCF(KA,M)+COMPTT(JA,1
     &,M)*CLDCF(KA,M))+SPLITA(KA,2)*(COMPTL(JA,2,M)+COMPTT(JA,2,M))
     &+SPLITA(KA,3)*(COMPTL(JA,3,M)+COMPTT(JA,3,M))
240   FLSWCU(N,K)=FLSCIJ(N,K)+CDENS(K,M)*FLSU(N,K)*SPLITF/SPLITA(KA,1)
250   CONTINUE
C*****SET UP BASIC INFO FOR NEW FLOWS
      DO 260 K=1,3
      KA=KCL(K)
      DO 270 L=1,4
      IA=NOPRZ(K)-4+L
      IP=IPRZN(IA,K)
      NEWCIJ=CIJ(IA,K)
      INDZ=0
      DO 280 N=1,100
      IF(INDEST(N,K).LE.5)GO TO 280
      INDZ=INDZ+1
      NFLNB(L,INDZ,K)=N
      IF(INDZ.GT.29)GO TO 285


      NFLCIJ(L,INDZ,K)=NEWCIJ
      JA=IFLWM(IP,N)
      DO 290 M=1,3
      TREEC(M)=COMPTL(JA,1,M)*CLHCF(KA,M)+COMPTT(JA,1,M)*CLDCF(KA,
     &M)
      UTEST(M)=SPLITA(KA,1)*TREEC(M)+(COMPTL(JA,2,
     &M)+COMPTT(JA,2,M))*SPLITA(KA,2)+(COMPTL(JA,3,M)+COMPTT
     &(JA,3,M))*SPLITA(KA,3)
      IF(UTEST(M).LE.-100.) GO TO 500
      UPATH(M)=EXP(UTEST(M))
      GO TO 290
500   UPATH(M)=.0000000000001
290   CONTINUE
      U1=UPATH(1)
      U2=UPATH(2)
      U3=UPATH(3)
      DO 817 MO=1,3
      ARG(MO)=UPATH(MO)/(U1+U2+U3)
      PARM(1)=.5
      PARM(2)=PAR(K)
      FRACT(MO)=PNORM(ARG(MO),PARM,IZZ)
817   CONTINUE
      NFLU(L,INDZ,K)=0.
      DO 849 MO=1,3
849   NFLU(L,INDZ,K)=NFLU(L,INDZ,K)+UTEST(MO)*FRACT(MO)/
     &((FRACT(1)+FRACT(2)+FRACT(3))*SPLITA(KA,1))
      AVDENS=1.
      NFLWCU(L,INDZ,K)=NFLCIJ(L,INDZ,K)+AVDENS*NFLU(L,INDZ,K)*SPLITF
      GO TO 280
285   WRITE(6,11)K,L,N
280   CONTINUE
270   CONTINUE
260   CONTINUE
```

```
C*****SHUFFLE RECORDS WITHIN DESTINATIONS
      DO 300 K=1,8
      NRA=1
      NRB=0
      NRADD=0
      DO 310 J=1,120
      IA=INDEST(J,K)
      NRA=NRA+NRADD
      NRB=NRB+IA
      NRADD=IA
      IF(IA.LE.5)GO TO 310
      NRB1=NRB-1
      DO 320 N=NRA,NRB1
      NP1=N+1
      DO 330 L=NP1,NRB
      IF(FLSWCU(N,K). LE.FLSWCU(L,K)) GO TO 330
      IA=NAS(L,K)
      NAS(L,K)=NAS(N,K)
      NAS(N,K)=IA
      IA=NBS(L,K)
      NBS(L,K)=NBS(N,K)
      NBS(N,K)=IA
      IA=MOS(L,K)
      MOS(L,K)=MOS(N,K)
      MOS(N,K)=IA
      XA=FLS(L,K)
      FLS(L,K)=FLS(N,K)
      FLS(N,K)=XA
      XA=FLSCIJ(L,K)
      FLSCIJ(L,K)=FLSCIJ(N,K)
      FLSCIJ(N,K)=XA
      XA=FLSU(L,K)


      FLSU(L,K)=FLSU(N,K)
      FLSU(N,K)=XA
      XA=FLSWCU(L,K)
      FLSWCU(L,K)=FLSWCU(N,K)
      FLSWCU(N,K)=XA
330   CONTINUE
320   CONTINUE
      T=0.0
      DO 340 N=NRA,NRB
340   T=T+FLS(N,K)
C*****PRINT PERTINENT EXISTING FLOWS
      WRITE(6,12)K,J
      WRITE(6,13)
      CT=0.0
      DO 350 N=NRA,NRB
      CT=CT+FLS(N,K)
      F=CT/T
350   WRITE(6,16)NAS(N,K),MOS(N,K),FLS(N,K),FLSCIJ(N,K),FLSU(N,K),
     &FLSWCU(N,K),F
C*****PRINT NEW FLOWS
      WRITE(6,15)
      DO 360 L=1,4
      DO 370 M=1,30
      IF(J.EQ.NFLNB(L,M,K))GO TO 365
370   CONTINUE
      WRITE(6,14)K,J,L
      GO TO 360
365   WRITE(6,17)L,NFLCIJ(L,M,K),NFLU(L,M,K),NFLWCU(L,M,K)
360   CONTINUE
310   CONTINUE
300   CONTINUE
      STOP
      END
```

PROGRAM MMTREE

```
      PROGRAM MMTREE(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7,
     &TAPE16,TAPE17,TAPE18,TAPE50,TAPE19)
      REAL LOADCF
      INTEGER RCO(1000),RCD(1000),PNTR(130)
      DIMENSION NC(130),TRNDL(1040)
      INTEGER TRND(1040),TRNDJ(1040),TRRC(1040),LI(130,8)
      DIMENSION RC(1000,3),TC(50,4,4),MA(4),JN(500),JNJ(500),JRC(500)
      DIMENSION RC1(1000,3),RC2(1000,3),RC3(1000,3),TC1(50,4,4)
      DIMENSION CLHCF(53,3),CLDCF(53,3),TLE(130),TC3(50,4,4)
      COMMON/B1/RCO,RCD,PNTR,NC,TRND,TRNDJ,TRRC,LI,TRNDL,RC,TC,JN,
     &JNJ,JRC,TLE,MA
      DIMENSION NOPRZ(8),IPRZN(31,8),SPLITA(54,3),KOL(8)
      DIMENSION TC2(50,4,4)
34    FORMAT(4(I10,F10.2))
85    FORMAT(8F10.4)
86    FORMAT(3F10.4)
90    FORMAT(8I10)
99    FORMAT(3F10.7)
C*****READ DATA FROM TAPE7
      READ(7,90)IA
      READ(7,90)NR,NARCSC,NNCR,N31
      READ(7,90)IA
      READ(7,90)NC
      READ(7,90)IA
      READ(7,90)PNTR
      READ(7,90)IA
      READ(7,90)RCO
      READ(7,90)IA
      READ(7,90)RCD
      READ(7,90)IA
      READ(7,85)CLDCF
      READ(7,90)IA
      READ(7,85)CLHCF
      READ(7,90)IA
      READ(7,85)RC1
      READ(7,90)IA
      READ(7,85)RC2
      READ(7,90)IA
      READ(7,85)RC3
      READ(7,90)IA
      READ(7,85)TC1
      READ(7,90)IA
      READ(7,85)TC2
      READ(7,90)IA
      READ(7,85)TC3
      REWIND 7
C*****READ RESULTS FROM DETCIJ
      READ(16,90)NOPRZ
      DO 110 K=1,8
      NZ=NOPRZ(K)
110   READ(16,34)(IPRZN(J,K),X,J=1,NZ)
      READ(16,99)SPLITA
      REWIND 16
C*****READ OTHER DATA
      READ(5,90)KOL
C*****ESTABLISH SOME PARAMETERS
      NARCS=NARCSC
      NRCP=0
      UPAB=0.
      INAJ=1
      INB=0
      INBJ=0
      IFBP=0
      DO 120 M=1,4
120   MA(M)=1


C*****SET UP MASTER LOOP FOR EIGHT COMMODITIES
      IT=17
      DO 500 KA=1,8
      IF(KA.GE.5.AND.KA.LE.6) IT=18
      IF(KA.GT.6) IT=50
      K=KOL(KA)
      DO 210 N=1,1000
      DO 210 M=1,3
210   RC(N,M)=((RC1(N,M)*SPLITA(K,1))*CLHCF(K,M)+RC2(N,M)*SPLITA(K,2)+
     &RC3(N,M)*SPLITA(K,3))*(-1.0)
      DO 220 N=1,50
      DO 220 I=1,4
      DO 220 J=1,4
      IF(I.EQ.J) GO TO 739
      IF(I.EQ.1.OR.J.EQ.1) GO TO 737
      LOADCF=(CLDCF(K,I-1)+CLDCF(K,J-1))/2.
```

```
      GO TO 220
737   IF(I.EQ.1) GO TO 736
      LOADCF=CLDCF(K,I-1)
      GO TO 220
736   LOADCF=CLDCF(K,J-1)
      GO TO 220
739   IF(I.EQ.1) GO TO 738
      LOADCF=CLDCF(K,I-1)
      GO TO 220
738   LOADCF=1.
220   TC(N,I,J)=((TC1(N,I,J)*SPLITA(K,1))*LOADCF+TC2(N,I,J)*SPLITA
     &(K,2)+TC3(N,I,J)*SPLITA(K,3))*(-1.0)
C*****SET UP SUB-LOOP FOR PRODUCTION ZONES
         NZ=NOPRZ(KA)
         DO 490 IZ=1,NZ
         INA=IPRZN(IZ,KA)
         CALL MMSPTD(INA,INAJ,INB,INBJ,IFBP,NRCP,UPAB,NARCS)
C*****WRITE RESULTS ON TAPE 17
         IO=90000+KA*1000+INA
         IZ=IZ
         WRITE(IT,99)IO,IZ
         DO 230 J=1,541
230   WRITE(IT,99)TRN(J),TRNOJ(J),TRRC(J)
         DO 240 J=1,120
240   WRITE(IT,99)(LI(J,I),I=1,6)
         WRITE(19,99) IO,IZ
         WRITE(19,86)TLS
490   CONTINUE
500   CONTINUE
         STOP
         END
         SUBROUTINE MMSPTD(INA,INAJ,INB,INBJ,IFBP,NRCP,UPAB,NARCS)
C*****MULTIMODAL SHORTEST PATH ROUTINE,USING MOORE TYPE TREE BUILDING
C*****PROGRAMMED BY G. SHARP,SCHOOL OF ISYE,GEORGIA TECH,APRIL 1977
C*****ARGUMENTS FOR SPECIFIC USE ARE
C        INA      START NODE
C        INAJ     START NODE MODIFIER
C        MA       MODES ALLOWED,ARRAY
C        INB      STOP NODE,OPTIONAL
C        INBJ     STOP NODE MODIFIER,OPTIONAL
C        IFBP     FORWARD-BACKWARD PATH INDICATOR,OPTIONAL
C        NRCP     NUMBER OF ARCS IN PATH,OUTPUT
C        LPAB     LENGTH OF NODE-NODE PATH,OUTPUT
C*****BY GIVING VALUES TO INB,INBJ A NODE-NODE PATH WILL BE FOUND,
C     SETTING INB,INBJ TO ZERO YIELDS ENTIRE TREE
C*****MA 1-1 ARRAY ALLOWS FOR ANY COMBINATION OF ALLOWABLE MODES
C*****SETTING IFBP=-1 YIELDS PATH IN STOP NODE-START NODE DIRECTION,
C     OTHERWISE FORWARD PATH WILL BE OUTPUT
C*****MODAL REPRESENTATION IS ACHIEVED BY (NODE,NODE MODIFIER):


C     MOD=1: SHIP,ORIGINATION    MOD=2: RECEIVE,DESTINATION
C     MOD=3: MODE 2 INBOUND      MOD=4: MODE 2 OUTBOUND
C     MOD=5: MODE 3 INBOUND      MOD=6: MODE 3 OUTBOUND  ETC.
C*****LINE HAUL ARCS ARE BETWEEN
C        (NODE,MOD=4,6,...) AND (NODE,MOD=3,5,...)
C     TRANSFER AND FORWARDING ARCS ARE BETWEEN
C        (NODE,MOD=3,5,...) AND (NODE,MOD=4,6,...)
C     LOADING ARCS ARE (NODE,MOD=1) TO (NODE,MOD=4,6,...)
C     UNLOADING ARCS ARE (NODE,MOD=3,5,...) TO (NODE,MOD=2)
C*****VARIABLE DIMENSION ARGUMENTS
C        N        NUMBER OF NODES (MODIFIERS SUPPRESSED)
C        NARCS    NUMBER OF LINE HAUL ARCS (MODES SUPPRESSED)
C        NMO      NUMBER OF MODES
C        NM2      NMO*2
C        N2NMO    N*2*NMO
C        N2NMOF   N2NMO/MOF
C        MOF      MATRIX DIMENSION FACTOR,RATIO BETWEEN NUMBER OF NODES
C                 IN NETWORK AND NODES IN PATH, USUALLY 2-3
C        NNC      NUMBER OF NODE CHARACTERISTICS
C        NMO1     NUMBER OF MODES - 1
C*****INPUTTED DATA ARRAYS
C        PNTA(N)                  POINTER TO FIRST ARC FROM NODE
C                                 IN AN ORDERED ARC LIST
C        RCO(NARCS)               ARC ORIGIN
C        RCD(NARCS)               ARC DESTINATION
C        RC(NARCS,NMO1)           ARC COSTS FOR MODES 2,3,....
C        NC(N)                    NODE CHARACTERISTIC FOR TRANSFER COSTS
C        TC(NNC,NMO,NMO)          TRANSFER COST ARRAY
C*****OUTPUTTED DATA ARRAYS
C*****FOR NODE-NODE OPTION
C        JN(N*2*(NMO )/MOF)       NODE IN PATH POSITION
C        JNJ( )                   NODE MODIFIER IN PATH POSITION
C        JRC( )                   ARC TO NODE IN PATH POSITION
```

```
C*****FOR TREE OPTION
C             TRND(N*2*(NMD))                 TREE NODE
C             TRNDJ( )                        TREE NODE MODIFIER
C             TRNDL( )                        NODE LABEL
C             TRRC( )                         ARC TO TREE NODE, NOTE CONVENTION
C                                             LINE HAUL: TRRC IS ARC NUMBER
C                                             TRANSFER : TRRC IS PREVIOUS TRNDJ
C             LI(N,NM2)                       POSITION IN TREE OF (NODE,MODIFIER)
C             LE(N,NM2)                       DISTANCE FROM ORIGIN TO (NODE,MODIF)
C                                             LI,LE ARE REDUNDANT, FOR CONVENIENCE
C*****EXPLANATION OF OTHER VARIABLES
C             TRL       CURRENT TREE LENGTH
C             SCNR      CURRENT SCANNER POSITION
C             TEMPL     TEMPORARY LABEL
C             NP        NODE POSITION IN TREE (ARGUMENT FOR ARRAY)
C             NA        NODE FROM WHICH BRANCHING OCCURS
C             NAJ       NA MODIFIER
C             NB        NODE BEING CONSIDERED FOR LABELING
C             NBJ       NB MODIFIER
C*****DECLARATIONS
            INTEGER RCO(1000),RCD(1000),PNTR(130)
            DIMENSION NC(130)
            INTEGER TRND(1040),TRNDJ(1040),TRRC(1040),LI(130,8)
            DIMENSION TRNDL(1040),RC(1000,3),TC(50,4,4),JN(500)
            DIMENSION JNJ(500),JRC(500),TLE(130),MA(4)
            INTEGER TRL,SCNR
            COMMON/B1/RCO,RCD,PNTR,NC,TRND,TRNDJ,TRRC,LI,TRNDL,
     &RC,TC,JN,JNJ,JRC,TLE,MA
   20 FORMAT(16I5)
C*****ZERO OUT WORKING ARRAY
            DO 10 J=1,8
            DO 10 I=1,130


10        LI(I,J)=0
            DO 30 J=1,500
            JN(J)=0
            JNJ(J)=0
30        JRC(J)=0
            DO 40 J=1,1040
            TRND(J)=0
            TRNDJ(J)=0
            TRRC(J)=0
40        TRNDL(J)=0.
            DO 50 J=1,130
50        TLE(J)=0.
C*****LABEL ORIGIN NODE
          TRL=1
          SCNR=1
          TRND(1)=INA
          TRNDJ(1)=INAJ
          TRNDL(1)=0.
          TRRC(1)=0
          LI(INA,INAJ)=1
C*****INITIALIZE NA AND NAJ
          NA=INA
          NAJ=INAJ
100       IF(NAJ.EQ.2)GO TO 170
          IF(MOD(NAJ,2).EQ.0)GO TO 130
C*****CONSIDER TRANSFER ARCS NOW
          DO 110 NBM=1,4
          IF(MA(NBM).EQ.0)GO TO 110
C*****CHECK FOR PERMANENT LABEL,TEMPORARY LABEL
          NBJ=NBM*2
          IF(LI(NA,NBJ).LE.SCNR.AND.LI(NA,NBJ).NE.0)GO TO 110
C*****COMPARE TEMPORARY LABELS
          NCNA=NC(NA)
          NAM=(NAJ+1)/2
          TEMPL=TRNDL(SCNR)+TC( NCNA,NAM,NBM)
C*****BRANCHING IMPLIES NODE UNLABELED
          IF(LI(NA,NBJ).EQ.0)GO TO 120
          NP =LI(NA,NBJ)
C*****NEXT TWO BRANCHINGS IMPLY NEW LABEL DOMINATED
          IF(TEMPL.GT.TRNDL(NP))GO TO 110
          IF(TEMPL.EQ.TRNDL(NP).AND.NBM.NE.NAM)GO TO 110
C*****UPDATE TEMP LABEL NOW
          TRNDL(NP )=TEMPL
          TRRC( NP)=NAJ
          GO TO 110
C*****LABEL UNLABELED NODE
  120 TRL=TRL+1
          TRND(TRL)=NA
          TRNDJ(TRL)=NBJ
          TRNDL(TRL)=TEMPL
          TRRC(TRL)=NAJ
          LI(NA,NBJ)=TRL
  110 CONTINUE
          GO TO 170
```

```
C*****CONSIDER LINE ARCS NOW
  130 IARC=PNTR(NA)
C*****IARC IS FIRST ARC IN LIST STARTING FROM NA
C*****NEXT  BRANCHING IMPLIES ALL ARCS FROM NA EXAMINED
  140 IF(RCO(IARC).NE.NA)GO TO 170
      NB=RCD(IARC)
C*****CHECK FOR PERMANENT,TEMPORARY LABEL
      NBJ=NAJ-1
      IF(LI(NB,NBJ).LE.SCNR.AND.LI(NB,NBJ).NE.0)GO TO 160
C*****COMPARE TEMPORARY LABELS
      NAM1=NAJ/2-1


      TEMPL=TRNDL(SCNR)+RC(IARC,NAM1)
C*****BRANCHING IMPLIES NODE UNLABELED
      IF(LI(NB,NBJ).EQ.0)GO TO 150
C*****BRANCHING IMPLIES NEW LABEL DOMINATED
      NP =LI(NB,NBJ)
      IF(TEMPL.GE.TRNDL(NP ))GO TO 160
C*****UPDATE TEMP LABEL NOW
      TRNDL( NP)=TEMPL
      TRRC( NP)=IARC
      GO TO 160
C*****LABEL UNLABELED NODE
  150 TRL=TRL+1
      TRND(TRL)=NB
      TRNDJ(TRL)=NBJ
      TRNDL(TRL)=TEMPL
      TRRC(TRL)=IARC
      LI(NB,NBJ)=TRL
  160 IARC=IARC+1
      IF(IARC.LE.NARCS)GO TO 140
C*****EXIT LABELING,BEGIN SHUFFLE
  170 CONTINUE
C*****BRANCHING IMPLIES     NO NEED TO SHUFFLE 0 OR 1 ARC
      NDIF=TRL-SCNR
      IF(NDIF.LE.1)GO TO 220
      L=SCNR+1
      LA=L+1
      DO 210 M=LA,TRL
      IF(TRNDL(L).LE.TRNDL(M))GO TO 205
      IVE=TRRC(L)
      TRRC(L)=TRRC(M)
      TRRC(M)=IVE
      XVE=TRNDL(L)
      TRNDL(L)=TRNDL(M)
      TRNDL(M)=XVE
      IVE=TRND(L)
      IVF=TRNDJ(L)
      LI(IVE,IVF)=M
      IVG=TRND(M)
      IVH=TRNDJ(M)
      LI(IVG,IVH)=L
      TRND(L)=IVG
      TRNDJ(L)=IVH
      TRND(M)=IVE
      TRNDJ(M)=IVF
  205 CONTINUE
  210 CONTINUE
  220 IF(NDIF.EQ.0)GO TO 230
C*****NOW   PLACE  NODE ON PERMANENT TREE
      SCNR=SCNR+1
  230 IF(INB.EQ.TRND(SCNR).AND.INBJ.EQ.TRNDJ(SCNR))GO TO 240
C*****BRANCHING MEANS  TREE FINISHED
      IF(NDIF.EQ.0)GO TO 400
      NA=TRND(SCNR)
      NAJ=TRNDJ(SCNR)
      GO TO 130
C*****BRANCHING:  GO BACK AND LABEL FROM NEWLY PLACED PERMANENT NODE
C*****NOW TRACE PATH FOR NODE-NODE PAIR
  240 UPAB=TRNDL(SCNR)
      LJN=500
      J=1
      JN1=TRND(SCNR)
      JNJ1=TRNDJ(SCNR)
      JRC1=TRRC(SCNR)
      JN(J)=JN1
      JNJ(J)=JNJ1


      JRC(J)=JRC1
C*****BRANCHING IMPLIES TRACING COMPLETED
      IF(JN1.EQ.INA.AND.JNJ1.EQ.INAJ)GO TO 300
C*****BRANCHING ACCORDING TO LINE HAUL OR TRANSFER ARC
      IF(MOD(JNJ1,2).NE.0)GO TO 260
```

```
C*****IDENTIFY NODE REACHED BY LINE HAUL ARC IN FORWARD PATH
  270 J=J+1
      IF(J.GT.LJN)GO TO 420
      JN(J)=JN1
      JNJ1=JRC1
      JNJ(J)=JRC1
      IF(JN1.EQ.INA.AND.JNJ1.EQ.INAJ)GO TO 300
      NP=LI(JN1,JNJ1)
      JRC1=TRKC(NP)
      JRC(J)=JRC1
C*****IDENTIFY NODE REACHED BY TRANSFER ARC IN FORWARD PATH
  260 J=J+1
      IF(J.GT.LJN)GO TO 420
      JN1=RCO(JRC1)
      JN(J)=JN1
      JNJ1=JNJ1+1
      JNJ(J)=JNJ1
      IF(JN1.EQ.INA.AND.JNJ1.EQ.INAJ)GO TO 300
      NP=LI(JN1,JNJ1)
      JRC1=TRKC(NP)
      JRC(J)=JRC1
      GO TO 270
  300 NRCP=J
      JRC(J)=0
C*****BRANCHING IMPLIES REVERSE PATH ORDER MAINTAINED
      IF(IFBP.EQ.-1)GO TO 500
C*****REVERSE PATH INFORMATION NOW
      IVH=NRCP/2
      DO 310 L=1,IVH
      IVE=JN(L)
      IVF=JNJ(L)
      IVG=JRC(L)
      M=NRCP+1-L
      JN(L)=JN(M)
      JNJ(L)=JNJ(M)
      JRC(L)=JRC(M)
      JN(M)=IVE
      JNJ(M)=IVF
  310 JRC(M)=IVG
      GO TO 500
C*****PREPARE OUTPUT INFORMATION FOR COMPLETE TREE
400   DO 410 L=1,130
         NP=LI(L,2)
410   TLE(L)=TRNOL(NP)
      GO TO 500
  430 FORMAT(1H0,"LJN EXCEEDED",7I4)
  420 WRITE (6,430)INA,INAJ,(MA(I),I=1,NMD)
  500 RETURN
      END
```

PROGRAM MMSPLT

```
C*****PROGRAM MMSPLT PERFORMS THE MODAL SPLIT ON
C     THE FLOW SAMPLE AND PRODUCES TAPE 20
      PROGRAM MMSPLT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
     &TAPE16,TAPE19,TAPE20,TAPE22)
      DIMENSION NOPRZ(8),IPRZN(31,8),SPLITA(54,3),CLHCF(53,3),
     &MINSIZ(5),IFLWM(120,120),COMPTL(993,3,3),COMPTT(993,3,3),
     &XLE(133),TLE(133,120),KCL(8),U(8),CLOCF(53,3)
      DIMENSION PARM(2),PAR(8)
      DATA PAR/.38,2*.162,.12,4*.162/
34    FORMAT(4(I10,F10.2))
36    FORMAT(2I10,4F10.0,4F10.4)
85    FORMAT(8F10.4)
90    FORMAT(8I10)
37    FORMAT(" ","NORMAL TERMINATION OF MMSPLT")
86    FORMAT(8F10.4)
99    FORMAT(8F10.7)
C*****READ DATA FROM DETCIJ
      READ(16,90) NOPRZ
      DO 110 K=1,8
      NZ=NOPRZ(K)
110   READ(16,34) (IPRZN(J,K),X,J=1,NZ)
      READ(16,99) SPLITA
      READ(16,85) CLHCF
      READ(16,85) CLOCF
      READ(16,90) MINSIZ
      READ(16,90) IFLWM
      READ(16,85) COMPTL
      READ(16,85) COMPTT
      REWIND 16
C*****READ DATA FROM MMTREE,TAPE19
      N=0
      DO 200 KA=1,8
      NZ=NOPRZ(KA)
      DO 190 IZ=1,NZ
      READ(19,90) IA
      READ(19,86) XLE
      N=N+1
      DO 180 I=1,120
180   TLE(N,I)=XLE(I)
190   CONTINUE
200   CONTINUE
      REWIND 19
C*****READ OTHER DATA
      READ(5,90) KCL
C*****READ TAPE22, PERFORM MODAL SPLIT, AND WRITE
C     RESULTS ON TAPE 20
      NT=0
      N=0
      DO 500 KA=1,8
      K=KCL(KA)
      NZ=NOPRZ(KA)-L
      DO 440 I=1,NZ
      NT=NT+1
      READ(22,90) ND
      WRITE(20,90) ND
      DO 450 NN=1,ND
      N=N+1
      READ(22,36) NA,NB,X
      JA=IFLWM(NA,NB)
      DO 460 M=1,3
460   U(M)=SPLITA(K,1)*(COMPTL(JA,1,M)*CLHCF(K,M)
     &+COMPTT(JA,1,M)*CLOCF(K,M))+SPLITA(K,2)*
     &(COMPTL(JA,2,M)+COMPTT(JA,2,M))+SPLITA(K,3)*
     &(COMPTL(JA,3,M)+COMPTT(JA,3,M))
      U(4)=-1.*TLE(NT,NB)


      DO 600 L1=1,4
      IF(U(L1).LE.-100.) GO TO 610
      U(L1+4)=EXP(U(L1))
      GO TO 600
610   U(L1+4)=.0000000000001
600   CONTINUE
      DO 815 M=1,3
      IF(ABS(U(M)-U(4)).GE.-.05*U(M).AND.ABS(U(M)-U(4)).GE..01)GO TO 815
      U(8)=0.
815   CONTINUE
      U5=U(5)
      U6=U(6)
      U7=U(7)
      U8=U(8)
      UT=U5+U6+U7+U8
```

```
      PARM(1)=.5
      PARM(2)=PAR(KA)
      ARG5=U5/UT
      ARG6=U6/UT
      ARG7=U7/UT
      ARG8=U8/UT
      FRA1=PNORM(ARG5,PARM,IZZ)
      FRA2=PNORM(ARG6,PARM,IZZ)
      FRA3=PNORM(ARG7,PARM,IZZ)
      FRA4=PNORM(ARG8,PARM,IZZ)
      FRAT=FRA1+FRA2+FRA3+FRA4
      F1=X*FRA1/FRAT
      F2=X*FRA2/FRAT
      F3=X*FRA3/FRAT
      F4=X*FRA4/FRAT
      WRITE(20,36) NA,NB,F1,F2,F3,F4,(U(LI1),LI1=1,4)
450   CONTINUE
440   CONTINUE
      NT=NT+4
500   CONTINUE
      WRITE(6,37)
      STOP
      END
```

PROGRAM MMHIJK

```
C       PROGRAM MMHIJK DETERMINES THE NEW HIJK FOR NEW
C       FACILITIES BASED ON CHANGES IN THE NETWORK.
        PROGRAM MMHIJK(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
       &TAPE12,TAPE16,TAPE19)
        DIMENSION NOPRZ(8),IPRZN(31,8),CIJ(31,8),NOREC(8),
       &INDEST(120,8),SPLITA(54,3),CLHCF(53,3),CLDCF(53,3),
       &IFLWM(120,120),COMPTL(999,3,3),COMPTT(999,3,3),
       &COENS(8,3),NFLNB(4,30,8),TRELC(3),UPATH(3),KCL(8),
       &TLE(32,120),TLX(130),UTEST(3)
        REAL NFLU(4,30,8),NFLWCU(4,30,8),NFLCIJ(4,30,8)
              DIMENSION PARM(2),PAR(8)
              DATA PAR/.08,2*.162,.12,4*.162/
              DATA NOREC/116,32,212,119,109,111,183,135/
11      FORMAT(1H0,"INDZ EXCEEDED",3I5)
31      FORMAT(10X,I3,10X,I3,10X,I1,10X,F13.0)
32      FORMAT(5I10)
33      FORMAT(5I10,F10.2)
34      FORMAT((4(I10,F10.2)))
85      FORMAT(8F10.4)
86      FORMAT(8F10.4)
87      FORMAT(8F10.2)
90      FORMAT(8I10)
12      FORMAT(1H1,"EXISTING FLOWS    COM=  ",I2,"    DEST=   ",I4)
13      FORMAT(1H0," ORIG   MODE    TONS          CIJ      EXP ARG    HIJK",
       &6X,"CUM.TONS",/)
14      FORMAT(1H0,"CANNOT FIND NEW FLOW",3I5)
15      FORMAT(1H0,"COMPETING COSTS FOR PRODUCT",1X,I1,1X,"FROM 4 CORRIDOR
       & TEST ZONES",/)
19      FORMAT(" ","COMPETING COSTS FROM ZONE ",I1," TO MARKET ",
       &I3,/)
16      FORMAT(1H ,2I5,5F10.2)
17      FORMAT("0",I5,10X,3F10.2)
99      FORMAT(8F10.7)
C*****READ RESULTS FROM DETCIJ
              READ(16,90)NOPRZ
              DO 110 K=1,8
              NZ=NOPRZ(K)
110     READ(16,34)(IPRZN(J,K),CIJ(J,K),J=1,NZ)
              READ(16,99)SPLITA
              READ(16,85)CLHCF
              READ(16,85)CLDCF
              READ(16,90)IA
              READ(16,90)IFLWM
              READ(16,87)COMPTL
              READ(16,87)COMPTT
C*****READ OTHER DATA
              READ(5,87)SPLITF
              READ(5,90)KCL
              READ(5,87)COENS
C*****READ TLE FROM TAPE 19
        NT=0
        DO 130 K=1,8
        NZ=NOPRZ(K)-4
        DO 120 IZ=1,NZ
        READ(19,90) IO
        READ(19,85) TLX
120     CONTINUE
        DO 141 L=1,4
        NT=NT+1
        READ(19,90) IO
        READ(19,86) TLX
        DO 151 J=1,120
151     TLE(NT,J)=TLX(J)
141     CONTINUE
130     CONTINUE


              DO 135 K=1,8
              DO 135 N=1,120
135     INDEST(N,K)=0
C*****DETERMINE DESTINATIONS
              DO 140 K=1,8
              NR=NOREC(K)
              DO 150 N=1,NR
              READ(12,31)IA,IB
150     INDEST(IB,K)=INDEST(IB,K)+1
140     CONTINUE
              REWIND 12
C*****SET UP BASIC INFO FOR NEW FLOWS
        NT=0
              DO 260 K=1,8
              KA=KCL(K)
```

```
          DO 270 L=1,4
      NT=NT+1
          IA=NOPRZ(K)-4+L
          IB=IPRZN(IA,K)
          NEWCIJ=CIJ(IA,K)
          INDZ=0
          DO 280 N=1,120
          IF(INDEST(N,K).LE.5)GO TO 280
          INDZ=INDZ+1
          NFLNB(L,INDZ,K)=N
          IF(INDZ.GT.29)GO TO 285
          NFLCIJ(L,INDZ,K)=NEWCIJ
          JA=IFLWN(IB,N)
          DO 290 M=1,3
          TREEC(M)=COMPTL(JA,1,M)*CLHCF(KA,M)+COMPTT(JA,1,M)*CLDCF(KA,
     &M)
      UTEST(M)=SPLITA(KA,1)*TREEC(M)+(COMPTL(JA,2,
     &M)+COMPTT(JA,2,M))*SPLITA(KA,2)+(COMPTL(JA,3,M)+COMPTT
     &(JA,3,M))*SPLITA(KA,3)
          IF(UTEST(M).LE.-165.) GO TO 500
          UPATH(M)=EXP(UTEST(M))
          GO TO 290
500   UPATH(M)=.0000000000001
290   CONTINUE
      U1=UTEST(1)
      U2=UTEST(2)
      U3=UTEST(3)
      U4=-1.*TLC(NT,N)
      U5=UPATH(1)
      U6=UPATH(2)
      U7=UPATH(3)
      U8=EXP(U4)
      UT=U5+U6+U7+U8
          PARM(1)=.0
          PARM(2)=PAR(K)
          ARG1=U5/UT
          ARG2=U6/UT
          ARG3=U7/UT
          ARG4=U8/UT
          FRA1=PNORM(ARG1,PARM,IZZ)
          FRA2=PNORM(ARG2,PARM,IZZ)
          FRA3=PNORM(ARG3,PARM,IZZ)
      FRA4=PNORM(ARG4,PARM,IZZ)
      FRAT=FRA1+FRA2+FRA3+FRA4
      F1=FRA1/FRAT
      F2=FRA2/FRAT
      F3=FRA3/FRAT
      F4=FRA4/FRAT
      NFLU(L,INDZ,K)=(F1*U1+F2*U2+F3*U3+F4*U4)/SPLITA(KA,1)
      NFLWCU(L,INDZ,K)=NEWCIJ+NFLU(L,INDZ,K)*SPLITF


      GO TO 280
285   WRITE(6,11) K,L,N
280   CONTINUE
270   CONTINUE
260   CONTINUE
C*****PRINT NEW FLOWS
      DO 300 K=1,8
      WRITE(6,15) K
      DO 310 J=1,120
          DO 360 L=1,4
          DO 370 M=1,30
          IF(J.EQ.NFLNB(L,M,K))GO TO 365
370   CONTINUE
          GO TO 360
365   WRITE(6,19) L,J
      WRITE(6,17)L,NFLCIJ(L,M,K),NFLU(L,M,K),NFLWCU(L,M,K)
360   CONTINUE
310   CONTINUE
300   CONTINUE
          STOP
          END
```

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PROCEDURES FOR MULTI-STATE MULTI-MODE ANALYSIS: TASK 6, DATA SOURCES

Submitted by

Georgia Institute of Technology

in collaboration with:

The University of Alabama
Arkansas State University
Auburn University
Memphis State University
Mississippi State University
The University of Missouri
The University of North Florida and
Tennessee Technological University

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PROCEDURES FOR MULTI—STATE MULTI—MODE ANALYSIS: FIRST YEAR'S RESEARCH

Paul S. Jones, Editor
Submitted by

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in collaboration with:
The University of Alabama
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16. Abstract

This document presents an analytical, network based procedure designed to measure quantitatively the interactions between economic development potential and transportation service improvements. The transportation services of interest include both existing and developmental modes and intermodal services based on efficient transfer technology. The analysis focuses on a single area - the Multi-State Corridor extending from Brunswick, Georgia to Kansas City.

Significant results from the first year's research are: 1) Establishing variable-sized network zones, based on APDC's and BEA sectors. 2) Identifying network arcs, consisting of Interstate, Federal aid primary, and state highways, class I and II rail lines, and navigable inland waterways. 3) Defining 53 industry/commodity groups, along with production coefficients for labor, energy, capital, and materials. 4) Preparing a 111 zone, 53 commodity flow table for the U.S. 5) Calibration of abstract mode split equations for seven industry/commodity groups. 6) Developing and calibrating market share equations based on the distribution of delivered price for each of eight commodities. 7) Testing the overall procedure in four zones in Northern Mississippi. Although no developmental conclusions should be drawn from this limited test, the results are encouraging and warrant further research efforts.

17. Key Words	18. Distribution Statement
Multi-modal, corridor development, multi-state, regional planning, rural development, commodity flow, mode split, market share	This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

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PREFACE

This report describes the results of the first year's effort on a continuing research project entitled, "Analytical Procedures for the Study of a Specific Multimodal Transportation Corridor." The corridor under study is the Multi-State Corridor that extends from Brunswick, Georgia to Kansas City, Missouri. The research has focused on the economic development opportunities that are brought about by the creation of new transportation facilities and services. Knowledge of the key relationships between transportation and economic development can benefit planning for both.

The research is sponsored by the Office of Transportation Systems Analysis and Information of the Office of the Secretary of the U.S. Department of Transportation. Dr. Byron Nupp is Contracting Officer's Technical Representative.

The research has been performed by a consortium of nine universities under the direction of Dr. Paul S. Jones of the Georgia Institute of Technology. Principal research areas together with participating universities, contributing faculty and graduate students are listed below:

Research Area	Contributing Personnel	Institution
Legal Considerations	Dr. Stanely J. Hille, Principal Investigator Edward R. Bruning	Univ. of Alabama
Economic Modeling	Dr. John S. Kaminarides, Principal Investigator	Arkansas State University
Transportation Alternatives	Dr. Robert L. Vecellio, Principal Investigator	Auburn University
Project Leadership, Transportation Overall Analysis	Dr. Paul S. Jones, Principal Investigator, Dr. Gunter P. Sharp, Graduate students: Michael A. Mullens, H. C. David Yu	Georgia Institute Technology
Evaluation Technology, Zone Structure	Dr. Martin E. Lipinski, Principal Investigator, Dr. Subbarayan Prasanna, Graduate students: Wade Morgan, Harold L. Petty, Mark Damlouji	Memphis State University

Research Area (cont'd)	Contributing Personnel (cont'd)	Institution (cont'd)
Northern Mississippi Test	Dr. J. William Rush, Principal Investigator	Mississippi State University
Transportation Data	Dr. David L. Guell, Principal Investigator	University of Missouri
Industry Analysis	Dr. Jay A. Smith, Jr., Principal Investigator, Dr. H. Barry Spraggins	University of North Florida
Transportation Data, Transportation Costing	Dr. Frank M. Holloway, Principal Investigator	Tennessee Technological University

Preliminary results of the research have been reported in five interim reports. These are:

"Legal Considerations in the Development of a Multi-Modal Corridor," by Stanley S. Hille and Edward R. Bruning [1]

"Procedures for Multi-State, Multi-Mode Corridor Analysis: Task 2, Analytical Guidelines," by Paul S. Jones [2]

"National Zone Structure for Transportation Analysis," by Subbarayan Prasanna, Wade Morgan and Mark Damlouji [3]

"Development of a Multi-Modal Evaluation Procedure," by Martin E. Lipinski, and Harold L. Petty [4]

"Procedures for Multi-State, Multi-Mode Corridor Analysis: Task 5, Model Formulation," by Gunter P. Sharp [5]

The contents of these reports are covered in the present document.

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EXECUTIVE SUMMARY

Background

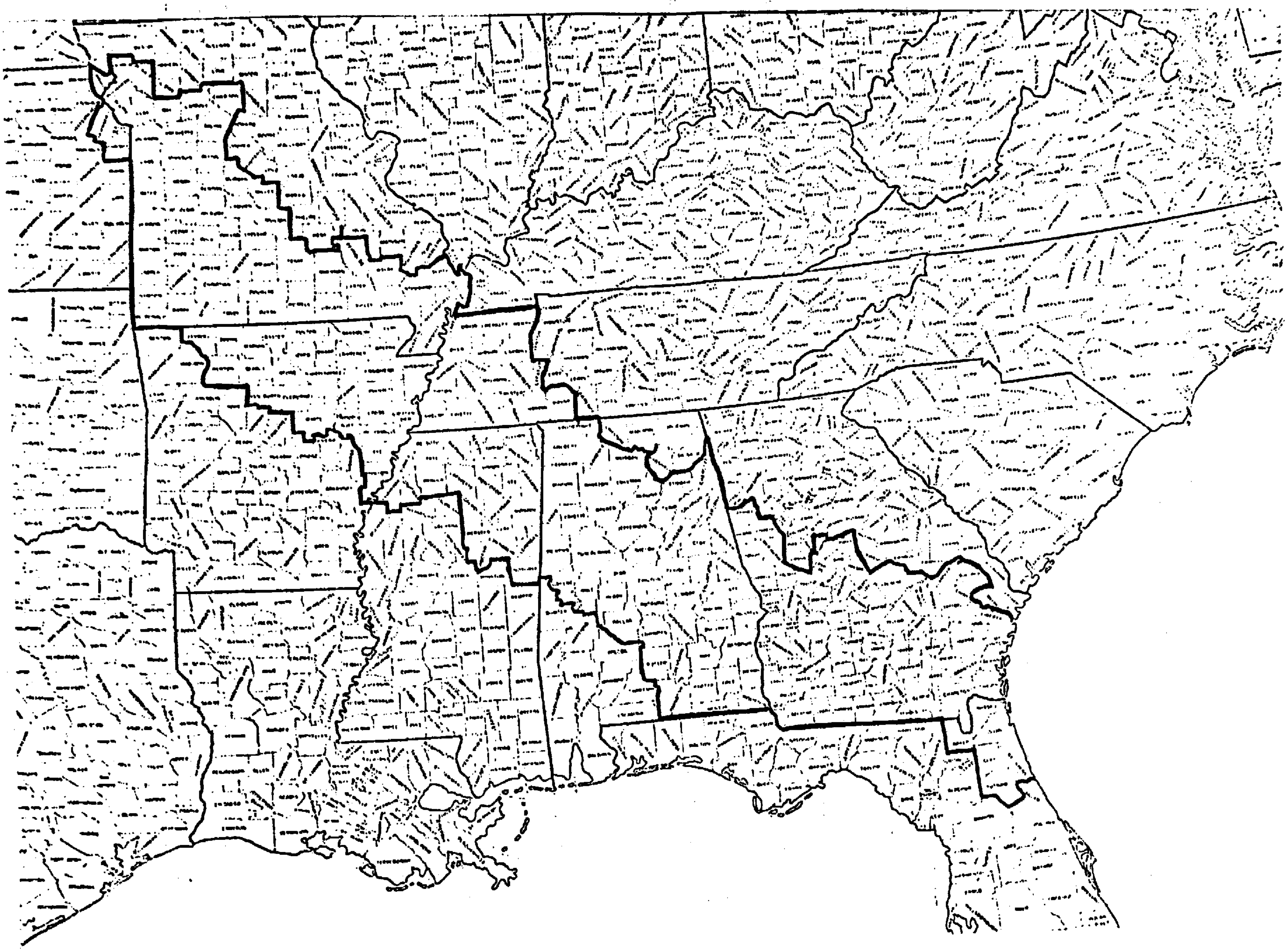
The objective of this research is to develop analytical procedures that can quantify the interactions between programs of transportation service improvement and the economic development opportunities that such programs facilitate. The research is directed toward a specific geographical area: the Multi-State Transportation Corridor, shown in Figure 1. The Corridor is approximately 1200 miles long and nominally 100 miles wide, and includes parts of eight states - Florida, Georgia, Alabama, Mississippi, Tennessee, Arkansas, Missouri and Kansas. The area is largely underdeveloped and presently has limited transportation services, thus providing an ideal setting for investigating new transportation services.

The initial research effort is restricted to freight transportation, but includes present modes - highway, rail, and water - future modes that may be developed, and intermodal combinations of present and future modes. The approach is viewed as the first of a succession of screening steps. The new transportation services are identified in terms of mode, capacity, and approximate route, while details concerning alignment, design, points of ingress and egress and specific technology are left for later study. Similarly, development opportunities are described in terms of industry group, approximate location, approximate markets, approximate size and undesignated ownership. Only basic industry is considered, and total market for each industry group is assumed to remain fixed, with market competition conducted on the basis of cost. The research is heavily concerned with intermodal transportation movements, and the network modeling reflects this purpose. In this respect the work differs substantially from previous research.

An important perspective is that the first year's effort has been devoted to developing a complete, global framework for dealing with the analytical problem. It is anticipated that subsequent work will treat more thoroughly some of the highly technical and challenging data and modeling problems - notably the commodity flow data, the mode split model, and the market share model. Finally, the analytical method has been tested for only a small area, Northern Mississippi, and for only eight commodity groups. No firm conclusions can be drawn from such limited work.

The Multi-Mode, Multi-State research can be broadly divided into two

FIGURE 1
MULTI-STATE SYSTEM AREA



investigations, each of which essentially stands alone. The first concerns the identification of legal, administrative, organizational and procedural barriers to the development of multi-modal transportation services in the Multi-State Corridor. The second is the development and testing of an analytical method that can identify potentially successful transportation and economic development opportunities. The results of each investigation are summarized here and presented in detail in the main body of the report.

Legal, Administrative, Organizational and Procedural Barriers

There are substantial legal, organizational and administrative barriers to the creation of multi-modal transportation facilities in the Multi-State Corridor. The plethora of federal agencies with transportation interests deal with the planning, financing, environmental policy, design, construction, operation, maintenance, regulation and safety of transportation facilities on a mode by mode basis.

Federal-state participation is most thoroughly developed for highway projects, which have been the focus of governmental attention and support for six decades. However, even in the highway arena, uniform size and weight standards are needed for the Corridor States. Motor carriers would also benefit from less restrictive operating rights and greater rate setting freedom.

Railroad regulation by the Interstate Commerce Commission (ICC) is of long standing, but governmental support in rail planning and finance is a recent development. Many rail issues are being examined and debated. These include public ownership of rail lines, reduction in physical plant, intra-industry competition, labor policy, operating rules, public finance of rail facilities and other forms of financial assistance. Little attention has been given to removing prohibitions against rail-motor carrier combinations. Those railroads that have succeeded in establishing multi-modal enterprises are constrained to keep the modal activities separated so that the benefits of joint operation are not realized.

Waterway construction is largely in the hands of the Corps of Engineers once project funds have been appropriated by the Congress. Water carriers are free to use these facilities without charge.

Federal, state, local governments and private carriers cooperate effectively in the aviation industry. Airport planning and construction generally reflects a high degree of joint cooperation. However, air freight is still very small relative to other transport modes.

Most pipeline facilities are built with little or no government intervention. The one notable exception is the Alaska pipeline where environmental issues predominated.

Only environmental issues get reasonably uniform treatment across modes. The Environmental Protection Agency sets and enforces uniform standards for all transportation projects.

Of the Corridor States, Florida, Georgia and Tennessee have created State departments of transportation, with jurisdiction over highway, rail, airport and some port activities and facilities. However, because of continuing mode specific funding from federal and state sources, highway activities overpower the other modes.

If multi-modal facilities are to become a reality, governmental activities with multi-modal responsibilities must be created. The federal government is the logical place to start with an intermodal planning agency and the amalgamation of all modal regulatory agencies. Present prohibitions against multi-modal companies and intermodal cooperation need to be reversed. Legislation needs to encourage common use of transportation facilities by several modes. Individual carriers need the freedom to seek the lowest cost solution to their problems. Rate structures need to be altered so that intermodal rates can reflect the true economics of intermodal service. Procedures for the development and use of mixed public and private facilities are needed. All of these changes are achievable through the legislative process. Many could be included in the 1978 Highway Act which can become the first intermodal transportation act.

Analytical Method

The analytical method developed to quantify interactions between programs of transportation service improvement and economic development opportunities contains a cost based network representation of freight traffic throughout the Continental United States. The programs of transportation improvements are limited to the Multi-State Corridor, but within that corridor a program can contain improvements in existing modes, new transportation modes and new modal interchange facilities in any of a large number of combinations. Economic development opportunities are opportunities to successfully install or expand industrial facilities in Corridor locations to a magnitude that can have significant impacts on national markets.

The general nature of the method is illustrated in Figure 2. There are four distinct areas of investigation - commodity flow analysis, economic modeling, network modeling and improvement analysis. Each area contains several important analytical steps that are closely interrelated. Individual steps interact in a variety of complex ways. The first three areas - commodity flow analysis, economic modeling and network modeling - comprise the fundamental structure of the analytical method and have been the focus of the first year's research. The fourth area, improvement analysis, is the application of the model to generate transportation improvement and economic development opportunities. This area has been demonstrated for a limited example comprising eight industry/commodity groups in a Northern Mississippi setting.

Commodity Flow Analysis

The commodity flow analysis defined the dimensionality of the analytical method and produced the commodity flow data base necessary for further work. This area, which is divided into three steps, needed to be completed before the economic and transportation modeling could progress very far.

Commodity/Industry Groups. It would be attractive, but not very practical, to deal with individual commodities and with the industries that produce them. A more modest approach has been taken by which 53 more or less homogeneous commodity groups have been selected for analysis. These are listed in Table 1 together with the SIC (Standard Industrial Classification) Codes [6] that are contained in each group. Each group is an amalgamation of commodities that have similar raw material needs and that undergo similar processing. Each commodity group is produced by a single industry or a small group of industries that use similar processing facilities. The intent was to select industries that can be represented as a single mean that draws on common raw materials and produces products in comparable facilities that have similar market and transportation characteristics. Each industry group is associated with a single commodity group.

Network Zones. Network zones are areas where principal commodity

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[6] Office of Management and Budget, Standard Industrial Classification Manual, U.S. Govt. Printing Office, Washington, D.C., 1972.

FIGURE 2
ANALYTICAL FRAMEWORK

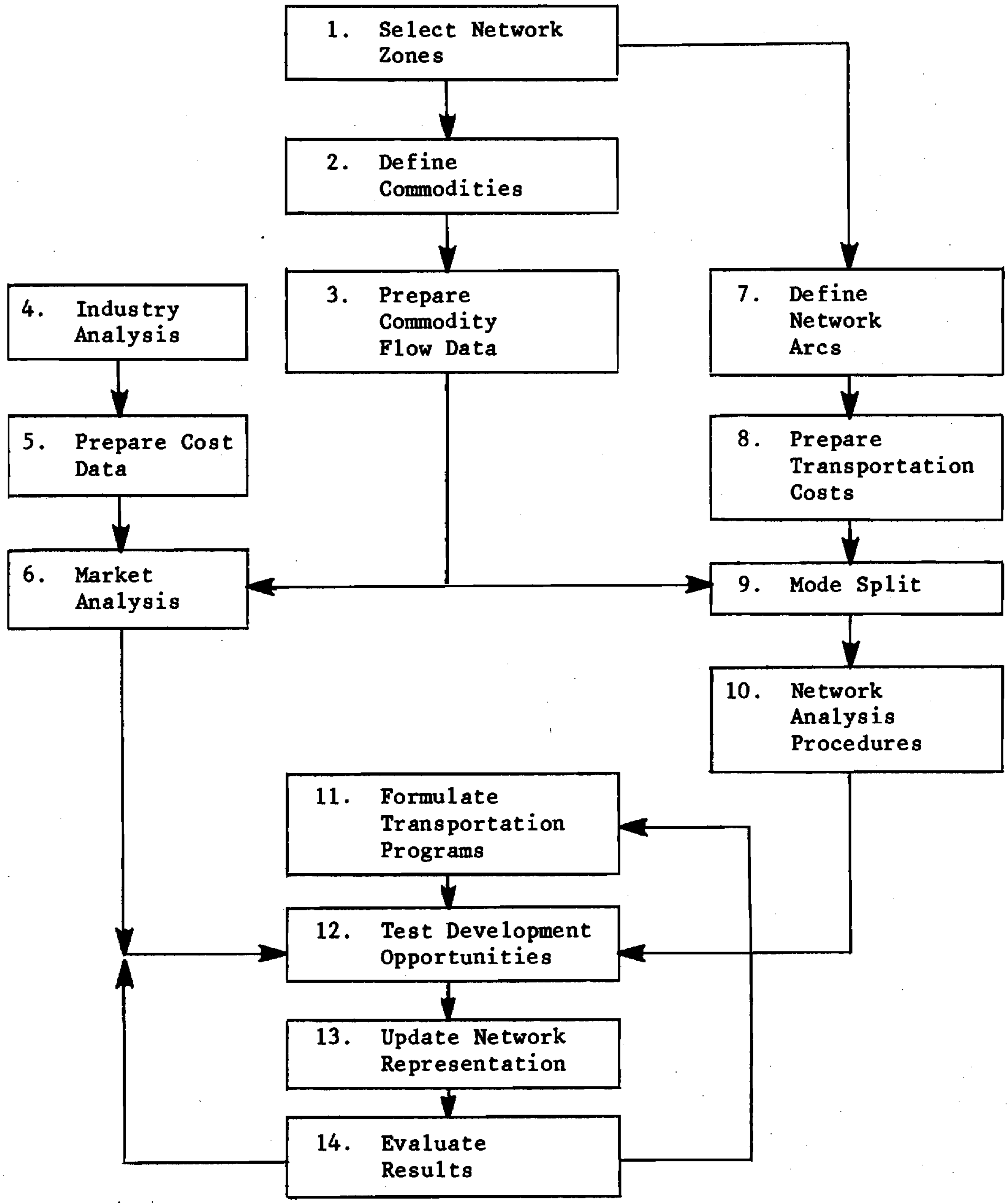

TABLE 1

COMMODITY CLASSIFICATIONS

NO.	DESCRIPTION	SIC CODES
011	Grain	011
013	Field Crops	013,016,018,019
021	Livestock	021
024	Dairy	024
025	Poultry & Eggs	025
080	Forestry	08
090	Commercial Fishing	09
101	Iron Ore	101
102	Non Ferrous Ores	102,103,104,105 106,108
110	Coal	11,12
130	Oil& Gas Extraction	13
140	Non-Metallic Minerals	14
201	Meat	201
202	Dairy Products	202
203	Canned & Preserved Food	203
204	Grain Products	204
205	Bakery Products	205
206	Confectionary	206
207	Fats & Oils	207
208	Beverages	208
209	Misc Food	209
210	Tobacco	21
220	Textile Mill Products	22
230	Apparel	23
240	Lumber & Wood	24
250	Furniture & Fixtures	25
260	Paper	26
270	Printing & Publishing	27
281	Industrial Inorganic Chemicals	281
282	Plastics	282
283	Drugs	283
284	Soap	284
285	Paint	285
286	Industrial Organic Chemicals	286
287	Agricultural Chemicals	287
289	Miscellaneous Chemicals	289
290	Petroleum Refining	29
301	Tires & Tubes	301
302	Rubber & Plastic Products	302,308,304,306 307
310	Leather & Leather Products	31
324	Cement	324
321	Stone,Clay,Glass&Concrete Prod.	321,322,323,325 326,327,328,329
331	Iron & Steel	331,332
333	Non Ferrous Metals	333,334,335,336 339
341	Metal Cans & Shipping Containers	341
342	Fabricated Metal Products	342,343,344,345, 346,347,348,349
350	Machinery, Except Electrical	35
362	Electrical Industrial Apparatus	362
361	Electrical Machinery	361,363,364,365, 366,367,369
371	Motor Vehicles & M.V. Equip.	371
372	Transportation Equipment	372,373,374,375, 376,379
380	Measuring Instruments	38
390	Miscellaneous Manufacturing	39

movements originate or terminate. Each zone is represented by a centroid city which serves as the focus for economic and transportation activities. A zone is treated as though all economic activity occurs at its centroid city. All transportation routes originate and terminate at centroid cities and all transportation terminals are located at centroids.

Because of the nature of the zone representation, zone size is critical to the accuracy of the work. If zones are small, the error in equating zonal and centroid activity is small. If zones are large, the error can be appreciable. However, uniform small zones, e.g. counties, pose serious problems because of the immensity of the networks needed to connect them and the lack of commodity flow data for them.

A compromise was adopted for the Multi-State Corridor analysis. Small zones are used in the Multi-State Corridor. These are generally planning and development districts designated by the states. They contain six to ten counties. Adjacent to the Corridor, larger zones are used. These are BEAs (Basic Economic Areas) designated by the Office of Business Economics of the Department of Commerce. Although activities remote from the Corridor can have considerable impact on Corridor development, precise geographical location is not so important and hence zones can be larger. Remote zones are made up of multiple BEAs. Figure 3 illustrates the 120 transportation zones selected for the analysis. Zone centroid cities are listed in Table 2. Detailed zone area descriptions are presented in Appendix B.

Commodity Flow Data. Commodity flow data were prepared to describe the movements of each commodity group between zone pairs. Accurate data for this purpose are not available, because of differences in reporting requirements and regulation among the modes. The best available source, prepared by the Transportation Systems Center of U.S. DOT [7], was adapted, using Bureau of the Census sources, to approximate movements of the 53 different commodity groups between pairs of the 120 zones.

Economic Modeling

The economic model provides a representation of each industry group as it

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[7] Schuessler, R. W. and P. A. Cardellichio, "NTP Commodity Flow Projections - Data and Methods Description," U.S. DOT, Transportation Systems Center, Cambridge, Mass., 1976.

FIGURE 3
TRANSPORTATION ZONES

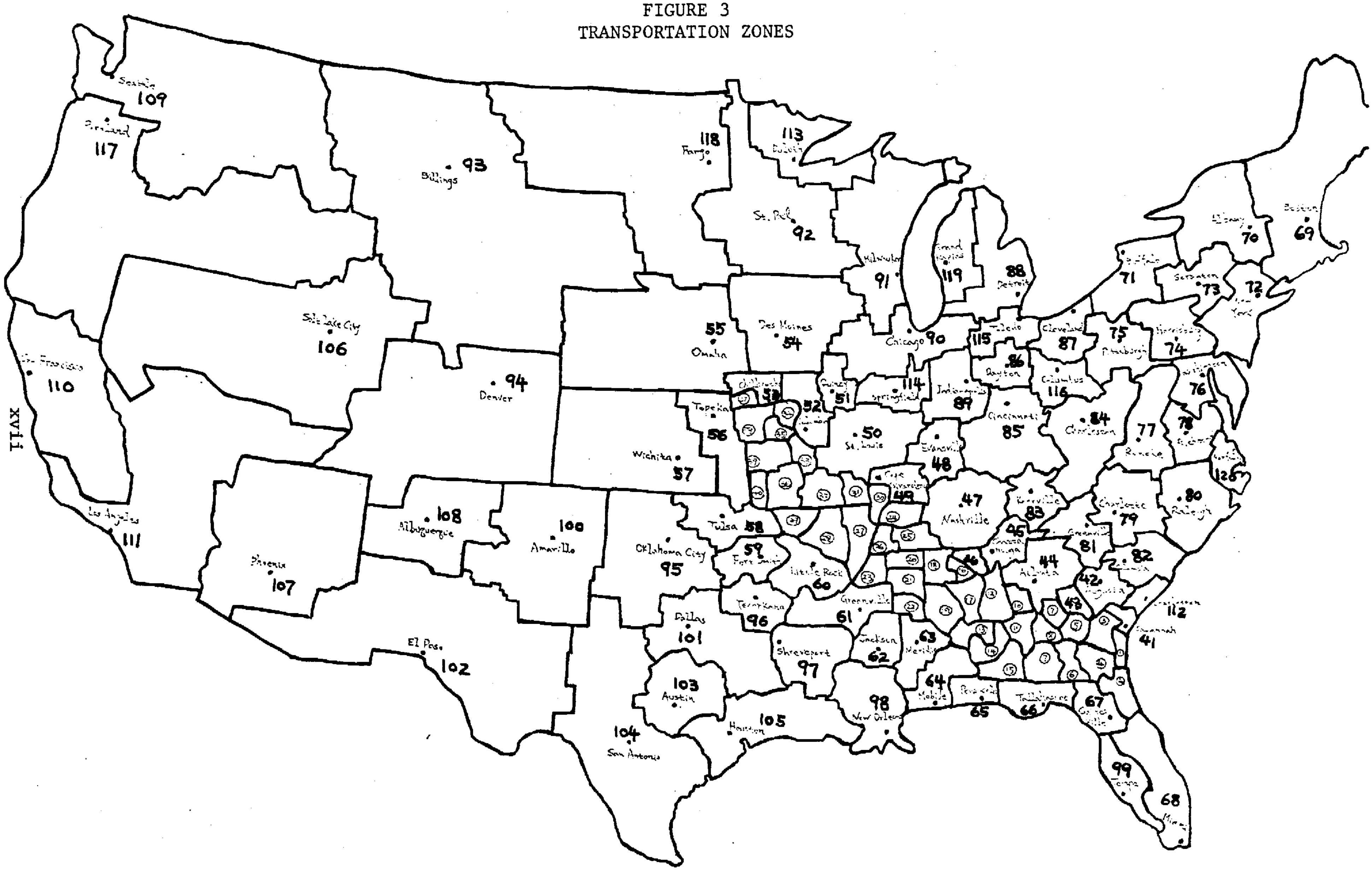

TABLE 2
TRANSPORTATION ZONE CENTROIDS

Multi-State Corridor Zones		External Zones
1. Brunswick, Ga.	41. Savannah, Ga.	81. Greenville, SC
2. Jacksonville, Fl.	42. Augusta, Ga.	82. Columbia, SC
3. Statesboro, Ga.	43. Milledgeville, Ga.	83. Knoxville, Tn.
4. Waycross, Ga.	44. Atlanta, Ga.	84. Charleston, WV
5. Dublin, Ga.	45. Chattanooga, Tn.	85. Cincinnati, Oh.
6. Valdosta, Ga.	46. Huntsville, Al.	86. Dayton, Oh.
7. Macon, Ga.	47. Nashville, Tn.	87. Cleveland, Oh.
8. Cordele, Ga.	48. Evansville, In.	88. Detroit, Mi.
9. Albany, Ga.	49. Cape Girardeau Mo.	89. Indianapolis, In.
10. LaGrange, Ga.	50. St. Louis, Mo.	90. Chicago, Il.
11. Columbus, Ga.	51. Quincy, Il.	91. Milwaukee, Wi.
12. Anniston, Al.	52. Columbia, Mo.	92. St. Paul, Mn.
13. Montgomery, Al.	53. Chillacothe, Mo.	93. Billings, Mt.
14. Troy, Al.	54. Des Moines, Ia.	94. Denver, Co.
15. Dothan, Al.	55. Omaha, Ne.	95. Oklahoma City, Ok.
16. Decatur, Al.	56. Topeka, Ks.	96. Texarkana, Tx.
17. Birmingham, Al.	57. Wichita, Ks.	97. Shreveport, La.
18. Florence, Al.	58. Tulsa, Ok.	98. New Orleans, La.
19. Tuscaloosa, Al.	59. Ft. Smith, Ak.	99. Tampa, Fl.
20. Corinth, Ms.	60. Little Rock, Ak.	100. Amarillo, Tx.
21. Tupelo, Ms.	61. Greenville, Ms.	101. Dallas, Tx.
22. Columbus, Ms.	62. Jackson, Ms.	102. El Paso, Tx.
23. Clarksdale, Ms.	63. Meridian, Ms.	103. Austin, Tx.
24. Dyersburg, Tn.	64. Mobile, Al.	104. San Antonio, Tx.
25. Jackson, Tn.	65. Pensacola, Fl.	105. Houston, Tx.
26. Memphis, Tn.	66. Tallahassee, Fl.	106. Salt Lake City, Ut.
27. Jonesboro, Ak.	67. Gainesville, Fl.	107. Phoenix, Ar.
28. Searcy, Ak.	68. Miami, Fl.	108. Albuquerque, NM
29. Harrison, Ak.	69. Boston, Ma.	109. Seattle, Wa.
30. Sikeston, Mo.	70. Albany, NY	110. San Francisco, Ca.
31. Poplar Bluff, Mo.	71. Buffalo, NY	111. Los Angeles, Ca.
32. West Plains, Mo.	72. New York, NY	112. Charleston, SC
33. Lebanon, Mo.	73. Scranton, Pa.	113. Duluth, Mn.
34. Marshall, Mo.	74. Harrisburg, Pa.	114. Springfield, Il.
35. Sedalia, Mo.	75. Pittsburgh, Pa.	115. Toledo, Oh.
36. Springfield, Mo.	76. Washington, D. C.	116. Columbus, Oh.
37. St. Joseph, Mo.	77. Roanoke, Va.	117. Portland, Or.
38. Kansas City, Mo.	78. Richmond, Va.	118. Fargo, ND
39. Nevada, Mo.	79. Charlotte, NC	119. Grand Rapids, Mi.
40. Joplin, Mo.	80. Raleigh, NC	120. Norfolk, Va.

draws raw materials from available sources, uses labor and capital and incurs costs to produce its product which it ships to existing markets. The model is a geographical one based on the network structure. All economic decisions are cost based.

Industry Analysis. Production costs and raw material requirements per ton of product were developed for each industry group. Production costs include direct labor, indirect labor, energy, capital and taxes. Of these, all but capital and indirect labor are location sensitive. Mean values of component costs and principal raw material requirements were prepared for each industry from Census data. These values constitute the norm from which geographical differences are measured. Direct labor requirements were divided into broad skill categories to reflect the needs of different industries.

Principal producing zones, consuming zones and zone to zone movements were identified for each commodity group from the commodity flow data. These data provided a picture of the distribution pattern for each industry with actual volumes identified for each producing zone. Raw material sources were also identified by equating industry raw material needs with the distribution patterns for the raw material commodities. Due to the complexity of this work, it was completed for only the eight commodities used in the test.

Industry Cost Data. Geographically sensitive component cost data were collected for each industry group for each of its major production zones. Labor data were collected by the different skill categories so that a skill weighted wage could be prepared for each industry group in each producing zone. Raw material costs were based on source production costs or established markets adjusted for differences in transportation costs. Indirect labor and capital costs were assumed to be the same for all locations. Energy and tax costs were taken from state and local data sources. The product of this analysis was a manufacturing cost for each of the major production zones for each commodity/industry group.

Market Analysis. The market analysis was based on the assumption that the principal market share determinant is cost, in this case production cost plus customer service cost. This assumption can be interpreted in a number of different ways:

1. Production facilities are treated as branches in multi-facility

companies. Thus, the parent company can elect to locate and assign markets in accordance with relative costs.

2. Over the long run, the low cost supplier to a market can afford promotional, sales and pricing strategies that will lead to a higher market share than a higher cost supplier.

3. Product quality is very difficult to establish in an objective, quantitative sense and if established, it is difficult to cost.

Market share functions were prepared for each of the eight test commodities. These expressed the market share that a producing zone could expect to achieve as a function of the difference between its market cost (production cost plus customer service cost) and the market cost of the low cost producer.

The introduction of a new producing zone will upset the relationships among existing suppliers to each market. Market shares are readjusted to fit the cost differences among suppliers. If the new producing zone has a market cost that is lower than any supplier that participates in the most costly 25 percent of the market, then the new zone can participate in the market. Its share is determined by the adjusted market share function.

Network Modeling

The network modeling is concerned with developing transportation costs for moving different commodity groups between zone pairs via existing and proposed modal services and via intermodal combinations. The network is defined by the zone centroids, the transportation service arcs connecting pairs of centroids and the transfer activities that occur within centroids. Transportation costs include three measures of transportation service utility - cost, delivery time and delivery time dependability. The three measures are combined into a single cost by estimating perceived values of delivery time and time dependability for each commodity group.

Present Arcs. Initially, separate arcs were identified for each present transportation mode - highway, rail and water. Although the separate arcs were later combined for analytical convenience it is useful to describe the present arcs as originally conceived. Detailed arc listings for each mode are presented in Appendix C.

Network arcs represent the majority of the routes used for interzonal freight movement. Intrazonal movements are not included in the analysis. The variability of zone sizes complicates the problem of arc selection. Within the small Corridor zones, arcs include almost all intercity routes. As zone size increases, the amount of intrazone traffic grows and interzone traffic tends to move toward higher quality routes. Thus for highway arcs, Interstate, Federal Aid Primary, Federal Aid Secondary and State routes are included in arc designations between Corridor zones. In areas remote from the Corridor where zones are large, highway arcs are made up almost exclusively of Interstate routes. In a similar fashion, all through rail routes are included in rail arcs within the Corridor and only principal routes in remote areas. Because of the limited available services, inland water arcs include all waterways with seven foot channel depth or more.

Network arcs are described in terms of length, capacity, mean speed (or mean travel time) and travel time variability. Where two or more parallel routes are combined into a single arc, length, speed and variability describe the higher quality route. The lower quality route serves as additional capacity when the higher quality route becomes congested.

Nodes are associated with loading, unloading and intermodal transfer activities. Each activity has a cost, an expected time and a time variability associated with it for each commodity/industry group.

Present Customer Service Costs. Customer service costs (transportation cost plus cost equivalents for transport time and transport time variability) posed a particularly serious problem. In general, cost data were better than transport time and time variability data. However, cost data left much to be desired.

Many carriers do not know the cost of moving individual shipments over particular routes or through particular terminals. Cost determinations by the ICC (Interstate Commerce Commission) are not regarded highly by many carriers - particularly railroads. After considerable exploration a set of cost equations prepared by H. O. Whitten [8] was modified and used as a basis for the initial cost estimates. These equations, which were largely derived from ICC procedures, provide consistent treatment for rail and highway modes. New costs were generated for water shipments.

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[8] Gill, C. G. and H. O. Whitten, Development of Transport Cost Functions, Herbert O. Whitten & Associates, Annandale, Virginia, 1976.

Transport times and transport time variabilities were also generated by the research team. The results are believed to reflect modal differences with reasonable accuracy. However, there is room for further improvement.

Mode Split. A key requirement for the success of multi-modal or intermodal investigations is the ability to predict the amount of traffic that is likely to select a new transportation option. Such a prediction can only be based on the quantitative characteristics of the mode or intermodal combination, or stated another way, it requires a mode abstract modal split model - one that does not have mode specific coefficients. This step is beyond the capability of existing mode split work, which is all of a mode specific nature.

A mode abstract modal split model was developed from mode choice information included in the NTP commodity flow data [7]. A separate set of coefficients was calibrated for each of the eight test commodities. The equations give estimates of modal share as a function of comparisons between transportation cost, time and time variability for the competing modes. The same coefficients are used for all existing O-D pairs and for pairs that include new transportation services or intermodal combinations.

Network Analysis. Network analysis procedures were devised to (1) load commodity flow data on the network using a shortest path (least utility) criterion, (2) determine transportation costs, time and time variability from all production zones to markets served, (3) search out and identify intermodal routes, and (4) provide evaluation data for use in comparing alternative transportation programs. The network problem was complicated by the need to deal with the movement of 53 different commodity groups over a network containing 120 nodes and 400 arcs. Ultimately 20 separate computer programs were prepared to perform the network analysis and to manipulate the data files. The principal steps in the analysis are:

1. Introduce existing and new arc and node information,
2. Construct a dual-node numbering system for the network with appropriate line haul and transfer arcs,
3. Obtain shortest path trees for each existing origin,

4. Load existing commodity movements,

5. Obtain shortest path trees for candidate new production zones,

6. Determine production costs for candidate zones,

7. Determine market shares for candidate zones,

8. Update commodity movement assignments.

At this time, the network model is not capacity constrained. Non-linear flow impedances that reflect congestion effects would have vastly complicated the model development. However, congestion can be a serious problem and it will be treated in future work. During development, the programs have been kept separate to facilitate error location and to retain flexible use. It is doubtful that a single massive program will ever be needed; however, some future combinations seem likely.

Improvement Analysis

Improvement analysis procedures are still under development. Experience with the Northern Mississippi test has suggested a number of desirable changes. As the research team begins to work with all 40 Corridor zones, all 53 commodity groups and a wide range of transportation improvements, the need for more modifications will become evident. The discussion below summarizes the Northern Mississippi test and suggests directions for future exploration.

Transportation Improvement Programs. Only three transportation improvement programs were explored in the Northern Mississippi test:

1. Improve the highway and rail accessibility of the test zones to the network as a whole,

2. Improve accessibility and upgrade principal highway and rail arcs along the Corridor, and

3. Improve accessibility, upgrade principal highway and rail arcs and provide efficient intermodal transfer terminals at major Corridor nodes.

These programs were selected to illustrate the analytical method; it is not likely that any one represents the best, or even a good solution to the Corridor development problem.

What is needed for future work is an analytical procedure that can postulate and compare large numbers of candidate transportation programs so that the full, complex analysis need be applied to only a few. The nature of this screening process is not known at this time but it may be a heuristic procedure based on a carefully selected set of criteria that set forth tentative transportation requirements.

Development Opportunities. In the Northern Mississippi test each of the eight commodities was tested in each of the four test zones. When the analysis is expanded to 53 commodities and 40 test zones, this approach will be found to be wanting. It seems likely that a simple dominance criterion can be applied to compare alternate zones in terms of market costs at the different markets. Procedures are also needed to reduce the number of commodities tested.

Update Network. The impact of transportation service improvements together with the redistribution of commodity markets among test zones and existing producers results in substantial changes in the traffic moving over different network arcs. In particular, new and improved corridor arcs will carry heavier traffic while parallel arcs and their feeders will carry reduced traffic. In the Northern Mississippi test, traffic on the improved Corridor arcs increased greatly for the second and third alternatives, even before production from the test zones is added.

The process of generating new trees and reassigning traffic flows is an extremely complex one that is expensive in computer time. Two approaches will be pursued to ease this burden:

1. Update the network after the transportation programs have been screened and then for only the most promising program, or
2. Selectively update the arc flows without recomputing the sets of trees.

Both of these and perhaps other approaches will be explored.

Evaluation. There are many different interests that need to consider the relative merits of the different transportation improvement programs and the consequent economic development. These include residents, businessmen and politicians in adjacent zones, state transportation officials, carriers, environmental groups, federal agencies and others. A detailed evaluation scheme has been developed that reflects the viewpoints of the different groups. Specific evaluation criteria have been selected to test economic, fiscal, physical, social, aesthetic and environmental issues. At this time, means have not been devised for aggregating the criteria into one or two measures. This task will be the subject of future work.

Test Results

Although no developmental conclusions should be drawn from the Northern Mississippi test, the results are interesting and encouraging. Initially, market costs for the four test zones appeared to be consistent with market costs for other zones producing the eight test commodities. Using the present transportation services, there appear to be development opportunities for apparel, furniture and electrical equipment. This result is consistent with recent development experience within the zones.

Alternative 1, improved access, would do little to stimulate economic development in the test area, suggesting that the transportation problem goes beyond the issue of access.

Alternative 2, improved access and better line haul service, would stimulate significant expansion beyond the base case in plastic products and lumber, and lesser expansion in other industries.

The addition of efficient intermodal transfer terminals along the Multi-State Corridor (alternative 3) further enhanced the opportunities in the lumber industry, but efficient and economic mode interchange would offer little further stimulus for other industries.

The basic data used in the analysis leave much to be desired. Manipulations of these data introduce further error. One, therefore, needs to view conclusions with some circumspection. Error analysis is inconclusive at this time. However, the reasonable nature of the test results offers encouragement.

Future Research

Although the results of the first year's research are encouraging, much remains to be done. The second year's research will be directed toward improving the structure and the analysis in many important ways. Eight specific research tasks will be undertaken. Each is summarized briefly below.

Task 1: Transportation Modeling

Improve the analytical structure of the Multi-State Network Model, giving particular attention to mode split relationships, intermodal route determination, means for specifying desired transportation improvements, and an evaluation of the network structure. The task will be made up of four distinct subtasks.

1-a. Develop a new set of commodity specific, mode abstract modal split equations for three specific commodity industry groups.

1-b. Develop a new heuristic procedure for identifying near-optimal intermodal route opportunities from among the available routes between origin-destination pairs.

1-c. Develop a new procedure for identifying network arc and node improvements in terms of market share improvement costs and other parameters.

1-d. Test the unbalanced structure of the network for technical and empirical correctness in representing the Multi-State Corridor transportation environment.

Task 2: Economic Analysis

Study the impact of new economic development on the local economies in the Multi-State Corridor and devise a better scheme for estimating the potential market shares of new industries. This task will be made up of three distinct subtasks.

2-a. Expand the economic analysis to include the impact of new industry on non-basic economic activities. Test the analytical approach in a Northern Mississippi setting.

2-b. Develop better cost based, market share estimators for three or more key industry/commodity groups. Expand the procedure to encompass all industry/commodity groups.

2-c. Develop a material flow based method for estimating future activity in the Multi-State Corridor and its impacts on the rest of the country.

Task 3: Industry Structure Analysis

Upgrade the industry structure representations by expanding the number of industry/commodity groups and by improving the representation of basic raw material prices. This task will be performed as three distinct subtasks.

3-a. Test all of the more complex industry/commodity groups and determine whether the analysis can benefit by enlarging the number of groups.

3-b. Develop a market based technique for estimating basic raw material prices at the production or extraction site.

3-c. Estimate the magnitude of potential error reduction associated with different levels of aggregation.

Task 4: Transportation Facility Analysis

Develop new concepts for improved line haul and terminal transportation facilities. This task will be divided into two subtasks.

4-a. Develop at least three concepts for intermodal transfer terminals, taking into account both present equipment productivity and the goals needed for Multi-State Transportation Corridor enhancement.

4-b. Develop two or three new line haul transportation concepts that have the potential to support industries likely to be attracted to the Multi-State Corridor.

The work will include an assessment of the technical feasibility of each concept together with the development of cost and performance parameters that relate to its construction and use.

Task 5: Evaluation Methods

Continue the development of an evaluation methodology by developing an interactive computer program, by using this program to develop weights for use by the different stakeholder groups and by considering the impacts of quality of life criteria. This task will be divided into three subtasks.

5-a. Develop an interactive computer program by which untrained operators can test their value judgements and thereby develop sets of parameter weights.

5-b. Identify and describe the key stakeholder groups that will influence transportation and economic development in the Multi-State Corridor. Devise and execute a means for measuring their viewpoints in quantitative terms.

5-c. Explore quality of life as a parameter of economic development. Develop means for relating levels of life quality to different industry/

commodity groups.

Task 6: Transportation Costing

Improve methods for estimating transportation customer service parameters on network arcs and through intermodal transportation terminals. The parameters include cost, transport time and transport time variance. This task will be divided into four subtasks.

6-a. Develop cost, time and time variance models for highway, rail and waterway modes. Include all facilities, events and procedures that influence parameter values.

6-b. Seek out data services for all model elements.

6-c. Investigate the impact of errors in parameter values.

6-d. Update and improve the first year's procedures for estimating cost, time and time variance.

Task 7: Policy Issues

Extend the investigation of legislative constraints to include the policies of agencies associated with highway, urban mass transportation, and airport facilities. This task will be divided into two subtasks.

7-a. Document the initiation, planning, approving, programming, scheduling, design, and construction activities of agencies concerned with highway, urban transportation, and airport construction. Include key Federal/State interfaces.

7-b. Formulate, evaluate, and compare policy positions that concern funding, management, right-of-way acquisition, construction, operation, and control of multi-mode transportation facilities.

Task 8: Implementation Planning

Devise and compare alternative means for implementing a multi-mode transportation and economic development program for the Multi-State Corridor. This task will consider public and private roles, state and Federal participation. It will establish an initial time table for implementation activities. This task will be divided into four subtasks.

8-a. Establish no fewer than three implementation scenarios. Each will include financial, legislative and administrative assumptions that will describe the implementation environment.

8-b. Identify a set of potential projects and a set of economic development opportunities for each implementation scenario.

8-c. Prepare a procedure for scheduling projects that takes into account the relative impacts of each on the development program, financial requirements and state and Federal transportation programs.

8-d. Explore procedures for coupling private development planning to transportation facility planning.

I. INTRODUCTION

Powerful forces are illuminating the inescapable truth that the United States must reassess its transportation resources and improve both the efficiency and economy by which people and goods are transported throughout the country. Some of the more important forces include:

1. Energy - to attain petroleum self-sufficiency, use of this vital resource must be drastically reduced.
2. Urbanism - social stresses suggest that America may be over urbanized.
3. Quality of life - many individuals are challenging transportation vehicles' contributions to air, water and noise pollution.

There is strong desire in many quarters for a change in the direction of U.S. transportation development. However, the desired change of direction has yet to be identified and the means to accomplish change in so mature an industry are anything but clear. Any abrupt change will undoubtedly work to the disadvantage of powerful industry and consumer groups. A change that is not abrupt may fail to meet the challenge.

The U.S. Department of Transportation (DOT) will play a key role in any action that is taken. DOT is now wrestling with a number of important policy issues that concern future transportation development. These include:

1. Methods to restrict petroleum consumption;
2. The future building of fully access controlled intercity highways (Interstate quality);
3. The future role of the Federal Government in the railroad industry, and
4. The use of slurry pipelines to transport western coal to eastern markets.

No one of these issues can be resolved by itself. Each has far reaching impacts on the future of American industry and on the American standard of living. The challenge is to find a new direction that can provide the same or higher quality transportation than we enjoy today while still meeting stringent energy, urbanism and life quality requirements.

The research described here is a pioneering effort to devise analytical tools that can be used to identify and evaluate promising future strategies.

Objective

The objective of this research is to develop analytical procedures that can quantify the interactions between programs of transportation service improvement and the economic development opportunities that each facilitates. The research is directed toward a specific geographical area: the Multi-State Transportation Corridor that extends from Brunswick, Georgia to Kansas City, Missouri.

The Multi-State Corridor

The selection of the Multi-State Transportation Corridor as the basis for this analysis is no accident. Development of this corridor is actively supported by the Multi-State Transportation System Advisory Board, which is made up of state and local government officials, business leaders and private citizens from each of the eight states through which the corridor passes.

Since 1972, this Board has been active in promoting new multimodal transportation services for the Corridor. As a result of this activity, the research team has received outstanding support from business and government throughout the Corridor. An abbreviated history of the Multi-State Transportation System Board is presented in Appendix A.

The Multi-State Corridor, illustrated earlier in Figure 1, provides an ideal setting for investigating new transportation services:

1. It contains a region of high development potential for which sound early guidance can lead to large future benefits.
2. Transportation services, at present, are limited, creating substantial opportunities for improvement.
3. Sufficient past work has been done to simplify data collection.
4. The corridor is largely undeveloped and hence it presents a relatively simple environment for economic modeling.
5. The linear nature of the area permits consideration to be restricted to relatively simple networks of new transportation services.

The Multi-State Corridor is approximately 1200 miles long and nominally 100 miles wide. It includes parts of eight states - Florida, Georgia, Alabama, Mississippi, Tennessee, Arkansas, Missouri and Kansas. It contains four major metropolitan areas - Jacksonville, Birmingham, Memphis and Kansas City - and a handful of cities with populations greater than 100,000 people (e.g., Columbus and Macon, Georgia, Montgomery, Alabama, and Springfield, Missouri). For the most part, the area is rural. A large fraction of the population is engaged in marginal agriculture. The rural populations have the lowest per capita income of any part of the United States. The Corridor has some natural resources, notably coal, iron ore, and timber. It also has abundant water resources. The terrain is gentle, having few major geographic obstacles. It includes the base of the Appalachian chain and the eastern Ozarks.

There has been some development in the Multi-State Corridor. Just to the north, under the stimulus of the space program, Huntsville, Alabama, has blossomed from an agricultural marketing center to a major research and engineering center. Elsewhere new facilities - principally textile - have been located in rural areas to take advantage of low wage rates and abundant unskilled labor.

The Multi-State Corridor is a natural site for new multimodal development. New transportation facilities can be built without the citizen protests that accompany most major projects in urban and industrialized areas. Economic development is desperately needed to improve the lives of an impoverished population. In addition, the predominantly rural corridor provides an opportunity to test whether substantial populations can be supported in rural areas without the necessity of migrating to major urban areas and contributing to a worsening of urban problems.

Traffic volumes in the Multi-State Corridor are not high. No Interstate highway runs the length of the Corridor although a number cross it. With few exceptions, longitudinal roads are of moderate to poor quality. A main line of the Frisco Railroad extends from Kansas City to Birmingham and a secondary main line of the Seaboard Coast Line Railroad continues to Jacksonville. Through freight service is available. The area is crossed by the major waterways of the Southeast, including the Chattahoochee/Apalachicola Rivers, the Tennessee-Tombigbee project, the Tennessee River, the Mississippi River, and the Missouri River. Ocean port facilities are located at Brunswick, Georgia, and Jacksonville. Major river ports are situated at Columbus, Georgia, Birmingham and Decatur, Alabama, Memphis, and Kansas City.

Scope

The task of forging new directions in Transportation is much too large to undertake in a single step. It needs to be scaled down if any real progress is to be made. This initial effort focuses on the interaction between transportation service characteristics and economic development opportunities. The work is therefore restricted to freight transportation. However, the full spectrum of freight transportation services is subject to analysis. This includes both present modes - highway, rail, water and air - future modes that may be developed, and intermodal combinations of present and future modes.

The thesis of the research is that transportation services can and should bear a unique relationship to the facilities and individuals that they serve. There is no universal transportation system. New transportation developments should be selected to meet the specific needs of the area to be served. Thus the selection of facilities requires a prior knowledge of developmental goals which are then translated into transportation requirements.

The process is of necessity a complex one. In particular, the knowledge, effort and money needed to perform specific location studies suggests that one should not launch into detailed planning without a high probability of success. What is apparently called for is a screening process by which the problem can be viewed in several levels of detail, with each level narrowing the scope of study for successive work.

This research is viewed as the first of a succession of screening steps. The product of this work is an analytical method that can identify potentially attractive transportation development opportunities in terms of the industrial development that each can stimulate. The transportation services are identified in terms of mode, capacity, and approximate route. Details concerning alignment, design, points of ingress and egress and specific technology are left for later study. Development opportunities are described in terms of industry group, approximate location, approximate markets, and approximate size. Details concerning specific products and activities, raw materials, specific location, and corporate ownership are left to others.

The first year's research is concerned only with basic industry - that is, new facilities that will produce goods or services that are largely exported from the producing area to national markets. The total market for each industry group is assumed to remain fixed with respect to size and location. Thus, new facilities built in the Multi-State Corridor must compete with existing facilities for existing markets. Market competition among suppliers is conducted on the basis of cost. Product quality is assumed to be equal. This assumption, in effect, treats new facilities as though they are branch plants to which higher management has the authority to allocate production on the basis of cost.

Secondary, nonbasic, or multiplier effects of new facilities are not considered at this time nor are the development of new market demands induced by the establishment of new facilities. Although both issues are of immense importance to the development of the Multi-State Corridor, consideration of these issues is postponed to a later date.

The industrial markets used to test new development opportunities are restricted to the 48 contiguous United States. Alaska, Hawaii, and Puerto Rico are grossly lumped with overseas markets for the purposes of the present work. At a later time, overseas and export opportunities will be examined.

Although the research is concerned with future transportation services and future economic development, the forecasting dimension of the work has not yet been introduced. Sufficient data problems have been uncovered in developing the analytical procedure that the addition of future uncertainties could do little but further cloud the problem. Therefore, the first year's work is based on 1975 transportation, economic activity and costs. This constraint will be removed in subsequent work.

The research is heavily concerned with intermodal transportation movements - the enroute transfer of shipments between transportation modes to facilitate faster, more economical and more dependable delivery. To properly consider such combinations, it is necessary to identify and compare large numbers of potential intermodal routes with the same efficiency used to identify single mode routes.

The research will eventually consider a large number of transportation alternatives that include both new services and new combinations of services. This is also a new and unique approach. Many others have purported to examine new and unique transportation services. However, in most analyses all but the most conventional transportation services are dismissed with little justification. One wonders how many are dismissed simply because they are hard to deal with. It is important not to dismiss any services on the basis of rudimentary analysis or "instinctive adverse reactions." Because a spectrum of transportation needs requires a spectrum of transportation services, it is necessary to deal with combinations of complementary services. Thus, what the Multi-State Corridor needs is not the one "best" service but the best set of services that jointly meet the needs of all. To find this set, alternative transportation services will be assembled into programs, each of which represents a complete transportation strategy for the Multi-State area. Programs will be evaluated and compared in terms of complex criteria that include traffic volume, economic development, user benefits, employment, potential profit, and others. Specific environmental and public acceptance issues will not be addressed at this level of analysis.

Literature Search

The Multi-State University Consortium is not the first group to attempt to understand the relationships between transportation and other activities. Leontief [9] in his development of the input-output model provided the basis for most recent work. Harris [10] used this approach to construct a very detailed model for comparing highway alternatives. He expresses the quality of transportation service in terms of cost between origin and destination points. Routing is prescribed as part of the cost determination. Harris' work does not address either multimodal or intermodal transportation. Polenske [11] has effectively applied input-output analysis to regional planning in a framework that includes transportation costs. Finally, Wendt [12] has developed a procedure, including input-output analysis, for developing relationships between transportation quality and land use. He too considers but a single mode - highway.

The state of the art in network modeling is well demonstrated by the set

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[9] Leontief, W. W., Input-Output Economics, Oxford University Press, New York, 1966.

[10] Harris, Curtis C., Jr., Regional Economic Effects of Alternative Highway Systems, Ballinger, Cambridge, Mass., 1974.

[11] Polenske, K. R., C. W. Anderson and M. M. Shirley, A Guide for Users of the U.S. Multiregional Input-Output Model, Massachusetts Institute of Technology, Dept. of Urban Studies and Planning, Cambridge, Mass., 1974.

[12] Wendt, P. F., Transportation Planning Land Use Studies - the State of the Art, Research Report #5, Georgia DOT, Atlanta, Georgia, 1975.

of models prepared by U.S. DOT [13]. These models, which have been applied to a wide range of urban, intercity and freight transportation problems, use shortest path algorithms to identify the most desirable routes between origins and destinations. These algorithms effectively preclude intermodal transportation services. Ellis [14] attempted to assess multimode transportation needs in the Multi-State Corridor using conventional models. He found it necessary to project future economic development from a combination of past history and existing estimates. Although three different projections were used, they produced very similar results. This approach could not include potential future breakthroughs. Ellis' multimode consideration was limited to the study of seven alternative transportation improvements - four highway and three rail. Only the third rail alternative included intermodal features and then only between highway and rail. This alternative was treated as a single mode that limited highway movement to pick up and deliver. More detailed consideration of intermodal and multimodal transportation services was effectively prevented by the size and complexity of the computer programs used in the analysis.

The present work focuses on a less detailed economic model than input-output analysis would provide and a more comprehensive consideration of the network problem. By this means economic breakthroughs are identified and the intermodal problem is more effectively addressed.

The first year's research has been devoted to developing a complete framework for dealing with the analytical problem. In the process of maintaining a global perspective, it has been necessary to give short shrift to some highly technical and challenging problems - notably the mode split and market share models. Subsequent work will deal with these problems to the depth that they require. Some data used in the analysis leave something to be desired. Although the best available comprehensive sources have been used, there is much room for improvement. Finally, the analytical method has been tested for only a small area, Northern Mississippi, and for only eight commodity groups.

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[13] Dial, Robert B., "Urban Transportation Planning System: Philosophy and Function," Transportation Research Record, No. 599, 1976.

[14] U.S. DOT, Multi-Modal Transportation Feasibility Study of the Brunswick, Georgia to Kansas City, Missouri Route, U.S. Govt. Printing Office, Washington, D.C., July 1977.

No telling conclusions can be drawn from such limited work. More comprehensive investigations are needed before meaningful conclusions can be drawn about economic opportunities or transportation needs for the Multi-State Corridor.

Report Organization

This report presents the results of the first year's work. It is descriptive in nature because no conclusions have yet been drawn. That task will come at a later time. The report is intended to familiarize the reader with the problem that has been addressed, the approaches that have been followed, the methods that have been selected and the shortcomings that have been found.

The Executive Summary presented an overview of the analytical process that is intended to both summarize the results and to integrate the subjects that are presented in detail later. Chapter II, Legal and Administrative Considerations, stands alone. It reports on the substantial legal and administrative barriers that must be overcome before multimodal facilities can become a reality. The other chapters deal with the development of the analytical model and its testing in the Northern Mississippi setting.

II. LEGAL AND ADMINISTRATIVE CONSIDERATIONS*

The legal and organizational structures of Federal and state governments are not favorably disposed toward the construction and operation of multimode transportation facilities. Prior to the 1935 Highway Act, it would have been possible to create a multimodal organization and, in fact, some organizations did provide multimodal and intermodal services. However, the 1935 act prohibited railroads from future ownership of motor carriers (and subsequently water carriers) and focused on intermodal competition which has been the theme of transportation development since that time.

The formation of the Federal Department of Transportation (DOT) in 1967 brought together agencies that represent a variety of transportation interests. These were assembled into a structure that stresses modal unity and discourages cross-modal cooperation. In addition, the continuation of past funding programs and the strong vested interests representing mode competition have prevented effective cooperation across modes. State transportation departments are still heavily dominated by highway activity and have few personnel and scant funds available for use with other modes.

Federal Agency Interest

Transportation is so pervasive that, in one form or another, it touches almost all units of government. In the Federal Government, there are no less than 24 agencies, inside and outside of DOT, that have a primary interest in transportation. These agencies and interests are summarized in Table 3.

In the aggregate, the 24 agencies of Table 3 are responsible for planning, evaluating, approving, financing, and regulating a wide range of transportation projects and transportation services [15]. One technique for presenting the complex federal role is to display the different agency interests in terms of nine key functions - planning, financing, environmental review, design, construction, operation, maintenance, safety and regulation - for the seven principal modes - highway, rail, inland marine, ocean marine, air,

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*The material in this chapter summarizes the Task 1 report prepared by Dr. Stanley J. Hille and Mr. Edward R. Bruning [1].

[15] General Services Administration, Office of the Federal Register, <u>U.S. Government Manual</u>, U.S. Govt. Printing Office, Washington, D.C.

TABLE 3
TRANSPORTATION INTERESTS OF FEDERAL AGENCIES

Agency	Interests
U.S. Department of Transportation	
Office of the Secretary (OST)	Transportation analysis, finance, organization and implementation from a policy making viewpoint
U.S. Coast Guard (USCG)	Navigation, marine environmental safety, marine safety, search and rescue, icebreaking, port security, Great Lakes pilotage, marine traffic monitoring
Federal Aviation Administration (FAA)	Airspace navigation and usage, air traffic control, airport financial assistance
Federal Highway Administration (FHWA)	Highway design standards, highway safety standards, highway finance, highway system design, research, testing, hazardous material movement
Federal Railroad Administration (FRA)	Railroad policy, safety, financial assistance, planning, research, Alaska Railroad
Urban Mass Transportation Administration (UMTA)	Equipment development and standards, financial aid, demonstration projects, research and planning
National Highway Traffic Safety Administration (NHTSA)	Motor vehicle and driver safety analysis, vehicle inspection procedures, safety standards, national speed limit
Materials Transportation Bureau (MTB)	Hazardous material transportation regulations, pipeline safety, finance state safety programs
St. Lawrence Seaway Development Corp. (SDC)	Operation and maintenance of U.S. portion of St. Lawrence Seaway
Interstate Commerce Commission (ICC)	Regulate interstate surface transportation services, routes, rates, combinations of common carriers, economic analysis, rail services planning

TABLE 3 (CONT.)

Agency	Interests
Federal Maritime Commission (FMC)	Regulates waterborne foreign and domestic offshore commerce, coastal water pollution regulation
Appalachian Regional Commission (ARC)	Planning, financial aid, design review, environmental review for developmental highways
Civil Aeronautics Board (CAB)	Regulates civil air transport routes, rates, combinations of common carriers, financial aid
Federal Power Commission (FPC)	Regulates interstate transport of electric power and natural gas, including routes and rates
National Transportation Safety Board (NTSB)	Accident investigation, regulates accident reporting, hazardous material transportation
Environmental Protection Agency (EPA)	Reviews environmental impact statements, sets and enforces standards, research, technical support, financial aid
Department of Energy (DOE)	Research, coordination on energy matters
U.S. Forest Service (USFS)	Designs, constructs, maintains roads in national forests
U.S. Army Corps of Engineers (COE)	Designs, constructs, maintains harbors and inland waterways and pollution abatement works, planning and analysis
U.S. Maritime Administration (MA)	Ship construction and operation financing and subsidy, research, development and education
Architectural and Transportation Barriers Compliance Board (A&TBCB)	Assure compliance with federal standards for the handicapped
Tennessee Valley Authority (TVA)	Constructs, operates and maintains waterways and power generation and distribution facilities, regional planning

TABLE 3 (CONT.)

Agency	Interests
Bureau of Outdoor Recreation (BOR)	Review transportation impacts on wilderness areas, planning
National Parks Service (NPS)	Constructs and maintains roads and transportation services in national parks
General Services Administration (GSA)	Owns and operates vehicle fleets and maintenance facilities

pipeline and urban. This display is presented as Table 4. Some modes, notably highway and inland marine have multiple coverage of most interests. The interfaces among these agencies are generally geographical, e.g. the SDC and TVA are concerned with specific regions while the Corps of Engineers' outlook is more universal. Interfaces, other than planning and environmental review, tend to be well defined. For example, in the area of pipeline regulation, the ICC is concerned with common carrier pipeline companies while the FPC is concerned exclusively with natural gas pipelines.

It is not possible to present a uniform treatment of federal and state participation in the planning and implementation of different modal facilities. The discussion to follow leans heavily on highway practice because highway procedures are both larger and more fully developed than procedures for other modes. Particular attention is paid to practices that are favorable to multimode development and practices that pose particular problems.

Planning

Transportation planning takes a variety of forms and occurs in a variety of places. On the Federal level, no less than 14 agencies are concerned with some type of transportation planning. Most of these agencies are mode specific, e.g. FHWA, FRA, UMTA, FAA, and many are region or project specific, e.g., SDC, TVA, ARC, USFS. Only the Office of the Secretary of Transportation has a charter that is broad enough to encompass multimode and intermode planning. Except for region specific agencies, federal planning is on a policy or general guidance level. Specific planning is performed at a more local level by government or industry.

Highway Planning

The highway statutes specifically delegate the authority to plan, establish, improve, and regulate highways to the appropriate state highway authorities. With the express constitutional power to build roads, the Congress has the authority to dictate the terms and conditions under which highway construction is carried out. According to 49 CFR [16], the Secretary of Transportation is authorized to carry out the law according to the highway statutes. In addition, the Secretary is authorized to delegate authority to the Federal

[16] Code of Federal Regulations, U.S. Govt. Printing Office, Washington, D.C.

TABLE 4
FEDERAL AGENCY TRANSPORTATION INTEREST RELATIONSHIPS

TRANSPORTATION FUNCTIONS	TRANSPORTATION MODES: HIGHWAY	RAILROAD	INLAND MARINE	OCEAN MARINE	AIR	PIPELINE	URBAN
PLANNING	OST, FHWA, DOE, USFS, NPS, GSA, ARC	OST, FRA, DOE	OST, SDC, DOE, COE, TVA	OST, MA	OST, FAA, DOE		OST, UMTA, DOE
FINANCING	GHWA, USFS, NPS, GSA, ARC	FRA	SDC, COE, TVA	MA	FAA, CAB	MTB	UMTA
ENVIRONMENTAL REVIEW	FHWA, EPA, BOR, ARC	EPA, BOR	EPA, BOR	EPA	EPA, BOR	EPA, BOR	UMTA, EPA
DESIGN	FHWA, USFS, A&TBLB, NPS, ARC	A&TBCB	SDC, COE, TVA	MA	A&TBCB		UMTA, A&TBCB
CONSTRUCTION	USFS, NPS		SDC, COE, TVA				
OPERATION	GSA	FRA	SDC, TVA		FAA		
MAINTENANCE	USFS, NPS, GSA	FRA	SDC, COE, TVA				
REGULATION	ICC	ICC	ICC	FMC	CAB	ICC, FPC	
SAFETY	FHWA, NHTSA, NTSB	FRA, NTSB	USCG	USCG	NTSB	MTB	UMTA

Highway Administration for the development of the Federal-Aid Highway and Interstate Systems. In 23 CFR, 1.3, the FHWA is required to cooperate with the states, through their respective highway departments, in the construction of the Federal-Aid System. Each state highway department is authorized, by the laws of the state, to make final decisions for the state in all matters relating to contracts and agreements for projects which may be needed in order to comply with Federal laws. Thus, the state highway departments, in effect, perform the actual planning and development functions for all Federal-Aid and Interstate Highway projects.

The FHWA specifies additional criteria that planning agencies must adhere to:

1. Proper channels of communication must be observed. When the state highway department begins considering an improvement using FHWA assistance, the regional A-95 clearinghouse must be contacted so that all agencies will have the opportunity to present their views. The regulation, found in Office of Management and Budget (OMB) Circular No. A-95, furnishes guidance to federal agencies for cooperation with state and local governments in the evaluation, review, and coordination of federal assistance programs.

2. To assure that state highway officials cooperate with cities in the development of long-range highway plans and transportation programs, any plan for a Federal-Aid highway project that affects transportation in a city must include public hearings concerning the economic and social effects of the plan.

3. Some special provisions appear. A proposed project within the Appalachian region, as defined in section 403 of the Appalachian Regional Development Act of 1965, cannot be approved by the Secretary of Transportation until the Federal Co-Chairman of the Appalachian Regional Commission has been consulted. A proposed project within an economic development region as defined in Title V of the Public Works and Economic Development Act of 1965, cannot be approved until the Federal Co-Chairman and the Secretary of Commerce have been consulted.

4. As soon as the plans for a project have been approved, the Secretary of Transportation enters into a project agreement with the state

highway department concerning the construction and maintenance of the project. The state highway department is given authority to make the necessary arrangements or agreements with the appropriate local officials where a part of the project is to be undertaken by a local subdivision of the state.

The highway statutes give the state highway department responsibility for a periodic statewide needs study [17]. Representatives from the highway department are required by law to work closely with local government and groups throughout the state.

To supplement the efforts of the state highway department in identifying the social, economic and environmental effects of transportation projects the statutes specify procedures for contacting the Federal agencies identified in Table 3. The agencies are requested to give the highway department their views and comments concerning the improvement, especially with respect to the social, economic, and environmental impacts of the improvement. However, formal agreements with these agencies are not required.

The Federal-Aid Highway Act of 1962 requires that all urbanized areas have a continuing comprehensive transportation planning process executed cooperatively by states and local communities. Recent congressional actions require that the urban transportation planning process be multimodal. This includes mass transportation, airports and airways, railroads, pipelines, and water transportation, but only within urban areas.

Section 143 of the Federal Highway Act of 1976 requires that the public officials of the jurisdictional governing body where the project is located be consulted about highway projects in urban areas.

Oftentimes a project will traverse an area under the control or management of another agency, and a Memorandum of Understanding must be executed by the Highway Department or the FHWA and that agency.

Planning for Other Modes

Federal agencies have also been concerned with planning for airports and waterways. The FAA has a comprehensive airport planning program whereby states are required to prepare state, regional and local airport plans as a condition for receiving financial assistance. National planning is performed

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[17] United States Code, U.S. Govt. Printing Office, Washington, D.C.

by the FAA. Airport planning also carries requirements for A-95 review, environmental impact statements and public hearings.

The Corps of Engineers performs waterway planning on a formal basis. Extensive traffic analysis and evaluation is performed to provide economic support for new projects. Environmental impact statements are prepared and public hearings are held for all projects prior to implementation. The Corps' activities are limited to the waterways themselves. They dredge channels, drive bulkheads and build locks but do not erect port facilities. The latter is a state, local or private function.

Until recently, rail planning was the exclusive domain of the private railroads. With the passage of the 3R and 4R acts, the FRA is becoming more heavily involved in rail planning. To date, this has largely been restricted to studies of industry structure, the evaluation of little used lines, and the planning of the U.S. Railway Association (Conrail). The extent of future activities is not clear at this time.

The Urban Mass Transportation Administration has become heavily involved in non-automotive urban transportation planning through its programs of demonstration, capital and operating grants. The paucity of funds as compared with requests has placed UMTA in a key evaluation position. Requirements exist for A-95 review, environmental impact studies and public hearings.

With establishment of the U.S. Department of Transportation in 1967, efforts were begun to bring about coordination of the individual modal planning programs. Beginning in 1972 with the publication of its first National Transportation Study, DOT has embarked upon a program of assessing the needs in each transportation functional area.

The legislative beginning for an intermodal coordinating mechanism was provided by the 1962 Highway Act through its requirements in Section 134 for comprehensive urban transportation planning processes in each urbanized area. This process today includes highway planning, transit planning, planning for all parking and intercity terminal facilities, and with the passage of the 1973 and 1976 Highway Acts, railroads, airports, and waterways. However, typically the portion of the planning process funded by FHWA has stressed highway planning while UMTA funding has stressed transit. Thus, imbalances in the planning process are observed today.

In 1973, the Secretary of Transportation formally established intermodal planning groups in the ten Standard Federal Regions. These groups were composed of representatives of the Coast Guard, Federal Aviation Administration, Urban Mass Transportation Administration, the Federal Railroad Administration, and the regional representatives. The purpose of these groups is to promote intermodal planning, unified work programs, and the recognition of a single agency in each metropolitan area for coordinating transportation planning.

Thus, the institutional structure for comprehensive and coordinated intermodal transportation planning exists. The present challenge is to initiate use of this structure and to organize transportation planning at the state and local level to best facilitate coordination with the planning activities of the federal agencies.

State Transportation Planning

The traditional form of organization at the state level is a highly decentralized one, in which numerous autonomous agencies operate independently, with each agency responsible for a single, or small number of transportation modes (see Table 5). The states of Arkansas, Alabama, and Mississippi have transportation organizational structures that fit this traditional mold. These organizations developed before there was widespread recognition of the need for interaction among the modes.

The state role in transportation has been changing over the last few years for Florida, Georgia, Tennessee, and Missouri as state Departments of Transportation have been created. These new organizations combined numerous previously autonomous agencies, each of which had a relatively narrow responsibility.

The modes of transportation and the transportation related activities with which most state DOT's are concerned are highways and highway development, aviation and airport development, railroads and rail preservation, water transport, pipelines, motor vehicles, safety, and regulation. All the DOT's include highways among their responsibilities, except Missouri, reflecting that DOT's are, in terms of budgets, reorganized highway departments. A second area of commonality among the four state DOT's is the absence of pipelines as a transportation mode within their planning domain. Almost as uniformly, the state DOT's reviewed for this study have not been given regulatory responsibility.

TABLE 5
STATE PLANNING AGENCIES AND FUNCTIONS

State	Comprehensive State Planning Agency	A-95 Review Agency	Intra-State Trans. Regulation	TRANSPORTATION MODAL PLANNING								Environmental
				Highway	Rail	Urban	Port	Inland Water	Air	Pipeline	Multi-Modal	
Alabama	Alabama Development Office (ADO)	ADO	Alabama Public Service Commission	State Highway Dept.	-	-	Alabama State Docks		Dept. of Aeronautics	—	—	Environmental Health Admin.
Arkansas	Arkansas Office of Planning (AOP)	AOP	Arkansas Transportation Commission	Arkansas Highway & Transp. Dept.	-	AH&TD		Arkansas Waterways Comm.	Dept. of Aeronautics	—	AH&TD	Environmental Health Service
Florida	Division of State Planning (DSP)	DSP	Florida Public Service Commission	Florida DOT	Florida DOT	Florida DOT	Florida DOT	Florida DOT	Florida DOT	—	Jacksonville Area Planning Board	Dept. of Pollution Control
Georgia	Bureau of State Planning and Community Affairs (BSPCA)	BSPCA	Georgia Public Service Commission	Georgia DOT	Georgia DOT	Georgia DOT	Georgia Ports Assn.	Georgia DOT	Georgia DOT	Georgia DOT	Georgia DOT	Div. of Environmental Protection
Mississippi	State Legislature	Federal-State Programs Office	Mississippi Public Safety Service Commission	Miss. Highway Dept.	Local	Local	Local		Miss. Aeronautics Comm.			Air & Water Pollution Control Comm.
Missouri	Office of Administration	Div. of Budget & Planning	Missouri Public Service Commission	Missouri Highway Dept.	Missouri DOT	Missouri DOT	Missouri DOT	Missouri DOT	Missouri DOT	—	—	Dept. of Natural Resources
Tennessee	Office of State Planning	Office of Urban & Federal Affairs	Tennessee Public Service Commission	Tennessee DOT	Tennessee DOT	Tennessee DOT	Tennessee DOT	Tennessee DOT	Tennessee DOT	—	—	Bureau of Environmental Health

Sources: Alabama Code, Title 55, Sec. 373 (6) (a) (5); Arkansas Code, Title 9, Sec. 301, Title 76, Sec. 2203; Florida Code, Title 23, Sec. 011; Georgia Code, Title 49, Sec. 2[illegible]01; Mississippi Code, Title 65, Sec. 5; Missouri Code, Title 251, Sec. 190; Tennessee Code, Title 4, Sec. 1003

Finance

Federal, state and local governments all have important financial responsibilities for transportation. The Federal Government provides major financial assistance for highways, airports, and waterways and urban public transportation systems. A modest program is underway for supporting low density rail lines. State governments provide the local share for most highway projects and local governments furnish matching funds for public transit.

Federal Role

Over the last twenty years, Federal transportation aid programs have become increasingly diversified. Categorical grants have proliferated; formula grants have been introduced and modified; Federal matching ratios have increased steadily; grant recipient eligibility has broadened; pass-through provisions to local governments have been introduced; functional earmarking of trust fund allotments has increased; and administrative requirements for receipt of aid have been instituted. All of these developments have increased the complexity of the aid program structure. The DOT is now contemplating a single bill to cover the financing of all transportation.*

Highways

The major funding acts for highway projects are:

1. Federal Highway Act of 1956. This Act established the Highway Trust Fund to finance Federal contributions to the ABC and Interstate systems, and raised the Federal matching share for Interstate construction to 90 percent. It also apportioned trust fund money to the different states according to their relative proportion of Federal aid highway construction costs.

2. Highway Beautification Act of 1966. This Act introduced several categorical grant programs. Up to 75 percent of the highway beautification program was made eligible for financing from the Highway Trust Fund.

3. Federal Highway Act of 1968. This Act established two more allocations within the Highway Trust Fund, one provided $400 million for

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*Secretary of Transportation in a speech before the American Public Transportation Association in Atlanta, Ga., October 12, 1977.

an urban traffic management program (TOPICS) and the other authorized a revolving fund for right-of-way acquisition.

4. Federal Highway Act of 1970. This Act authorized $200 million for a Federal aid urban system program, and authorized the financing of exclusive bus lanes and fringe parking lots from the Highway Trust Fund.

5. Federal Highway Act of 1973. This Act revised the highway aid program. It increased Federal aid authorizations for the non-interstate portions of the Federally aided highway system, expanded the road mileage eligible for urban system aid, and provided for state earmarking of urban system funds. The Act permitted Highway Trust Funds to be used for certain mass transit purposes. It earmarked 0.5 percent of available Federal highway aid for distribution to metropolitan officials for transportation planning, and instituted several new categorical grant programs.

The Highway Trust Fund is used to reimburse the states for expenditures on Federal-Aid highways. This fund was established by the Highway Revenue Act of 1956 as a mechanism to finance the highway program. The principal revenue source of the Trust Fund is the motor fuel tax of 4 cents per gallon, which accounts for about two thirds of the revenue. There are also taxes of 6 cents per gallon on motor oil, 10 cents per pound on highway vehicle tires and inner tubes, and 5 cents per pound on retread rubber. There is an annual use tax of $3 per 1,000 pounds of gross vehicle weights on heavy trucks and buses (over 26,000 lbs.), a ten percent sales tax on new trucks, buses, and trailers, and an eight percent tax on truck and bus parts and accessories.

The highway statutes specify a procedure for distributing funds to the states for highway construction. The first step is the authorization of funds for the programs in accordance with the Federal-Aid Highway Acts enacted by Congress every two years. Programs thus granted "contract authority," are apportioned among the states according to formulas prescribed by law. Other funds are divided among the states administratively as allocations. Once apportioned, the funds are available for use by the states for a total of 4 years. Programs that are authorized under "contract authority" are different from those in which an authorization must be followed by a congressional appropriation of "budget authority." Some of the smaller and discrete highway programs are financed from general funds, and a subsequent appropriation of "budget authority" is required before obligations can be incurred. A few examples are: Highway Beautification, Territorial Highways, Safer Off-System Roads, Off System, and Rail-Highway Crossings.

Controls have sometimes been placed on highway spending. These limitations, called impoundments, are actions to prohibit or delay the obligation of contract authority granted by Congress. Presently, there are three types of impoundments related to the highway program: deferrals, recessions, and legislative limits on obligations.

Airports

The Federal Airport Act of 1946 established a formula grant with 75 percent apportioned to states on a population-area basis and the remainder disbursed on a discretionary basis. Legislation in 1961 and 1964 followed the same pattern for earmarking funds for general aviation, airport construction, and it increased the Federal share for navigational aids. It also required airport zoning as a pre-condition for receipt of Federal airport aid.

The 1970 Airport and Airway Development Act established the Airport Trust Fund for financing airport development. This program provides aid for both airport construction and planning. It includes a revised formula allotment to expand secretarial discretion to take fuller account of increasing and shifting air traffic volumes.

Water

Marine navigational and port development projects are performed by the U.S. Army Corps of Engineers upon request by state and local governments. The Corps provides such assistance free of charge up to a specified limit, and the local governments provide necessary assistance which usually involves securing rights-of-way for Corps work.

Rail

Railroad financial aid is all of recent origin. In 1970, Congress enacted the Rail Passenger Service Act that created the National Rail Passenger Corporation (AMTRAK), an independent body, to manage the intercity rail passenger routes by contracting for service with existing railroads. The bankruptcy of the Penn Central Railroad and other northeastern companies prompted the passage of the Regional Rail Reorganization Act of 1973 whereby these bankrupt railroads were reorganized into the Consolidated Rail Corporation (CONRAIL). The Act provided about $1.5 billion in loan guarantees and also provided for Federal loans to state and local transportation authorities that wish to subsidize rail lines that would otherwise be abandoned. The Railroad Revitalization and Regulatory Reform Act of 1976 directed the Secretary of Transportation to take a comprehensive look at Federal assistance policies for all modes of transportation and to formulate a coordinated Federal transportation assistance program. Title V of the Act created a temporary fund to improve and modernize rail facilities.

Public Transportation

The Urban Mass Transportation Act of 1964 established a two-part grant program for mass transit financing. The first part provided capital grants and loans to eligible public agencies subject to one-third local matching. The second program provided a mass transit research and development grant program, with a variable matching ratio.

UMTA amendments in 1968 and 1970 permitted private contributions to meet the non-Federal share of UMTA goals. The 1970 Act also stipulated funding limitations - no more than 12.5 percent to be spent in any one state - while at the same time earmarking 15 percent of UMTA authorizations to be spent at the discretion of the Secretary of Transportation. Discretionary categorical grants were also established to help meet the transportation needs of the handicapped and the elderly.

The National Mass Transportation Act of 1974 provided funds for operating as well as capital expenditures. A formula distribution program based on population and population density allows Federal matching funds of up to 80 percent for capital purposes and up to 50 percent for operating purposes.

State Role

State governments generally finance their transportation responsibilities from a combination of transportation-related taxes, intergovernmental aid, user charges, and bond issuance. In most states highway funds are provided by a per gallon tax on motor fuels, licensing fees for vehicles, and several minor fees relating directly to the vehicle and its use, such as registration fees, in-transit fees, auto division fees, and oversize/overweight fees. Numerous legal provisions affect the use of gasoline tax revenues. Three states, Alabama, Georgia and Missouri, have constitutional provisions that prohibit the diversion of revenues from fuel taxes for non-highway purposes.

State use of revenue sharing funds for transportation purposes has been limited. Arkansas indicated that they would use more than half of their revenue sharing for highway transportation while Missouri has used revenue sharing funds for mass transit purposes. Experience with revenue sharing does not indicate that transportation has been a top priority item for most state governments.

Tennessee has no restrictions on the issuance of debt. The remaining six states in the Multi-State Corridor have either a specified constitutional limitation on borrowing or have to incur debt through a statewide referendum. Alabama and Georgia have the strictest limitations - limitations on the absolute dollar amount of debt a state can incur and accompanying requirements for statewide referenda before the bond issue.

Land Acquisition

"Eminent domain" or "the power to take private property for public use" is an attribute of both the Federal and state governments within their respective spheres of activity. This power is limited, however, by applicable constitutional provisions. The power of eminent domain extends to every kind of property right. This delegation of "private taking" must be limited to:

1. Condemnation for a specific purpose or use,
2. Property needed to accomplish that purpose, and
3. A prescribed procedure.

The government, or an agency of its choosing, may condemn all or any part of the rights to a piece of land, or to movables or intangibles [18].

The states encompassing the corridor planning area have vested in them the right of eminent domain to all modes of transportation with the exception of petroleum and coal slurry pipelines. The states of Alabama and Tennessee do not grant petroleum pipelines rights of eminent domain, and Arkansas is the only state in the corridor that will grant coal slurry pipelines these rights.

Two particular problems are raised with respect to transportation acquisitions:

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[18] Sax, "Takings and the Police Power," 74 Yale Law Journal 36, 1964, p. 318.

1. Acquisitions for future use. As the anticipated use becomes more remote in time, the taking tends to come into conflict with the requirement that there be a need for the property. Also, as the time of the intended use becomes remote, the need for the particular property tends to become more uncertain, hence unnecessary [19].

2. Excess land. Condemner may desire to acquire more property than is needed for a particular public project, or, to acquire additional lands anticipating a benefit from the improvement and ultimate sale at some profit so as to reduce overall costs of acquisitions. Condemnation of land for this purpose would appear to be in conflict with the requirements that the property be necessary and that it be acquired for a public use.

The courts have been unwilling to hold that the state may, even when acting consistently with the public interest, impose limitations on the use of property. The state must compensate the owner if it imposes an undue burden. The presence of continuing invasion almost always requires compensation.

In many circumstances the value of property is diminished by government action that is neither appropriation nor regulation. The extension of the meaning of "taking" by judicial decision has led to liberal rules for recovery, sometimes for circumstances in which an "invasion" is hard to find. Almost invariably the property owner must show not only damage of a relatively permanent nature, but some special damage that distinguishes him from other property owners.

In determining the fair cash market value of the property taken, the owner is not limited to the value of the property for the purposes for which it was actually used. The valuation of property has been based upon its most profitable legal use. Any reasonable future use to which the land might be adapted or applied may be considered in arriving at the present market value. The market value standard excludes "incidental" or consequential damages, including loss of profits, damage to goodwill, expense of relocation, damage resulting from the owner's inability to obtain a new location, traffic noise and fumes from increased traffic, circuity of travel, and diversion of traffic. The value that concerns the courts is the value at the time of taking.

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[19] Grad, F., Treatise on Environmental Law, Bender, New York, 1975, pp. 102-107.

No condemnation suit will be accepted by the courts until all damages to the condemnee (landowner) are considered. These include damages resulting from dividing a property into two or more parts. Any reduction in the value of the remaining area caused by severance from the parcel taken for public use is considered to be damage that is an inescapable part of the "taking" and it is compensable.

The landowner has the right to ingress and egress from his premises, because the original function of a conventional highway was to serve the landowner as well as the motorists. This right accrues to the occupant of abutting land as well as to the owner, even if the property is vacant. However, the right of the public in the highway is superior to private rights. The landowner may not therefore interfere with the use of the highway by the public.

Where an existing highway is converted into a multimodal corridor, existing access rights must be bought. If the landowner is left without reasonable access to the corridor, even though no land is taken, he has a constitutional right to compensation. Where part of the abutter's land is taken and the abutter no longer has reasonable access to the corridor, he must be paid for the loss of access as well as for the land taken for right-of-way and damages to the remainder.

Recognizing that the acquisition of rights-of-way requires lengthy planning and negotiations if it is to be done at a reasonable cost, DOT has authorized funds for acquisition of rights-of-way in anticipation of construction. The agreement between the DOT and the state highway departments for the reimbursement of the cost is based on the actual construction of a road on such rights-of-way within a period not exceeding ten years after the request is made. A right-of-way revolving fund is established to finance such acquisitions. Funds so advanced may be used to pay the entire costs of projects including the cost to the state of property management, and related moving and relocation payments.

Environmental Impact

All transportation projects require that environmental impact statements be prepared, that public hearings be held and that the environmental consequences of the project be thoroughly aired. Specific requirements differ. The discussion below describes highway procedures.

The FHWA requires that a systematic interdisciplinary approach be used to assess adverse social, economic, environmental and other project effects. In addition, project development must involve consultation with local, state, and federal agencies as well as the public. Decisions must be made in the best overall public interest and upon a balanced consideration of the need for fast, safe, and efficient transportation.

It is national policy that special efforts be made to preserve objects, sites, or buildings of national, state or local historical significance. It is a Federal crime to appropriate, excavate, injure, or destroy any historic or prehistoric ruin or monument, situated on government lands without permission of the head of the department having jurisdiction over such lands.

The National Environmental Policy Act of 1969 defines a national policy for the environment. Objectives of this policy are stated in Section 101 (b):

1. Attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable consequences;
2. Preserve important historic, cultural, and natural aspects of our national heritage;
3. Achieve a balance between population and resource use, enhance the quality of renewable resources, and approach the maximum attainable recycling of depletable resources.

In order to meet the requirements of the National Environmental Policy Act of 1969, the FHWA issued Policy and Procedure Memorandum 20-8, which required the state highway agency in requesting Federal location and design approvals to consider the effects of a highway project on the environment including:

1. Regional and community growth including land use and total transportation requirements;
2. Conservation and preservation including soil erosion and sedimentation, the general ecology of the area and natural resources;
3. Public facilities and services including religious, health, educational facilities, public utilities, fire protection and other emergency services;

4. Community cohesion including residential and neighborhood character and stability, highway impacts on minorities and other specific groups and interests, and effects on local tax base and property values;
5. Displacement of people, businesses, and farms including relocation assistance, availability of adequate replacement housing and economic activity;
6. Air, noise, and water pollution including consistency with approved air quality implementation plans, FHWA noise level standards (as required under PPM 90-2), and federal or state water quality standards; and
7. Aesthetic and other values including visual quality, and joint development and multiple use of space.

Noise Pollution

Until recently the Federal Government did little to control highway noise. Federal statutes now require the Government to act to reduce noise both by affecting the location and design of Federal-aid highways and by regulating the noise emission characteristics of highway vehicles.

The FHWA has adopted a set of rules issued in Policy and Procedure Memorandum 90-2, (February, 1973) that prescribe acceptable noise levels for different types of developed land near highways. These include three standards for exterior noise: 60dB(A) for areas in which "serenity and quiet are of extraordinary significance,"; 70dB(A) for exteriors of residences, hotels, public buildings, and outdoor recreation areas; and 75dB(A) for other developed land uses. There is also a design noise level of 55dB(A) for the interiors of homes and other occupied buildings. No limit applies to highways abutting undeveloped lands. The numerical levels in PPM 90-2 are not to be exceeded more than ten percent of the time during the hour of the day when the most traffic noise will occur.

Air Pollution

Although the initial Federal air pollution legislation simply provided for Federal assistance to states and local agencies, it set the pattern for Federal-state cooperation and interaction in the field of air pollution control. The Federal Government has enacted legislation which provides incentives to the states to meet higher standards. Through categorical grants in aid, the Federal Government has encouraged states to enact higher state standards.

Once national ambient air quality standards are adopted, the initiative for achieving them shifts from the Federal to the state governments. Each state must adopt and submit to the Administrator of the Environmental Protection Agency an implementation plan for the accomplishment of the national standard. Table 6 summarizes the authority and responsibility of the state agencies which regulate air pollution standards in the corridor area.

The state must demonstrate the legal authority to prevent construction and operation of pollution sources in locations that will prevent attainment of the national ambient air quality standards. This provision of the regulations has potentially far-reaching consequences for multimodal corridor development, because it implies the exercise of powers in land use policy and control by the state and Federal pollution control agencies.

Water Pollution

Surface water quality is affected by both direct waste water discharges and increases in contaminants. Ground water quality is affected by the changes in ground water flows, by changes in the quality of surface waters that recharge ground water aquifers, and by direct waste water discharges to the land.

Since there is increasing concern about the adverse effects of highway construction, Congress has enacted specific legislation to control the resulting water pollution. The 1972 Water Pollution Control Act is supposed to assist the states and localities in providing for water quality at the most economic price. This is an example of legislative technology-forcing. The entire thrust of the 1972 Act is to accomplish what the best pollution control technology is able to accomplish in the shortest time. Through Federal water quality standards (Table 7) the Federal government seeks to improve water quality, but could accept situations where water quality does not deteriorate as long as quality is adequate for designated purposes.

Relocation Assistance

The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (PL 91-646) requires all Federal and Federally aided programs under which families or businesses are displaced to provide uniform and equitable relocation services.

Table 6

Air Pollution Act Provisions for Corridor States

	Alabama	Arkansas	Florida	Georgia	Mississippi	Missouri	Tennessee
Declaration of Purpose	X	X	X	X	X	X	X
Technical Feasibility Requirement	X	X	X	X		X	X
Pollution Defined							
Contaminants which may be injurious	X	X	X	X	X	X	
Contaminants which are injurious							
Air Pollution Control Agency	H	E	E	E	E	H	H/E
Powers:							
Adopt rules and regulations	X	X	X	X	X	X	X
Conduct hearings and investigations	X	X	X	X	X	X	X
Issue orders	X	X	X	X	X	X	X
Require access to records	X		X	X			
Enter into contracts	X		X			X	X
Prepare comprehensive plan	X	X	X	X	X	X	X
Conduct studies	X		X	X	X	X	X
Continuing study of auto emissions	X		X				
Collect and disseminate information	X	X	X	X	X	X	X
Advise and consult interested parties	X	X	X	X	X	X	
Accept and administer grants and funds	X	X	X	X	X	X	X
Provide for performance of personnel	X						
Power for establishment of voluntary commission	X						
Inspection	X		X	X	X	X	X
Grant of variances	X	X	X	X		X	X
Issue permits	X	X	X	X	X	X	X
Monitor; require reports	X	X	X	X	X	X	X
Require submission of plans for construction			X	X	X	X	
Act as agent of state in all programs concerning air pollution		X			X	X	X
Coordinate management of air resources			X				
Authority to set standards:							
Establish air quality regions							
Ambient air quality standards	X		X	X	X	X	X
Classify air contaminant sources			X			X	
Specific standards in statute							
Emission controls: general	X			X		X	X
Emission controls: combustion	X						
Emission controls: manufacturing							
Emission controls: fuel	X						
Motor vehicle emission	X						
Enforcement:							
Conciliation required				X	X	X	
Compliance orders	X	X	X	X	X	X	X
Court action authorized	J	X	X	X	J	X	X
Injunctive relief authorized	X	X	X	X	X	X	X
Civil penalty or misdemeanor	C		C	C/M	M	C	M
Additional penalty for willingness	X			X			
Liability for restoration			X		X		
Citizen suit provision		O	(X)	O		O	O
Local jurisdiction:							
Local programs authorized	P	O	P	P		P	P
Enforcement primarily local							
Localities specifically empowered to bring court action	X		X			X	
Miscellaneous emergency procedures	X		X		X	X	X

X - State air pollution control law has the provision indicated.

A - Local air pollution control programs to be assumed by the state.

C - Civil penalty.

E - State environment or pollution control agency.

H - State department of health or agency within department of health.

J - State attorney general/or local district attorneys may bring suit.

L - Other state or local political unit.

M - Misdemeanor penalty.

O - State law expressly prohibits indicated regulation or procedure.

P - Local air pollution control program authorized if consistent with state controls. Local rules may not be more stringent than those of the state; state has power to preempt local programs.

S - Local requirements may be more stringent.

(X) - State has provision indicated in a statute other than air pollution control law.

Source: Grad, F. Treatise on Environmental Law, (New York: Matthew Bender, 1975), pp. 102-107.

Table 7

Federal Water Standards

Substance	Primary	Secondary
SO_2	80 microgm/m^3 (0.03 p.p.m.)	60 microgm/m^3 (0.02 p.p.m.)
	annual arithmetic mean 365 microgm/m^3 (0.14 p.p.m.)	annual arithmetic mean 260 microgm/m^3 (0.1 p.p.m.)
	maximum in 24 hours	maximum in 24 hours 1300 microgm/m^3 (0.5 p.p.m.)
		maximum in 3 hours
Particulates	75 microgm/m^3 annual geometric mean	60 microgm/m^3 annual geometric mean
	260 microgm/m^3 maximum in 24 hours	150 microgm/m^3 maximum in 24 hours
Co	10 milligm/m^3 (9 p.p.m.) maximum in 8 hours	10 milligm/m^3 (9 p.p.m.) maximum in 8 hours
	40 milligm/m^3 (35 p.p.m.) maximum in 1 hour	40 milligm/m^3 (35 p.p.m.) maximum in 1 hour
Photochemical Oxidates	160 microm/m^3 (0.08 p.p.m.) maximum in 1 hour	160 microgm/m^3 (0.08 p.p.m.) maximum in 1 hour
HC (corrected for methane)	160 microgm/m^3 (0.24 p.p.m.) maximum in 3 hours 6 a.m. - 9 a.m.	160 microgm/m^3 (0.24 p.p.m.) maximum in 3 hours 6 a.m. - 9 a.m.
NO_2	100 microgm/m^3 (0.05 p.p.m.) annual arithmetic mean	100 microgm/m^3 (0.05 p.p.m.) annual arithmetic mean

Source: [19] Grad, F., Treatise on Environmental Law, Matthew Bender, New York, 1975, p. 183.

The payment schedule provides for landowners' moving and related costs, replacement housing for homeowners, mortgage insurance for replacement housing, replacement housing for tenants and others. A range of relocation assistance advisory services also must be provided and relocation activities must be coordinated with project work.

The relocation law requires that satisfactory arrangements be made for assistance payments before a Federal grant, contract, or agreement is made with a state or local agency. The cost of providing payments and assistance under the Act is considered an eligible expense for Federal financial assistance.

The FHWA has issued PPM-1 to establish procedures to insure the prompt and equitable relocation and reestablishment of persons, businesses, farms, and non-profit organizations displaced as a result of Federal highway construction. A hearing and appeals procedure is provided to encourage equitable resolutions of relocation controversies.

All of the states involved in the corridor area have relocation assistance sections included in their highway statutes. The state statutes are all quite similar in content, and essentially following the example of the Federal Government.

Regulation

This section outlines the current institutional requirements and impediments to coordinated intermodal transportation in the Corridor.

Federal

A Certificate of Public Convenience and Necessity is granted to transportation carriers upon their showing the ability to provide a needed service in an efficient and equitable manner. A certificate issued to regular-route motor common carriers specifies the routes on which they may operate, the termini between which they may operate, and the intermediate and off-line points to be served. Requirements for rail, air and water carriers are similarly detailed.

The Interstate Commerce Commission requires railroads to establish connections with other rail lines and with water carriers. Motor carriers and pipelines are not required by law to interchange traffic. The ICC's jurisdiction in this matter is exclusive, with the states no longer exercising control over traffic interchange.

The ICC will allow mergers as long as they are consistent with the public interest. Measures of public interest include:

1. The effect of the proposed transaction on adequate transportation for the public,
2. The effect on the public interest of including, or failing to include, other carriers in the proposed transaction,
3. The total fixed charges resulting from the proposed transaction, and
4. The employee's interests.

The ICC is vested with broad discretion. Although the Commission has no power to enforce the Sherman Act or decide whether a combination or consolidation constitutes a restraint of trade or an attempt to monopolize, the Commission does approve all mergers of transportation companies.

The statutes that govern intermodal ownership and control are inconsistent. Many forms of carrier integration are subject to restrictive statutory tests and other integration schemes are not covered by existing legislation. In several instances there are discrepancies between statutory treatment of applications by carriers of one mode to institute new services in another form of transportation. Airlines, motor carriers, and water carriers may own railroads, but freight forwarders are barred by Section 411 from owning them. A railroad may not own motor carriers unless it can prove that consolidation with a motor carrier will not unduly restrain competition. Other modes can own common carrier pipelines. Furthermore, new pipelines can be built and old ones may be abandoned without regulation.

The ICC requires five basic conditions to be inserted in rail or rail subsidiary-motor carrier mergers:

1. The motor carrier service must be auxiliary to and supplemental to rail operation,
2. The motor carrier can only serve points on the parent rail line,
3. Shipments are limited to those on a through bill of lading,
4. All contractual arrangements between applicant motor carrier and parent railroad shall be reported to the Commission and subject to revision, and
5. The motor carrier service is subject to any further conditions that

the Commission might find it necessary to impose.

Sections 5(14) through (16) of the Interstate Commerce Act contain the intermodal ownership guidelines to be followed in cases involving rail-water combinations. Railroads, pipelines, express and sleeping car companies are prohibited from owning water carriers operating through the Panama Canal. There are restrictions against ownership of other water carriers. However, the Commission will allow ownership of a water carrier not operating through the Panama Canal if the transaction is consistent with the public interest. While multimodal ownership has been permitted, the carriers have been limited in the amount of integration that they can achieve.

Several different kinds of coordinated service are available, including through routes and joint rates. A "through route" is an arrangement between connecting carriers for the continuous carriage of goods on a single bill of lading. A "joint rate" is a single rate from point of origin to destination rather than a combination of the rates of the separate carriers. The ICC can require the establishment of through routes and joint rates involving railroads and water carriers. The Commission has no authority to require through routes and joint rates involving railroads and motor carriers, or motor and water carriers. Through routes and joint rates, however, may be established voluntarily. Rail carriers, historically, have been reluctant to coordinate through movements with motor carriers, except for certain trailer-on-flat-car movements.

The development of a multimodal corridor brings with it important issues relating to intercarrier rate relations. The ICC is empowered to investigate rates upon receiving a complaint or on its own initiative. It can conduct a public hearing and determine what rate or rates will be lawful in the future. It has the power to set minimum, maximum, and actual rates. This power does not apply, however, until after an existing rate has been declared unreasonable or otherwise unlawful.

The present ICC rate policy is to base rates on the fully distributed cost of the low cost carrier. In determining which carrier is the low cost carrier, and therefore entitled to protection from rate cutting, the carrier protesting the rate reduction must show that it is indeed the low cost carrier. Recently, the Commission has considered "public costs" (i.e., taxpayer defrayed costs in providing and maintaining facilities) as a part of the total cost of operation. The public policy question which arises by the introduction of "public cost" must be given serious thought in light of the multimodal corridor development.

The Federal statutes are silent on the matter of public ownership of terminal facilities. The Port Authority of New York and New Jersey has successfully owned and operated a variety of terminal facilities. These are financed through the use of a value capture technique. This is basically a means that allows public groups to condemn land and then use the land or property to incur a profit or defray a cost in the interest of the public. The breadth of the definition of public use will determine the potential for value capture through public ownership or public/private partnership.

State

State highway regulatory authority is comprehensive in respect to the licensing of vehicles and drivers, safety, and levying taxes. The state may fix regulations for the safety of highway users and regulate the size and weights of vehicles permitted on its highways. However, the state is limited in matters of rates and services to intrastate traffic.

Limitations on motor vehicle size and weight present reconciliation problems. On the one hand, the carrier is interested in hauling the largest load possible to increase his revenue. On the other hand, state governments are concerned with maintaining the highways and assuring safety for the traveling public. The states within the Corridor area do not have uniform weight and size limits. The maximum gross weight limit in Florida, Georgia, and Alabama is 80,000 pounds. Arkansas, Missouri, Tennessee, and Mississippi limit maximum gross weight to 73,300 pounds. To facilitate commerce, it is desirable to standardize the weight and size limits for all states in the Corridor.

Safety

A number of governmental organizations have transportation safety responsibilities. The National Transportation Safety Board promulgates transportation safety requirements for marine, railroad, highway, pipeline, and civil aviation modes. The safety board gives primary attention to investigating the causes of aircraft accidents. Most surface accident investigations are carried out by the Federal agencies directly involved: the Federal Railroad Administration, the U.S. Coast Guard, the Federal Highway Administration, or the Office of Pipeline Safety.

Highway safety regulations are promulgated by the Federal Highway Administration and the National Highway Traffic Safety Administration. The Federal Highway Administration issues standards regarding highway design, construction and maintenance, traffic engineering services, identification and surveillance of accident locations, and pedestrian safety. The National Highway Traffic Safety Administration is responsible for developing safety standards relating to vehicles and drivers. The Bureau of Motor Carrier Safety in the Federal Highway Administration has jurisdiction over safety requirements for all motor carriers including those whose operations are exempt from ICC regulations.

Recommendations

The highway statutes provide a sound basis for developing multimodal corridor statutes. Amendments are added to the existing body of highway law every two years. Additional provisions could be provided in the 1978 act that will facilitate multimodal corridor development:

1. Establish a Bureau of Inter-Modal Planning within the Department of Transportation. This agency would represent the interests of intermodalism and multimodalism in policy decisions. Membership would include representatives from FRA, FHA, FAA, U.S.C.G., UMTA, and MTB. The Bureau would monitor all inter/multimodal projects sponsored by DOT and propose policy to insure coordinated and efficient transportation service.

2. Establish a single regulatory agency with jurisdiction over all certified carriers. This agency could be called the Federal Transportation Regulatory Commission (FTRC) and would result from the consolidation of the ICC, CAB and the FMC. The FTRC would include an office concerned solely with inter/multimodal regulation and planning. This office could resemble the existing Rail Services Planning Office (RSPO).

3. Rescind present prohibitions in the Interstate Commerce Act against common ownership, and allow the FTRC to establish merger rules based on market conditions existing at the time of a proposed merger.

4. Require all carriers to incorporate through routes and joint rates.

5. Establish legislation that would encourage common use of transportation

facilities thereby allowing multimodal transportation (utility) facilities to develop where economically feasible.

6. Alter the rate structure to allow greater flexibility in establishing rates. Ideally, traffic should accrue to the carrier who can move the goods at the lowest price in the long run. Thus, long-run marginal cost should be the minimum standard used by the FTRC in establishing rates.

7. Broaden operating rights in the motor carrier industry.

8. Equalize weight and size limits within the Corridor planning area to facilitate the free-flow of commerce.

9. Encourage states to establish intermodal planning bodies.

10. Set up a framework of laws to allow mixed (private and public) ownership of facilities along with appropriate Federal loan guarantees for the raising of capital.

11. Provide for use of highway rights-of-way by privately owned transportation and public utility companies. These firms are to pay user charges for the privilege of using publicly owned facilities. A gross receipts tax would be an appropriate vehicle for use of the right-of-way.

12. Use value capture techniques to provide multimodal facilities.

III. COMMODITY FLOW ANALYSIS*

The purpose of the commodity flow analysis is to structure the analytical problem in a manner that provides a simplified framework without sacrificing essential detail. There are three key areas that require attention: the commodity representation, the geographical representation and the development of commodity flow data to fit the two representations. One needs to attack this problem with one view toward the dimensionality of the eventual analysis and another to the available sources of data. A compromise is clearly in order. Even though the economy of the Multi-State Corridor is relatively simple when compared with other parts of the country, it is necessary to consider a complex set of development opportunities, and the manner in which they integrate with the balance of the United States.

Commodity/Industry Groups

The desired commodity/industry divisions would produce homogeneous groupings such that all of the production facilities within a group have a marked similarity to one another. These like facilities would use similar raw materials and similar resources to produce similar products that have the same geographical markets. To achieve the desired level of homogeneity, it would be necessary to use a very fine breakdown into specific industries.

There are two commodity classifications in common use in the United States that are capable of producing the desired breakdown - the SIC and the STCC (Standard Transportation Commodity Classification). The former is used principally by the Department of Commerce and the latter by DOT and the ICC. Both provide multi-digit commodity designations. Large groups are identified by the two-digit classifications. As digits are added, the group of included commodities becomes narrower and more specific. The two classifications are essentially identical at the two- and three-digit levels. Differences begin to appear at the four-digit level. The four-digit classifications would provide the desired specificity but there are over four thousand four-digit SIC classifications. In addition to the large number of groups there would also be data difficulties. The Bureau of the Census is the only source of comprehensive production data broken down to four-digit groups. However, Census

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*The work described in this chapter was performed by P. S. Jones, W. Morgan, M. A. Mullens and S. Prasanna.

zealously protects industry from disclosure and therefore does not provide data for geographical areas with three or fewer facilities in the same classification. Even some state data at the four-digit level have significant omissions to avoid disclosure. At the other extreme, from the viewpoint of analytical simplicity, it would be desirable to select the two-digit classifications as commodity/industry groups. This division would produce only 27 groups; however, it would produce some strange bedfellows, e.g. paint and agricultural chemicals, ferrous and non-ferrous metal production, and motor vehicles and ships.

The approach followed was to expand the two-digit classifications to the extent judged essential for the analysis. Attention was given to the different industries contained in the same two-digit group. Financial and trade data were reviewed to compare capital structure, labor skills, management structures, raw materials and other resources within each two-digit group. After much consideration the team elected to expand the following areas beyond the two-digit code:

10 Metal Mining,

20 Food & Kindred Products,

28 Chemicals & Allied Products,

30 Rubber & Miscellaneous Plastic Products,

32 Stone, Clay, Glass, & Concrete Products,

33 Primary Metal Industries,

34 Fabricated Metal Products except Machinery & Transportation Equipment,

36 Electrical & Electronic Machinery, Equipment, & Supplies, and

37 Transportation Equipment.

All other commodities were treated in terms of the two-digit SIC (or STCC) commodity codes.

The final list of the 53 commodity/industry groups selected for analysis is presented in Table 1, shown earlier.

Transportation Zones

The selection of transportation zones also requires careful compromise.

A transportation zone structure was sought that would be detailed enough to reflect local movements within the Multi-State Corridor and yet general enough to retain analytical tractability. Some investigators, notably Harris [10], have worked with county-sized zones. With more than 3000 counties in the continental United States, this degree of detail presents formidable data and analytical problems. Harris has been able to investigate only a limited number of transportation alternatives because of the time and expense associated with each investigation. Other investigators have used state-sized zones. This size, while convenient from a data viewpoint, would have little value within the Multi-State Corridor because of its grossness. State data also introduce difficulties because of the large number of major production centers that straddle state boundaries - e.g., New York, Philadelphia, Chicago, St. Louis.

The zone size, composition, and representation play key roles in identifying economic development opportunities for the Multi-State Corridor. Each zone is described in terms of its area and its nodal point or centroid. The centroid represents its zone in the following important ways:

1. All transportation arcs are represented by routes that originate and terminate at zone centroids.
2. Transportation costs and service to and from the zone are represented by transportation costs and service to and from the centroid.
3. Production costs - labor, material, energy and tax costs - represent costs throughout the zone.
4. Intermode transfers are allowed to occur only at zone centroids.
5. Intra-zone movements are neglected as having no bearing on development opportunities.

These conditions do not appear to be unduly burdensome for small zones that contain one dominant urban center. However, small zones that have several candidate centroids and large zones with considerable rural area or with a varied urban development can present serious problems.

In small zones, intra-zone shipments may amount to little more than local drayage - commerce between firms that are close together. While many of these movements represent important shipments from producers to customers they are often based on relationships that require close proximity. In the large zones, intra-zone shipments could be several hundred miles long and represent a substantial part of the zone's commerce.

The solution to the zone size dilemma appears to lie in the use of a variable zone size throughout the United States. Zones within the Multi-State Corridor are small to preserve detail, while zones remote from the Corridor are large because detail there is not important. Intermediate zones are of intermediate size. Although there are many precedents for the use of a variable zone size - e.g. most state and urban transportation studies - there has never been a thorough investigation of the errors introduced by this approach. Although no evidence is offered here, this will be the subject of future research.

Building Blocks

A large number of different territorial subdivisions have been made for the continental United States. These have been used for regulation, rate making, data collection, evaluation, and other purposes. Several have been produced in an effort to produce geographical divisions that are smaller than states but larger than counties. Two of these are of particular interest. The U.S. DOT has prepared a set of 440 Transportation Zones for which they have defined modal transportation networks and they have collected a good bit of data on transportation facilities. Regrettably, no commodity flow data have been collected for these zones. The Office of Business Economics (OBE) of the Department of Commerce has prepared a set of 171 Basic Economic Areas (BEAs) for the continental U.S. The OBE has prepared economic data and it has made economic growth projections for each BEA. U.S. DOT has prepared a comprehensive set of commodity flow data from BEA to BEA. After careful study, it appeared easier to translate facility data from Transportation Zones to BEAs than to translate commodity flow data from BEAs to the Transportation Zones. Therefore, the BEA was selected as the basic building block for use outside the Multi-State Corridor.

BEAs are too large for use within the Multi-State Corridor. Each BEA contains about thirty counties. In all, the Corridor would contain only 12 BEA-sized zones. This level of detail was judged unsatisfactory and a smaller building block was sought for use in the Corridor. The most suitable building block found was the Planning and Development District (PDD) which is comprised of six to ten counties. PDDs have been designated by all Corridor states. In addition, data have been collected and local transportation studies have been performed by almost all PDDs within the Corridor.

Zone Selection

The building block selection - BEAs and PDDs - largely determined the zone sizes and boundaries in and near the Multi-State Corridor. Corridor zones are PDDs and the zones close around the Corridor are BEAs. However, zones larger than a BEA are needed for three-quarters of the nation. These zones are made up of multiple BEAs. Using five different criteria a basis was developed for combining BEAs in a manner likely to yield a set of zones that can support the analysis of the Corridor's commercial relationships with the nation.

1. Each zone should have a dominant urban centroid,
2. Each zone should have homogeneous economic activity,
3. Each zone centroid should be served by the transportation modes that serve the zone,
4. Each zone centroid should contain a major terminal for at least one transportation mode, and
5. Each zone should have a major direction of access from each of the Corridor zones.

The zone selection process began with the designation of the PDDs within the Multi-State Corridor. The PDD boundaries do not match the BEA boundaries. Thus, a uniform transition from PDDs to BEAs was not possible. The interface between PDDs and BEAs contained some counties that were excluded from a selected PDD and the adjacent BEA and other counties that were included in both a PDD and the adjacent BEA. The transition problem was resolved to produce a larger number of small zones in preference to a too early transition to BEA-sized zones. Thus, extra counties were accommodated in one of three ways:

1. The county was added to the nearest PDD,
2. The county was added to the nearest BEA, or
3. The county was combined with other adjacent extra counties to form a sub-BEA sized zone.

Counties included in both a PDD and BEA were assigned to the BEA zone if they fell outside the nominal Multi-State Corridor (Figure 1). This action tended to preserve BEA integrity which was desirable for purposes of preparing commodity flow data. Counties that fell inside the nominal Multi-State Corridor were assigned to the PDD zone to preserve the small zone size nature of the Corridor. The resolution process produced a few small zones outside the Corridor, but in general, the structure conformed to the guidelines that were established for the variable zone sizes.

The next step in the zone selection was to develop the external zones from the BEA building blocks. The zones immediately around the Corridor were BEA sized or BEAs augmented with miscellaneous counties. The balance of the zones are made up of two or more BEAs.

BEAs were first organized in accordance with the first two criteria - dominant urban centroid and homogeneous economic activity. BEAs that shared common principal industries and that could focus on a single centroid were combined using population data and data on the value of shipments for the three largest commodity/industry groups, from the OBERS data for 1972 [20]. This procedure produced a set of relatively homogeneous zones.

Modifications were made to reflect the major crop regions of the midwestern and western states using data on Water Resource Regions, grain districts, and timber districts. In most cases, these changes did not upset industry balances.

An independent set of zones was prepared using the third, fourth, and fifth criteria - modal transportation routes, transportation terminals, and access from the Multi-State Corridor. Maps were prepared of the major modal transportation routes. The highway map consisted of the Interstate and Defense Highway System augmented by a few federal aid primary routes. The railroad map contained the class A Mainlines as designated by the U.S. DOT, augmented with potential Class A mainlines and a few Class B mainlines to round out a balanced network [21]. The waterway map included all of the inland waterways maintained by the Corps of Engineers together with coastal and intercoastal routes. Centroid cities were identified first in terms of their impacts on

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[20] U.S. Dept. of Commerce, OBERS Projections: 1972 Regional Economic Activity in the U.S., Vol. 2, BEA Areas, Washington, D.C., 1976.

[21] Handy Railroad Atlas of the United States, Rand McNally & Co., Chicago, 1973.

the transportation networks. Zones were collected around the centroid cities in a manner that generally reflected the market areas served by each city.

The two alternative approaches were pursued independently to complete the zone designations for the 80 zones external to the Corridor. The two results were then compared. Twenty-one of the zones were identical. Differences among the balance were quite varied but many differences represented a choice between adding a BEA to one zone or another. These differences were resolved in conference to the satisfaction of all. The resulting zone map is given in Figure 3, shown earlier. Zone centroids were listed earlier in Table 2. Appendix B contains a complete list of the network zones, including the BEAs and/or counties included in each. This structure has been used throughout the balance of the analysis.

Commodity Flow Data

Commodity flow data that describe the present movements of goods in commerce from major producing to major market zones are a key ingredient in the analysis of development opportunities. Unfortunately, accurate commodity flow data are not available in the form needed for analysis. This shortcoming is due to differences in the reporting requirements made of the different transportation modes, differences in the purposes of data collection efforts, omissions necessitated by disclosure regulations, and simply to the errors and omissions attendant to any massive data collection effort.

By far the best data available are for commodity movements by rail. All railroads are common carriers and all commodity movements by rail are subject to regulation by the ICC. Railroads take a one percent sample each year of all carload rail shipments. For each waybill in this sample, data are recorded on commodity, origin station, destination station, shipment size, car type, mileage, short line mileage,* revenue, and routing gateways. Although the sample is but a small fraction of the shipments, it gives a reasonable representation of moderate and high volume commodity movements between major terminals. Recent unpublished research by Day and Zimmerman and the University of California suggests that when treated in three year combinations the waybill sample does give a statistically reliable, railroad specific representation of

*Short line mileage is the length of the shortest possible rail route between origin and destination.

commodity movements for two-digit STCC groupings [22]. However, these data do contain a large number of errors, particularly in the routing and need to be carefully purged or corrected.

Commodity movements by highway are much more difficult to estimate because of differences in regulations, less detail in reporting requirements, and the large number of non-regulated and private truckers. Truckers that generate substantial commodity movements can be divided into five categories:

1. Common carriers operating over prescribed routes in prescribed territories and subject to ICC regulations,
2. Common carriers hauling exempt commodities* for back haul,
3. Contract (or irregular route) carriers acting as shipper's agents who carry goods that are subject to only limited regulations, with or without back hauls of exempt commodities,
4. Private truckers moving their own goods or exempt commodities anywhere without restriction or regulation, and
5. Individual truckers or firms that move only exempt commodities without restriction or regulation.

A majority of all highway shipments are handled by private truckers who are not obliged to report on their activity except as they may be requested to make periodic inputs to the Census of Transportation surveys [23]. In addition, all short hauls within designated terminals are free from regulations and reporting.

Even the reports of regulated motor common carriers are less detailed than are the railroad reports. Typically, highway carriers report only tonnage originated by commodity classification. They do not give geographical movement or shipment size data.

Data on commodity movements by water, where private carriage also

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*Exempt from ICC regulations; principally unprocessed agricultural products.

[22] Harris, R. G., "A Statistical Analysis of the FRA Waybill Sample," Federal Railroad Administration, Office of Rail Economics and Policy Development, Washington, D.C., 1977.

[23] U.S. Bureau of the Census, <u>1972 Census of Transportation</u>, Washington, D.C., 1975.

predominates, are subject to many of the same difficulties experienced with highway movements. Many manufacturing firms operate tow boats and barges to carry their own products and supplies. The vast Great Lakes ore movements are almost entirely in private hands that are free from reporting requirements. Some companies also operate coastal and intercoastal steamship services. Common carriers by water that operate on inland waterways or in coastwise or intercoastal trade are subject to ICC regulations. However, like highway carriers, they report only tons carried by commodity. The Corps of Engineers keeps some data on port and waterway activity. However, these data do not include origin to destination movements, nor are uniform data kept for all ports and waterways.

The Census of Transportation [23], performed at five year intervals, provides the only comprehensive data for all modes. Manufacturers and producers are requested to provide data on a sample of individual shipments including commodity, origin, destination, carrier mode, shipment size, route and revenue where appropriate. These data are combined by geographical location, industry group, and other measures and summarized in a variety of useful documents. The detailed data are subjected to disclosure protection before publication. Thus, geographical jurisdictions with three or fewer producers or consumers are eliminated from the published data. Disclosure problems are avoided by preparing data in terms of large geographical amalgamations. If one amalgamates both by geography and commodity, completeness is achieved at the expense of detail. The research team chose to use geographical amalgamations with commodity detail. This compromise did not give complete coverage but it provided a useful base for future work.

NTP Data

Assembling the available data into a reliable set of zone-to-zone movements for transportation analysis is an immense task. Fortunately, TSC has undertaken this formidable task, and has made substantial progress. By combining the 1972 Census Commodity Transportation Survey with a special study of bulk commodity movements, TSC has produced what is likely the most comprehensive set of commodity flow data available for the United States. This work is described in Reference 7. The major omission from the NTP data is movements of unprocessed agricultural products, except field crops. These data were omitted because of the extreme difficulty in identifying nationwide commodity flows with reasonably uniform accuracy.

TSC organized the data by commodity, origin-destination BEA zones, transport mode, volume, shipping cost and shipping time. Use of the BEA zones in combination with 20 commodity classes, provided the amalgamation needed to circumvent disclosure problems and to fit available data sources together. The NTP data were made available to the project team on a magnetic tape. The specific fields on the tape are listed in Table 8. These data constitute the starting commodity flow data for all of the first year's analysis.

Commodity Flow Data Preparation

A commodity flow set was prepared from the data resources at hand to give zone-to-zone origin-to-destination movements for the zones illustrated in Figure 3 and the commodities listed in Table 5. The NTP data were the original source of zone-to-zone movement information. These data were adjusted using other data sources, to yield the desired form and detail. The principal source used for the adjustment was a magnetic tape of the 1972 Census of Transportation [23] giving state-to-state movements of commodities to four-digit STCC detail. These data were expanded where important disclosure omissions were observed and they were supplemented with demographic and employment data as required. Two types of expansion and one type of contraction were needed to modify the NTP data to suit the research needs. The 20 commodity NTP data needed to be expanded to the 53 commodity groups selected for the analysis. The BEA-to-BEA commodity flow data needed to be expanded to the smaller zone sizes in the Multi-State Corridor. Finally, the BEA-to-BEA data needed to be compacted for the multi-BEA sized zones distant from the Corridor.

The data preparation task was a formidable one requiring extensive manual and computer manipulation. Some understanding of the scope of the undertaking can be grasped from the size of the data sources. The NTP tape contains more than 200,000 card image records, each one structured as set forth in Table 8. The Census of Transportation tape contains state-to-state movements for over 4,000 four-digit commodity groups for a total of more than five million records. Problems of reading, storing, and manipulating these records were most complex.

Commodity Expansion. Table 9 lists the NTP commodity groupings by STCC codes and the sources of the commodity flow data. Only one group, field crops, contains less than one two-digit STCC classification. Four groups contain multiple two-digit STCC classifications. Four of the NTP commodity groups could

TABLE 8
NTP MAGNETIC TAPE DATA FIELDS

Data Field	Description	Format
1-2	Year Code	I2
3-4	Commodity Number	I2
5-7	Origin BEA Code	I3
8-10	Destination BEA Code	I3
11	Transport Mode Code	I1
	1 = Rail	
	2 = Motor Carrier	
	3 = Private Truck	
	4 = Water	
	5 = Pipeline	
	6 = Air Freight	
12-21	Annual Commodity Flow (tons)	I10
22-27	Shipping Cost ($/ton)	F6.2
28-33	Time Value ($/ton/day)	F6.2
34-39	Time in Transit (days)	F6.2
40-51	"K" Value for Mode Split	E12.7
For a Mode Split Alternative:		
52-57	New Shipping Cost ($/ton)	F6.2
58-63	New Time Value ($/ton/day)	F6.2
64-69	New Time in Transit (days)	F6.2
70-79	Calculated Commodity Flow (tons)	I10

TABLE 9
NTP COMMODITY GROUPINGS

Commodity No.	Name	STCC Codes	Source
1	Field Crops	011	B
2	Forestry & Fishery Products	08,09	B
3	Coal	11	B
4	Crude Petroleum	13	B
5	Metallic Ores	10	B
6	Non-Metallic Minerals	14	B
7	Food & Kindred Products	20	C
8	Textile Mill Prod. & Apparel	22,23	C
9	Mfgr. Not Otherwise Identified	*	C
10	Chemical & Allied Products	28	B,C
11	Lumber & Furniture	24,25	C
12	Machinery (Except Electrical)	35	C
13	Electrical Machinery	36	C
14	Transportation Equipment	37	C
16	Paper & Allied Products	26	C
17	Petroleum & Coal Products	29	B,C
18	Primary Metal Products	33	C
19	Fabricated Metal Products	34	C
20	Miscellaneous Products	21,30,31,32,38,39	C

B = Bulk Survey

C = Census Data

* = This commodity group contains an amalgamation of all of the manufacturers that were removed from other groups to avoid disclosure.

be used without modification - coal, non-metallic minerals, paper and allied products, and petroleum and coal products. All of the rest needed to be broken down into two or more distinct commodities for the analysis. Several of the NTP commodity flow groupings are sufficiently broad to contain commodities with very different flow patterns. For example, NTP Category 5 contains all metallic ores. However, iron ore and bauxite have very different movement patterns.

NTP commodity flow data were disaggregated into smaller classes using fractions developed from the Census of Transportation state-to-state data.

$$f^m_{ij\ell} = a^m_{iJL} \cdot d^m_{Ij\ell} \tag{1}$$

where:

$f^m_{ij\ell}$ is the movement of commodity i from BEA zone j to BEA zone ℓ via mode m,

$d^m_{Ij\ell}$ is flow of NTP commodity class I from BEA zone j to BEA zone ℓ via mode m, and

a^m_{iJL} is the fraction of NTP commodity class I that is represented by commodity i that moves from state J to state L via mode m.

Commodity i is a subclass of NTP commodity I. States J and L are selected to be those that most nearly approximate the economic behavior of zones j and ℓ. In most cases $i \in I$ and $j \in J$. Thus

$$a^m_{iJL} = F^m_{iJL} \Big/ \sum_{k \in C_I} F^m_{kJL} \tag{2}$$

where:

F^m_{iJL} is the movement of commodity i from state J to state L via mode m, and

C_I is the set of commodities comprising NTP class I.

Expanding to Corridor Zones. Production and consumption within the BEAs containing multiple PDD-sized zones were divided among the PDD zones in accordance with available measures that most nearly approximate the actual division.

Production was divided according to employment in the different industries. Employment data were taken from state directories of manufacturers which list manufacturer by county together with the number of employees and the SIC codes of their products. Consumption was divided according to the particular commodity. Commodity groups that were dominated by consumer products were divided according to population. Commodity groups dominated by industrial products were divided in accordance with manufacturing employment or value added by manufacturing. For example, production was allocated by employment in the following manner. The number of persons in each zone j that are employed by industry i was estimated:

$$e_{ij} = \frac{E_{ij}}{\sum_{j=1}^{J} E_{ij}} \tag{3}$$

where:

e_{ij} is the fraction of industry i workers in BEA zone J that work in zone j,

E_{ij} is the number of employees in industry i in zone j, and

J is the number of zones in the BEA that contains zone j.

Production reported for each BEA was allocated to the smaller zones comprising the BEA on the basis of the employment fractions.

$$\hat{P}_{ij} = e_{ij} P_{ij} \tag{4}$$

where:

$\hat{P}_{ij}$ is the estimated production of commodity i in zone j,

P_{ij} is the reported production of commodity i in BEA zone J based on tons of commodity i originating in zone J.

Similarly, consumer dominated markets for commodities produced in PDD zones were divided as follows:

$$d_{ij\ell} = \frac{P_\ell}{P_L} d_{ijL} \tag{5}$$

where:

$d_{ij\ell}$ is the movement from BEA zone j to market ℓ,

P_{ℓ} is the population of zone ℓ,

P_{L} is the population of zone L, and

d_{ijL} is the movement of commodity i from zone j to BEA L.

Compaction for Multi-BEA Zones. The compaction process for the multi-BEA zones distant from the corridor was very straightforward.

$$f^{m}_{ij\ell} = \sum_{L=1}^{Q} \sum_{J=1}^{K} d^{m}_{iJL} \tag{6}$$

where:

$f_{ij\ell}$ is the movement of commodity i from zone j to zone ℓ via mode m where j and ℓ are zones of the network,

d^{m}_{iJL} is the reported commodity movement from BEA zone J to BEA zone L via mode m, where zone J is part of zone j and zone L is part of zone ℓ,

Q is the number of BEA zones in zone ℓ, and

K is the number of BEA zones in zone j.

The product of these steps was the desired set of commodity flow data giving zone-to-zone movements for each of the 53 commodity groups.

IV. ECONOMIC MODELING*

The economic model deals with development opportunities by which new industry in Multi-State Corridor zones can effectively compete for national markets with existing suppliers. The analysis is based on two parameters - a production cost parameter and a customer service parameter. The production cost parameter is a measure of the cost per ton to produce a commodity in a production zone. The customer service parameter is a measure of transportation cost plus the cost equivalent of transport time and transport time variability necessary to move a ton of the commodity from the production zone to the market zone. Thus, each production zone has a unique production cost for each commodity, but customer service cost depends on the commodity, the production zone, the market zone, and the route and mode by which the commodity moves. This chapter is concerned with the development of production cost estimates and the use of the production cost plus customer service cost to estimate market share. Customer service costs are developed in Chapter V.

The economic model is cost based. It presumes that the sum of the production cost and customer service cost is the major determinant of market share. This approach is perhaps naive because it overlooks the impacts of product quality, advertising, customer relations and other factors that play major roles in marketing. However, these latter factors are associated with the identity of the producing firm, not with the location of the producing site. Since the research is concerned only with locational opportunities, it is not unreasonable to set aside those factors that are not related to location. This approach resembles the situation in which a new plant in a Corridor zone is a branch plant of a multi-plant company whose management controls the assignment of production to plant locations and the shipment of products from plants to markets. However, one must be careful to avoid treating all plants as part of a single producing company; for in that case, one need only solve a massive transportation problem. The economic model preserves competition in all market places. Thus the producer with the lowest delivered cost can enjoy the largest market share but he cannot completely capture the market, nor can any producing zone deliver all of its product to the nearest market.

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*The work described in this chapter was performed by P. S. Jones, G. P. Sharp, H. B. Spraggins and H. C. D. Yu.

There are three major preparatory steps in the economic modeling - industry analysis, preparation of cost data and market analysis. The products of this work are introduced into the network model for the final analysis.

Industry Analysis

The purpose of the industry analysis is to prepare a quantitative and geographic representation of the facilities that produce each commodity group. The quantitative representation describes the cost structure of the industry that produces the commodity and the principal raw materials that are needed. The geographic representation identifies principal producing zones, principal markets and the present pattern of shipment from producers to consumers.

Industry Structure

Each of the 53 commodity groups is treated as a single homogeneous product of a single industry group whose components have common raw material needs, common labor, and common capital requirements. Production input factors were developed for each industry group based on national average data from the Census of Manufacturers [24]. Table 10 shows typical data for commodity 250, Furniture and Fixtures. The data give industry average values per ton of product for direct labor hours, indirect labor cost, energy cost, tax cost, and capital investment. The table also lists principal raw materials and the tons of raw material per ton of product. Similar data for all of the manufacturing industries are listed in Appendix D. These data are based on average experience throughout the industry. They do not reflect facility size, individual efficiencies or other measures that vary from facility to facility. However, new industry will not be encouraged to produce any commodity in a Corridor Zone unless the Corridor facilities can be large enough to have an impact in the national market. This requirement assures facility sizes large enough to exhibit both capital and operating efficiencies better than mean values. Thus the use of mean values represents a reasonably conservative approach.

Of the elements of production cost considered, capital and indirect labor are presumed to be independent of location. Capital can be drawn from a national market. Differences in capital costs from region to region are

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[24] U.S. Bureau of the Census, 1972 Census of Manufacturers, Washington, D.C., 1976.

TABLE 10

INDUSTRY DATA FOR COMMODITY 250
FURNITURE AND FIXTURES

Companies	8482
Establishments	9232
Input Per Annual Ton Shipped	
Direct Labor, Hours	134
Indirect Labor	$ 155
Capital Investment	$2550
Energy, KWH	1250
Raw Materials, Tons	
220 Testiles	0.01
240 Lumber	1.08
285 Paint	0.003
331 Steel	0.38
333 Non Fe. Metal	0.01
342 Fab. Metal	0.15

generally small and can be overlooked. Indirect labor is a measure of the amount of supervision and support needed by a production facility. Following the branch plant scenario, much of the indirect labor can be located away from the plant - accounting, finance, inventory management, production scheduling and other functions are often centralized. Direct supervision and management comprise only a small fraction of the indirect labor.

The costs of direct labor, energy, taxes and raw materials are heavily influenced by location. Direct labor cost depends on the skills required by the industry as well as on labor costs in the production zone. The skill dimension is measured by the difference between the mean wage rate for the industry and the mean wage rate for all industry. Locational differences are reflected in zonal differences by skill category. Raw material costs depend on the location of the source and price at the source which may reflect production cost, national market influences or both.

Production costs are modeled in a linear form:

$$P(i,k) = \sum_{q} (c(i,q))\ (a(k,q)) \tag{7}$$

where:

P(i,k) = production cost in zone i for commodity k,

c(i,q) = unit cost of input factor q in zone i, and

a(k,q) = input coefficient of factor q for production of commodity k.

This equation is assumed to be valid for all producing zones.

Geographic Representation

The purpose of the geographic representation was to identify major producing zones and markets for each of the 53 commodity groups and to determine principal supply patterns. This work was based on the commodity flow data as modified using the procedures described in Chapter III. The work was performed in two steps. First, a threshold shipment volume was selected for each commodity group. Second, commodity flow data were extracted from the commodity flow data file for each of the shipments that exceed the threshold size.

In selecting shipment size thresholds, we sought to reduce the amount of data that needed to be analyzed without compromising the quality of the geographic representation. Most of the 53 commodity groups were shipped in some volume between a very large number of network zone pairs. No commodity groups were dominated by very large movements. Therefore the thresholds selected to screen out small movements needed to be relatively small. Because of the universe size of the commodity flow data file, it was not possible to examine the entire data file for any commodity group. Rather, several different thresholds were tested and compared in terms of the size of the market that each would retain in the analysis. For most commodities, the threshold selected was less than 0.3 percent of total U.S. production. Table 11 lists the thresholds selected for each of the commodities used in the Northern Mississippi test and the fraction of the total U.S. market retained for analysis.

Once the thresholds had been selected, the commodity flow file was entered to extract the shipment data for all commodity movements that exceeded the threshold values. Sample data are illustrated in Table 12 for Commodity Group 250, Furniture and Fixtures. These data represent 40 percent of the commodity flow and they represent only a small fraction of the zone-to-zone movements. The major destinations identified in Table 12 constitute the major markets for the commodity. Thus, if a new production zone is to be created in the Multi-State Corridor, it must compete with the production zones identified in Table 12 for the markets also identified in Table 12.

Preparation of Cost Data

The method used to prepare each item of cost data is described below.

Raw Material Costs

Raw materials or input commodities as reported in the Census of Manufacturers and other secondary source documents are divided into two types: manufactured items; and mine, forest, or agricultural commodities. Average national costs are used for manufactured items with no distinction by zone.

The costs of mine, field and forest products are based on costs established by national markets, such as the Chicago commodity exchange. National market costs are adjusted for transportation costs.* Thus, the cost of material k in zone i, c(i, k), is determined by the following equation:

$$c(i,k) = \min_{j} \left[c(j,k) - t(j,o) + t(j,i) \right] \qquad (8)$$

*For these movements, transport time and time variability are assumed to have no value.

TABLE 11

COMMODITY THRESHOLDS FOR GEOGRAPHICAL ANALYSIS

Commodity Group	Shipment Size Threshold, Percent of Total Flow	Fraction of Commodity Flow Retained for Analyses
220 Textile Mill Products	0.26%	55%
230 Apparel	0.27	51
240 Lumber & Wood	0.15	55
250 Furniture & Fixtures	0.23	40
287 Agricultural Chemicals	0.23	51
302 Rubber & Plastic Products	0.29	43
350 Machinery, ex. Electrical	0.18	37
361 Electrical Machinery	0.26	39

TABLE 12

MOVEMENT DATA FOR COMMODITY 250, FURNITURE & FIXTURES

Origin Zone	Destination Zone	Mode	Annual Tons
69	69	2	115794.
69	70	2	20142.
69	71	2	18406.
69	72	2	355151.
69	75	1	16.
69	75	2	30793.
72	69	1	2741.
72	69	2	28972.
72	72	1	456.
72	72	2	93667.
72	72	3	230.
72	76	1	150.
72	76	2	16201.
73	69	1	426.
73	69	2	21714.
73	72	1	296.
73	72	2	27796.
74	69	1	2399.
74	69	2	14835.
74	72	1	1147.
74	72	2	49091.
74	74	1	1098.
74	74	2	14954.
75	87	2	17510.
77	90	1	6919.
77	90	2	8325.
77	105	1	16887.
77	105	2	821.
77	111	1	28515.
77	111	2	3978.
79	72	1	4695.
79	72	2	38662.
79	79	2	18831.
79	88	1	2357.
79	88	2	34884.
79	90	1	5760.
79	90	2	26557.
80	72	1	18279.
80	72	2	19835.
80	79	1	179.
80	79	2	20898.
80	80	1	15.
80	80	2	16053.
85	90	1	2573.
85	90	2	37435.

TABLE 12 (CONT.)

Origin Zone	Destination Zone	Mode	Annual Tons
88	88	1	200.
88	88	2	43801.
88	90	2	19458.
91	88	2	20100.
91	91	2	18923.
91	92	2	21502.
97	97	1	1613.
97	97	2	16811.
105	105	1	2.
105	105	2	23515.
109	94	1	481.
109	94	2	18880.
109	106	2	21511.
110	106	1	3818.
110	106	2	12877.
110	110	1	25.
110	110	2	98763.
110	111	1	96.
110	111	2	29839.
110	117	1	7765.
110	117	2	15738.
111	107	1	4166.
111	107	2	16607.
111	109	1	16140.
111	109	2	6784.
111	111	1	116.
111	111	2	63555.
78	72	2	39571.
120	90	1	23775.
120	90	2	9702.
27	110	1	14735.
27	110	2	1207.
47	72	1	8397.
47	72	2	24081.
47	75	1	10186.
47	75	2	11764.
47	85	1	7708.
47	85	2	32497.
47	90	1	271.
47	90	2	72264.
47	91	2	17154.
47	107	1	15250.
47	107	2	9
48	90	2	18044.
119	72	1	4948.
119	72	2	12997.
50	50	2	16314.
50	110	1	19008.

TABLE 12 (CONT.)

Origin Zone	Destination Zone	Mode	Annual Tons
50	110	2	2528.
63	110	1	21677.
64	50	1	6707.
64	50	2	34930.
64	55	1	24243.
64	55	2	3309.
64	62	2	15360.
64	64	2	23450.
64	65	2	15906.
64	69	1	5805.
64	69	2	9908.
64	72	1	1312.
64	72	2	48047.
64	90	1	14915.
64	90	2	2563.
64	91	1	68029.
64	91	2	3468.
64	98	2	81882.
98	62	1	11594.
98	62	2	43585.
98	62	3	3605.
98	98	1	29378.
98	98	2	208741.
98	98	3	3149.
98	105	1	4467.
98	105	2	11739.

Mode

1 = Highway
2 = Rail
3 - Water

where:

$t(j,o)$ = is the transportation cost from a source at j to the national market at o, and

$t(j,i)$ = is the transportation cost from a source at j to production zone at i.

Direct Labor

Direct labor cost is estimated for each commodity by using the industry data and zone-specific labor costs. The process requires two steps: (1) determine the relative labor skill level required by the industry, and (2) establish the cost of labor of the requisite skill level at each of the major producing zones. The major data sources to support labor cost determination are the industry data, the summaries of major commodity movements, and wage statistics published by the U.S. Department of Labor (DOL).

Industry labor skill levels are determined by comparing the average direct labor wage for the industry with the DOL data for the major producing zones. Inasmuch as DOL data are presented by skill level - e.g. craft, operative, unskilled - rather than industry, it is first necessary to prepare a weighted wage spectrum for the major producing zones. Thus, if:

L_q^n = weighted hourly wage rate for skill q in zones producing commodity n,

Then:

$$L_q^n = \sum_{i \varepsilon E_n} W_i^n \ell_{iq} \tag{9}$$

where:

W_i^n = fraction of commodity n produced in zone i,

ℓ_{iq} = wage rate for skill q in zone i, and

E_n = the set of zones producing commodity n.

When L_q^n have been determined for all skill categories, then the mean wage rate for industry n can be placed in the spectrum of skills. An average skill is then selected for industry n and local wage rates in each producing zone i are the wage rates associated with the selected skill.

Energy Costs

Energy costs for a commodity are obtained for each type of energy used to produce the commodity in each zone in which major production occurs. Cost data from Federal Energy Administration reports are combined in the proportions used by each industry to generate zone-specific equivalent KW-hour costs for each commodity.

Capital and Taxes

An annual capital cost recovery factor of 0.15 was used for all industries. This factor is based on a discount rate of 8% and a recovery period of 10 years [25]. Commodity specific factors can be obtained from more detailed industry analysis. Similarly, building cost indexes could be used to adjust for location so that capital investment need not be applied uniformly for all zones. These issues will be explored in future work.

Taxes were computed according to the following concept: Total business taxes per capita were obtained for each state from Tax Institute of America [26] data. These figures are taken as a proxy measure of the sum of property taxes, sales taxes on input commodities, and state and municipal corporate income taxes. Next, the specific taxes were computed for each commodity in each production zone, using zone-specific tax data [27] and industry data on capital investment, input commodities, sales, and profit. The taxes for other zones were then computed using the ratios of the total business taxes per capita for the respective states. Future research will focus on more detailed data, both for industries and for zones.

Matrix Iterative Procedure

To support the first year's analysis, production costs were determined as described above. Because of the interrelationships among the different factors, future attention will be given to a matrix iterative procedure for determining commodity production costs by zone. This method is outlined

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[25] Thuesen, H. G., W. J. Fabrycky and G. J. Thuesen, Engineering Economy, 5th Ed., Prentice-Hall, Englewood Cliffs, N.J., 1977.

[26] Tax Institute of America, State and Local Taxes on Business, Princeton, N.J., 1965.

[27] Rogers, George, Georgia Principal Industrial Taxes, Georgia Dept. of Industry and Trade, Atlanta, Georgia, 1971.

broadly by the following steps:

1. Begin with national average costs c_{ik},
2. Adjust the c_{ik} by zone-specific direct labor, energy, and capital costs,
3. Adjust the c_{ik} by zone-specific taxes,
4. Identify sources of input commodities for existing facilities by observing the commodity movement data. For new facilities find the best source.
5. Update the c_{ik} based on the input commodity costs determined in step 4. Return to step 3.

Customer Service Parameters

Customer service parameters are those factors that influence shipper choice of transportation mode and purchaser choice of supply source location. Customer service parameters, in general, relate to a purchaser's ability to realize prompt, dependable delivery of undamaged goods at minimum personal and organizational expense and inconvenience. Long lists of customer service parameters have been prepared and evaluated for specific shipments and classes of shipments. Most parameter lists can be divided into five categories - cost, transport time, transport time variability, loss and damage, and organizational. Inasmuch as the present research deals only with locational issues, the organizational category was set aside. It was also necessary to set aside the loss and damage category because comprehensive data are not available to support estimates of loss and damage probabilities on an arc by arc basis. At a future time, the loss and damage criterion will be re-examined and, if appropriate, introduced into customer service measurement.

The remaining parameters - cost, transport time and transport time variability are considered to be sufficiently important to carry through the analysis. Cost is measured in dollars and includes loading, local collection, terminal, line haul, local distribution and unloading costs, as appropriate. Transport time is the elapsed time from a shipper request for service to delivery of the shipment at the consignee's dock. As thus interpreted, frequency of service is a part of transport time and is reflected in delays waiting for service and delays in transit. Transport time variability is defined as the variance in transport time. This measure was selected so that individual arc variances could be added to yield route variance.

When evaluating customer service parameters for alternative transportation services and routes, shippers tend to make positive selections. This suggests that shippers have at least informal techniques for combining service parameter values to yield a single value by which one candidate service can be compared with another. This result has been achieved by assigning money values to transport time and transport time dependability. In this fashion, the customer service parameter value g^n_{ijm} for commodity n moving from i to j via mode m is

$$g^n_{ijm} = \sum_{\text{path } k} f_n\left(C^n_{km} + A^n_1 T^n_{km} + A^n_2 V^n_k\right) \tag{10}$$

where:

f_n = functional form for commodity n,

C^n_{km} = cost to move commodity n over arc k via mode m,

T^n_{km} = Transport time for commodity n on arc k via mode m,

A^n_1 = value of transport time for commodity n,

V^n_{km} = transport time variability for commodity n, on arc k via mode m, and

A^n_2 = value of transport time variability for commodity m.

Unique values for f_n, A^n_1 and A^n_2 were sought for each commodity group that reflect the customer service requirements of that group. The functional form and coefficient values were developed as part of the mode split analysis of present transportation practices. This work is reported in Chapter V.

Market Share Analysis

The market share that a new facility can expect to achieve in an existing market depends on how its combination of production cost and customer service cost compares with similar costs of other producers serving the same market. The size of the share is based on a comparison between the cost and service estimated for the new facility and the cost and service determinations for the lowest cost facility now serving the market. If the proposed new facility enjoys a cost and service advantage over all other facilities that serve the market, the new facility is assured a reasonable share of the market; however, the new facility will not capture all of the market. If the new facility does not enjoy an advantage over a sufficient number of other producers, the new facility is not likely to attract a significant share of the market. In the first year's analysis a new production zone was excluded from a market altogether, if its production plus customer service cost were not in the lower 75 percentile of all suppliers to the market.

Market Share Function

The estimated size of a new facility's market share depends on the nature of the commodity/industry group as well as on cost and service relationships. Agriculture, forest and mineral product markets are close to perfectly elastic. Thus, a new entry must meet the existing market price in order to supply any product to the market at all. Markets for manufactured goods exhibit different amounts of elasticity. The functional form was known to be nonlinear for all commodities except those enjoying perfect competition.

The price-market share relationship for each commodity group was tested using several functional forms in a regression analysis of existing market patterns. The form finally selected is:

$$MS^i_{j\ell} = a_i^{\,-\alpha_i \Delta H^i_{j\ell}} \tag{11}$$

where:

$MS^i_{j\ell}$ = market share in zone ℓ enjoyed by a producer of commodity i located in zone j,

$\Delta H^i_{j\ell} = (c_{ij} + g^i_{j\ell}) - (c_{ik} + g^i_{k\ell})$,

c_{ij} = production cost for commodity i in zone j,

$g^i_{j\ell}$ = customer service cost for commodity i produced in zone j and shipped to zone ℓ,

k = producer with the lowest delivered cost to market ℓ,

$c_{ij} + g^i_{j\ell}$ = market cost for product i at market ℓ for a producer at j, and

a_i, α_i = coefficients for commodity i.

Values of the a_i and α_i were determined by multiple regression of the commodity flow data extracted for analysis. Table 13 lists coefficient values for the eight test commodity groups.

For each existing production zone and market zone, a market cost was determined by adding production and customer service cost. Suppliers to a given market were ranked in order of increasing market costs and market shares were calculated for each production zone.

$$MS^i_{j\ell} = V^i_{j\ell}/MV_{i\ell} \tag{12}$$

where:

$V^i_{j\ell}$ = volume of commodity i supplied to market ℓ by producers in zone j, and

$MV_{i\ell}$ = total volume of commodity i shipped to zone ℓ.

The largest market share is fixed as the share enjoyed by the lowest cost producer, thus establishing the y-axis intercept of the market share function (a_i). The total market share for the sum of the major movements is constrained to equal the same total that was recorded when the movements were extracted from the commodity flow data.

Market Share of a New Facility

If a new facility can supply commodity i to an existing market at ℓ, the new facility will upset the balance among the suppliers to that market. Two situations can accompany the entry of the new facility:

1. It will have a market cost that is lower than the present lowest market cost, or
2. It will have a market cost that is higher than the present lowest market cost, but the new facility will be competitive with other suppliers.

In the first instance, the new facility will displace the lowest cost producer and all previous producers will lose market share at the expense of the new facility. The market share of the new facility will be equal to a_i.

In the second instance, the new facility will displace higher cost

TABLE 13

MARKET SHARE PARAMETERS

	Commodity	a_i	α_i
1.	Textile	0.0680	-0.0005
2.	Apparel	0.1455	-0.0017
3.	Lumber	0.1174	-0.0910
4.	Furniture	0.0854	-0.0039
5.	Ag. Chemicals	0.0770	-0.0035
6.	Plastic Prod.	0.1314	-0.0089
7.	Machinery	0.0656	-0.0004
8.	Electrical Equipment	0.1049	-0.0031

suppliers, but it will not upset those that supply the market at lower cost. This is accomplished by establishing a market share for each producer that is adjusted to reflect the new entry and constrained by the share of the market that is left over from the unaffected suppliers, or

$$MS'^{i}_{j\ell} = MS^{i}_{j\ell} \cdot \frac{\sum_{j\epsilon J} MS^{i}_{j\ell} - \sum_{j\epsilon J_1} MS^{i}_{j\ell}}{\sum_{p\epsilon P} MS^{i}_{p\ell}} \qquad (13)$$

where:

$MS'^{i}_{j\ell}$ = revised market share in zone ℓ enjoyed by a producer of commodity i in zone j,

J_1 = set of major producers with market costs lower than those of the new facility, and

P = set of major producers with market costs higher than those of the new facility.

V. NETWORK MODELING*

The network model provides the geographical framework for the analysis, and develops the least cost customer service parameters associated with zone-to-zone commodity movements. This task is greatly complicated by the need to consider multiple transportation modes as well as intermodal combinations and by the need to manipulate the large commodity flow data files.

The transportation network contains 120 nodes that represent the 120 production and market zones. The nodes account for freight traffic origination (production), termination (consumption), mode interchange and terminal operations. Network arcs consist of the transportation routes taken by present commodity movements together with new routes that might be part of a transportation improvement program. The transportation modeling requires an understanding of present commodity movements and the bases for electing those movements. In fact, the present decision making process needs to be so well understood that the responses to transportation improvement and economic development programs can be predicted.

Several conventions were adopted to simplify the research effort:

1. All line haul arcs originate and terminate at nodes representing zone centroids,
2. Transportation costs and services to and from a zone are represented by costs and services to and from the zone centroid,
3. Intermode transfers can occur only at zone centroids, and
4. Intra-zone movements are not considered.

These assumptions could be easily changed, but they seemed appropriate for the first-year effort.

The basic resources used in the network modeling are the commodity flow data described in Chapter III. The data include estimates of present zone-to-zone movements for each of the 53 commodity groups and for each of the three surface transport modes - highway, rail and water.

The three tasks comprising this work - prepare network analysis procedures, define present network, and mode split analysis - are closely

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*The work described in this chapter was performed by G. P. Sharp, F. M. Holloway and M. A. Mullens.

interrelated and were performed more or less simultaneously. It is useful to present them in the order listed above so that one can firmly grasp the purpose of the work before it is necessary to consider the detailed data required to prepare for the network investigations.

Network Analysis

The purpose of the network analysis was to devise a method for representing the flows of the 53 commodity groups on the 120 node network, containing highway, rail, and waterway arcs while allowing for new arcs representing new or improved services and for intermodal services. The network analysis included the development of algorithms for identifying single mode and intermodal routes between zone pairs that have the lowest customer service costs for the different commodity groups.

Network Representation

A multicommodity flow network was used to represent the flow of each of the 53 commodities on each network arc. The flow variables are of the type

$$f(i,j,n) = \text{flow of commodity } n \text{ on arc } (i,j).$$

At each node there are constraints of the type

$$\sum_j f(i,j,n) - \sum_h f(h,i,n) = s(i,n). \tag{14}$$

The first summation represents all flow of commodity n away from node i; and the second summation represents all flow of commodity n in to node i. A positive difference is equal to the net outbound shipments of commodity n that originate at node i, and a negative difference is the net market for commodity n at node i. Customer service costs are represented for each arc (i,j) and for each commodity by the coefficients g(i,j,n).

Within this general framework, three methods were examined for distinguishing between the different transportation modes, such as highway, rail, and water:

1. An expanded network, form 1. Using this method one represents each mode connecting two points by a separate arc with appropriate cost. Additional nodes and arcs are then inserted into the network to represent transfers between modes and forwarding operations on a

mode [28].

2. Expanded network, form 2. In this method a separate arc is created between any two nodes for each path that can be followed without changing modes. Appropriate dummy nodes and arcs are created to represent transfers [29].

3. Dual node numbers with subscripted flow variables. This method requires one additional subscript in the flow variables and cost coefficients to represent the mode. Also, a modified shortest-path algorithm is needed to deal with the dual node numbers.

Methods 1 and 3 are essentially different ways of implementing the same concept. For a network consisting of N nodes, A one-way arcs, and M modes, method 1 builds an expanded network of $N(1+M)$ nodes and $(AM + M^2 + 2M)$ one-way arcs. Method 3 theoretically requires the same amount of computer storage, but in practice affords opportunities for compacting the data storage. Both methods represent customer service attributes in additive form along paths.

Method 2 can deal with non-additive customer services since each path by one mode is modeled by a separate arc. For example, the cost of a direct shipment between A and C is often less than the sum of costs for a shipment from A to an intermediate point B and then from B to C. However, for a network of 120 zones the number of arcs can become disturbingly large. This type of expanded network is more suited for modeling public transit systems, for which it was designed, than for modeling large freight networks.

Dual Node Numbers with Subscripted Flow Variables

The dual node numbering method was selected because it offered the most convenient form for input data preparation and promotes flexibility in finding single-mode and multimode shortest paths. The flow variables and cost coefficients change to:

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[28] Sharp, G. P. and P. S. Jones, "Evaluating Modal Transfer Operations With Network Flow Models," Proceedings, Third Intersociety Conference on Transportation, Atlanta, Georgia, 1975.

[29] LeClerq, F., "A Public Transport Assignment Method," Traffic Engineering and Control, June 1972, pp. 91-96.

$f(i,j,m,n)$ = flow of commodity n by mode m on arc (i,j), and

$g(i,j,m,n)$ = corresponding customer service cost coefficient.

The node constraints become

$$\sum_j \sum_m f(i,j,m,n) - \sum_h \sum_m f(h,i,m,n) = s(i,n). \qquad (15)$$

Each node carries a two subscript designation, (i,i'), in which the i represents the node location and i' represents one of the following:

1 origination	2 destination
3 mode 1 (highway) inbound	4 mode 1 outbound
5 mode 2 (rail) inbound	6 mode 2 outbound
.	.
.	.
.	.

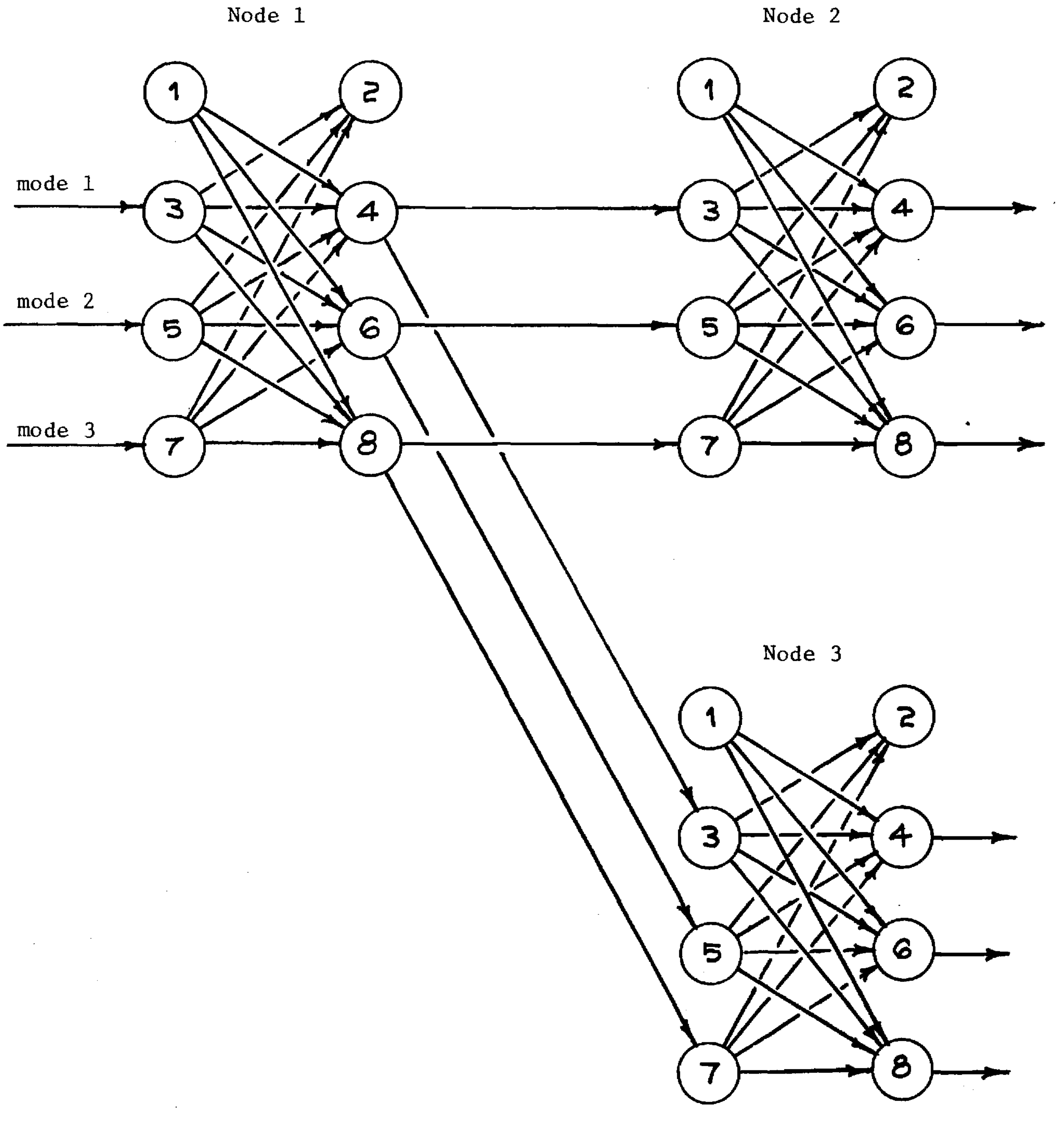
Line haul arcs always connect two nodes with consistent i' numbers. Transfers and forwarding at nodes can occur wherever costs are favorable. Figure 4 illustrates how this dual numbering system can be represented in an expanded network.

Transfer costs for each node are represented by a symmetric array:

position	movement	position	movement
1,1	not used	2,3	highway-rail
1,2	load, highway	2.4	highway-water
1,3	load, rail	3,3	forward, rail
1,4	load, water	3,4	rail-water
2,2	forward, highway	4,4	forward, water

Using this method for representing a multimodal network an input editor for building an expanded network is avoided and data are easily prepared for both the initial network and for subsequent alterations. With an appropriate shortest path algorithm, such as the one described below, it is easy to determine single-mode or two-mode paths by excluding other modes from consideration.

FIGURE 4
DUAL NODE NUMBERING SYSTEM,
ONE-WAY ARCS



Flow Assignment

Uncongested network assignment is achieved using a Moore-type tree building algorithm developed specifically for this research. The algorithm accepts as input the different arc customer service costs by mode and the transfer costs at each node. It treats these costs as if it were dealing with an expanded network of form 1. The costs on line haul arcs and the node transfer costs are assumed to be additive for determining an overall cost for an O-D (origin-destination) path.

The algorithm itself is an adaptation of a well-known procedure [30] to the dual node numbering system. It accepts as input the modes allowable in a particular run. Thus, it can be used for finding single-mode paths as well as compound-mode paths. The use of the program is discussed further in the mode split section.

The assignment program assumes that customer service costs are unaffected by the volume of freight traffic over the ranges of interest. This assumption may be valid for the line haul arcs in the Multi-State Corridor. As a first approximation one can assume that the diversions to new and improved routes and the additional flows generated on line haul arcs by products from new facilities do not change transport characteristics. In effect, one can then simply observe customer service costs, and use these as values for assigning new flows in an uncongested network.

Congestion may well occur at the mode transfer terminals. The second-year research effort will examine this matter in detail. Based on queueing theory, typical average delay times can be developed as a function of flow through a terminal. Thus terminals can be represented as congestion-affected arcs. During the second year the research team will program a congestion-affected multicommodity flow assignment algorithm which has been developed already [31]. This algorithm is an extension of other, reasonably efficient assignment algorithms.

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[30] Christofides, Graph Theory, Academic Press, New York, 1975.

[31] Sharp, G. P., "Equilibrium Traffic Assignment for Multiclass-User Transportation Networks," ISyE Research Report W-77-1, Georgia Institute of Technology, School of Industrial and Systems Eng., Atlanta, Georgia, 1977.

Define Present Network

The present transportation network consists of the 120 zone centroids (nodes) and a set of arcs connecting pairs of nodes that represent the existing transportation routes and services. The basic network was developed for one mode at a time - highway, rail and water - and it will be described in terms of that development. The modal networks were then combined using the dual node numbering procedure. Each network arc is described in terms of:

1. Terminal nodes,
2. The transportation modes serving the arc, and
3. Customer service parameters - cost, transport time and transport time variability - for each mode.

Detailed network arc descriptions are presented in Appendix C for each of the three modes studied to date. Origination, termination, mode transfer and forwarding activities at nodes are also associated with cost, time, and time variability for each mode.

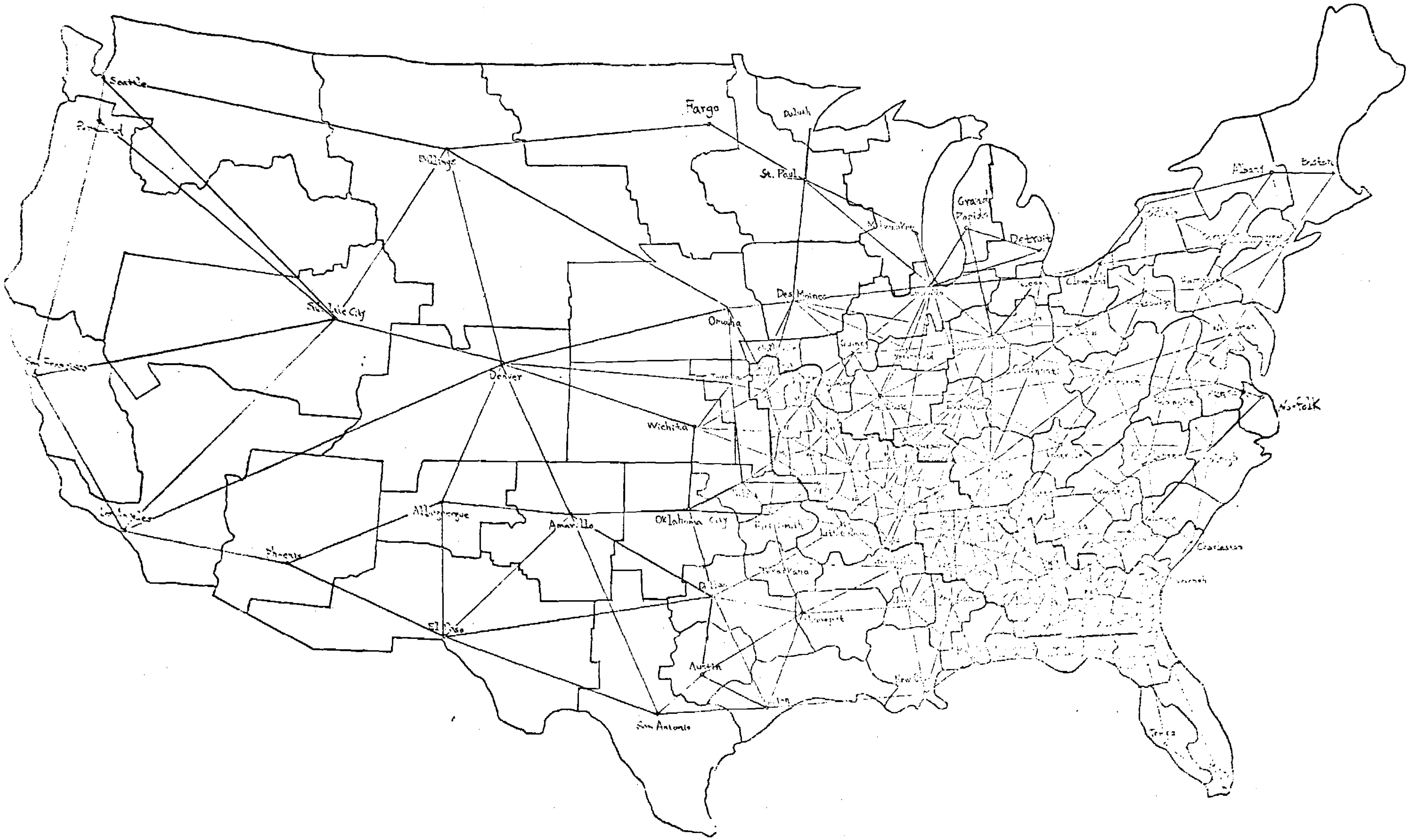
Highway Network

The highway network, illustrated in Figure 5, is made up of the principal freight supporting intercity routes that connect the different zones. Two different methods were used to select highway arcs, one for Corridor and adjacent arcs, and the other for remote arcs.

The internodal distances between Multi-State Corridor nodes are on the order of 50 to 75 miles. Nodal cities are served by Federal Aid Primary, secondary, state, and county roads, but not generally by Interstate highways. Many of the existing highways are not of sufficiently high quality to support regular truck traffic. State traffic density maps were used to select a set of candidate arcs on the basis of alignment and traffic volume. Each candidate arc was described in terms of origin, destination, highway designation and number of traffic lanes. Routes included as many as three different highway numbers that jointly provide a path between the two nodes. In other instances, two or more parallel routes were identified between the same pair of nodes.

State transportation officials reviewed all of the candidate routes. They suggested dropping some, adding others and modifying still more. Where two or more parallel routes were available, a preferred route was selected.

FIGURE 5
HIGHWAY NETWORK



The preferred route became the basic highway arc. All arc descriptions apply to this route. Additional parallel routes are included as extra lanes on the primary arc. The presumption is that as the basic arc becomes congested with traffic, the point will be reached where the parallel route can offer equivalent service.

Non-Corridor arcs in the seven corridor states were developed in the same manner described for corridor arcs. However, arcs serving the more remote zones were developed in a different way. Long distance intercity movements take place predominantly on the Interstate and Defense Highway Network. Therefore, Interstate routes formed the backbone of the remote highway network. Care was taken to include all Interstate routes on the highway network. These were augmented with principal Federal Aid Primary routes where suitable Interstate routes were not available.

Arc lengths were expressed in terms of the basic arcs, using state maps and atlases as principal sources of highway distances.

Customer service parameters for the highway arcs were taken from many sources. Transportation costs, expressed as cost per ton mile, were taken from the Whitten equations [8]. If:

LHM^n_{ij} = total line haul costs/ton of commodity n moving from zone i to zone j,

Then:

$$LHM^n_{ij} = \sum_{e \varepsilon E_M} p^{en} \sum_{g \varepsilon MCCA} \sum_{c \varepsilon C_m} d^{gc}_{ij} \cdot ML^{ec}_g \cdot I^n \tag{16}$$

where:

E_M = set of trailer types,

p^{en} = fraction of commodity n using trailer type e,

MCCA = set of motor carrier cost areas,

C_M = set of highway classifications,

d^{gc}_{ij} = distance on arc i,j in MCCA g on highway class c,

ML^{ec}_g = highway line haul cost/ton mile for any commodity using trailer type e, highway class c in MCCA g, and

I^n = density multiplier for commodity n.

Three trailer types were used - van, refrigerated and tank. The p^{en} were estimated from national aggregate statistics [32] and are shown in Table 14. Cost areas are those established by the ICC for analyzing motor carrier costs, shown in Figure 6.

The revenue density multipliers are based on an expansion of Whitten's 20 commodities into 53, and are shown in Table 15. The d^g_{ij} are obtained from the physical characteristics of the arc and the rate district containing it. Costs are given for van by Whitten, and following his suggestions, tanker costs were established at 200% of van cost and refrigerator truck at 110% of van cost.

Costs per ton mile, ML^{ec}_g were calculated for each condition that occurs on a highway arc. These in turn were extended to yield arc costs. Where an arc crosses a cost area boundary and where an arc is composed of more than one highway classification, weighted averages were prepared to represent arc costs.

Highway travel times were determined from estimated truck speed for each arc. Trucks can operate over almost all Interstate routes at the national speed limit of 55 miles per hour including rest and fuel stops. Speeds on lower quality routes were estimated with help from state highway officials. Where expert estimates were not available, a speed of 40 mph was assigned to high quality roads through relatively level terrain and a speed of 30 mph was assigned to other routes.

Travel time variability comes from delays and from conditions that prevent the attainment of estimated speeds. Thus, almost all variations result in longer than expected travel times. Excessive delays result from accidents, mechanical problems, undue driver fatigue or driver dalliance. Most such delays are of a short duration, rarely exceeding four hours.* If:

LHV^n_{ij} = highway time variance in transporting commodity n from i to j

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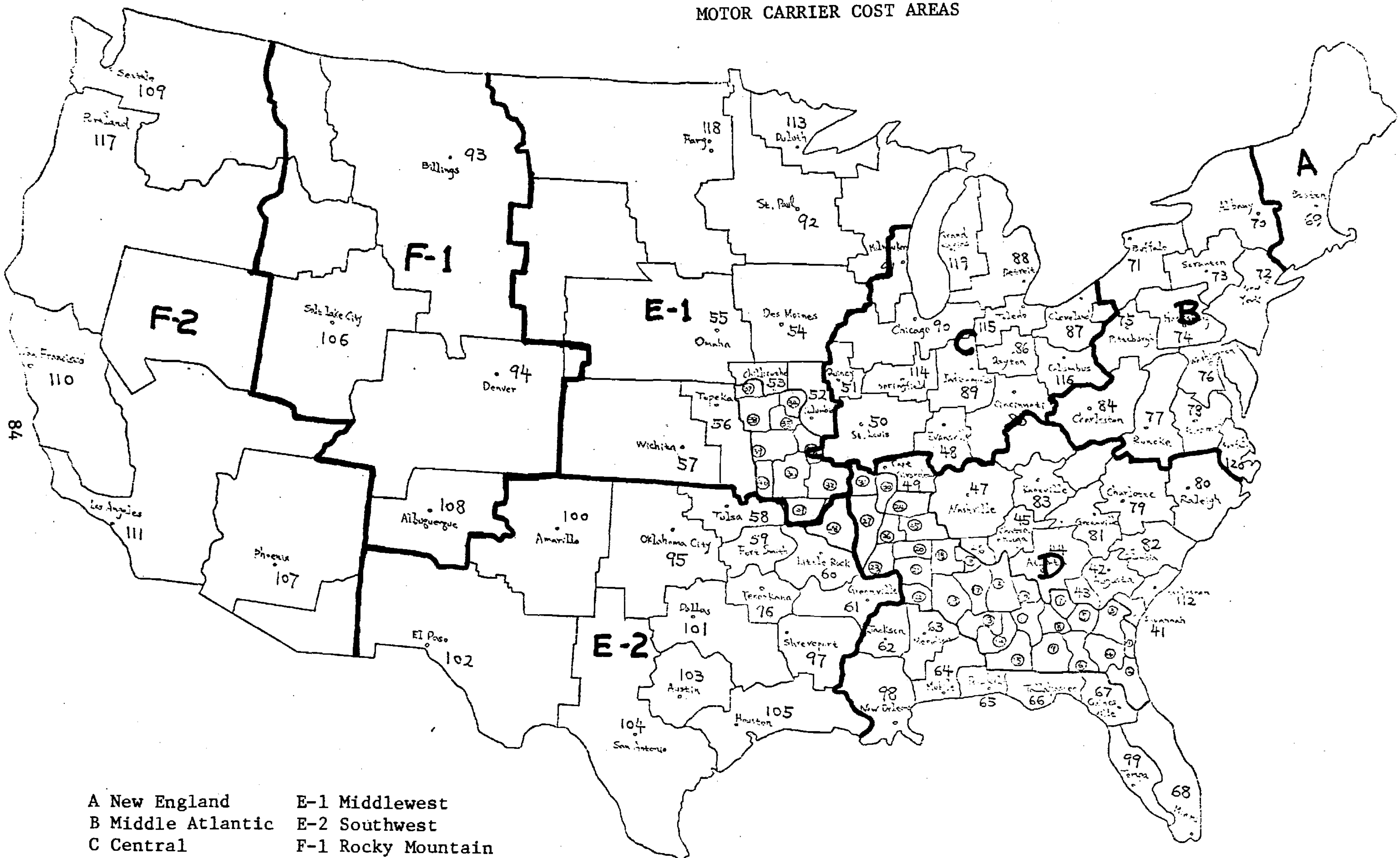
*Serious accidents generally destroy the cargo and are not counted as delays.

[32] Interstate Commerce Commission, Cost of Transporting Freight by Class I and Class II Motor Common Carriers of General Commodities, 1975, U.S. Govt. Printing Office, Washington, D.C., 1976.

TABLE 14
COMMODITY SHIPMENTS BY MOTOR CARRIER

COMMODITY	Fraction by Trailer Type: VAN	TANKER	REFRIG.
011 Grain	0.67	0.27	0.06
013 Field crops	1.0	0	0
021 Livestock	1.0	0	0
024 Dairy	0	1.0	0
025 Poultry & Eggs	0.4	0	0.6
080 Forrestry	1.0	0	0
090 Comm. Fish	0	0	1.0
101 Iron ore	0	1.0	0
102 Non-Fe. ore	0	1.0	0
110 Coal	0	1.0	0
130 Oil & Gas	0	1.0	0
140 Non-Metal Min.	0.05	0.95	0
201 Meat	0.4	0.4	0.2
202 Dairy Prod.	0.4	0	0.6
203 Pres. Foods	1.0	0	0
204 Grain Prod.	1.0	0	0
205 Bakery Prod.	1.0	0	0
206 Confectionary	0.85	0.15	0
207 Fats & Oils	0.5	0.5	0
208 Beverages	1.0	0	0
209 Misc. Food	1.0	0	0
210 Tobacco	1.0	0	0
220 Textile Mill Pr.	1.0	0	0
230 Apparel	1.0	0	0
240 Lumber	0.59	0.41	0
250 Furniture	1.0	0	0
260 Paper	1.0	0	0
270 Print & Pub	1.0	0	0
281 Inorg. Chem.	0.32	0.68	0
282 Plastics	0.84	0.16	0
283 Drugs	1.0	0	0
284 Soap	0.96	0.04	0
285 Paint	0.6	0.4	0
286 Org. Chem.	0.32	0.68	0
287 Ag. Chem.	0.07	0.93	0
289 Misc. Chem.	0.65	0.35	0
290 Petr. Ref.	0.15	0.85	0
301 Tires	1.0	0	0
302 Rubber & Pl.	1.0	0	0
310 Leather	1.0	0	0
321 Stone C. & Gl.	0.25	0.75	0
324 Cement	0.79	0.21	0
331 Iron & Steel	0.16	0.84	0
333 Non-Fe Metal	0.86	0.14	0
341 Metal Cans	1.0	0	0
342 Fab. Metal Pr.	0.23	0.77	0
350 Machy. Ex. Elec.	0.7	0.3	0
361 Elec. Mach.	1.0	0	0
362 Elec. App.	1.0	0	0
371 Motor Veh.	1.0	0	0
372 Trans. Equip.	0.95	0.05	0
380 Meas. Inst.	1.0	0	0
390 Misc. Mfg.	1.0	0	0

FIGURE 6
MOTOR CARRIER COST AREAS



A New England
B Middle Atlantic
C Central
D Southern
E-1 Middlewest
E-2 Southwest
F-1 Rocky Mountain
F-2 Pacific

TABLE 15
MOTOR CARRIER REVENUE DENSITY FACTORS

Commodity		Factor
1	Grain	1.0
2	Field Crops	1.0
3	Livestock	1.6
4	Dairy	1.0
5	Poultry & Eggs	2.7
6	Forrestry	1.0
7	Comm. Fishing	1.0
8	Iron Ore	1.0
9	Non Ferr. Ores	1.0
10	Coal	1.0
11	Extraction Oils & Gas	1.0
12	Non-metal Min.	1.0
13	Meat	1.0
14	Dairy Prod.	1.0
15	Canned & Pres. Food	1.0
16	Grain Prod.	1.0
17	Bakery	1.5
18	Confections	1.0
19	Fats & Oils	1.0
20	Beverages	1.0
21	Misc. Food	1.0
22	Tobacco	1.6
23	Textile	1.1
24	Apparel	2.6
25	Lumber & Wood	1.0
26	Furnit. & Fixt.	2.0
27	Paper	1.0
28	Print & Publish	1.0
29	Ind. Inorg. Chem.	1.0
30	Plastics	1.0
31	Drugs	1.0
32	Soap	1.0
33	Paint	1.0
34	Ind. Org. Chem.	1.0
35	Agric. Chem.	1.0
36	Misc. Chem.	1.0
37	Petrol. Ref.	1.0
38	Tires & Tubes	1.5
39	Rubber & Plastic Prod.	1.6
40	Leather	1.6
41	Cement	1.0
42	Stone, Clay, Concrete Prod.	1.0
43	Iron & Steel	1.0
44	Non Ferrous Metals	1.0
45	Metal Cans, etc.	2.9
46	Fabricated Metal Prod.	1.0
47	Machinery Exc. Elect.	1.1
48	Elect. Ind. App.	1.1
49	Elect. Machinery	1.6
50	Motor Veh. & Equip.	2.7
51	Transp. Equip.	2.7
52	Measuring Insts.	1.1
53	Misc. Mfg.	1.3

Then:

$$LHV_{ij}^{n} = \sum_{c \varepsilon C_M} k_c \cdot d_{ij}^{c} \tag{17}$$

where:

k_c = delay factor for highway classification c, and

d_{ij}^{c} = distance between i and j on highway category c.

No differentiation was made among trailer types when calculating travel time variability.

Highway nodes have customer service parameters that reflect the time and cost associated with loading and unloading trucks at the originating and terminating nodes. No impedance is assessed against trucks that are forwarding (passing through a node while enroute to another node). Loading and unloading costs were also based on the Whitten equations.

If:

LM_i^n = loading cost per ton for commodity n at zone i,

Then:

$$LM_i^n = \sum_{e \varepsilon E_M} p^{en} \cdot p_1^{en} \cdot MT_{g(i)}^{e} \cdot I^n \tag{18}$$

where:

p_1^{en} = fraction of terminal cost for commodity n, trailer type e attributable to loading, and

$MT_{g(i)}^{e}$ = terminal cost per ton for any commodity using trailer type e in the MCCA associated with zone i.

Similarly, for unloading if:

UM_i^n = unloading cost per ton for commodity n at zone i,

Then:

$$UM_i^n = \sum_{e \varepsilon E_M} p^{en} (1 - p_1^{en}) MT_{g(i)}^{e} \cdot I^n \tag{19}$$

Lacking knowledge of p_1^{en}, we assumed that for all trailer types exactly half of the terminal expense is attributable to loading and half to unloading.

Loading and unloading times depend on commodity, trailer type, facility size, loading crew size, location and other factors. Times were estimated on the basis of commodity, trailer type and location only. Thus if:

LTM_i^n = loading time per trailer for commodity n at zone i,

Then:

$$LTM_i^n = \sum_{e \varepsilon E_M} p^{en} \cdot LTM_i^{en} \tag{20}$$

where:

LTM_i^{en} = loading time per trailer for commodity n in trailer type e at zone i.

Loading time variability was also based on commodity and trailer type.

VM_i^n = loading time variation per trailer for commodity n at zone i.

$$VM_i^n = \sum_{e \varepsilon E_M} p^{en} \cdot VM_i^{en} \tag{21}$$

where:

VM_i^{en} = loading time variation per trailer for commodity n in trailer type e at zone i.

Rail Network

The rail network, illustrated in Figure 7 and specified in Appendix C, was developed in a manner similar to the highway network, but using different sources of data. Nodal delays occasioned by switching movements play a key role in determining rail transportation times and time variations, and required careful attention.

Almost all intercity rail lines within the Multi-State Corridor have been identified as potential rail arcs, even though some are little used and of poor quality. Poor quality lines have been included because it is easier and cheaper to rehabilitate an existing rail line than to build a new one. Thus even a poor quality line represents a potential focus for future development should a future demand for rail service arise. Branch lines were excluded because they serve only local traffic. By concentrating zone activities at the zone centroid, branch line originations and terminations are modeled as

FIGURE 7
RAIL NETWORK

though they take place at the centroid.

Rail line quality was estimated from zone maps prepared by the Federal Railroad Administration [33]. These maps show type of signaling and traffic volume on all rail lines. Line quality is generally reflected by traffic volume. Very low levels of traffic suggest a line of poor or marginal quality. The selected arcs were checked against state rail plans, where available, and they were reviewed with a few railroad managements. Although the review was not complete, it did confirm the approach used.

In a number of instances, two or more parallel routes were identified. The highest quality route was selected as the basic arc. The additional routes were recorded to act as additional capacity in the event that the basic route becomes congested.

The ownership of different lines was recorded. To the extent possible, arcs were selected so that each arc is owned by a single railroad, or by two railroads known to cooperate. Interchange between railroads was restricted to nodes.

Non-Corridor arcs were developed from the FRA zone maps on the basis of traffic volume. For these arcs we sought principal traffic-carrying routes. We began by plotting all rail lines that carry traffic level 4 or more (5 million gross tons per year or more). The level 4 route network provided most of the desired arcs. These needed to be augmented in the west with level 3 routes in order to complete paths from zone to zone. Parallel routes and ownership were treated as for Corridor arcs. Because non-Corridor arcs are much longer, exclusive ownership was sometimes difficult to achieve. In these instances, the best available compromise was sought.

Arc lengths were taken from railroad time tables giving mile posts, FRA zone maps and from railroad atlases, e.g. [21].

Customer service parameters were developed for rail arcs from secondary sources including time tables, speed estimates, opinion and published data. Transportation cost per ton mile for each arc was calculated using the Whitten equations.

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[33] Federal Railroad Administration, United States Transportation Zone Maps, U.S. Govt. Printing Office, Washington, D.C., 1975.

If:

LHR^{n}_{ij} = line haul cost per ton of commodity n moving by rail from zone i to zone j

Then:

$$LHR^{n}_{ij} = \sum_{e \varepsilon E_R} p^{en} \sum_{g \varepsilon RCCA} \sum_{c \varepsilon C_R} d^{gc}_{ij} \left(\frac{M^{ec}_{g}}{q^{en}} + L^{ec}_{g} + k^{ec}_{g} \right) \tag{22}$$

where:

E_R = the set of rail car types,

p^{en} = fraction of commodity n using car type e,

RCCA = the set of rail carrier cost areas [8],

C_r = the set of rail line classifications,

d^{gc}_{ij} = length of arc i,j in RCCA g on rail line classification c

M^{ec}_{g} = variable line haul cost per car-mile in RCCA g, line class c, car type e,

q^{en}_{ec} = tons per car of commodity n in car type e,

L^{ec}_{g} = variable line haul cost per ton mile in RCCA g, line class c, car type e, and

k^{ec}_{g} = fixed line haul cost per ton mile in RCCA g, line class c, car type e.

Values for p^{en} and q^{en} are listed in Table 16. Data for other terms are contained in Whitten's report [8] or ICC or FRA publications. Rail line haul costs were calculated by computer for different conditions. Weighted averages were used for arcs crossing RCCA boundaries and for arcs containing end-to-end connections of different rail line classifications.

Rail travel times were drawn from several sources. Schedule times for merchandise freight trains traveling over the designated arcs were used when available. Other travel times were estimated on the basis of number of tracks, signalling, line quality and terrain.

TABLE 16
PERCENT OF COMMODITY MOVEMENT BY RAIL CAR TYPE,
(TONS OF COMMODITY PER CAR TYPE)

Commodity	Desc.	Box		Tank Hopper		Refrig.		Flat		TOFC	
		%	q	%	q	%	q	%	q	%	q
1	Grain	66	53	27	48	6	24	---	--	1	27
2	Field Crops	100	39	--	--	--	--	--	--	--	--
3	Livestock	100	25	--	--	--	--	--	--	--	--
4	Dairy	--	--	100	57	--	--	--	--	--	--
5	Poultry & Eggs	40	25	--	--	60	25	--	--	--	--
6	Forrestry	--	--	--	--	--	--	100	44	--	--
7	Comm. Fishing	--	--	--	--	100	49	--	--	--	--
8	Iron Ore	--	--	100	78	--	--	--	--	--	--
9	Non Ferr. Ores	--	--	100	88	--	--	--	--	--	--
10	Coal	--	--	100	81	--	--	--	--	--	--
11	Extraction Oils & Gas	--	--	100	77	--	--	--	--	--	--
12	Non-Metal Min.	5	51	95	73	--	--	--	--	--	--
13	Meat	25	40	25	40	13	40	--	--	37	40
14	Dairy Prod.	40	42	--	--	60	42	--	--	--	--
15	Canned & Pres. F.	100	45	--	--	--	--	--	--	--	--
16	Grain Prod.	100	41	--	--	--	--	--	--	--	--
17	Bakery	17	17	--	--	--	--	--	--	83	17
18	Confections	85	61	15	61	--	--	--	--	--	--
19	Fats & Oils	50	66	50	66	--	--	--	--	--	--
20	Beverages	85	49	--	--	--	--	--	--	15	49
21	Misc. Food	85	51	--	--	--	--	--	--	15	51
22	Tobacco	88	32	--	--	--	--	--	--	12	32
23	Textile	100	20	--	--	--	--	--	--	--	--
24	Apparel	100	20	--	--	--	--	--	--	--	--
25	Lumber & W	42	52	41	47	--	--	17	52	--	--
26	Furnit. & Fixt.	95	9	--	--	--	--	--	--	5	9
27	Paper	95	41	--	--	--	--	2	41	3	41
28	Print & Publish	80	29	--	--	--	--	--	--	20	29
29	Ind. Inorg. Chem.	31	72	68	72	--	--	--	--	1	30
30	Plastics	80	72	16	72	--	--	--	--	4	30

TABLE 16, CONTINUED

Commodity	Desc.	Box %	Box q	Hopper %	Hopper q	Refrig. %	Refrig. q	Flat %	Flat q	TOFC %	TOFC q
31	Drugs	100	32	--	--	--	--	--	--	--	--
32	Soap	60	33	4	33	--	--	--	--	36	23
33	Paint	60	50	40	50	--	--	--	--	--	--
34	Ind. Org. Chem.	31	71	68	71	--	--	--	--	1	30
35	Agric. Chem.	7	68	93	68	--	--	--	--	--	--
36	Misc. Chem.	62	55	35	55	--	--	--	--	3	27
37	Petrol. Ref.	14	35	85	56	--	--	--	--	1	25
38	Tires & Tubes	100	20	--	--	--	--	--	--	--	--
39	Rubber & Plastic Prod.	100	21	--	--	--	--	--	--	--	--
40	Leather	80	20	--	--	--	--	--	--	20	20
41	Cement	25	73	75	73	--	--	--	--	--	--
42	Stone, Clay, Concrete P.	65	54	21	54	--	--	14	54	--	--
43	Iron & Steel	8	62	84	62	--	--	8	62	--	--
44	Non Ferrous Metals	80	59	14	59	--	--	6	59	--	--
45	Metal Cans, etc.	95	12	--	--	--	--	5	12	--	--
46	Fabricated Metal Pr.	14	37	77	37	--	--	9	37	--	--
47	Machinery Exc. Elec.	32	23	30	23	--	--	38	23	--	--
48	Elect. Ind. App.	92	47	--	--	--	--	8	47	--	--
49	Elect. Machin.	92	14	--	--	--	--	8	14	--	--
50	Motor Veh. & Equip.	59	23	--	--	--	--	41	23	--	--
51	Transp. Equip.	5	26	--	--	--	--	95	26	--	--
52	Measuring Insts.	97	21	--	--	--	--	--	--	3	16
53	Misc. Mfg.	100	15	--	--	--	--	--	--	--	--

Line haul rail travel time variations are caused by routine delays in dispatching trains, variations in train weight and power, delayed meetings and accidents. These occasions all tend to increase travel time. With the exception of major derailments, they can be measured in hours per arc. They are expressed as a function of geography and rail line classification. If:

LVR_{ij} = line haul variability for a train moving from i to j

Then:

$$LVR_{ij} = \sum_{g \varepsilon RCCA} \sum_{c \varepsilon C_R} d_{ij}^{gc} \, LVR_{ij}^{gc} \qquad (23)$$

where:

LVR_{ij}^{gc} = travel time variation for rail line class c in RCCA g with grade and signal attributes from i to j.

Terminals and classification yards play a key role in the operation of railroads. Each individual railroad operates its yards and terminals in a manner that minimizes cost while facilitating the movement of traffic. The American railroads do not operate yards at all of the nodes of the transportation network, nor does the network have a node at each yard. Thus, some accommodation has been necessary. Within the Corridor, it has been possible to associate major yards with specific nodes without much difficulty. Thus the Seaboard Coast Line's (SCL's) new yard at Waycross, Georgia, is easily located at the Waycross node. Major switching activities at Birmingham, Memphis, and Kansas City are properly located at these nodes.

Outside the Corridor, more accommodation has been needed. Major Norfolk and Western, Richmond, Fredericksburg and Potomac and SCL yards in the Richmond-Petersburg area have been concentrated at Richmond. Conrail's large Conway yard has been combined with other yards at Pittsburgh. As zones get larger, more displacement is needed. Conrail's Elkhart yard is shifted to Chicago, Southern Pacific's Roseville yard is shifted to San Francisco and so forth. Every effort has been made to preserve essential rail functions despite the necessary adjustments.

Classification functions were assigned to the yards at each node. Terminal switching occurs at every node and is an essential part of freight originations and terminations. The complexity of the terminal switching depends on the amount of activity at the node and its geometrical configuration.

Classification of through traffic occurs at several levels. In some yards minimum classification occurs when cuts of cars are transferred between local and through trains. In major classification yards, all arriving trains are broken up and their cars sorted into a variety of outbound destinations. At gateways two or more railroads interchange traffic. At its worst, this may involve two or more complete classifications* plus local movements between inbound and outbound yards.

Two types of rail node costs are identified - terminal costs and classification costs. In loading and unloading costs, let:

LR_i^n = total loading costs per ton of commodity n at zone i

Then:

$$LR_i^n = \sum_{e \epsilon E_R} P_1^{en} \cdot \frac{F_{g(i)}^e}{q^{en}} + (P_2^{e,n} \cdot T_{g(i)}^e + P_3^{en} \cdot J_{g(i)}^{en} + b^n B^n) \qquad (24)$$

where:

P_1^{en} = fraction of variable terminal car cost for commodity n, car type e attributable to loading,

$F_{g(i)}^e$ = variable terminal car cost per car of type e in RCCA associated with zone i,

P_2^{en} = fraction of variable terminal cost for commodity n, car type e, in RCCA associated with zone i,

P_3^{en} = fraction of fixed terminal cost for commodity n, car type e attributable to loading,

$J_{g(i)}^e$ = fixed terminal cost per ton of any commodity, car type e, in RCCA associated with zone i,

b^n = fraction of loss and damage claims for commodity n attributable to loading, and

B^n = loss and damage per ton of commodity n.

---

*A terminal and switching company may also handle the traffic.

By this formulation, loading costs depend only on location as determined by the RCCA and commodity. Unloading costs are similar. If:

UR_i^n = unloading cost per ton of commodity n at zone i

Then:

$$UR_i^n = \sum_{e \varepsilon E_R} p^{en} \left[(1-p_1^{en}) \frac{F_{g(i)}^e}{q^{en}} + (1-p_2^{en})\, T_{g(i)}^e + (1-p_3^{en})\, J_{g(i)}^e + (1-b^n)\, B^n \right] \quad (25)$$

Classification costs are more zone specific. Thus, if:

CR_i^n = classification cost per ton for commodity n at zone i

Then:

$$CR_i^n = \sum_{e \varepsilon E_R} p^{en} \left(\frac{CL_{g(i)}^e}{q^{en}} + CF_{g(i)}^e \right) \quad (26)$$

where:

$CL_{g(i)}^e$ = classification cost per car of type e at zone i, and

$CF_{g(i)}^n$ = fixed classification cost per ton of commodity n at zone i.

The cost per car depends on the type of yard activity and the operations associated with each car classification. The fixed cost per ton depends on the capital investment and the level of classification yard use. If sufficiently detailed data were available, each zone could be given a unique value of $CL_{g(i)}^e$ and $CF_{g(i)}^n$. However, for present purposes only four levels of activity have been identified and associated with the different zones.

Terminal and yard time is even more difficult to establish than cost. Time spent in terminals in support of loading and unloading is heavily location dependent. It varies with the nature, amount and scheduling of way switcher and yard switcher crews and equipment. Pick up and set off times can vary from an hour or less to several days. Four categories of pick up and set off activity have been identified and associated with the different zones.

Classification time also varies widely. Some railroads follow the policy of dispatching trains on time regardless of the number of cars available for them. Other railroads hold trains for traffic accumulation or until particular inbound trains have been classified. A car late in arriving may have to wait a day or longer under the first policy, while under the second, the delay would only be a few hours. Classification times have been associated with the level of classification activity at each node. Thus, if:

CRT_i = classification time per car at zone i

Then:

$$CTR_i = CL_{g(i)} \cdot CT \tag{27}$$

where:

CT = normalized classification time per car.

Terminal and yard time variation is based on the likelihood of missing an outbound train, requiring classification services or requiring repair. Values are based on the quality of inbound and outbound rail service as an indicator of train frequency. Thus, where only daily outbound service is available, the variation in terminal and yard time comes in increments of one day, and the standard deviation is set equal to one day. Where more frequent service is available, the standard deviation is appropriately reduced.

Water Network

The waterway network was selected to include all major domestic waterways within the continental United States. This includes facilities to support both barge and ship traffic. Barge movements occur throughout the inland waterways, on the intercoastal waterway system, on the Great Lakes and across open seas. Ship movements are limited to those waterways that can accommodate ships of commercial draft. For the purposes of the first year's work, the movement categories are artificially restricted. Barge movements are considered only on waterways with channel depths less than 30 feet. All deep water movements are assumed to occur in ships.

All inland waterways with channel depths of seven feet or greater are included in the water network. Only those waterways that occur within large zones are omitted, e.g., the Columbia River and the Sacramento-San Joaquin Rivers. The network includes the Hudson River - New York State Barge Canal, the Savannah River, the Apalachicola/Chattahoochee River, the Alabama River, the Tennessee-Tombigbee project and the Mississippi River system including the Mississippi, Missouri, Arkansas, Illinois, Ohio, Kanawha, Cumberland and

Tennessee Rivers and the Chicago Canal. Terminal points of each river are indicated in Figure 8.

It was difficult to fit the inland waterways into the zone structure, particularly in the case of the Mississippi River System. Major river ports were generally network nodes. However, several Corridor cities selected as nodes do not lie on the river, but the river flows through their zone and has port facilities within them. To provide realistic commodity flows, the water arcs were directed to some of these non-port nodes. In this fashion, the Mississippi River arcs pass through Jackson, Greenville, and Clarksdale, Mississippi and Dyersburg, Tennessee. Of these, all are within 15 miles of the river except Jackson, which is 45 miles from the river. However, for other reasons, Jackson was selected over Vicksburg as the zone centroid.

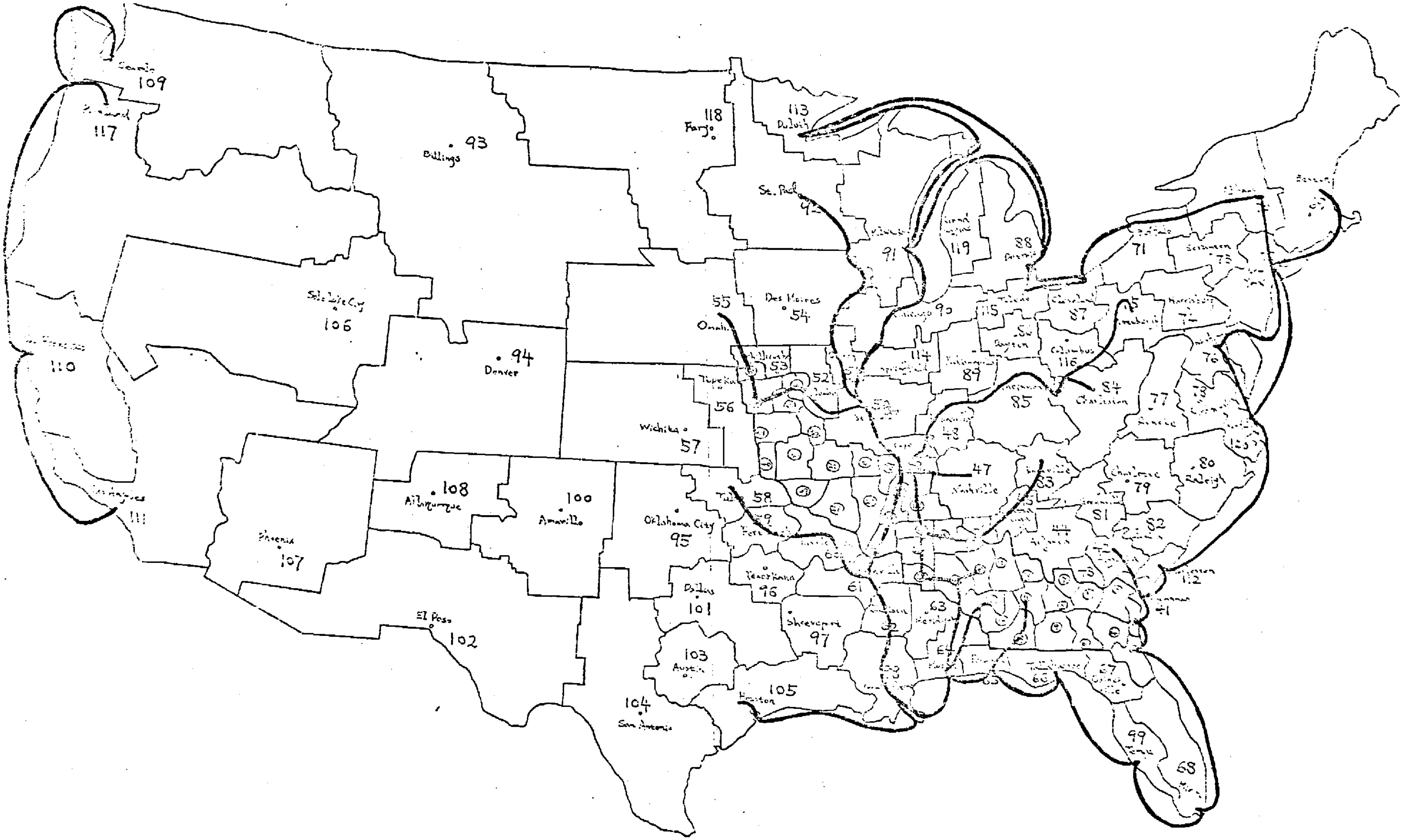
The deep water network includes the Great Lakes, the St. Lawrence Seaway, coastwise and intercoastal service. The Great Lakes - St. Lawrence Seaway system can accommodate ships up to 27 ft. draft. The coastwise and intercoastal traffic has been limited to the same ship size in order to include the Cape Cod Canal, the Delaware-Maryland Canal and the Port of Brunswick, all with 30 ft. channel depths.

Although direct routes are available between each pair of coastal nodes, coastwise shipping is modeled like a linear network with intermediate nodes. This convention slightly increases distances for longer trips, but no impedance is imposed on through movements so that longer shipments do not suffer an additional port penalty.

Arc lengths were taken from nautical charts, channel descriptions and published reports.

Customer Service Parameters. Accurate utility measures for water movements were difficult to obtain. After careful analysis, the Whitten equations [8] were rejected because water costs generated with them were not consistent with cost data used for highway and rail arcs. However, a good alternative was not easy to find. Common and contract carriers by water are regulated by the ICC and they are required to report their financial and operating performance to the ICC. Unfortunately, these regulated carriers are responsible for only a small fraction of the water movements. Most domestic marine traffic - including the vast Great Lakes ore movement and major traffic in coal, petroleum and chemicals - is in private hands. Private carriers are under no obligation to report their performance. They do periodically report via the

FIGURE 8
WATER NETWORK



Census of Transportation surveys in which they receive disclosure protection. Similarly, operators carrying exempt commodities - notably grain - are under no obligation to report to the ICC.

The Corps of Engineers has made a number of studies of traffic on rivers and in ports. A study now underway will attempt to specify travel time, loading and unloading time and cost for a variety of port-to-port movements. In the absence of these results, the project team had to make do with what was available. Available data included reports to the ICC by common and contract carriers, Census of Transportation data on movements between states and past reports by a variety of study groups.

Using all available data, an expression was developed for barge movement costs. If:

LHW^n_{ij} = line haul cost per ton to move commodity n by water carrier from i to j,

Then:

$$LHW^n_{ij} = \sum_{g \varepsilon WCCA} TW_{ij} \cdot WL_g \cdot I^n \tag{28}$$

where:

WCCA = set of water carrier cost areas that are based on draft and maximum tow size,

TW_{ij} = time in hours for a tow boat to travel from i to j, and

WL_g = cost per hour for tow and tow boat operation in area g.

Hourly costs, WL_g, are based on modern tow boats powered by 3,000 to 4,000 horsepower engines, pushing maximum tows made of jumbo barges. Because of data difficulties, specific distinctions were not made among barge types.

Great Lakes, coastwise and intercoastal water movement costs are calculated in a slightly different way.

$$LHW^n_{ij} = \sum_{e \varepsilon E_W} p^{en} \sum_{g \varepsilon WCCA} d^g_{ij} \cdot WL^e_g \cdot I_n \tag{29}$$

where:

p^{en} = fraction of commodity n using shipping configuration e,

d_{ij}^{g} = distance between i and j in g, and

WL_{g}^{e} = cost per ton-mile for any commodity using configuration e in WCCA g.

Only two configurations were used in the first year's work, linear and container type ships. Additional variations such as large bulk ships can be added in the future.

Travel times were also difficult to estimate on the inland waterways because they are heavily influenced by current, number of locks, traffic level, water depth and other factors which vary widely through the year. An expression was ultimately developed that considers only distance, speed and number of locks.

$$TW_{ij} = d_{ij}/s_{ij} + aL_{ij} \tag{30}$$

where:

TW_{ij} = transit time by water from i to j.

d_{ij} = distance along the channel between i and j,

s_{ij} = mean speed from i to j,

L_{ij} = number of locks between i and j, and

a = constant

Mean values of speed were selected for the principal waterways where available. Otherwise an upstream speed of 5 mph and a downstream speed of 7 mph were used. Lock operating times were examined for a large number of different locks. The constant a represents a mean traverse time including entry, gate operation, lift and departure.

Travel times for Great Lakes, coastal and intercoastal movements were based on average over water speeds of 16 to 18 knots. Allowances for leaving and entering port were included in loading and unloading time so as not to prejudice the convention adopted for long journeys.

Travel time variability for movements on rivers and canals is heavily influenced by the number of locks traversed, because this is where most delays occur. Thus, if:

VW_{ij} = travel time variation for water movement from i to j

Then:

$$VW_{ij} = \sum_{g\varepsilon WCCA} a_1^g L_{ij} + a_2^g d_{ij} \qquad (31)$$

where a_1^g and a_2^g are constants for WCCA g.

Travel time variability for Great Lakes, coastwise and intercoastal movement is largely a result of weather. The likelihood of a weather delay is a function of distance, area, time of year and other factors. However, a simple function of distance has been adopted for the first year's work.

Water node activities are restricted to loading and unloading. No terminal impedances are assigned to through traffic. If:

LW_i^n = loading cost per ton for commodity n at zone i,

Then:

$$LW_i^n = \sum_{e\varepsilon E_W} p^{en} \cdot p_1^{e,n} \cdot WT_{g(i)}^e \cdot I^n \qquad (32)$$

where:

$WT_{g(i)}^e$ = cost per ton of any commodity using water configuration e in WCCA g associated with zone i.

In this case, three configurations are used - barge, container and linear vessel. The cost factor includes daily port costs for the vessel, stevedore and crew costs divided by mean loading or unloading activity. Similarly if:

UW_i^n = unloading cost per ton for commodity n at zone i,

Then:

$$UW_i^n = \sum_{e\varepsilon E_W} p^{en} (1-p_1^{en}) WT_{g(i)}^e \cdot I^n \qquad (33)$$

Loading and unloading times are based on average productivity and include an allowance for entering and leaving port. Loading and unloading time variation includes allowances for productivity differences, dock congestion, stevedore availability and berth availability. These variations are port specific depending on the port facilities and the expected level of activity.

Intermodal Transfers

Two forms of intermodal transfer are common today, water-highway and highway-rail. In addition, there is some water-rail activity. Intermodal transfers can be broadly classified as break-bulk transfers and container transfers.

In a break-bulk transfer, the inbound carrier is completely unloaded, the cargo is sorted by outbound carrier and the outbound carriers are loaded. Cost and time requirements to perform this kind of a transfer are closely related to loading and unloading costs and times. Thus if:

TT^n_{XYi} = break-bulk terminal transfer costs per ton of commodity n from mode X to mode Y at zone i,

Then:

$$TT^n_{XYi} = 0.8\ [LY^n_i + UX^n_i] \tag{34}$$

where:

LY^n_i = cost per ton for loading commodity n into mode Y at i, and

UX^n_i = cost per ton for unloading commodity n from mode X at i.

The use of a factor of 0.8 reflects loading and unloading economies that can be achieved at a transfer terminal.

Container terminals require large capital investments in sophisticated special purpose equipment. In addition, large land areas are required for storing empty and loaded containers. The cost of operating a container terminal depends very heavily on the use made of the terminal's capital assets. Thus, if:

TT'^n_{XYi} = container terminal transfer cost per ton of commodity n from mode X to mode Y at location i,

Then:

$$TT'^n_{XYi} = \left[\frac{TC_{XY}}{V_i} + TO'_{XYi} \right] I^n/q^n \tag{35}$$

where:

TC_{XY} = the equivalent annual capital cost of a transfer terminal to interchange between modes X and Y,

V_i = expected number of containers per year to be transferred at i,

TO'_{XYi} = operating cost per container to transfer between modes X and Y at i,

q^n = tons of commodity n per container.

Values of $TC_{X,Y}$ and $TO_{X,Y}$ are as follows:

	$TC_{X,Y}$	$TO_{X,Y}$	Capacity, Container Per Year
Highway-rail	$ 50,000	$1.50	200,000
Highway-water	1,000,000	2.50	400,000
Rail-water	1,200,000	3.00	400,000

TC_{XY} is calculated with interest at 20 percent per annum. TO'_{XY} depends on the terminal facilities and on labor cost and efficiency at location i.

Transfer times are based on productivity data for the different terminal types. If:

TTT'^{n}_{XYi} = break-bulk terminal transfer time for commodity n between modes X and Y at i

Then:

$$TTT'^{n}_{XYi} = UX^n_i + LY^n_i + a_i \tag{36}$$

where:

a = a constant to account for expected accumulation and delay times at i,

and if

TTT'^{n}_{XYi} = container terminal transfer time for commodity n between modes X and Y,

Then:

$$TTT'^{n}_{XYi} = \frac{N_X C^i_X}{2} + \frac{N_Y C^i_Y}{2} \tag{37}$$

where:

N_X = number of containers expected on carrier X

C_X^i = expected cycle time for unloading carrier X at i

N_Y = number of containers expected on carrier Y

C_Y^i = expected cycle time for loading carrier Y

Unload and load cycles are generally equal and may be simultaneous at a container terminal. A uniform distribution is assumed for container location in a shipment. Thus, a given container may be unloaded at any time during the unloading operations.

Transfer time variability depends on productivity variations, equipment delays, crew delays, and other factors. Delay factors have generally been expressed as a fraction of terminal time.

Compact Representation of Transportation Costs

The research team understood clearly that the transportation costs being used during the first-year research effort left much to be desired. Specifically, the costs were based largely on secondary sources which determined costs from summary financial statistics and allocated fixed costs by somewhat arbitrary methods. At the same time the need was recognized to determine O-D customer service costs for each of 53 commodities for the 120 zone network.

In order to generate all the O-D network costs for just one commodity required the generation of 360 trees, one for each of three modes for each of the 120 origin nodes. This computation consumed about 15 minutes of computer time, including the CPU time required to write the trees onto magnetic tape. If separate trees had to be constructed for each commodity, the computer time would quickly become excessive. On the other hand, if one set of trees could be used for all 53 commodities, the resulting commodity paths might not be the true shortest paths.

To achieve a compromise between the desire for commodity specific routes and the problems of generating and storing these data, the line haul arc costs were formulated in the following way:

$$t(i,j,m,k) = t(i,j,m) \times s(m,k) \tag{38}$$

where:

$t(i,j,m)$ = an average cost for transporting goods from node i to node j by mode m

$s(m,k)$ = a commodity specific factor that applies to all arcs of a given mode

An analysis was made of the line haul costs determined by the formulas developed for the different modes. Surprisingly, the commodity specific factors were remarkably consistent throughout the different geographic regions. A similar analysis was made of the Whitten based loading and unloading costs. There resulted again fairly consistent commodity specific factors.

However, the commodity factors for line haul and loading-unloading were not the same. Upon closer examination, there appeared to be a monotonic relationship between the two sets of factors: the highest factor for line haul was also highest for loading-unloading, the lowest factors in both cases were for the same commodity, etc.

Accordingly, it was conjectured, but not proven, that a shortest path consisting of line haul arcs and transfer movements for a hypothetical average commodity would be a true shortest path for any of the 53 commodities, but that the length of the path could not be determined with only one commodity-specific factor. The multimodal shortest path algorithm was subsequently revised to optimize the overall path length for the "average" commodity but to keep track separately of the line haul portion and the transfer portion. The "true" commodity specific path length for the resulting path was then obtained by multiplying the line haul portion and the transfer portion by the commodity-specific line haul cost factor and transfer cost factor, respectively. Further compaction resulted when the geographic area cost factors were multiplied by the true arc lengths to achieve modified arc lengths.

The net effect of all the computations described in this chapter was to take the original, Whitten based, formula of

$$LHM^{n}_{i,j} = \sum_{e \varepsilon E_M} P^{e,n} \sum_{g \varepsilon MCCA} d^{g}_{i,j} \times ML^{e}_{g} \times I^{n} \tag{39}$$

and convert it to one of

$LHM^{n}_{i,j}$ = (modified arc length) x (average cost) x (commodity factor)

With the analogous simplification of transfer costs, the overall effect was the elimination of the need for commodity-specific trees and a great simplification of subsequent analysis. Average costs for the highway, rail and water modes are listed in Appendix E.

Mode Split Analysis

The mode split analysis was directed toward two very important needs: (1) to find the value of transport time and transport time variability for each commodity group, and (2) to estimate the modal share of present and potential traffic that existing and potential transport modes and intermodal combinations can expect to carry. By the procedure followed, the first need became a very important by-product of the search for an adequate mode split representation.

Requirements

The requisite mode split model must meet all or most of the following requirements if it is to be useful in the Multi-State Transportation Corridor study.

Abstract Mode Representation. Because the research focuses on new and intermodal means for transporting freight, an abstract mode model is essential. This type of model characterizes a mode entirely by customer service parameters. Any new mode or compound mode journey can then be characterized by these same factors and compared with existing modes in the model. An extension of this argument leads to the requirement that the model be independent of origin zone, since new production facilities will be postulated for zones from which no specific commodity flow originates today.

Calibration Time and Results. In view of the need to calibrate the model for each of the 53 commodity groups, the model should be amenable to standard regression techniques and/or optimization routines that are robust and efficient with respect to computer time. In order to have confidence in the model, a good fit must be produced for each commodity so that the model can predict accurately the flows on new modes and between new O-D pairs.

Irrelevance of Independent Alternatives. This requirement deals with the change in the proportion of flow divided between two modes that is brought about by changes in or addition of a third mode. If a third mode were to be improved, one would expect flow on the other two modes to be reduced, but the proportion of flows between the two modes would be unchanged. The implication is that a strict choice utility function should be used.

Path Customer Service Costs Transformable to Additive Arc Costs. In order to find the compound-mode journey with least customer service cost equivalent, one would prefer to have path cost equal to the sum of the respective arc costs. Then, one can use a shortest path algorithm to find the best path; otherwise, some less efficient enumeration scheme would have to be used. Actually, all that is needed is that path costs be uniquely transformable into additive linear arc parameters - time, cost and reliability.

To illustrate this concept, assume that path customer service cost equivalent has a linear form:

$$D_{ijmn} = a_1 C_{ijmn} + a_2 T_{ijmn} \tag{40}$$

where D, C, and T are path customer service cost equivalent, path cost, and path time between nodes i and j for commodity n using mode m. Since the transportation attributes are additive along arcs, one can simply assign to each arc and transfer activity its cost equivalent as determined by the above expression. Application of a shortest path algorithm to a network of the type shown in Figure 4 will then find the path with the least, or best, cost equivalent.

Now if path cost equivalent were exponential,

$$U_{ijmn} = \exp(D_{ijmn}) = \exp(a_1 C_{ijmn} + a_2 T_{ijmn}) \tag{41}$$

the same process will still work: Each arc and transfer activity is assigned the value of its cost equivalent argument, in this case D_{ijmn} for arcs and a similar D_{imkn} for transfer activities (including loading, unloading, and forwarding), and the shortest path routine will find the path with least, or best, cost equivalent. The two important properties of the path cost equivalent function needed are:

1. The argument must be linear, and

2. The path cost equivalent function must be monotonic over the range of the argument.

Survey of Existing Models

A review of the literature indicates that very little work has been performed on freight modal split as compared to passenger mode split and particularly urban transit mode split. The only type of model that has been calibrated for forecasting purposes is the multiplicative model described below. All of the models presented here recognize the need to distinguish among commodity types based on such factors as freight rates by the different modes, dollar value per ton, and susceptibility to damage, spoilage, and theft.

The Multiplicative Demand, Abstract Mode Model was first presented by Baumol & Quandt in 1966 [34]. It is formulated to predict both total demand between an O-D pair and the respective modal shares. The multiplicative version [35] is as follows:

$$F_{ijm} = a_0\ P_i^{a_1}\ P_j^{a_2}\ Y_i^{a_3}\ Y_j^{a_4}\ M_i^{a_5}\ M_j^{a_6}\ N_{ij}^{a_7}\ f_1(T)\ f_2(C)\ f_3(D) \qquad (42)$$

where:

$$f_1(T) = T_{ijb}^{b_0}\ T_{ijm}^{b_1}$$

$$f_2(C) = C_{ijb}^{d_0}\ C_{ijm}^{d_1}$$

$$f_3(D) = D_{ijb}^{e_0}\ D_{ijm}^{e_1}$$

F_{imj} = demand from i to j by mode m

P_i, P_j = populations of zones i,j

Y_i, Y_j = Mean incomes of zones i,j

M_i, M_j = institutional and manufacturing characteristics of zones i,j

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[34] Quandt, R. E. and W. J. Baumol, "The Demand for Abstract Transport Modes: Theory and Measurement," Journal of Regional Sciences, Vol. 6, No. 2, 1966.

[35] Quandt, R. E., The Demand for Travel: Theory and Measurement, Heath, Lexington, Mass., 1970.

N_{ij} = number of modes serving i to j

T_{ijb} = best transport time from i to j

T_{ijm} = relative transport time from i to j by mode m

C_{ijb} = best (lowest) cost from i to j

C_{ijm} = relative cost from i to j by mode m

D_{ijb} = best frequency of service from i to j

D_{ijm} = relative frequency of service from i to j by mode m

$a_0, a_1, \ldots, a_7, b_0, b_1, d_0, d_1, e_0, e_1$ = coefficients, usually obtained by regression

Given the populations, incomes, and institutional characteristics, a reduced model is obtained:

$$F_{ijm} = a_0 \, N_{ij}^{a_7} \, f_1(T) \, f_2(C) \tag{43}$$

with the constraint that the total flow between i and j is equal to 100%. For a specific commodity k the model becomes

$$F_{ijmk} = a_{0k} \, N_{ij}^{a_{7k}} \, f_{1k}(T) \, f_{2k}(C) \tag{44}$$

with the 100% flow constraint.

Since this model is an abstract mode approach, the user can examine new modes by specifying transport time and cost. If these two items do not characterize a mode adequately, then other factors must be put into the equation, such as delivery time variance. There are difficulties with respect to shifting flows that arise when new modes, or new compound-mode paths, are considered and the total flow between i and j remains the same. However, this problem occurs with all of the known modeling approaches, not just this particular one.

The model uses relative time and cost advantage of one mode against another. Thus, only one regression equation is needed for each mode (each commodity effectively constitutes a separate calibration problem). The use of absolute values instead of relative values would necessitate an equation for virtually each O-D pair. The general model is linear in the logarithms, and thus linear regression techniques can be easily used to estimate the coefficients, while the reduced model has the additive constraint which must be incorporated in the regression. The above type of model has been calibrated in a variety of settings [35, 36], but none of these applications provide directly usable results for the Multi-State Corridor study.

An Impedance Model is used in the National Transportation Plan (NTP) modal split model [37]. The model uses an analogy to Kirchoff's law from electrical networks.

$$f_{ij1n} Z_{ij1n} = f_{ij2n} Z_{ij2n} = \ldots = f_{ijnn} Z_{ijnn} = A_{ijn} \tag{45}$$

where A_{ijn} is the basic attractiveness between i and j for commodity n, analogous to the electrical potential.

The impedance for commodity n is defined as

$$Z_{ijmn} = a_{ijmn} \left[b_k T_{ijmn} + C_{ijmn} \right] \tag{46}$$

where:

T_{ijmn} = the time in transit for a unit of commodity n moving by mode m from i to j

C_{ijmn} = the cost of moving a unit of commodity n by mode m from i to j

a_{ijmn}, b_n = coefficients; b_n is usually given as the time value of commodity n, and a_{ijmn} is usually found by regression.

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[36] Herendeen, J. H., "Theoretical Development and Preliminary Testing of a Mathematical Model for Predicting Freight Modal Split," Report TTSC6908, Pennsylvania State University, Pennsylvania Transportation Institute, University Park, Penn., 1966.

[37] U.S. DOT, "The National Transportation Plan Modal Split Model," unpublished paper.

The modal share for mode ℓ then is

$$f_{ij\ell n} = \frac{\dfrac{1}{Z_{ij\ell n}}}{\sum_{m=1}^{k} \left[\dfrac{1}{Z_{ijmn}} \right]} \tag{47}$$

The actual NTP model also considers time, in annual periods. The model has been calibrated for the 20-commodity, 173-BEA zone data set. Since the a_{ijmn} are specified for each O-D pair, and only for 20 commodities, those results would not be particularly useful to the Corridor study.

The impedance model can be classified as a strict choice utility model, whereby modal attractiveness or utility is determined for each competing mode and the shares allocated by the strict choice utility function

$$f_{ij\ell n} = \frac{U_{ij\ell n}}{\sum_{m=1}^{n} U_{ijmn}} \tag{48}$$

Here we have $U_{ij\ell n} = 1/Z_{ij\ell n}$.

The Additive Linear Form expresses path utility as

$$U_{ijmn} = a_0 + a_1 C_{ijmn} + a_2 T_{ijmn} \tag{49}$$

with the a_0 constant being positive and the a_1 and a_2 constants negative. Linear regression to obtain the constants is straightforward.

The Exponential Form is sometimes called the logit form. It expresses mode utility as

$$U_{ijmn} = \exp(a_0 + a_1 C_{ijmn} + a_2 T_{ijmn}) \tag{50}$$

Again, the a_0 term is positive and the a_1 and a_2 terms negative. This form generally gives a much better regression fit than the strict linear form. A typical regression equation is:

$$f_{ijmn} \exp(a_0 + a_1 C_{ijln} + a_2 T_{ijln})$$

$$+ f_{ijmn} \exp(a_0 + a_1 C_{ij2n} + a_2 T_{ij2n})$$

$$+ f_{ijmn} \exp(a_0 + a_1 C_{ijmn} + a_2 T_{ijmn})$$

$$= \exp (a_0 + a_1 C_{ijmn} + a_2 T_{ijmn}) \tag{51}$$

Alternatively, one can compare the share of each mode k to a base mode m and use linear regression

$$\frac{f_{ijkn}}{f_{ijmn}} = \frac{\exp(a_0 + a_1 C_{ijkn} + a_2 T_{ijkn})}{\exp(a_0 + a_1 C_{ijmn} + a_2 T_{ijmn}} \tag{52}$$

or $$\log (f_{ijmn}/f_{ijkn}) = a_1(C_{ijkn} - C_{ijmn}) + a_2(T_{ijkn} - T_{ijmn}) \tag{53}$$

The range of observations of the dependent variable may exceed 1.0, causing the regression procedure to give undue weight to those observations. Also, there is a bias introduced by the log transformation of the data.

In the <u>Modified Exponential Form</u> the utility of a mode is given by

$$U_{ijmn} = \frac{\exp(a_0 + a_1 C_{ijmn} + a_2 T_{ijmn})}{1 - \exp(a_0 + a_1 C_{ijmn} + a_2 T_{ijmn})} \tag{54}$$

This formulation is applied only to non-base modes. The utility for the base mode is defined to be 1.0. For example, if the base mode is highway, then a rail path utility can be defined as

$$U_{ijrn} = \frac{\exp(a_0 + a_1(C_{ijrn} - C_{ijhn}) + a_2(T_{ijrn} - T_{ijhn}))}{1 - \exp(a_0 + a_1(C_{ijrn} - C_{ijhn}) + a_2(T_{ijrn} - T_{ijhn}))} \tag{55}$$

where subscripts r and h refer to rail and highway, respectively. For consistency,

$$U_{ijhn} = \frac{\exp(a_0)}{1 - \exp(a_0)} \tag{56}$$

which implies that $a_0 = \log (0.5)$. One advantage of this form is that linear regression can be used with the dependent variable being the ratio of the mode under consideration to the sum of that mode plus the base mode. Again, considering rail, mode r, with highway, mode h, as the base mode, one has

$$\log\left(\frac{f_{ijrn}}{f_{ijrn} + f_{ijhn}}\right) = \log\ (0.5) + a_1(C_{ijrn} - C_{ijhn}) + a_2\ (T_{ijrn} - T_{ijhn}) \quad (57)$$

Thus, one can eliminate most of the bias from those data points where the base mode has a small share. On the other hand, the model occasionally exhibits ill behavior by having the exponential argument assume negative values.

Calibration and Final Model Selection

The procedure followed in applying the exponential and modified exponential forms consists of three steps:

1. Linear regression of the log-transformed data
2. Cyclic coordinate search
3. Transformation by cumulative normal distribution function

Calibrations were performed for seven commodities selected for testing the overall analytical procedure:

1. Textile mill products
2. Apparel
3. Lumber & wood
4. Furniture & fixtures
5. Rubber & plastic products
6. Machinery, except electrical
7. Electrical machinery

Table 17 shows the results after performing step 2. In every case the exponential form was nearly as good or better than the modified exponential form. Generally, the cylic coordinate search [38] reduced the true sum of squares by 5% to 10%, removing the bias of the log-transformation of the data. Since

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[38] Zangwill, Nonlinear Programming: A Unified Approach, Prentice-Hall, Englewood Cliffs, N.J., 1969.

TABLE 17

COMPARISON OF EXPONENTIAL AND MODIFIED EXPONENTIAL FORMS

Commodity	Data Points in Sample	Exponential Form a_1^*	a_2	a_3	SS***	Modified Exponential Form* a_1	a_2	a_3	SS***
1	28	-.0287	-.0073	-.0648	2.57	-.0126	-.0029	-.0264	2.66
2	32	-.0022	-.0000	-.0669	2.64	-.0008	-.0013	-.0175	2.77
3	73	-.0100	-.0001	-.0150	6.15	-.0075	-.0003	-.0120	7.06
4	39	-.0227	-.0160	-.0108	3.18	-.0117	-.0083	-.0038	3.83
5	45	-.0106	-.0137	-.0000	3.77	-.0066	-.0076	-.0000	4.18
6	64	-.0245	-.0269	-.0016	2.99	-.0086	-.0095	-.0014	3.21
7	130	-.0178	-.0256	-.0000	8.14	-.0022	-.0055	-.0005	9.12

* a_0 in modified exponential form is -.6932

** Units used are: cost-$/ton, time-days, time variance-days

***True sum of squares for highway fraction to sum of highway and rail fractions the execution time of the cyclic coordinate search did not depend too much on the starting point (about 4 seconds for 45 data points), most of the runs were performed without the first step of linear regression. Multiple correlation coefficients were in the range of 0.7 to 0.75, yielding an R^2 of approximately 0.5. While not completely satisfying, these values compare well with results achieved from other mode-abstract models.

A disturbing aspect of all the runs was the tendency of the predicted values to cluster near the mean of the shares, while the observed values ranged from 0.1 to 0.9. It was felt that this phenomenon arose from the inadequacy of cost, time, and time variance as explanatory variables and from the heterogeneity present within the commodity classifications. To remedy this situation a cumulative normal transformation was performed on the mode splits predicted by the exponential form:

$$f'_{ijmk} = \frac{F^{\mu,\sigma}\,(f_{ijmk})}{\sum_{\ell=1}^{n} F^{\mu,\sigma}\,(f_{ij\ell k})} \qquad (58)$$

where:

f_{ijmk} = original predicted share of mode m, as estimated with exponential form

f'_{ijmk} = revised predicted share of mode m

F = cumulative normal distribution with parameters μ and σ

The cyclic coordinate search was again employed to reestimate the constants of the now-embedded exponential form. Values used for the normal function were mean = 0.5 and variance = 0.25. As expected, the predicted splits were more dispersed, although there was no measurable quantitative improvement. Table 18 shows the summary criteria for the seven commodities. While there is no theoretical foundation for using this type of transformation, the results were quantitatively as good as and subjectively more appealing than the original predicted mode splits.

Limiting the Number of Modes

Virtually no model exists that is unaffected by the consideration of additional paths, and it is unlikely that a straightforward model could be so

TABLE 18
COMPARISON OF EXPONENTIAL FORM AND EXPONENTIAL FORM
TRANSFORMED BY CUMULATIVE NORMAL DISTRIBUTION

	Exponential Form		Transferred Exponential Form				
Commodity	SS*	SAD**	SS*	SAD**	a_1	a_2	a_3
1	2.57	7.40	2.57	7.42	-.0107	-.0020	-.0276
2	2.64	7.91	2.64	7.92	-.0010	-.0000	-.0281
3	6.15	18.94	6.26	18.34	-.0075	-.0025	-.0004
4	3.18	10.20	3.18	10.20	-.0087	-.0050	-.0083
5	3.77	11.67	3.76	11.63	-.0045	-.0058	-.0000
6	2.99	11.35	3.02	11.48	-.0082	-.0092	-.0018
7	8.14	26.15	8.22	26.68	-.0054	-.0090	-.0000

* True sum of squares for highway fraction/sum of highway and rail fractions
**True sum of absolute deviations for highway fraction and sum of highway and rail fractions

developed. Consider, for example, a rail path serving a pair of modes, with U(rail) = 8 and U(highway) = 2. The typical modal share function would assign 8/10 of the shipping volume to rail and 2/10 to highway. Suppose another, less desirable rail path existed with U = 5. The act of admitting three paths now results in the first rail path receiving 8/15 of the flow, the second rail path 5/15, and the highway path 2/15. In all likelihood the second rail path would actually carry little or no flow. For single mode flows the question of admissible paths is usually resolved by selecting the best path for each mode. When compound-mode journeys are involved, however, the issue is not so clear.

To overcome these difficulties the number of paths is limited as follows:

1. the best all-highway path
2. the best all-rail path
3. the best all-waterway path
4. the predominant waterway path with short highway or rail connecting arcs (used in case no path of type 3 exists, only)
5. an efficient compound-mode path
6. a new technology mode

The first three provide no difficulty: the best highway path is the least-time path, since time-related costs tend to dominate in the trucking industry. The best rail path is the one with the lowest shipping costs, since those tend to dominate in the selection among rail paths. Last, there is usually no more than one reasonable waterway path, and it is selected on the basis of shipping cost. This designation of a critical attribute for each mode, that is, an attribute used for path selection, simplifies the process of building the shortest path trees for each mode using the multimodal path algorithm. Of course, the other, non-critical attributes are carried along in the tree-building process. Similarly, the fourth category is selected on the basis of shipping costs, since anyone seriously considering a type 4 path is concerned mainly about cost. Paths in category 6 are generally unique, thus posing no problems in identifying them. Paths of type 5 are unlike the others, and the method for their selection is different. Using the exponential form, the trip modal customer service cost is transformed uniquely to a function that is additive linearly in arc characteristics, and the selection of compound-mode journeys is achieved by a shortest path routine.

VI. IMPROVEMENT ANALYSIS*

Up to this point, the work has been concerned with building the analytical method for identifying joint transportation service improvement and economic development programs. Once the method has been completed and tested, there is much significant research yet to be done. This research concerns the postulation, testing and evaluation of programs of new transportation services.

Only preliminary work has been completed on the improvement analysis. The structure has been identified. Sufficient work has been performed to complete the Northern Mississippi test and to establish that the approach is a sound one. The bulk of the development work will be done as part of the second year's research. This chapter presents the problems, summarizes what has been accomplished and points to work yet to be accomplished.

The improvement analysis is divided into four tasks - formulate transportation improvement programs, test development opportunities, update network representation, and evaluate results. Collectively they should lead to the joint identification of the most desirable transportation improvement program and the development opportunities that the program will support. This information constitutes the screening step that is the objective of the research. Subsequent work of a more detailed nature needs to be performed by state transportation offices, state development agencies, local agencies and private interests before the full scope of the opportunities can be known.

Transportation Improvement Programs

A suitable technique for identifying promising transportation improvement programs has not yet been devised. The three improvement programs used in the Northern Mississippi test were selected for their ability to exercise the analytical procedure rather than for their promise of successful implementation. The task of developing a search procedure for transportation improvement programs will be undertaken as part of the second year's research. The discussion presented here is merely intended to illuminate the problem.

The analytical method is responsive in that it identifies the economic opportunities that result from postulated transportation improvement programs,

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*The work reported in this chapter was performed by G. P. Sharp, M. A. Mullens, M. E. Lipenski and H. L. Petty.

but it does not have a procedure for identifying the new transportation improvement programs to be tested. There are an infinite number of transportation programs that could be postulated. Clearly some means is needed to guide the search for better programs. To be useful a procedure for identifying new programs must:

1. Have a simple measure for comparing successive programs that relates to both transportation cost and development potential,
2. Give positive directions for program changes,
3. Deal only with technically feasible improvements - parametric studies could merely add complexity to an already complex problem - and
4. Converge in a small number of trials.

To date, two approaches have been derived - a successive search approach and a requirements approach. They differ principally in the starting point. Neither promises to reach a global optimal solution.

Successive Search Approach

The successive search approach begins with a postulated transportation improvement program and seeks modifications to that program that will increase the ratio of the aggregate market for new corridor produced goods to the capital cost of the transportation improvement program. The general approach is as follows:

1. Postulate an initial transportation improvement program; estimate the capital cost of the program.
2. Test the program with the analytical method for all commodity groups, identifying the Corridor zone with the largest potential market for each group. Sum the markets for all groups. Calculate the ratio of total market tonnage to capital cost.
3. Examine the geographical location of each candidate production zone and the location of the markets that it serves.
4. Compare Corridor production tonnage to capital cost ratio with the previous trial. If the new ratio is larger, go to step 5; if the new ratio is smaller, go to step 6.
5. Check the volume of traffic diversion to each arc of the improvement

program. Postulate one added service improvement: estimate its capital cost, add to program capital cost; go to step 2.

6. Check the volume of traffic diversion to each arc of the improvement program. Postulate the removal of one service improvement; delete its cost from program capital cost, go to step 2.

By successively adding and deleting service improvements while seeking higher ratios of new corridor traffic to capital improvement cost, the procedure will seek the most attractive transportation improvement program that is available from the starting point. A stopping criterion is needed. This may be based on realizing lower traffic/capital ratios in response to both adding and deleting services.

The successive search approach is not exact. Considerable judgment is needed to select the transportation services to be added or deleted. Experience with the process may lead to intuitive changes that are better than the stepwise changes envisioned in this procedure. The analytical process includes many variables that are related in complex ways. For example, traffic diversions to corridor routes from competing production zones may cause a transportation improvement to reduce development potential in the corridor. Thus great care must be taken in selecting modifications for the improvement program.

Requirements Approach

The requirements approach begins with a set of local goals that specify the kind of industrial development sought by different corridor zones. The measure of performance is the ratio of total corridor production tonnage in desired commodity groups to the capital cost of the transportation improvement program. The starting solution for this technique is developed by examining routes to potential markets for the desired developments. Thereafter, improvements are added and deleted pretty much as described for the successive search approach.

Test Development Opportunities

Each transportation improvement program is tested with the combined economic and network models to identify the market opportunities that are created by the transportation program. This test is performed by a set of computer programs that is largely but not entirely complete. Additional work needs to be done on the computer programs that measure and collect the market and production opportunities for the different corridor zones.

Computer Programs

To date, 19 computer programs have been prepared. Each is written in FORTRAN IV for the Control Data Corporation CYBER 74 computer located at Georgia Tech. The ten most important programs are summarized below. Complete listings are available on request.

ARCDEV

Program ARCDEV reads three sets of undirected arcs, one for each mode, along with the distance and speed associated with each arc. It constructs an ordered set of directed arcs (base arcs) along with the distance, time, and time variability associated with each mode on each base arc.

AINDUTI

Program AINDUTI reads the set of base arcs together with unit transport costs including line haul, loading-unloading, forwarding, and intermodal transfer costs for each commodity, mode, and geographic region. From these, it develops an average cost (over all commodities) for each transport facility. It also develops commodity cost factors which can be used to translate these average costs into commodity specific costs.

MTREES

Program MTREES reads the average costs for all transport facilities and constructs three shortest path trees (one for each mode) for each node. It also stores the cost, time, and time variance associated with the shortest path between each O-D pair.

DETCIJ

Program DETCIJ estimates the cost of producing a commodity in each of its major production zones as well as in the corridor test zones. Cost includes the basic cost of raw materials, raw material transport cost, energy cost, labor cost, and cost of capital. All commodity groups are considered. The program also estimates single mode transport costs between current and potential commodity production zones and their most important markets. These costs are "total" transportation costs in the sense that they include cost, time, and time variance weighted by their respective modal split parameters.

HIJK

Program HIJK estimates the delivered costs of each commodity at its most important markets. Costs from current production zones as well as the corridor zones are computed. No intermodal transport is considered.

MMTREE

Program MMTREE estimates commodity specific "total" transport costs for all transport facilities including line haul arcs, loading-unloading terminals, intermodal transfer terminals, and forwarding terminals. For each of the commodity groups it then constructs shortest "total" cost trees for each major production zone and each of the corridor zones. It also stores the "total" cost associated with the shortest path between each relevant O-D pair.

MMSPLT

Program MMSPLT splits the total flow between each production zone-market zone pair identified by Program SEPFLOW. Flow is split among truck, rail, water, and the best multimodal path (when it is distinct from a single modal path) through the use of a mode-abstract modal-split model.

MMLOAD

Program MMLOAD loads multimodal flows of each of the commodity groups onto the network. Flows in production tons and freight tons are given for each transport facility.

SLOAD

Program SLOAD loads single-mode flows for each of the commodity groups onto the network. Output is in same form as MMLOAD.

MMHIJK

Program MMHIJK estimates a revised delivered cost for commodities produced in each of the corridor zones and delivered to each of the significant commodity markets. The revised cost is computed by allowing a portion of flow along the shortest multimodal path.

Sequence of Computer Programs

To achieve computational efficiency the sequence of program execution is generally as follows:

1. Postulate transportation service improvements,
2. Update network representation, skip to 4,
3. Obtain shortest path trees for each origin,
4. Obtain shortest path trees for test zones,
5. Determine material costs for selected commodities,
6. Determine production costs for selected commodities, and
7. Determine market share for selected commodities purchased by potential new facilities.

By skipping the time consuming step 3 for several iterations at a time, a far greater number of alternatives can be examined in the same computer time, since the other six steps are performed rapidly. The second-year effort will focus on this problem as well as identifying those existing commodity flows affected by network changes [39].

Update Network Representation

The computer program sequence described above does not consider changes in traffic flow that would accompany the development of production sources in the Corridor zones. Thus, while market costs for producers in Corridor zones are based on the customer service costs of the improved transportation facilities, the traffic flow on new or improved arcs or through improved nodes merely reflects diversions from the normal routes of other producers. To measure the potential use of improved transportation services, one needs to assign production to the corridor zones and assign markets to be served by them. This updating of the production market relations was not performed as part of the Northern Mississippi test but it is an essential part of the analytical method.

Two problems must be addressed before revised network flows can be calculated:

1. Production by commodity must be assigned to specific Corridor zones, and
2. Markets must be assigned to new production zones.

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[39] Halder, A. K., "The Method of Competing Links," Transportation Science, Vol. 4, No. 1, Feb. 1970, pp. 36-51.

The analytical method treats each zone independently when exploring economic development opportunities. Thus only one zone can be selected for new production of each commodity group unless successive determinations are made, adding production first to one zone and then to another. The zone with the largest potential production is generally selected; however, other bases for selection are possible. Markets for the selected zone/commodity combinations are determined from the market share function, working one market at a time to adjust the shares, supplied by each producing zone. Market demand is kept constant in each consuming zone. Test market share determinations have been made by hand. During the second year a computer program will be prepared to perform this task.

Updating network flows is a time consuming and expensive task. It will be done only for those transportation improvement programs that show promise.

Evaluation Methods

No single voice can determine whether a transportation improvement program and the associated economic development opportunities serve the best interests of the Multi-State Transportation System. There are a large number of parties that are interested in this process. Some of these parties and their principal interests are listed in Table 19. The principal interests are highly abbreviated and intended only to suggest a viewpoint. However, even this summary suggests that no single development program is likely to satisfy all. Some of the more important relationships among groups are illustrated in Figure 9. The overall evaluation problem is to determine whether a particular input will yield a good output.

A formal evaluation framework is indicated that includes criteria reflecting major interests. These criteria can be weighted by different groups and can be assembled into a set of values or arrays from which meaningful comparisons can be made between transportation improvement programs.

Literature

A great deal of attention has been given to evaluating alternative transportation programs. This work focuses on urban transportation projects and it does not generally include an evaluation of economic development opportunities. A careful review of recent evaluation literature can be summarized as follows:

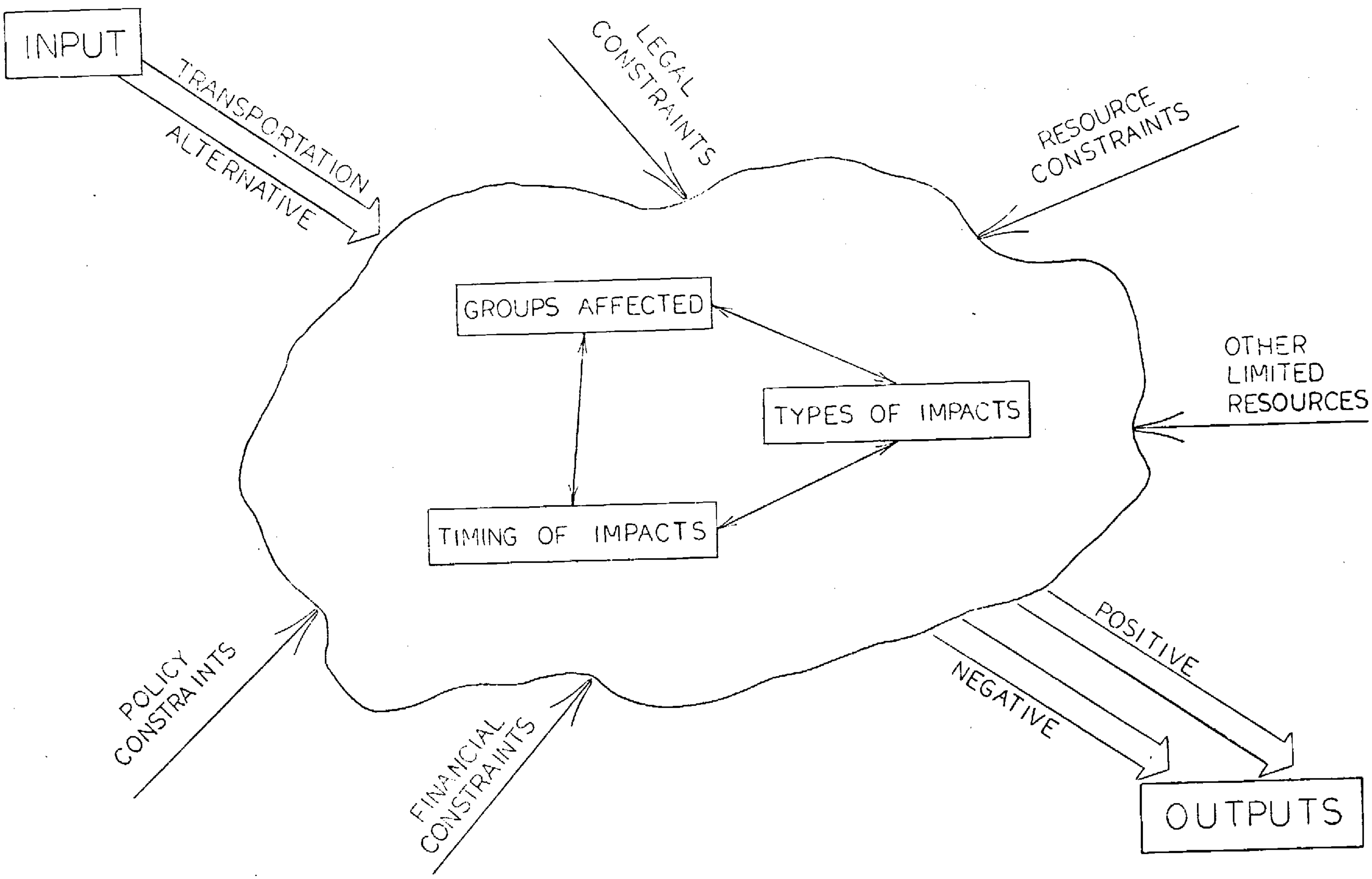
1. The vast majority of publications dealing with evaluation systems are

TABLE 19

MULTI-STATE STAKEHOLDER GROUPS

Stateholder Group	Principal Interest
Government	
U.S. DOT	Balanced national transportation
State DOT	Balanced state transportation Additional Sources of funding for projects within the State
State Economic Development Agency	New industry and commerce
State Legislature	Constituent interests New revenue sources Employment
Local Officials	Employment Revenue Sources Constituent interest
Private	
Land Developers	High intensity land use Expanding economy
Bankers	Expanding economy Industrial diversification
Chamber of Commerce	Expanding economy Better transportation
Transportation Carriers	Better routes More traffic Balanced traffic
Farmers	Low cost land Good transportation to market High crop prices Low costs
Existing Industry	Plentiful labor Low wages Good transportation
Minority Groups	Job opportunities Higher pay
Labor Unions	Jobs Pay Favorable political climate
Environmentalists	Preserve, air, water, aesthetic quality Limited growth and development
Citizen Groups	A wide variety of interests based on individual and group values

FIGURE 9
EVALUATION RELATIONSHIPS



directed toward the analysis of urban transportation alternatives.

2. Non-urban transportation evaluation deals mainly with techniques for rural highway route location.

3. A number of techniques for weighting and rating alternatives have been tried or proposed. In all cases they require some subjective decisions concerning the relative importance of certain key factors. Viewpoint is very important.

4. Little work has been done to quantify the economic development potential of transportation alternatives.

5. Few studies address multimodal alternatives. Exceptions are in urban situations where automobile dominated systems are compared with transit alternatives.

6. Attempts have been made to quantify variables such as neighborhood disruption, and to develop scales where quantifiable and nonquantifiable factors can be combined in a rating scheme.

7. The problem of freight movements has not been researched to any substantial degree.

Thus the existing literature provides several alternative frameworks for model development, but it does not offer precedents for any particular line of development.

Model Framework

The framework selected for evaluation is a relatively straightforward scoring model. The novelty of the procedure is restricted to the diversity of stakeholders and interests that must be considered. The procedure includes the following six steps:

1. Identify principal stakeholders groups and their viewpoints,
2. Nominate evaluation criteria,
3. Screen evaluation criteria,
4. Identify criteria measures,
5. Determine criteria weights, and
6. Select evaluators.

Each of the steps has been completed for the general problem. Specific execution for Northern Mississippi is discussed in Chapter VII.

Principal Stakeholder Groups

The principal stakeholder groups and their viewpoints are listed in Table 19.

Nominate Evaluation Criteria

Three different classes of evaluation criteria were nominated - transportation system, economic development, and social. These are listed in Table 20. Collectively, these criteria span the interests of all of the stakeholders groups.

The objective of transportation system performance is to provide fast, reliable, economic, and convenient transportation for a wide range of commodity types with a minimum of disruption to the existing environmental and social structure. Two categories of criteria were examined - those with impacts that vary directly with the volume of traffic carried and those with impacts that are independent of the network load.

The objective of economic development is to provide a transportation system that will maximize the opportunities for economic growth and development in the Corridor. Criteria were therefore selected to measure changing opportunities.

Society at large has many objectives. These include such items as minimizing negative effects on community form and development, creating aesthetically and environmentally pleasing living space, maximizing the "quality of life," maximizing the use of scarce resources, development of politically feasible plans, and others.

Screen Evaluation Criteria

Each of the evaluation criteria listed in Table 20 was tested, by asking the following questions:

1. Can the variable describe the consequence of the alternative transportation services? Is it possible to determine impacts, either in quantitative terms or through subjective evaluation?

2. Can the variable be used to differentiate between alternatives? Is there a way to show that one alternative is better or worse than another?

TABLE 20

POTENTIAL EVALUATION CRITERIA

Transportation System Performance

I. Costs
   a. Capital Costs
   b. Operating Costs
      1. Line-haul
      2. Terminal
         a. Inter-modal
         b. Intra-modal
   c. Maintenance and Administration Costs
      1. Line-haul
      2. Terminal

II. Capacity
   a. Line-haul
   b. Terminal

III. Connectivity of System, Ease of Transfers

IV. Mileage

V. Right-of-Way Needs

VI. Terminal Requirements

VII. Flexibility
   a) Mode - Interchanges
   b) Shipment Size
   c) Commodity Type
   d) Time Scheduling

VIII. Overall Level of Service Provided

IX. Energy Consumption

X. Air and Noise Pollution

XI. Reliability
   a) Line-haul
   b) Terminal

XII. Shipping Time
   a) Line-haul
   b) Terminal

XIII. Impacts on Urban Development, Natural Resources, and Agricultural Areas

TABLE 20 (CONT.)

Economic Development

I. Shipment Costs

II. Attributes of Potential Locations

III. Availability of Alternative Mode Transportation

IV. Effects on Construction Industry

V. Value of Commodities Flows

VI. Changing Patterns of Producer - Consumer Relationships

VII. Market Share Changes

VIII. Tax Base Changes

IX. Overall Industrial Development

X. Personal Income Changes

Societal Impacts

I. Environmental Quality

II. Land Use Changes

III. Community forms

IV. Aesthetics

V. "Quality of Life"

VI. Political Feasibility

VII. Social Changes

VIII. Resource Use

3. Have analytical methods been developed to measure expected changes in the variable that can be associated with alternative designs?

4. Are data available to estimate values for the variable? Are the data in a form that can be used in the analysis?

5. Is this measure closely related to other measures? Can it serve as a proxy for something else? Does it have advantages or disadvantages over related variables? Can it be combined with other variables to make up one measure?

6. Can a feasible range of expected values be determined for each criterion? Can variations in values across this range be represented by some function, either discrete or continuous?

These questions were submitted to a panel of reviewers who were asked to record their answers on the form illustrated in Table 21. The results of these reviews were summarized and are presented in Appendix G. This process produced the final set of evaluation criteria.

Criteria Measures

Units of measure were sought for each surviving criterion. One would prefer to measure all criteria in terms of cost. However, many criteria were not costable and others were not even quantifiable. The result was a mixture of different measures and a wide range of confidence in the different measures. The selected measures are listed in Appendix G.

Criteria Weights

Clearly all of the evaluation criteria are not equally important. Relative importance also varies by stakeholder group. The problem of assigning weights to the different criteria is a formidable one.

Several methods for combining criteria into one or a few values are discussed in the literature. These range from relatively simple ranking schemes to more complex methods such as utility theory, goal achievement matrix, and linear programming. The choice of a specific method depends on the format of variables and on the number and types of groups or individuals that will participate in the evaluation process.

Primary attention was given to the need for use by decision-makers at different levels of government - local, state, and national - and in the private

TABLE 21

CRITERION FEASIBILITY CHECKLIST

Criteria ____

Description ____

____

____

____

Units Measured ____

Quantifiable ____ Non-Quantifiable ____

Data Base Available ____ Yes ____ No

Level of Analysis National Corridor Regional Local

Forecasting Models Available ____ Yes ____ No

Which One (s) ____________________

____

____

Fill in the values for the end points and three points within the range representing the quantities of satisfaction. As an example, speed may range from a minimum level of 30 mph (48.3 km/hr) (minimum value) to 200 mph (322 km/hr) (maximum feasible value) with

100 mph (161 km/hr) representing 50% satisfaction of the criteria,
60 mph (96.6 km/hr) representing 25% satisfaction of the criteria,
150 mph (241.5 km/hr) representing 75% satisfaction of the criteria.

Minimum Acceptable Value

Maximum Feasible Value

sector. The evaluation process was viewed as a tool to aid in choosing between alternatives and not as a method to establish the "best choice." Thus flexibility is needed to accommodate a) different weighting schemes, b) subjective evaluations, and c) different outlooks.

Ultimately, an interactive weighting scheme was selected whereby different stakeholders could suggest weights and receive a ranking of known projects based on those weights. The stakeholder can then revise some or all of his weights to correct them to his perception of the desired outcome for the known projects.

The sequence of this process will resemble the following:

1. The stakeholder will be presented with a hierarchy of criteria that has groupings arranged under specific objectives such as minimizing shipping time, maximizing the location of new industries in the Corridor, and increasing personal income. The stakeholder, located at a computer terminal, will be asked to rate the relative importance of these criteria in terms of the overall satisfaction.

2. The second step will be to determine the extent to which each criterion is satisfied. Using a variation of the worth concept presented by Pardee [40], the evaluators will be furnished with the end points of a scale ranging from full satisfaction of the criterion to no satisfaction of the criterion. For example, a one week transport time may represent no satisfaction of the shipping time criterion and a one day transport time may represent full satisfaction. The reviewers will fill in perceived quartile values for 25, 50, and 75 percent satisfaction of the criterion. A scale developed by the research team will be used for criteria which these evaluators are not qualified to rate. Thus, if an individual does not feel qualified to determine what dBA level represents a 50 percent satisfaction of noise control, the scale developed by researchers would be used.

3. A short description of each alternative transportation system will be presented to each evaluator. A subjective evaluation of any special characteristics of the mode that might encourage use and economic

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[40] Pardee, F. S., Measurement and Evaluation of Alternative Transportation Mixes: Vol. I: Summary; Vol. II: Methodology; Vol. III: Example; RM-6324 - DOT, The Rand Corporation, Santa Monica, Calif., Aug. 1970.

development, can be made and combined in the analysis.

4. Each potential alternative transportation system will be assigned a value for each criterion being investigated. These values will be determined by the research team and will be based on its performance characteristics and potential impacts. A score will be prepared for each alternative rated by the stakeholder by multiplying the perceived relative weight and the perceived degree of satisfaction.

5. The stakeholder is given the opportunity to change his mind by repeating the process should he be dissatisfied with the outcome.

6. When the stakeholder is satisfied, his weights and ratings are recorded.

7. When all stakeholders have completed the process, a composite score is calculated for each alternative. This constitutes the final evaluation.

Methods for applying the final evaluation are yet to be devised.

Evaluators

The weights developed for evaluation will depend to a large extent on the viewpoints of the individuals participating in the process. To insure a comprehensive analysis, care must be taken to include individuals representing a wide range of interests.

The following factors are used to identify potential participants in the evaluation:

1. Individuals who are actively involved or can influence industrial location desires must include bankers, elected officials, developers, industry officials, and civic associations.

2. Existing carriers must be included.

3. Representatives of local, state, and federal governments with skills in planning, transportation, industrial development and public finance are needed.

4. Representatives of citizens' associations, agricultural organizations, environmental protection groups, and others are needed.

5. Input from all regions within the corridor is necessary. Both rural

and urban interests from several segments within the corridor must be represented.

Having stressed the necessary diversity of the evaluation group, one must use caution lest the group become too large. If possible, it should not exceed ten persons. Means for making maximum use of these limited inputs will be explored as part of the second year's work.

VII. THE NORTHERN MISSISSIPPI TEST*

A limited test of the analytical method was conducted for four Multi-State Corridor zones in Northern Mississippi. The test explored economic development opportunities for eight commodity/industry groups using four different transportation improvement programs.

The purpose of the test was to demonstrate the analytical procedure, not to investigate programs of transportation improvement. Therefore, the results of the test should not be interpreted as pointing to any sort of transportation improvement program for the Multi-State Corridor. Nonetheless, the test results are most encouraging and they tend to confirm the basic validity of the analytical procedures.

Zones

Four zones were selected for potential new facility locations:

Zone Number	Centroid Name	Area
20	Corinth	Northeastern Mississippi APDC
21	Tupelo	Three Rivers APDC, Mississippi
22	Columbus	Golden Triangle APDC minus Winston County, Mississippi
23	Clarksdale	North Delta APDC minus Tallahatchie County, Mississippi

Industries

Eight commodity/industry groups were selected for testing:

220 Textile Mill Products

230 Apparel

240 Lumber & Wood

250 Furniture & Fixtures

287 Agricultural Chemicals

*The work reported in this chapter was performed by G. P. Sharp, M. A. Mullens, H. C. D. Yu, M. E. Lipinski, H. L. Petty and P. S. Jones.

302 Rubber & Plastic Products

350 Machinery, Except Electrical

361 Electrical Machinery

The industry data for each of these are included in Appendix D.

Material Sources

The following material inputs for the eight test commodities were associated with national commodity markets and a limited number of sources:

logs

lumber

non-ferrous metals

potash

fiberglass

coal

For each of these the best delivered price to each production zone and to each test zone was determined.

Transportation Alternatives

Four separate transportation programs were explored in the test. The first program consisted of the existing transportation network and served as a base case. It included all of the highway, rail and waterway arcs listed in Appendix C. All terminals were conventional break-bulk types. This alternative was intended to produce traffic flows and economic opportunities that resemble present activities and opportunities in Northern Mississippi.

In addition to the base case, three programs of transportation improvements were tested. Each program was intended to be representative of a particular class of improvements. The first program consists of local highway and rail improvements in the Northern Mississippi test area that were selected to improve the accessibility of the test zones to the national network. The specific improvements included in this program are listed in Table 22. No new arcs were provided, but the quality of existing arcs was improved. There were no modal changes.

The second transportation improvement program consisted of Multi-State

TABLE 22
LOCAL TRANSPORTATION IMPROVEMENTS IN
NORTHERN MISSISSIPPI

Highway, upgrade	
US 78	Memphis to Birmingham
US 72	Membphis to Decatur, Alabama
US 82	Columbus, Mississippi to Tuscaloosa, Alabama
US 45	Corinth to Tupelo, Mississippi
US 82	Columbus, Mississippi to junction with US 45
US 45	US 82 to Tupelo
US 45	Corinth, Mississippi to Jackson, Tennessee
US 43	Spruce Pine to Hamilton, Alabama
Rail, upgrade	
Sou and ICG	Memphis to Corinth
ICG	Corinth to Birmingham
ICG	Corinth to Tupelo
Sou	Corinth to Decatur
L&N	Memphis to Jackson, Tennessee

Corridor wide improvements. These included the accessibility improvements of the first program plus a set of highway and rail improvements extending the length of the Corridor. The highway improvements were postulated for arcs extending from Brunswick to Kansas City. By this alternative, existing highways would be straightened and upgraded to support truck speeds of 55 mph. The set of railroad improvements extend from Jacksonville to Kansas City. These rail lines would be upgraded to support average train speeds of 35 mph and also to eliminate the more serious grades and curves. As with the first, this alternative did not include any new arcs. No waterway improvements were explored beyond the completion of the Tennessee-Tombigbee project. There were no modal changes.

The third transportation improvement program focused on terminal activity as a means of testing intermodal transportation opportunities. This program included the accessibility improvements of the first program, the line haul improvements of the second, and, in addition, all major mode transfer activities along the Corridor exhibited the characteristics of container terminals. Thus, transfer costs would be greatly reduced from break-bulk costs to encourage modal interchange. These improvements applied to highway-rail, highway-water, and rail-water transfers.

Cost Modeling and Assignment of Existing Flows

The procedures described in Chapter V were followed to develop costs, times, and time variances for line haul arcs and transfers at nodes. Subsequently, shortest path trees were constructed for each origin, for each mode. The existing commodity O-D movement data were then used to assign freight flows to the network, thus establishing a base load on arcs and nodes. This assignment was performed according to the mode designated for each data point.

Commodity Production Costs by Zone

The procedures described in Chapter IV were used to generate commodity production costs for 14 to 27 existing zones that constitute major suppliers of each test commodity. Production costs were also determined for each of the four test zones for each test commodity/industry group.

Delivered Cost Computation

The sample production data were reordered for each commodity by destination zone. After determining the customer service parameters, the market cost was computed for each data point:

$$d_{ij\ell} = e_{ij} + C + a_2T/a_1 + a_3V/a_1 \qquad (59)$$

where:

$d_{ij\ell}$ = the delivered cost in zone ℓ of commodity i produced in zone j,

c_{ij} = production cost for commodity i in zone j,

C = transportation cost from j to ℓ,

T = transportation time from j to ℓ,

V = transportation time variance from j to ℓ, and

a_1, a_2, a_3 = mode split parameters.

Here the transportation cost, time, and time variance attributes refer to the particular mode associated with each data point.

Analytical Results

The results of the Northern Mississippi test were most encouraging. The models appear to have performed as it was intended that they should. The results are consistent with logical expectations despite known data problems.

Market Data

Market costs were calculated for each major market of each commodity group for major producers plus the four test zones. Table 23 lists sample data for Commodity 5 (Agricultural Chemicals) in Market 85 (Cincinnati) and for Commodity 6 (Rubber and Plastic Products) in Market 90 (Chicago). Note that in both instances major tonnages are supplied by the producing zones with low market costs. There is not a uniform decrease in market share with increasing market cost, suggesting both data errors and the influence of non-costable marketing criteria. However the results are not bad. Houston, the nation's major petrochemical producer, has the lowest production cost for agricultural chemicals, followed by New Orleans. New Orleans can supply Cincinnati at the lowest cost because of favorable railroad costs. Water costs are higher from New Orleans than rail because of the circuity of the route.

Production costs in Northern Mississippi are higher than Houston, and about the same as New Orleans. As compared with New Orleans, labor costs are lower in Northern Mississippi and raw material costs are higher. Among the

TABLE 23
MARKET DATA FOR EXISTING TRANSPORTATION

1EXISTING FLOWS COM= 5 DEST= 85

O ORIG	MODE	TONS	CIJ	EXP ARG	HIJK	CUM.TONS
98	2	8411.00	281.75	-.21	311.32	.04
105	3	61842.00	250.37	-.66	341.79	.34
84	2	4794.00	327.60	-.12	344.73	.36
99	2	49401.00	322.32	-.22	353.30	.60
84	3	39050.00	327.60	-.22	358.41	.79
98	3	43535.00	281.75	-.59	363.77	1.00

0COMPETING NEW FLOWS

1	282.40	39.52	321.92
2	276.77	41.49	318.26
3	280.10	42.65	322.75
4	279.58	48.01	327.59

1EXISTING FLOWS COM= 6 DEST= 90

O ORIG	MODE	TONS	CIJ	EXP ARG	HIJK	CUM.TONS
90	1	102361.00	1104.70	0.00	1104.70	.18
90	2	53969.00	1104.70	0.00	1104.70	.28
90	3	10.00	1104.70	0.00	1104.70	.28
91	1	14884.00	1111.28	-.12	1139.05	.30
75	1	30367.00	1074.06	-.32	1145.43	.36
87	1	78321.00	1095.00	-.26	1152.42	.50
75	2	7622.00	1074.06	-.43	1168.71	.51
87	2	1994.00	1095.00	-.39	1182.09	.52
91	2	93028.00	1111.28	-.32	1183.34	.68
116	1	31141.00	1131.68	-.26	1190.38	.74
116	2	74.00	1131.68	-.39	1218.00	.74
89	1	35264.00	1180.88	-.18	1220.12	.80
72	1	33256.00	1114.28	-.48	1220.92	.86
72	2	16444.00	1114.28	-.53	1231.94	.89
69	2	8417.00	1132.77	-.55	1255.54	.90
89	2	9898.00	1180.88	-.35	1259.72	.92
69	1	44693.00	1132.77	-.59	1264.98	1.00

0COMPETING NEW FLOWS

1	1063.31	95.92	1159.23
2	1063.29	99.29	1162.58
3	1063.30	105.49	1168.79
4	1063.31	101.32	1164.63

four Northern Mississippi zones, Zone 2 (Tupelo) has the lowest production cost and the lowest market cost to Cincinnati. Zone 4 (Clarksdale) has the highest market cost despite a favorable production cost.

Considering market position, Zone 2 would rank right after New Orleans (rail). Using the market share equation:

$$MS^5_{2,85} = a_5\ \alpha^{-\alpha_5 \Delta H^5_{2.85}} \tag{60}$$

$$= 0.0770\ \alpha^{-0.0035(318.26\ -\ 311.32)}$$

$$MS^5_{2,85} = 0.075 \quad \text{Potential Market share for Zone 2}$$

Adjusting for the market shares of the other producers, Zone 2 has a potential market share in Cincinnati of 0.064 which is equivalent to 13,100 annual tons.

The market in Chicago for Rubber and Plastic products can be subjected to similar analysis. In this case, Northern Mississippi Zone 1 (Corinth) has the lowest market cost of the test zones and it ranks after Cleveland (87) in the Chicago market. Zone 1 could expect to market 45,000 tons of plastic products per year in Chicago. Though the tonnage is higher than that estimated for Cincinnati, above Zone 1 would have a more precarious position in the Chicago market for plastic products than Zone 2 would have in the Cincinnati market for agricultural chemicals. The Chicago market is dominated by local manufacturers who pay no transportation cost and by nearby sources, Milwaukee (91) and Cleveland (87) which have much lower transportation costs.

The introduction of transportation improvement programs changes the alignment of producers in both markets, see Table 24. Under alternative 3, Houston is able to take advantage of an intermodal movement from water to rail in the Corridor and greatly improve its delivered cost to Cincinnati. New producers in Corridor Zone 2 could reduce their production costs by taking advantages of reduced costs for raw material transportation. They would also realize reduced transportation costs, but they would rank second to Houston rather than second to New Orleans. Their market share would not appreciably change.

Corridor improvement programs would have a different impact on the plastic product market in Chicago. Existing producers' costs would not be affected by transportation developments in the Multi-State Corridor. However, producers in Corridor Zone 1 would benefit and they could improve their market position.

TABLE 24

IMPACT OF TRANSPORTATION IMPROVEMENT PROGRAMS ON MARKET COST

Commodtiy 5 in Market 85

Source Zone	Mode	Base Case CIJ	Base Case HIJK	Alt. 3 CIJ	Alt. 3 HIJK
98	2	282	311	282	311
105	3	250	342	250	289
84	2	328	345	328	345
C 2		277	318	270	294

Commodity 6 in Market 90

Source Zone	Mode	Base Case CIJ	Base Case HIJK	Alt. 3 CIJ	Alt. 3 HIJK
90	-	1105.	1105.	1105	1105
91	1	1111.	1139.	1111	1139
87	1	1095.	1152.	1095	1152
75	1	1074.	1145.	1074	1145
C 1		1063	1159	1063	1144

Development Opportunities

There are at least two ways to examine development opportunities in the Multi-State Corridor. The first method involves direct use of the market share equations. This method compares each test zone with the zone that has the lowest market price and thereafter applies the market function that was developed from a multiple regression analysis of all of the market data for that commodity. The second approach is more pragmatic. The market position of each candidate zone is compared with the major suppliers to the market and conclusions are drawn from a zone's relative market position. Both approaches are presented below.

The Market Share approach produces interesting and encouraging results. Table 25 lists the aggregate market potential for test Zone 1 for each of the eight test commodities. This listing indicates a maximum potential market share for apparel and little or no potential market share for lumber and machinery. It was most gratifying to learn that at present, the most attractive opportunities in Northern Mississippi as expressed in terms of recently developed industry, occur in apparel, furniture and electrical equipment. This corresponds exactly with the results of the analysis.

Repeating the analysis for each of the three transportation improvement programs produces the results listed in Table 26. It is interesting to note that Improvement Program 1 produces no change in the potential market in any commodity group. This suggests that access to the national transportation network is adequate in Northern Mississippi. However, improvement Program 2 produces dramatic changes in plastic products and lumber and substantial changes in agricultural chemicals and electrical equipment. This change projects plastic products into a potential contender with the expectation of reaching seven percent of the national market. Despite its strong improvement, lumber is not yet a contender; while electrical equipment and agricultural chemicals would improve their positions.

Improvement Program 3 produces more interesting results. Lumber potential continues to grow impressively, clearly demonstrating that this commodity is highly sensitive to transportation costs. Nonetheless, the potential for lumber production is only one percent of the national market. The intermodal improvements add only modestly to the plastic product potential. However, that potential would exceed eight percent of the national market - approaching the maximum share allowed a single production zone. Opportunities for apparel

TABLE 25

AGGREGATE MARKETS FOR TEST ZONE 1--
PRESENT TRANSPORTATION

Commodity	Estimated Annual Tonnage	Market Shares
1 Textile	230,691	6.2%
2 Apparel	105,640	11.2
3 Lumber	107,340	0.3
4 Furniture	118,719	7.7
5 Agricultural Chemicals	103,189	5.3
6 Plastic Products	83,558	2.6
7 Machinery	--	0
8 Electrical Equipment	210,948	7.1

TABLE 26

AGGREGATE MARKETS FOR TEST ZONE 1--TRANSPORTATION IMPROVEMENT PROGRAMS

Estimated Annual Tonnage

Industry	Base	Alternative 1 Tonnage	Alternative 1 % Inc.	Alternative 2 Tonnage	Alternative 2 % Inc.	Alternative 3 Tonnage	Alternative 3 % Inc.
1. Textile	230,691	230,691	0	246,233	+7%	246,233	0
2. Apparel	105,640	105,640	0	119,770	+13%	132,870	+11%
3. Lumber	107,340	107,340	0	185,316	+73%	383,200	+107%
4. Furniture	118,719	118,719	0	119,471	+1%	124,550	+4%
5. Ag. Chemicals	103,189	103,189	0	128,842	+25%	132,038	+2%
6. Plastic Prod.	83,558	83,558	0	233,063	+179%	262,485	+13%
7. Machinery	--	--	-	--	--	--	--
8. Electrical Equip.	210,948	210,948	0	268,498	+27%	268,498	0

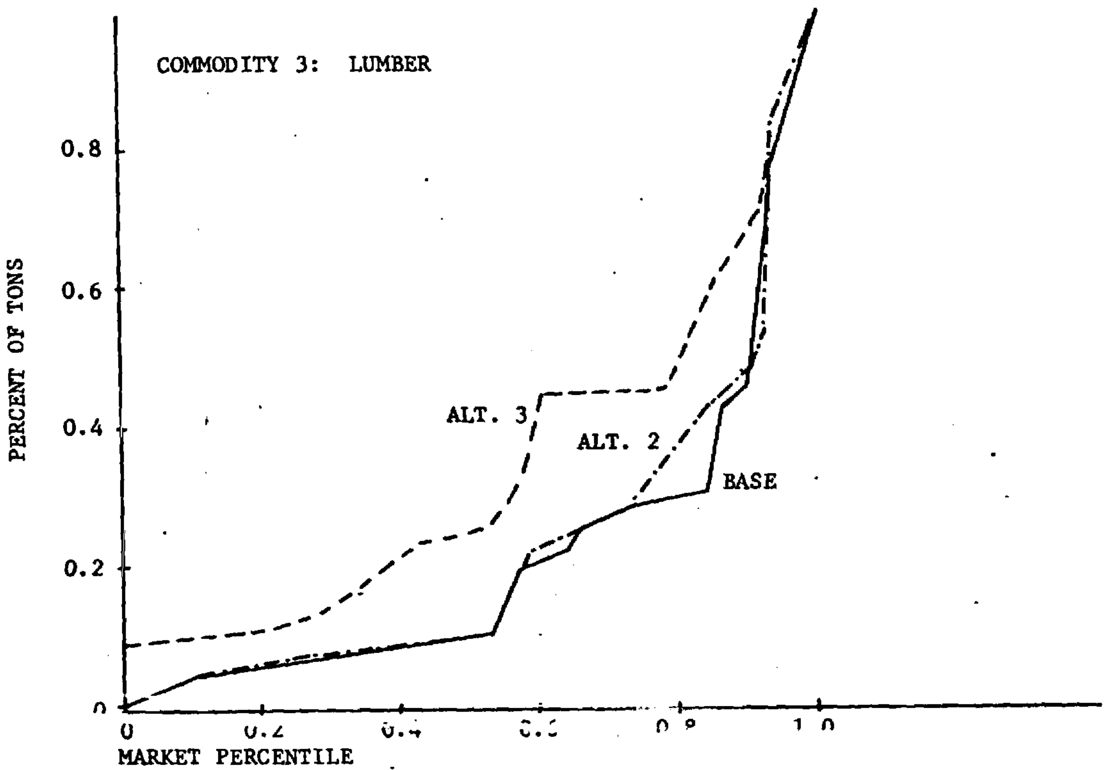
would continue to grow. However, electrical equipment would not benefit from more efficient transfer terminals, nor would textiles, furniture nor agricultural chemicals.

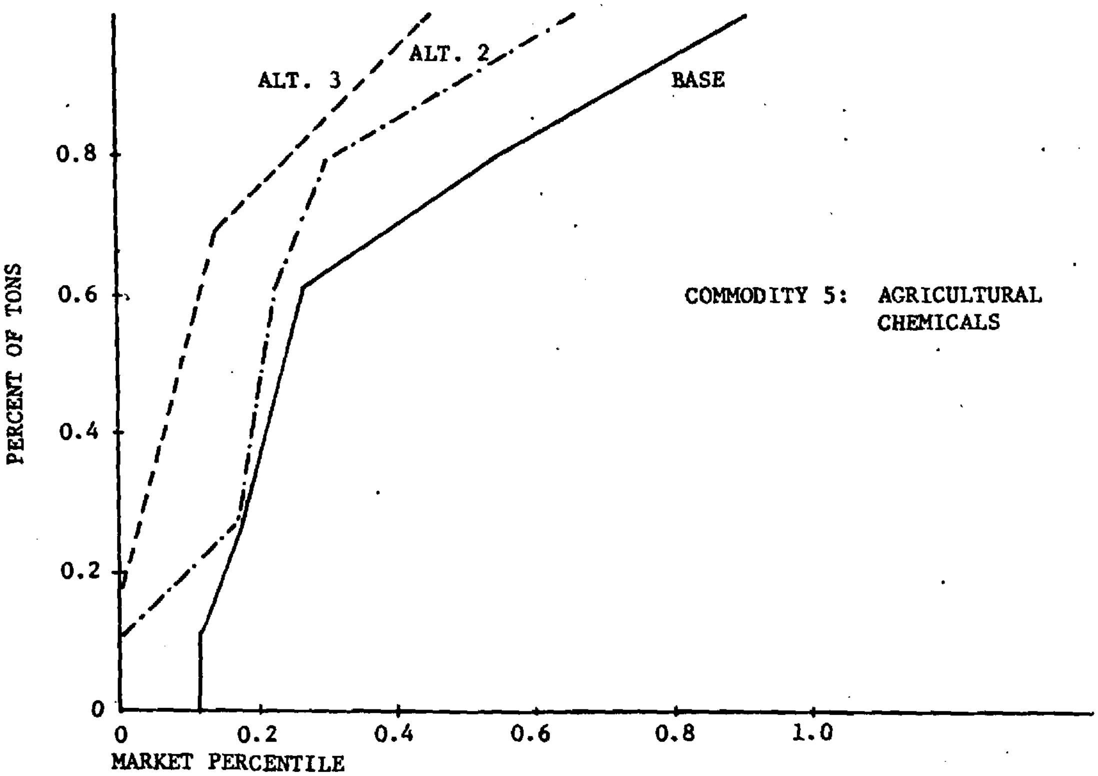
This analysis suggests that the greatest development opportunities generated by the two transportation improvement programs are for rubber and plastic products and lumber, though lumber could not be significant on the national market. Apparel, agricultural chemicals and electrical equipment would benefit to a lesser extent. Transportation alone is not likely to stimulate development of a machinery industry.

The Market Position approach provides a little less encouragement than the market share approach. In this approach, a market profile is plotted for the composite market for each commodity group under test. Figure 10 illustrates market profiles for lumber and agricultural chemicals. In each market, a test zone under study has a market cost that holds a particular ranking when compared with other zones supplying the same market. This position can be described in terms of a percentile - that is, the fraction of the total tons that can be delivered to that market at a cost below that of the test zone. By analyzing and collecting the percentile data for all of the markets, it is possible to plot percentile against fraction of the national market as is done in Figure 10. The solid line is the market profile for the base case and the dotted and dashed lines are the market profiles for the second and third improvement programs respectively.

Thus, in the base case for lumber produced in Zone 1, the new production would enjoy the lowest cost for one small market. It would be below 24 percentile for seven percent of the national market and below 53 percentile for only eleven percent of the market. This does not suggest a very strong development potential. Transportation Improvement Program 2 would improve Zone 1's expected performance slightly near the high end of the scale. However, the introduction of efficient intermodal terminals (Improvement Program 3) gives Zone 1 access to low cost water transport and greatly improves its market position. It would now have the lowest market cost for nine percent of the national market and it would be below the 40th percentile for over 20 percent of the national market. The large western markets would still be beyond the grasp of Northern Mississippi mills. However, Zone 1 mills could have strong enough positions in enough eastern markets to provide an attractive development opportunity.

FIGURE 10
MARKET CHARACTERISTICS





The situation is quite different for agricultural chemicals. With base case transportation, Zone 1 would not have the lowest market cost in any market. However it would be at or below the 26th percentile for 61 percent of the national market - an attractive position. Implementing Transportation Improvement Program 2 would give Zone 1 the lowest market cost in eleven percent of the national market and it would be below the 30th percentile in 80 percent of the market - a very strong position. This position would be strengthened by Improvement Program 3. Zone 1 would then have the lowest market cost for 18 percent of the national market and it would be below the 25th percentile for 80 percent of the market.

Combining the two approaches yields a quantitative method for quickly examining new market potential plus a diagnostic tool for providing sound interpretations. This combination suggests that the second Transportation Improvement Program would trigger the development of rubber and plastic product manufacturing in Northern Mississippi. The third Transportation Improvement Program would provide the additional thrust needed to establish a lumber industry in Northern Mississippi. Both programs would provide additional advantage to apparel, furniture, agricultural chemical and electrical equipment industries. Substantial growth in textiles and machinery appear to be beyond the reach of the types of transportation improvements that were investigated.

Network Traffic

The transportation improvement programs produce rather interesting changes in the amount and nature of the traffic that moves through the Multi-State Corridor. Table 27 illustrates that most corridor arcs carry little or no traffic in the base case. This is not to suggest that the facilities are unused for such local traffic as exists does use them. But clearly, the present need for improved facilities would be difficult to justify. Improvement Program 2 changes the situation drastically. The construction of high quality highway and rail routes will divert a substantial amount of through traffic over these routes. These figures are made up entirely of diversions, for no new traffic was added as a result of new industrial production in the Corridor. The traffic diversions, while impressive, are not large enough to underwrite large-scale construction of new or improved transportation facilities. However, if new industry needs were added to the diverted traffic an improvement program

TABLE 27

TRAFFIC RESPONSE TO IMPROVEMENT PROGRAMS

ANNUAL TONNAGE - ALL COMMODITIES

	Base Case		Program 2		Program 3	
Corridor Arc	Hwy.	Rail	Hwy.	Rail	Hwy.	Rail
2-4 Jacksonville - Waycross	0	0	135,000	130,000	0	507,000
8-11 Cordele - Columbus	0	0	109,000	355,000	0	412,000
11-17 Columbus - Birmingham	0	400	112,000	379,000	59,000	457,000
26-27 Memphis - Jonesboro	0	310,000	114,000	453,000	0	589,000
39-38 Nevada - Kansas City	15,812	0	91,000	253,000	8,000	471,000

HIGHWAY - RAIL TRANSFERS

Node	Program 2	Program 3
4 Waycross	0	55,000
8 Cordele	0	84,000
17 Birmingham	0	272,000
26 Memphis	0	17,000
38 Kansas City	0	22,000

may be justified.

By introducing efficient transfer terminals, Improvement Program 3 would shift almost all of the diverted through truck traffic to rail. Major transfer activities would occur all along the corridor.

Evaluation

A preliminary test was made of the evaluation method using Transportation Improvement Programs one and two for the four Northern Mississippi test zones. The criteria developed and listed in Appendix G were used as a starting point without further screening. The research team planned initially to use a test panel to prepare criteria weights. However, the procedure proved too cumbersome in the absence of the interactive computer program and had to be abandoned. In its place, the responses of the test panel were simulated by the research team. Table 28 lists the results of this process. An average was computed for the weights assigned by each national evaluator. This average was used in subsequent work. In the application of the full system a convergence technique will be used to improve weightings.

A measure was needed of the degree to which each criterion was satisfied by each of the alternatives. Because detailed descriptions of the alternatives and their system characteristics and impacts were not available, the measures of system performance were subjectively determined. For example, the system travel times across Northern Mississippi for the base case and the two improvement programs were assumed to be 2.75 hours, 2 hours, and 1.30 hours, respectively. The quality of life values - which are purely speculative at this state of the analysis - were also assumed to be 21, 24, and 28 for the three programs. This procedure was used to assign values to each of the criteria for each alternative.

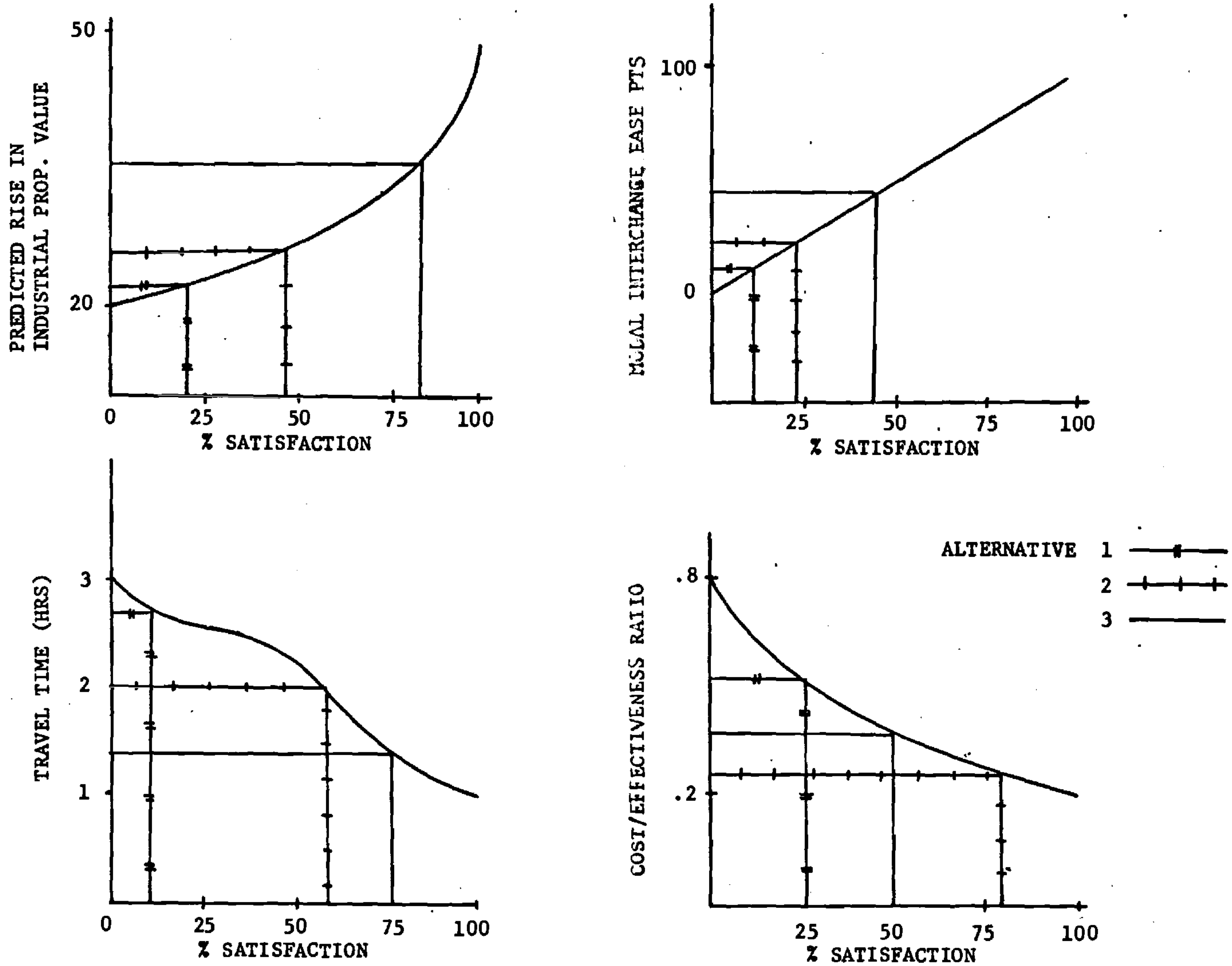
A necessary characteristic of the evaluation system is that it possess the capability to combine many individual criteria that are measured on different scales into an overall rating. The concept of the degree of satisfaction is used to accomplish this. The degree of satisfaction provided by each alternative for each criterion is determined by developing a function relating the potential values of each criterion to the perceived degree of satisfaction. Figure 11 illustrates four possible forms for these functions. These curves show the perceived relations between satisfaction and four variables - travel time, predicted rise in industrial property values, cost/effectiveness ratios,

TABLE 28

CRITERIA GROUP WEIGHTS

	Weights (within group)	Weights (for each group)
SOCIAL		
Quality of Life	.7	.1
Political Feasibility	.3	
POPULACE		.08
Redistribution	.4	
In-Migration	.6	
EMPLOYMENT		.13
Unemployment	.8	
Effects on Construction Industry	.2	
DEVELOPMENT		
Market Share	.2	.14
Overall Ind. Development	.6	
Influence on Res. Prop. Value	.05	
Influence on Ind. Prop. Value	.15	
LEVEL OF SCIENCE		.13
Peak Hour Capacity	.20	
Travel Time	.30	
Shipped Time	.50	
PHYSICAL PROVISIONING		.06
R-O-W width	.40	
Mileage	.40	
Modal Interchange	.20	
PHYSICAL PLANNING		.08
Energy	.70	
Flexibility	.15	
Adaptibility	.15	
FISCAL		.13
Cost/Effectiveness Ratio	.50	
Operating costs	.10	
Users' Costs	.40	
AESTHETIC		.15
Noise	.40	
Air	.40	
Water	.20	

FIGURE 11
SAMPLE SATISFACTION CURVES



and ease of mode interchange. The satisfaction is determined by finding the satisfaction level associated wtih a value on the criterion scale. For example, if the transportation improvement resulted in a 20 percent increase in industrial property values, this would represent no satisfaction to the evaluator. However, a 50 percent rise in these property values would represent 100 percent satisfaction. Similarly the travel time assumed for the base case (2.75 hours) would represent a 10% degree of satisfaction. Program 1 with a 2 hour travel time would have a 57% degree of satisfaction and Program 2 with a travel time of 1.40 hours would have 75% degree of satisfaction.

Once the satisfaction curve for each criterion has been determined, the satisfaction value for each alternative can be measured by combining the set of satisfaction values associated with the set of criterion values.

In this example, we assumed that the satisfaction curves are representative of all evaluators. In fact, each evaluator will have established his or her own set of curves. Therefore, in the full scale implementation of the system, the satisfaction values for each criterion will need to be combined into a single measure of worth. Table 29 illustrates the rating system as it is applied to each of the three alternatives. For each alternative, the worth (degree of satisfaction) is multiplied by the weight established for that particular criterion within each group. These weighted values of worth are then added and multiplied by the weight established for each group to yield a group weighted value. Adding the group weighted values gives a total rating value for each alternative. The total values for each alternative are compared and the alternative having the highest total value is the alternative judged best overall - in this case, Transportation Improvement Program Two.

TABLE 29

WEIGHTED VALUES OF WORTH

Group Name	Weight	Criteria Name	Weight	Base Case Worth	Base Case Weighted Worth	Base Case Group Weighted Value	Program One Worth	Program One Weighted Worth	Program One Group Weighted Value	Program Two Worth	Program Two Weighted Worth	Program Two Group Weighted Value
		Quality of Life	.7	.2	.14		.78	.55		.95	.67	
		Political Feas.	.3	.58	.17		.37	.11		.77	.23	
Social	.1				.31	.03		.66	.07		.90	.09
		Redistribution	.4	.80	.32		.60	.24		.35	.14	
		In Migration	.6	.35	.21		.84	.50		.90	.54	
Populace	.08				.53	.04		.74	.06		.68	.05
		Unemployment	.8	.18	.14		.26	.21		.70	.56	
		Const. Emplymt.	.2	.05	.01		.40	.08		.95	.19	
Employment	.13				.15	.02		.29	.04		.75	.10
		Market Share	.2	.40	.08		.53	.11		.97	.19	
		Overall Ind. Dev.	.6	.10	.06		.55	.33		.87	.52	
		Res. Prop. Val.	.05	.20	.01		.47	.02		.83	.04	
		Ind. Prop. Val.	.15	.04	.01		.57	.09		.88	.13	
Development	.14				.16	.02		.55	.08		.68	.12
		Pk. Hr. Cap.	.2	.15	.03		.75	.15		.97	.19	
		Travel Time	.3	.10	.03		.57	.17		.75	.23	
		Shipped Time	.5	.12	.06		.51	.26		.77	.38	
Level of Ser.	.13				.12	.02		.58	.07		.80	.10
		ROW Width	.4	.83	.33		.45	.18		.13	.05	
		Mileage	.4	.37	.15		.40	.16		.68	.27	
		Modal Int.	.2	.12	.02		.22	.04		.37	.07	
Phy. Provisioning	.06				.50	.03		.38	.02		.39	.02
		Energy	.7	.37	.26		.43	.30		.73	.51	
		Flexibility	.13	.54	.08		.79	.12		.96	.14	
		Adaptability	.15	.47	.07		.65	.10		.88	.13	
Phy. Planning	.08				.41	.03		.52	.01		.78	.06
		Cost/Eff Ratio	.5	.23	.12		.77	.39		.5	.25	
		Op. Cost	.1	.17	.02		.37	.04		.73	.07	
		Users Cost	.4	.20	.08		.37	.15		.68	.27	
Fiscal	.13				.22	.01		.58	.08		.59	.08
		Noise	.4	.35	.14		.30	.12		.25	.1	
		Air	.4	.12	.05		.17	.07		.25	.1	
		Water	.2	.99	.20		.35	.07		.35	.0	
Aesthetic	.15				.39	.08		.26	.04		.2	.04
						.26			.47			.66

VIII. FUTURE RESEARCH

Much has been accomplished during the first year's research. The structure of the analytical method has been formulated and assembled. The data problem has been addressed. Serious technical challenges have been faced in many quarters. The entire structure has been tested and found to give logical, explainable results. However, along the way, it has been necessary to side step some issues and provide only temporary or cursory treatment of others in order to complete the analytical structure. It is now appropriate to go back and strengthen each of the weak points to give a sounder structure that can yield more useful results.

The second year's research is directed toward solving the most serious problems that have been identified and toward continuing work in those areas that had to be cut short. This work is grouped into eight research areas: transportation modeling, economic analysis, industry structure analysis, transportation facility analysis, evaluation, transportation costing, policy issues, and implementation planning. The eight research areas intersect in the common analytical structure that has been prepared. However, the bounds of each area are sufficiently sharp to allow more independent action than has been possible to date. Thus the work can be fractionated to make good use of the dispersed faculty and facilities available in the multi-university research team. The general nature of the problem to be undertaken in each area is described below.

Transportation Modeling

The transportation model structure was completed as part of the first year's work. However, in pressing toward completion, it was necessary to use expedient fixes for several problems that are worthy of more careful investigation. Three key problems that will be undertaken during the second year are: (1) modal split analysis, (2) intermodal route determination, and (3) network improvements. In addition, the network structure will be examined in greater depth and tightened up for better execution efficiency.

Modal Split

A set of commodity specific, mode abstract modal split equations has been developed from a combination of NTP Commodity Flow Projections [7] and Whitten Cost equations [8] using multiple linear regression techniques. The unique feature of this work is the mode abstract formulation which was necessary in order to consider new transportation modes and services and combinations of new and existing modes. The data sources were picked for completeness and consistency. Cost information was used in lieu of rates because an adequate set of rates was not available. Transport times and time variabilities were estimated from the best sources that were readily available. The data fit achieved in this work compares favorably with other efforts that focus on mode specific equations. However, the data fit is not good. Moreover, the modal choices expressed in the NTP data reflect decisions made on the basis of actual rates charged rather than carrier costs incurred.

Because of the importance of modal split decisions to the success of the transportation planning effort, it is appropriate to re-examine and improve the modal split equations. Two approaches will be followed. In the first, we will replace cost data with 1975 transportation rate data for a select number of origins and destinations and for three of the more homogeneous commodity/industry groups - e.g., furniture and fixtures, paint, and tires and tubes. We will restrict this work to shipments for which better transportation time and time variability data are available. In the second approach, two or more completely new data sources will be tested. One will be taken from the Census of Transportation using sub-state data, and the other is yet to be determined.

Inter-Modal Route Determination

A simple heuristic procedure has been developed for identifying attractive inter-modal transportation routes. This procedure identifies compound mode routes that are potentially attractive and can be compared with existing or proposed single mode routes. The compound mode routes are particularly important for commodity movements that cross or parallel a portion of the Multi-State Corridor.

The heuristic procedure has been adequate for identifying compound mode routes for very different programs of transportation improvements such as those used in the Northern Mississippi test. However, a more elaborate procedure is needed to identify the complex compound mode routes expected in full Multi-State Corridor analysis. Two problems need to be explored: (1) identification of mode interchange opportunities and (2) means for generating and handling intermediate destinations in the shortest path determination.

This problem will be attacked by developing a new heuristic procedure aimed at achieving a path solution that minimizes the weighted sum of path utilities.

Path utility is in turn a commodity specific combination of transport cost, transport time, and time variability. The approach will seek to exploit the linear indifference surface of the shipper utility function to develop optimal relationships for individual arcs.

Network Improvements

For the initial tests, network improvements in the form of new arcs and transfer terminals were postualted on the basis of experience and judgment. This approach was satisfactory for purposes of testing the model. New starting solutions are needed, such as the successive search and requirements approaches presented in Chapter VI, and a more rigorous procedure is needed to deal with complex improvement sets.

One potentially attractive approach is to evaluate the cumulative sum of market share improvements per dollar of investment on each network arc. This approach requires extensive knowledge of the relationships between arc shipping characteristics and improvement expenditures. The data collection and modeling would be lengthy.

An alternate approach is to compute the change in market share as a function of changes in path utility. These derivatives can be included as network parameters and used to identify where network improvements can generate potential market penetrations for new Corridor located industry.

These two and other approaches will be investigated and a new network improvement procedure will be developed.

Problem Structure

The structure adopted for the first year's work is based on a variable zone structure that focuses on the Multi-State Corridor. Although there are ample precedents for this approach, a sounder theoretical base is highly desirable.

The analysis has adopted variable zone sizes to reduce data requirements and to keep the network within a manageable size. The network structure has several important assumptions imbedded in it. The most important of these are:

a. Long distance traffic will always move over the highest quality routes available,

b. Local traffic and the origin and destination local movements will use routes necessary for access.

c. By eliminating local traffic (intrazone) and lower quality routes, a reasonable representation of long distance traffic is achieved, and

d. Long distance traffic can be modeled as though it originates and terminates at zone centroids.

It is known that the above assumptions are qualitatively correct. However, they need to be tested quantitatively. Such a test will be undertaken on both theoretical and empirical bases.

Economic Analysis

The initial work on multi-mode analysis was based on a restricted view of key economic relationships. This work dealt only with basic industries that enjoy national markets. It dealt with stable markets and did not consider the influence of new facilities. The work also focused on a single time frame. New facilities established in the Multi-State Corridor are expected to wrest some market share from existing facilities. It is only this share that was measured. Although the approach followed is adequate to identify opportunities for establishing new facilities in the Multi-State Corridor, it did not include the impacts of economic development. To improve the economic interpretation of new Corridor opportunities, it is necessary to delve deeper into the problem. Several market share models will be formulated and evaluated. Three investigations will be undertaken as part of the second year's work: (1) an economic base study, (2) a market share analysis, and (3) the development of a forecasting technique that can estimate economic activity in a future design year.

Economic Base Study

The economic base study will explore the economy of the Multi-State Corridor in greater detail than has been undertaken heretofore. It will add nonbasic (local, service, and derivative) activities to the basic activities already explored. It will examine income and employment in both industry sectors, and establish the principal impacts of changes in basic industries on the size, growth, and stability of nonbasic activities. Initially, the work will focus on the Northern Mississippi test area. A procedure will be designed and tested for assessing the economic development opportunities that were identified in the Northern Mississippi test area. If possible, these results will be extended throughout the Corridor. A goal of this work will be to place the Multi-State Corridor into an economic perspective of the nation as a whole.

Market Share Analysis

A preliminary market share analysis was conducted for the eight test commodity/industry groups as part of the first year's work. This analysis assumed stable markets in which market share is a function only of delivered cost. Market share models were developed from commodity flow data and estimated delivered cost data by means of regression analysis. Greater sophistication is needed. Among the issues that need more careful treatment are cross elasticity, market shifts over time, raw material costs, substitutions, ownership, and integration. A market share framework will be constructed for each of the commodity/industry groups. The framework will reflect the exigencies of available data as well as the need for reliable estimates of market penetration. The approach will be on an industry by industry basis. Relevant economic data will be collected from public sources. Several market share models will be formulated and evaluated for each industry group. The sensitivity of the market share models to each issue will be tested and an improved framework will be developed that includes the critical issues. If possible, market share models will be prepared for all industry groups.

Forecasting Methods

The first year's work was based on 1975 data. It seemed appropriate to use the most recent reliable data for analytical development in order to minimize errors. However, the eventual application of the planning methods must be in terms of a future time. Indeed, the test of economic feasibility for new transportation facilities and services must be based on a future design year when the facilities and services can have been established. Conventional projection techniques are probably inaccurate. Input-output analyses [10, 11] are highly complex and require extensive data that often are not available. What is needed is a reasonably simple feedback model that can be applied without excessive data. Feedback dynamics may offer such a model.

Several different forecasting methods will be tested. Attempts will be made to balance industry changes on the basis of material flow rather than money flow (input-output). If possible, the method adopted will be compatible with OBERS methodology [20].

Industry Structure Analysis

The first year's analysis has dealt with 53 different commodity/industry groups. Each group has been treated as a homogeneous economic activity with common raw material needs, common labor, and common capital requirements. Product costs were developed for each industry group as a sum of material, labor, capital, tax, energy, and transportation costs. Two issues have been particularly nagging in this work: (1) the homogeneity assumption, and (2) material costs.

Industry Homogeneity

The selection of 53 commodity/industry groups was a compromise. On the one hand, NTP commodity flow data were available for only a 20 commodity breakdown. Manipulations with those data to a very large number of commodities would introduce unacceptable errors. On the other hand, the homogeneity problem was recognized. Several groups - e.g., rubber and plastic products, iron and steel, and non-ferrous metals - are far from homogeneous. During the second year, we will explore the implications of the commodity groupings in greater detail and also examine a series of groupings that might yield better results.

The investigation will begin with the selection of not more than ten commodity/industry groups for further study. Each of these will be broken down into not more than 10 subgroups. Industry data will be prepared for each subgroup. An assessment will be made of the errors of amalgamation and finally new classifications will be proposed for each commodity/industry group under study.

Material Costs

Raw materials can be divided into two catagories whose costs behave quite differently. In the first category, basic raw materials - products of mines and agriculture - have a price structure that works backward from relatively fixed completely elastic market prices to prices paid to the producer. Thus the producer typically receives the market price less transportation costs. When new facilities are proposed for locations that do not have established markets, cost determination is both difficult and imprecise. The second category of raw materials comprises the products of other industries. These commodities are typically priced from manufacturing or production costs plus transportation costs. These raw material prices can be readily estimated from knowledge of the producing industry.

This task will concentrate on estimating basic raw material costs. Means will be devised for collecting site specific cost data by subtracting transportation costs from costs in established markets. Thereafter, the question of amalgamation will be addressed so that raw materials can be treated in the same commodity/industry classes used for production.

Transportation Facility Analyses

Initial work has been performed to identify a small set of potential line haul and terminal facility improvements for the Multi-State Corridor. The initial set of improvements was limited to rather conventional facilities - those for which reliable performance and cost data are available. Not surprisingly, these conventional facilities would trigger only modest economic development in Northern Mississippi. The bold Multi-State plan needs and deserves more imaginative transportation facilities.

Faculty at participating universities have done preliminary work on several advanced transportation concepts, including (1) capsule pipelines using both air and liquid as operating media, (2) automatic highway type guideway for towing highway trailers with special driverless tractors, (3) broad gauge rail for overland transport of small barges, (4) point-to-point operation of short trains without intermediate switching, (5) mechanized container terminals, and (6) mechanized bulk terminals. Four of these will be investigated as part of the second year's work.

Terminal Facilities

Perhaps the greatest challenge to future intermodal transportation is the development of efficient, economical intermodal transfer terminals. Some of the experience with trailer-on-flat-car (TOFC), container-on-flat-car (COFC), and marine container terminals will provide useful data on performance, handling costs, equipment costs, and other features. However, to be sufficiently attractive, new intermodal facilities will need to achieve economies that have not yet been realized. These economies may be attained through higher volume, better scheduling and coordination, or new and unique methods of material flow, or material handling.

The approach taken will be to identify terminal parameters: physical state, package/container size, weight and dimensions, fragility, perishability (protective service needs), seasonality, shipment size, and shipment volume. A cost base will be developed from existing terminal data. Cost goals will be formulated from an investigation of potential intermodal transfer opportunities. Terminal concepts will be formulated, compared, and tested against the goals.

Configuration designs will be prepared for the most attractive candidates.

Line Haul Facilities

The line haul facilities of interest are those most likely to support new developments in the Multi-State Corridor. Before specific candidates are identified for analysis, a search will be made for the characteristics of likely candidates. Some insights have been gained from the Northern Mississippi test. Additional insights will be gained from a careful analysis of the market structures for the different commodity/industry groups. From among the potential candidates two or three will be selected that appear to have desirable characteristics. These will be developed as individual projects by faculty members best qualified to do the work. The following material will be developed for each concept:

1. Operating characteristics as functions of traffic level, shipment size, movement pattern, origins, destinations, and intermodal terminal activity.
2. Cost characteristics.
3. Conceptual design drawings.
4. Multi-State Corridor applications.

These data will be used to formulate sets of transportation improvements for further examination.

Evaluation Methods

An evaluation framework has been prepared to compare alternative transportation programs in terms of technical, industry, community, environmental and social parameters. An approach was prepared as part of the Northern Mississippi test. The need for better interaction with evaluators was identified. However, it was not possible to perform a clear quantitative comparison of alternatives. Major issues to be resolved include (1) identifying major stakeholder groups and preparing model weights, and (2) considering the quality of life as a major industry location parameter.

Stakeholder Groups

A number of important stakeholder groups have already been identified. These include congressional delegations, state transportation boards, chambers of commerce, business groups representing both new and existing industry, local governments, and private citizens. In the aggregate, there may be a dozen major stakeholder groups that have influential views about a transportation alternative. Each group needs to be contacted, examined and described so that its views on the acceptability and desirability of transportation improvement and economic development programs can be understood.

An interactive computer program will be developed to assist representatives of the different stakeholder groups to prepare weights for the different evaluation parameters. This program will be tested on members of the different Northern Mississippi groups. Weights will be compared across groups and schemes will be explored for combining the different stakeholder views to quantitative values. The entire evaluation structure will be reexamined and revised as appropriate.

Quality of Life

As new industry transforms a local area through new opportunities and new associations, the issue of quality of life needs to be examined. Expectations of citizens who enjoy regular industrial employment are quite different from those of citizens engaged in marginal agriculture. Areas of interest include education, culture, recreation, and social activities. Employees who are brought in to fill jobs that cannot be filled locally also have life style expectations that need to be considered. If life style expectations are not met, there may be discontent and even failure of the new enterprise. Life style requirements will be explored and described in as quantitative a fashion as possible. An attempt will be made to associate levels of life style with different industry classes.

Transportation Costing

Transportation costs for the first year's work have been largely based on equations developed by H. O. Whitten [8]. These equations are based on ICC data and reflect averages over large geographical areas. Other cost equations have been developed [41] that are similar in construction and detail. No

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[41] Reebie, R. G. et al., "National Intermodal Network Feasibility Study: Report No. FRA/OPPD-76/2.1, Federal Railroad Administration, Washington, D.C., 1976, PB 258 196.

known set of cost equations is sufficiently detailed to give the specific cost estimates that are needed for multi-modal work. In particular, there are no adequate means for structuring compound mode costs and for estimating mode change costs. There is significant theorectical work to be done. Arc specific fixed costs are needed together with operating costs that reflect mode of operations, and terminals costs that relate to specific terminal activities.

Transport time and time variability representations are even less reliable than cost equations. The preliminary values selected for time variability too nearly correlate with transport time data. New sources of time and time variability data need to be sought, examined, catalogued and evaluated. Structures for estimating time and time variability need to be prepared.

In this task, existing transportation cost, time and time variability work will be summarized. Sets of modal cost, time and time variability parameters will be prepared and tested. It is inevitable that proprietary problems will occur because some carrier data will be needed in addition to public data. A best effort will be made to establish a set of credible equations.

Policy Issues

Major legislative and administrative barriers to multi-mode transportation projects were investigated and documented as part of the first year's work. In order to initiate and carry forward positive action to eliminate these constraints, it is necessary to have Federal and state transportation policies that encourage multi-mode transportation while still protecting the shipping public. In addition, relationships between Federal and state agencies need to be considered as does the position of a multi-mode project in a state's transportation program.

This task will be attacked by first documenting relevent existing programs in considerable detail. Multi-mode policy positions will then be formulated that appear to be compatible with other programs. Finally, suggested forms of enabling legislation will be formulated and reviewed.

Program Documentation

The project team has a wealth of experience in dealing with Federal and state highway agencies in all phases of highway development. Experience is also available in dealing with urban mass transit and airport development agencies. This experience will be used and augmented to identify principal parties, issues, and procedures used to initiate program planning, to obtain approval for programming and scheduling, to execute preconstruction work, to secure rights-of-way, to execute design engineering and to let construction contracts. Particular care will be taken to define key relationships, critical reviews, and approval steps. Sources of funds, local-Federal match provisions and other factors will be considered. Throughout this work, the team will be alert to opportunities and constraints that may apply to multi-modal projects.

Practices for distributing projects among the states (funding formulas) and within states will also be documented. Resistance to change and inertia of vested interests will be identified and described. Particular care will be paid to procedures for identifying new project needs and for bringing them to the attention of the implementing bodies in a positive manner. Roles for multi-mode projects will be sought within this framework.

Three separate efforts are envisioned - one for highway, one for urban mass transportation, and one for airport improvements. Some effort will be devoted to the waterway projects of the Corps of Engineers and to special transportation projects such as that of the Appalachian Regional Commission.

Policy Positions

Multi-mode policy positions will be formulated from an analysis of existing programs together with the views of public and private officials on such issues as:

a. The form of modal cooperation to be encouraged,

b. The extent to which private ownership of multi-modal facilities and services is to be permitted and encouraged,

c. Control of multi-mode terminal ownership and operation, and

d. User fees for public facilities.

Alternative policies will be formulated that include funding sources, stake-holder interests, program initiation, implementation procedures, design responsibility, right-of-way acquisition and control, quality control, operation, use restrictions, and the like. The different policy alternatives will be reviewed with public and private officials. Their comments will be summarized.

Implementation Planning

To be successful, the Multi-State Transportation System must become real transportation facilities and services followed by real economic development. There is no precedent for implementation planning on the scale of the Multi-State System with the exception of the TVA. However, even the TVA is an inadequate guide because present conditions and constraints are very different from those of the 1930's. The implementation plan needs to consider the time phasing of both public and private construction, and the parties and procedures used to select, plan, finance, design and construct transportation facilities, the nature and extent of economic development support, and the entire communication structure through which all of these activities can be coordinated.

The Multi-State Transportation Advisory Board has given considerable attention to the problem of implementing a very large public project. It is clear that it cannot, and probably should not, be a single massive public works project. Rather, new multi-modal facilities should be built as they are needed and as they can be justified. This suggests that there is a best order and favorable timing for all projects. In this task, we will investigate methods for phasing and scheduling the complementary multi-mode projects. The scheme will consider the sequence of events necessary to initiate a project, and the required integration with existing Federal and state programs. It will need to accomodate different funding levels. It will also present a decision sequence that includes major Federal and state decisions together with a method for measuring the impact of delays.

Private development will also be carefully investigated. New industry must not be promoted before physical transportation facilities and services are available to support its establishment and growth. Existing state development programs will be explored, compared, and tested for applicability to multi-state corridor development.

Beyond the Second Year

The work projected for the second year will strengthen, tighten and extend the analytical technique for investigating multi-modal transportation and economic development in underdeveloped areas. Once this has been accomplished, there remains the task of applying the method to the Multi-State Transportation System in a comprehensive, imaginative, and consistant way to perform the screening of potential transportation projects that is the objective of this research. This fulfilling work will fill the third and final year of the multi-university research project.

APPENDIX A

A BRIEF HISTORY OF THE MULTI-STATE TRANSPORTATION SYSTEM ADVISORY BOARD

There has been interest in developing a transportation route between the South Atlantic Coast and the mid-continent for many years. During the nineteen thirties an interstate highway route was proposed. There was great concern among the states served when that route was dropped from the Interstate and Defense Highway System. A group of concerned public and private citizens gathered in February 1972 to discuss prospects for improving transportation services along this route. This and subsequent key meetings are summarized below. Table 30 lists present members of the Multi-State Transportation System Advisory Board.

TABLE 30

MULTI-STATE TRANSPORTATION SYSTEM ADVISORY BOARD

Elton B. Stephens, Chairman
Kermit B. Blaney, Executive Director

ALABAMA

Hon. George Wallace, Governor
Hon. Ray Bass, Highway Director
Hon. David Vann, Mayor, Birmingham
Mr. Lyman Mason, Vice Chairman
Mayor Jack M. Brown
Mr. William C. Davis, Jr.
Senior Vice Chairman
Councilman Don A. Hawkins
Senator George D. H. McMillan, Jr.
Mr. Elton B. Stephens, Chairman
Mr. Sim S. Wilbanks

ARKANSAS

Hon. David Pryor, Governor
Hon. Henry Gray, Highway Director
Mr. Ralph McDonald, Vice Chairman
Mr. Frank Carlisle, Jr.
Mr. Jimmy Driftwood
Mr. J. E. Dunlap
Mr. Randall W. Ishmael
Mr. Billy Rogers

FLORIDA

Hon. Reubin Askew, Governor
Hon. Tom Webb, Jr., Secretary, DOT
Hon. Hans G. Tanzler, Mayor,
Jacksonville
Mr. Tom V. Schifanella,
Vice Chairman
Mr. William M. Godfrey
Mr. K. N. Henderson
Mr. Edward A. Mueller
Mr. James E. Reeder
Representative Eric Smith
Dr. Jay A. Smith, Jr.

GEORGIA

Hon. George Busbee, Governor
Hon. Thomas D. Moreland, Commissioner, DOT
Hon. W. Milton Folds, Comm. Ind. & Trade
Mr. Alton H. Fendley, Vice Chairman
Commissioner Norman Dorminy
Mr. Percy Harrell
Senator Floyd Hudgins
Mr. Millard Kennedy
Mayor Bob Tonning
Mr. Billy Westbrook

MISSISSIPPI

Hon. Cliff Finch, Governor
Hon. John R. Tabb, Highway Director
Mrs. Everett Slayden, Vice Chairman
Mayor Sam Coopwood
Mayor H. D. McGee
Senator Perrin Purvis
Commissioner Bobby G. Richardson
Mr. Bill Rutledge
Representative Jerry Wilburn

MISSOURI

Hon. Joseph P. Teasdale, Governor
Hon. Jack Curtis, Chairman, Highway
Commission
Hon. Charles Wheeler, Mayor,
Kansas City
Councilman Victor F. Swyden,
Vice Chairman
Mr. T. Dick Fleming
Mr. Robert Hunter
Mr. George Innes
Councilman David D. James
Mr. Max Norman
Mr. Willard Wilkinson

TENNESSEE

Hon. Ray Blanton, Governor
Hon. Wyeth Chandler, Mayor, Memphis
Hon. Roy Nixon, Mayor, Shelby County
DOT Commissioner Eddie Shaw, Vice Chairman
Mr. George Dando
Mr. Frank C. Holloman, Senior Vice Chairman
Mr. George Houston
Mr. Frank Palumbo
Mr. Jack Ramsay
Mr. Bruce C. Taylor

First Multi-State Meeting - February 1972

The first Multi-State Meeting was held at Callaway Gardens, Georgia. In that meeting it was requested that a feasibility study be made on the corridor by the Federal Highway Administration and the states involved. In response to this request the advice from the state transportation officials was that a feasibility study would not be made unless it was called for in the Federal Highway Act.

Meeting with Congressmen - May 1972

Following this professional advice the Board set up a meeting in the President's Room in the United States Capitol with all the Congressmen from along the Corridor. The purpose of the meeting was to request that a paragraph be included in the Highway Act calling for a feasibility study of this route. The request was enthusiastically received and the response was that the congressional representatives from the region would do what they could to achieve the legislation.

Multi-Mode Concept Adopted - October 1972

An outstanding policy and organizational conference was held in Memphis, Tennessee. The agenda reflects that the four hundred conferees were encouraged by and honored to have the Assistant Secretary of Commerce, Robert Podesta, the late Federal Highway Administrator, Ralph Bartelsmeyer, and the colorful Mississippi Governor, Bill Waller, participating in the program. In this meeting the Multi-State Transportation Corridor Advisory Board was established and it was agreed that the Multi-Mode Concept would be pursued for the transportation Corridor.

First Highway Legislation - August 1973

The Federal Aid Highway Act of 1973 was signed into law on August 13th wherein Section 143 called for the Highway Feasibility Study of this route along with the studies of nine others throughout the nation. Initial discussion with Congress was for a Multi-Mode Feasibility Study for the route. Highway concern was expressed for the Multi-Mode Study subject being in the Highway Act and it was suggested that for this year only the Highway Feasibility should be studied.

Meeting with Governors - September 1973

During the Southern Governors' Conference at Point Clear, Alabama, the Board officers met with the six governors and the Honorable Robert H. Clement, Deputy Undersecretary of Transportation where all present participated in a substantive open discussion on this Corridor project.

Seminars - January-November 1974

The Board, in cooperation with the U.S. Department of Transportation's regional office in Atlanta, conducted a series of seminars on (1) the "Innovations in Transportation," (2) "Application of the Multi-Mode Concept," and (3) "Operation of the Multi-Mode Concept." These seminars brought together technical representatives from all areas of the transportation family. These seminars produced substantive ideas.

The discussion took an in-depth look at Commission and Authority type organizations, financial support and the legal aspects involved. Participants represented:

Alabama State Highway Department
Appalachian Regional Commission
Arkansas State Highway Department
Auburn University

Coastal Plains Regional Commission
Columbus College
Delta Airlines
Dames & Moore
Federal Aviation Administration Regional Office
Federal Highway Administration
Frisco Railway Company
General Motors Research Laboratories
Georgia Department of Natural Resources
Georgia Department of Transportation
Georgia Institute of Technology
Georgia Power Company
Georgia Public Services Commission
Greyhound Bus Lines
Highway Users Federation
Kansas City Chamber of Commerce, Kansas
Lockheed Corporation
L&N Rail Road Company
Memphis State University
Operation New Birmingham
Ozark Regional Commission
Wm. S. Pollard Consultants, Inc.
Stanford Research Institute
Seaboard Coast Line Railroad
Southern Bell
Southern Natural Gas Company
Southern Railway System
Tennessee Valley Authority (TVA)
Traffic Planning Associates
United States Department of Transportation

Meeting/Conference, Brunswick, Georgia - December 1974

At the Advisory Board Conference on Sea Island (Brunswick), Georgia, a complete review was made of the University Research Program, the Seminar Program, and the Highway Corridor Feasibility Study. The Advisory Board passed a resolution to establish the Multi-State Joint Development Committee (MSJDC) to advise the board on future courses of actions.

Study Report to Congress - December 1974

The U.S. Department of Transportation reported to Congress on Section 143, Federal Aid to Highway Act of 1973. Although the content of the report was not a surprise, it was a disappointment for the Board Members. It merely restated the Department's previously established policy that no additional mileage would be added to the Interstate Program and stated that there was no known source for funds to undertake any of the ten highway programs studied.

Joint Development Committee Meeting - May 1975

The Multi-State Joint Development Committee (MSJDC) held its initial meeting in Birmingham on February 11th. The Committee was composed of two appointed representatives by each Governor. The members of the Committee were from transportation and development agencies who were joined by two representatives from the Federal Regional Offices of Transportation and Commerce. In a series of meetings the Multi-State Joint Development Committee agreed on a draft of proposed legislation which would establish a joint Federal State Commission to develop the Multi-Mode Corridor. The Advisory Board in its mid-year meeting in Memphis, May 1975, agreed on the Draft Proposed Legislation for the establishment of a Joint Federal State Commission. It was further agreed to present the proposed legislation to Congressional members for appropriate action. Advice from members of the Administration at that time and U.S. Senators was to defer action for a new commission type organization but to use the existing Regional Commissions at this stage of the program.

Testimony to Congress - September 1975

The Board Chairman, Elton B. Stephens, testified before the U.S. House of Representatives' Sub Committee on Surface Transportation for legislation to advance the program. The testimony presented to the Sub Committee included an up-to-date report on the Board's Program. It additionally asked for the Multi-Mode Concept to be recognized as a National Need and that the Highway Element of the system to be approved as the first phase of the Multi-Mode Transportation System from Brunswick, Georgia to Kansas City, Missouri.

University Research Approved - November 1975

Ten Educational Institutions in a consortium with Georgia Institute of Technology including the University of Missouri, Arkansas State, Memphis State, Tennessee Tech, Mississippi State, University of Alabama, Auburn University, Columbus College and University of North Florida were approved for a research contract in a United States Department of Transportation sponsored Multi-Mode University Research Program. The $244,673 program was for FY 76.

Florida Joins Board - March 1976

The "State of Florida" and the Advisory Board executed a Certified Agreement whereby that state joined the Advisory Board program and became the seventh state in the region holding official membership. The Florida State legislature in the summer of 1975 passed legislation authorizing the state to join and participate in the Multi-State Advisory Board program.

1976 Highway Act Passed - May 1976

The 94th United States Congress enacted Public Law 94-280, "Federal-Aid Highway Act of 1976" and the Multimodal Concept studies were directed in Section 142, wherein this route was identified by reference to the 1973 Act and states: "The Secretary of Transportation is authorized and directed to study the feasibility of developing a multimodal concept along the route described in paragraph (1) of subsection (a) of this section, which study shall include an analysis of the environmental impact of such multimodal concept. The Secretary shall report to Congress the results of such a study not later than July 1, 1977."

Meeting with Commissions - August-September 1976

A delegation of the Advisory Board met with the Coastal Plains Regional Commission and the Appalachian Regional Commission to pursue joint Regional Commission action (administration and funding) of two studies, "Economic Impact" and "Energy Development and Distribution." A decision on the studies was referred by Coastal Plains for consideration of the Appalachian Commission. The Appalachian Regional Commission in September advised the Board that the Appalachian Commission was completely committed on priority programs to include the completion of the Appalachian Regional Highway Project and therefore, the Commission was unable to participate in the Economic and Energy Studies as requested by this Board.

APPENDIX B

NETWORK ZONE DESCRIPTIONS

The zones in the Multi-State Transportation Network are comprised of three types:

1. Zones inside the Multi-State Corridor that are smaller than BEAs,
2. Zones outside the Multi-State Corridor whose boundaries do not follow BEA boundaries, and
3. Zones made up of integral numbers of Basic Economic Areas (BEAs).

Zone composition is described below for each category. Type one zones are described in terms of their included counties and their nodal cities. Type two zones are often associated with a BEA but they are described in terms of their included counties and their nodal city. Type three zones are described in terms of their included BEAs and their nodal cities.

CORRIDOR ZONES

Zone No.	Nodal City	APDC*	Included Counties
1.	Brunswick, Ga.	--------------	Liberty, Long, McIntosh, Glynn, Camden Co., Ga.
2.	Jacksonville, Fl.	APDC 1, Fl.	Baker, Clay, Duval, Nassau, Putnam, St. Johns
3.	Statesboro, Ga.	Southern	Appling, Bullock, Candler, Evans, Jeff Davis, Tattnall, Toombs, Wayne
4.	Waycross, Ga.	Slash Pine	Atkinson, Bacon, Brantley, Charlton, Clinch, Coffee, Pierce, Ware
5.	Dublin, Ga.	Heart of Ga.	Bleckley, Dodge, Laurens, Montgomery, Pulaski, Telfair, Treutlen, Wheeler, Wilcox
6.	Valdosta, Ga.	Coastal Plain	Ben Hill, Berrier, Brooks, Cook, Echols, Irwin, Lanier, Lowndes, Tift, Turner
7.	Macon, Ga.	Middle Ga.	Bibb, Crawford, Houston, Jones, Monroe, Peach, Twiggs
8.	Cordele, Ga.	Middle Flint	Crisp, Dooly, Marion, Macon, Schley, Sumter, Taylor, Webster,
9.	Albany, Ga.	S.W. Ga.	Baker, Calhoun, Colquitt, Decatur, Dougherty, Early, Grady, Lee, Miller, Mitchell, Seminole Terrell, Thomas, Worth
10.	Lagrange, Ga.	Chattahoochee-Flint	Carroll, Coweta, Heard, Meriwether, Troup
11.	Columbus, Ga.	Lower Chattahoochee Valley APDC 10, Al.	Chattahoochee, Clay, Harris, Muscogee, Quitman, Randolph Stewart, Talbot, Ga., Lee, Russell, Al.
12.	Anniston, Al.	APDC-4	Calhoun, Chambers, Cherokee, Clay, Cleburne, Cosa, Etowah, Randolph, Talladega, Tallapoosa
13.	Montgomery, Al.	APDC-9+	Autauga, Dallas, Elmore, Montgomery, Perry
14.	Troy, Al.	APDC-5	Bullock, Butler, Crenshaw, Lowndes, Macon, Pike
15.	Dothan, Al.	APDC-7	Barbour, Coffee, Covington, Dade, Geneva, Henry, Houston
16.	Decatur, Al.	APDC-11	Cullman, Lawrence, Morgan
17.	Birmingham, Al.	APDC-1	Blount, Chilton, Jefferson, St. Clair, Shelby, Walker
18.	Florence, Al.	APDC-1	Colbert, Franklin, Lauderdale, Marion, Winston
19.	Tuscaloosa, Al.	APDC-2	Bibb, Greene, Fayette, Hale, Lamar, Pickens, Tuscaloosa
20.	Corinth, Ms.	N.E. Ms.	Alcorn, Benton, Marhsall, Prentiss, Tippah, Tishomingo

*Area Planning and Development Commission or equivalent comprehensive planning agency.

Zone No.	Nodal City	APDC*	Included Counties
21.	Tupelo, Ms.	3 Rivers	Calhoun, Chickasaw, Itawanba, Lafayette, Lee, Monroe, Pontotac, Union
22.	Columbus, Ms.	Golden Triangle	Clay, Choctaw, Lowndes, Noxubee, Ortibbeh, Webster
23.	Clarksdale, Ms.	No. Delta	Coahoma, DeSoto, Quitman, Panola, Tate, Tunica
24.	Dyersburg, Ten.	N.W. APDC-	Carroll, Crockett, Dyer, Gibson, Henry, Lake, Obion, Weakley
25.	Jackson, Tn.	SW APDC+	Chester, Decatur, Hardeman, Hardin, Haywood, Henderson, McNairy, Madison, Wayne
26.	Memphis, Tn.	Memphis Delta	Fayette, Lauderdale, Shelby, Tipton
27.	Jonesboro, Ak.	East	Clay, Craighead, Crittenden, Cross, Greene, Lawrence, Lee, Ms. Phillips, Poinsett, Randolph, St. Francis
28.	Searcy, Ak.	White River	Cleburne, Fulton, Independence, Izard, Jackson, Sharp, Stone, Van Buren, White, Woodruff
29.	Harrison, Ak.	--------	Baxter, Boone, Carroll, Marion, Newton, Searcy
30.	Sikeston, Mo.	Bootheel	Bunklin, Mississippi, New Madrid, Plemescot, Scott, Stoddard
31.	Poplar Bluff, Mo.	Ozark Foothills	Butler, Carter, Reynolds, Ripley, Wayne
32.	West Plains, Mo.	So. Cent. Ozark	Douglas, Howell, Oregon, Ozark, Shannon, Texas, Wright
33.	Lebanon, Mo.	Lake of the Ozarks	Camden, Laclede, Miller, Morgan, Pulaski
34.	Marshall, Mo.	Mo. Valley	Carroll, Chariton, Saline
35.	Sedalia, Mo.	Show-Me	Johnson, Lafayette, Pettis
36.	Springfield, Mo.	Lakes Country	Barry, Christian, Dade, Dallas, Greene, Lawrence, Polk, Stone, Taney, Webster
37.	St. Joseph, Mo.	Bi State	Andrew, Buchanon, Clinton, DeKalb, Mo., Doniphan, Ks.
38.	Kansas City, Mo.	Mid America Reg. Council	Cass, Clay, Jackson, Platte, Ray, Mo., Johnson, Leavenworth, Wyandatte, Ks.
39.	Nevada, Mo.	Kaysinger Basin	Bates, Benton, Cedar, Henry, Hickory, St. Clair, Vernon
40.	Joplin, Mo.	Ozark Gateway	Barton, Jasper, McDonald, Newton

2. NON BEA EXTERNAL ZONES

BEAs Disrupted: 33, 34, 40, 41, 42, 43, 44, 45, 46, 47, 111, 112, 114, 115, 116, 117

Zone No.	Nodal City	BEA	Included Counties
41	Savannah, Ga.		Bryan, Chatham, Effingham, Screven, Ga.; Jasper, S.C.
43	Milledgeville, Ga.		Oconee APDC, Ga: Baldwin, Hancock, Jasper, Putnam, Washington, Wilkerson
44	Atlanta, Ga.	BEA 44 minus:	Cleburne Co., Ala.; Carroll, Coweta Co., Ga.
46	Huntsville, Al.		Limestone, Madison, Marshall Co., Ala.; Lincoln, Franklin Co., Tenn.
49	Cape Girardeau, Mo.		Bolinger, Cape Girardeau, Mo.; Alexander, Hardin, Johnson, Massac, Pope, Pulaski, Union, Ill.; Ballard, Carlisle, Calloway, Fulton, Graves, Hickman, Livingston, Lyon, Marshall, McCracken, Ky.
50	St. Louis, Mo.	BEA 114 minus:	Laclede, Pulaski, Reynolds, Texas, Mo.
52	Columbia, Mo.	BEA 112 minus:	Putnam, Sullivan, Linn, Chariton, Morgan, Camden, Miller Co., Mo.
53	Chillicothe, Mo.		Northwest, Mo., Green Hills APCD, Mo., Atchison, Caldwell, Daviess, Gentry, Grundy, Harrison, Holt, Linn, Livingston, Mercer, Nodaway, Putnam, Sullivan, Worth

Zone No.	Nodal City	BEA	Included Counties
56	Topeka, Ks.		Allen, Anderson, Atchison, Bourbon, Brown, Cherokee, Craig, Crawford, Douglas, Franklin, Geary, Jackson, Jefferson, Labette, Linn, Lyon, Marshall, Miami, Montgomery, Nemaha, Neosho, Osage, Ottawa, Pottawatomie, Riley, Shawnee, Wabaunsee, Washington, Wilson, Woodson, Ks.
60	Little Rock, Ak.	BEA 117 minus:	White River APDC, Ak. (See zone 28 for omitted counties)
67	Gainesville, Fl.		Alachua, Bradford, Columbia, Dixie, Gilchrist, Hamilton, Lafayette, Levy, Marion, Sewannee, Union, Fl.

3. ZONES COMPRISED OF INTEGRAL BEAS

Zone No.	Nodal City	BEAs
42	Augusta, Ga.	32
45	Chattanooga, Tn.	48
47	Nashville, Tn.	49
48	Evansville, In.	55
51	Quincy, Il.	113
54	Des Moines, Ia.	80,81, 104, 105, 106
55	Omaha, Ne.	102, 103, 107,108
57	Wichita, Ks.	109, 110
58	Tulsa, Ok.	119
59	Ft. Smith, Ok.	118
61	Greenville, Ms.	134
62	Jackson, Ms.	135
63	Meridian, Ms.	136
64	Mobile, Al.	137
65	Pensacola, Fl.	39
66	Tallahassee, Fl.	38
68	Miami, Fl.	35, 36
69	Boston, Ma.	1, 2, 3, 4, 5
70	Albany, N.Y.	6, 7
71	Buffalo, N.Y.	8, 9, 10
72	New York, N.Y.	14, 15
73	Scranton, Pa.	12, 13
74	Harrisburg, Pa.	11, 16
75	Pittsburgh, Pa.	66, 67
76	Washington, D. C.	17, 18
77	Roanoke, Va.	19, 20
78	Richmond, Va.	21
79	Charlotte, N.C.	25, 26
80	Raleigh, N.C.	23, 24
81	Greenville, S.C.	27, 28
82	Columbia, S.C.	29, 30
83	Knoxville, Tn.	50
84	Charleston, W.V.	51, 52, 65
85	Cincinnati, Oh.	53, 54, 62
86	Dayton, Oh.	61, 63, 69
87	Cleveland, Oh.	68
88	Detroit, Mi.	71, 72, 74
89	Indianapolis, In.	56, 59, 60
90	Chicago, Il.	76, 77, 78, 79
91	Milwaukee, Wi.	82, 83, 84, 85, 86
92	St. Paul, Mn.	88, 89, 90, 91
93	Billings, Mn.	94, 95, 100, 101, 150
94	Denver, Co.	147, 148, 149
95	Oklahoma City, Ok.	120, 121
96	Texarkana, Tx.	131
97	Shreveport, La.	132, 133
98	New Orleans, La.	138
99	Tampa, Fl.	37
100	Amarillo, Tx.	122, 123

Zone No.	Nodal City	BEAs
101	Dallas, Tx.	127, 130
102	El Paso, Tx.	124, 145, 163
103	Austin, Tx.	128, 129
104	San Antonio, Tx.	125, 126, 142, 143, 144
105	Houston, Tx.	139, 140, 141
106	Salt Lake City, Ut.	151, 160
107	Phoenix, Ar.	162
108	Albuqurque, NM	146
109	Seattle, Wa.	153, 154, 155, 156
110	San Francisco, Ca.	166, 167, 168, 171
111	Los Angeles, Ca.	161, 164, 165
112	Charleston, S.C.	31
113	Duluth, Mn.	87
114	Springfield, Il.	57, 58
115	Toledo, Oh.	70, 75
116	Columbus, Oh.	65
117	Portland, Or.	152, 157, 158, 159, 169, 170
118	Fargo, ND	92, 93, 96, 97, 98, 99
119	Grand Rapids, Mi.	73
120	Norfolk, Va.	22

APPENDIX C

NETWORK ARC DESCRIPTIONS

This Appendix contains a detailed description of each two way arc in the transportation network. Separate tables and a separate format are presented for highway rail and water arcs.

Highway Arcs

Seven items of information are presented for each highway arc. They are:

Column 1. Arc number,

Column 2. Originating network node number*,

Column 3. Terminating network node number,

Column 4. Distance in miles between the two nodes,

Column 5. Travel time in minutes for a truck to move from node to node,

Column 6. Number of lanes of traffic in both directions, and

Column 7. The route designations for the highways comprising the arc

I = Interstate

US = Federal aid primary or secondary

S = State

Rail Arcs

The seven items of information that describe each rail arc are different from those used to describe highway arcs. Rail arc descriptors are:

Column 1. Arc number,

Column 2. Origin node,

Column 3. Terminating node,

Column 4. Arc length in miles,

Column 5. Average speed made good by the highest class freight train normally traversing the arc,

Column 6. Arc capacity in trains per day in both directions. This includes the capacity of all parallel routes considered part of the same arc.

Column 7. Railroad Company(s) owning the lines comprising the arc.

1. Atchison, Topeka & Santa Fe
2. Atlanta and West Point
3. Burlington Northern
4. Bessemer and Lake Erie

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*Flow can move in both directions between the pair of nodes designated origin and destination.

5. Baltimore & Ohio/Chesapeake & Ohio
6. Conrail
7. Chicago & North Western
8. Chicago, Rock Island & Pacific
9. Denver & Rio Grande Western
10. Detroit, Toledo & Ironton
11. Florida East Coast
12. Georgia
13. Illinois Central Gulf
14. Kansas City Southern
15. Louisiana & Arkansas
16. Louisville & Nashville
17. Milwaukee
18. Missouri-Kansas-Texas
19. Missouri Pacific
20. Norfolk & Western
21. Penn Central (other than Conrail lines)
22. Richmond, Fredericksburg & Potomac
23. Seaboard Coast Line
24. Southern
25. Soo Line
26. Southern Pacific
27. St. Louis-San Francisco
28. St. Louis Southwestern
29. Texas & Pacific
30. Union Pacific
31. Western Railway of Alabama
32. Western Pacific

All rail arcs are capable of carrying two way traffic.

Water Arcs

The eight water arc descriptors are:

Column 1. Arc number,

Column 2. Origin node,

Column 3. Destination node,

Column 4. Arc length in miles,

Column 5. Down stream speed in miles per hour,

Column 6. Number of locks along the arc --

a-1 entry designates an ocean arc with no locks,

Column 7. Channel depth in fee, a-1 entry designates an ocean arc.

Column 8. Waterway system

1. Alabama River
2. Arkansas River
3. Atlantic Coastwise
4. Black Warrior River
5. Chattahoochee River
6. Cumberland River
7. Great Lakes Waterway
8. Gulf Coastwise
9. Hudson River
10. Illinois River
11. Kanawha River
12. Mississippi River
13. Missouri River
14. N.Y. State Barge Canal
15. Ohio River
16. Pacific Coastwise
17. Savannah River
18. Tennessee River
19. Tennessee-Tombigbee Waterway

Water arcs also support two way traffic.

HIGHWAY ARCS

Arc	Orig.	Dest.	Dist.	Time	La. Routes
1	1	2	68	74	4 I-95
2	1	4	49	65	2US-84
3	1	41	70	76	4 I-95
4	2	66	163	177	4 I-10
5	2	67	49	53	4US301 S-24
6	2	68	349	379	4 I-95
7	3	4	108	144	2US-25US-82
8	3	5	72	96	2US-80
9	3	8	130	170	2 I-16 US-1US280
10	3	41	53	58	4 I-16
11	3	42	47	63	2US-25
12	4	2	78	104	2US-23
13	4	6	61	81	2US-84
14	4	8	111	139	2US-82 I-75
15	4	9	113	151	2US-82
16	4	41	94	120	2US-82 I-95
17	5	1	146	195	2US441US341
18	5	4	121	153	2 I-16 US-1
19	5	7	52	57	4 I-16
20	5	8	92	123	2US441US280
21	5	42	85	113	2US319 US-1
22	5	43	47	63	2US441
23	6	2	75	82	4 I-75 I-10
24	6	8	88	96	4 I-75
25	6	9	89	107	2 I-75US-82
26	6	66	71	82	2US-84US221 I-10
27	6	67	93	101	4 I-75
28	7	43	31	46	2 S-49
29	7	44	78	85	4 I-75
30	8	7	56	61	4 I-75
31	8	11	87	116	2US280
32	9	8	34	51	2S-257
33	9	11	77	104	2US-82 S-55US280
34	9	66	98	131	2US-19US319
35	10	44	49	53	4 I-85
36	11	7	98	131	2US-80
37	11	10	50	54	4I-185
38	12	10	69	95	2US431S-244
39	12	13	88	96	2US231
40	12	17	61	66	4 I-20
41	12	44	86	93	4 I-20
42	12	45	111	129	2US431 I-59
43	12	46	98	131	2US431
44	13	9	150	200	2US-82
45	13	10	88	96	4 I-85
46	13	11	86	100	2 I-85US280
47	13	14	44	48	4US231
48	13	17	94	102	4 I-65
49	13	19	105	140	2US-82
50	13	63	153	204	2US-80
51	13	64	179	195	4 I-65
52	13	65	154	187	2 I-65US-31US-29
53	14	64	159	185	2US-29 S-10 I-65
54	14	65	162	216	2US-29
55	15	9	82	122	2 S-62
56	15	11	105	140	2US431
57	15	14	56	61	4US231
58	15	65	141	161	2US231 I-10
59	15	66	101	117	2US231 I-10
60	16	18	41	45	4US-72
61	16	46	23	25	4US-72
62	16	47	116	126	4 I-65
63	17	11	148	197	2US280
64	17	16	81	88	4 I-65
65	17	19	56	61	4 I-59
66	17	21	165	220	2US-78
67	17	45	150	163	4 I-59
68	18	20	54	72	2US-43US-72
69	18	22	127	169	2US-43US-78 S-12
70	18	47	104	131	2US-43 I-65
71	19	18	116	155	2US-43
72	19	22	61	81	2US-82
73	19	63	75	82	4 I-59
74	19	64	197	262	2US-43
75	20	25	54	72	2US-45
76	20	26	94	125	2US-72
77	21	20	50	67	2US-45
78	21	23	110	164	2 S-6
79	21	26	97	129	2US-78
80	21	62	215	263	2 S-6 I-55
81	22	21	68	91	2US-45
82	22	23	165	220	2US-82US49E
83	22	61	160	213	2US-82
84	22	62	168	203	2US-82 I-55
85	22	63	89	118	2US-45
86	23	26	78	104	2US-61
87	23	28	136	181	2US-61US-49 S-1 S-64
88	23	60	140	173	2US-61US-49 I-40

Arc.	Orig.	Dest.	Dist.	Time	La. Routes
89	23	61	70	93	2US-61
90	23	62	186	217	2 S-6 I-55
91	24	27	100	121	2I-155 I-55 S-18
92	24	30	78	85	4I-155 I-55
93	24	48	203	232	2US-51PTNPKTPKWYPPKWY
94	25	24	41	61	2 S-20
95	25	47	150	163	4 U-40
96	25	48	235	271	2 I-40 S-13
97	26	24	74	80	4US-51
98	26	25	75	82	4 I-40
99	26	27	65	81	2 I-55US-63
100	26	28	92	123	2US-64
101	26	30	145	157	4 I-55
102	26	60	138	150	4 I-40
103	27	28	79	105	2 S-39US-64US-67
104	27	29	166	221	2US-63US-62
105	27	30	120	149	2 S-18 I-55
106	27	31	91	121	2US-63US-67
107	27	32	104	139	2US-63
108	28	29	165	220	2US167US-64US-65
109	28	32	142	189	2US167US-63
110	28	60	43	47	4US-67
111	29	32	109	145	2US-62 S-5US-160
112	29	36	65	87	2US-65
113	29	40	148	197	2US-62US-71
114	29	58	186	248	2US-62 S-33
115	29	59	132	176	2US-62US-71
116	29	60	134	171	2US-65 I-40
117	30	31	47	63	2US-60
118	30	47	190	223	2US-60 I-24
119	30	48	227	267	2 I-57 S-13US-60
120	30	49	38	41	4 I-55
121	31	32	100	133	2US160
122	31	50	202	231	2US-60 I-55
123	32	33	111	148	2US-60 S-5
124	32	36	110	146	2US-60
125	32	50	210	254	2US-63 I-44
126	32	52	205	273	2US-63
127	33	35	99	132	2 S-64US-65
128	33	39	123	164	2 S-5US-54
129	33	49	181	230	2 I-44 S-8US-67US-72
130	33	50	165	179	4 I-44
131	33	52	151	187	2 I-44US-63
132	34	51	75	100	2 S-41US-24
133	34	52	61	69	2US-65 I-70
134	34	53	65	87	2US-65

Arc.	Orig.	Dest.	Dist.	Time	La. Routes
135	35	34	24	32	2US-65
136	35	38	83	95	2US-65 I-70
137	35	52	68	78	2US-65 I-70
138	36	33	53	58	4 I-44
139	36	35	120	160	2US-65
140	36	39	91	121	2 S-13US-54
141	36	40	69	75	4 I-44
142	37	53	74	99	2US-36
143	37	54	181	204	2US-36 I-35
144	37	55	152	165	4 I-29
145	37	56	85	113	2US-59
146	38	34	76	85	2 I-70US-65
147	38	37	52	57	4 I-29
148	38	53	100	118	2I-35US-36
149	38	54	195	212	4 I-35
150	38	56	65	71	4 I-70
151	38	57	200	217	4 I-35
152	39	35	127	169	2US-54US-65
153	39	38	98	131	2US-71
154	39	57	170	226	2US-54
155	40	39	64	85	2US-71
156	40	57	218	279	2US166 I-35
157	40	58	95	103	4 I-44
158	40	59	149	199	2US-71
159	41	82	142	154	4 I-95 I-26
160	42	82	69	75	4 I-20
161	43	42	80	100	2 S-22 S-16US278 I-20
162	43	81	158	211	2US441
163	44	42	150	120	4 I-20
164	44	81	119	129	4 I-85
165	45	44	114	124	4 I-75
166	45	83	112	122	4 I-75
167	46	45	75	100	2US-72
168	47	45	128	139	4 I-24
169	47	46	187	209	2 I-65US-72
170	47	83	177	192	4 I-40
171	47	84	384	417	4 I-64
172	47	85	269	315	4 I-65 I-71
173	48	47	159	173	4US-41 I-24
174	48	84	392	426	4 I-64
175	48	85	224	243	4 I-64 I-71
176	49	47	171	194	2US-60 I-24
177	50	47	328	357	4 I-64 I-57 I-24
178	50	48	172	187	4 I-64
179	50	49	148	161	4 I-55
180	50	89	235	255	4 I-70

Arc	Orig.	Dest.	Dist.	Time	La. Routes
181	51	50	116	155	2US-61
182	51	52	119	159	2US-61US-54
183	52	50	106	115	4 I-70
184	53	51	130	172	2US-36US-61
185	53	54	149	171	2US-36 I-35
186	54	89	465	521	4 I-80 I-74
187	54	90	327	355	4 I-80
188	54	92	252	274	4 I-35
189	55	54	132	143	4 I-80
190	56	55	159	212	2US-75
191	57	56	127	138	4KTNPK
192	58	56	195	260	2US-75
193	59	58	117	127	4 I-40
194	59	101	243	264	4US-69 I-40
195	60	59	154	167	4 I-40
196	61	60	151	201	2US-65
197	62	61	120	113	2 I-20US-61
198	62	97	219	238	4 I-20
199	63	62	93	101	4 I-20
200	63	98	194	211	4 I-59
201	64	62	182	198	2US-49US-98
202	64	63	133	146	2US-45
203	64	98	144	157	4 I-10
204	65	64	62	67	4 I-10
205	66	65	186	202	4 I-10
206	67	66	133	145	4 I-75 I-10
207	68	99	268	291	4 I-75
208	70	69	163	177	4 I-90
209	71	70	283	308	4 I-90
210	71	73	246	330	4 I-90 I-81
211	72	69	206	224	4 I-84
212	72	70	154	167	4 I-87
213	72	74	180	196	4 I-78
214	72	76	233	253	4 I-95
215	73	70	173	188	4 I-81 I-88
216	73	72	138	150	4 I-84
217	74	71	278	365	4 2-79 I-90
218	74	73	118	128	4 I-81
219	74	75	189	205	4 I-76
220	75	71	216	236	4 I-79 I-90
221	76	74	107	116	4 I-83
222	76	75	221	240	4 I-76 I-70
223	76	84	344	374	4 I-81 I-64
224	77	74	289	314	4 I-81
225	77	76	225	245	4 I-81 I-66
226	77	78	164	180	4 I-64
227	78	76	106	115	4 I-95
228	79	77	189	205	4 I-77 I-81
229	79	80	167	182	4 I-85 I-40
230	80	77	163	177	4US220 I-85
231	80	78	173	188	4 I-85
232	81	42	104	139	2US-25
233	81	79	90	98	4 I-85
234	81	82	95	103	4 I-26
235	82	79	94	102	4 I-77
236	82	80	205	223	4 I-20 I-95
237	83	77	263	286	4 I-81
238	83	80	359	405	4 I-40
239	83	81	150	163	4 I-40 I-26
240	83	84	335	364	4 I-81 I-77
241	83	85	253	275	4 I-75
242	84	75	213	231	4 I-79
243	84	77	181	197	4 I-77 I-81
244	84	78	306	330	4 I-64
245	84	79	287	312	4 I-77
246	85	84	208	226	4 I-75 I-64
247	85	86	52	56	4 I-75
248	87	71	187	203	4 I-90
249	87	73	310	337	4 2-80 I-84
250	87	75	129	140	4I-80S
251	87	84	243	264	4 I-77
252	89	47	279	320	4 I-65
253	89	48	167	210	2 I-70US-41
254	89	85	106	115	4 I-74
255	89	86	107	116	4 I-70
256	90	48	296	322	4 I-57 I-64
257	90	49	376	409	4 I-57
258	90	51	308	363	2 I-55 S-125US-24
259	90	88	266	289	4 I-94
260	90	89	181	197	4 I-65
261	91	90	87	95	4 I-94
262	92	90	405	440	4 I-94 I-90
263	92	91	349	379	4 I-94
264	93	55	897	975	4 I-90 I-29
265	93	94	559	608	4 I-90 I-25
266	94	55	537	584	4I-80S I-80
267	94	56	540	587	4 I-70
268	94	57	509	553	4 I-70I-35W
269	94	100	423	510	2 I-25US-87
270	94	108	456	496	4 I-25
271	95	57	159	173	4 I-25
272	95	58	105	114	4 I-44

Arc	Orig.	Dest.	Dist.	Time	La. Routes
273	95	59	184	200	4 I-40
274	96	59	181	241	2US-71
275	96	60	140	152	4 I-20
276	96	61	206	275	2US-82
277	97	61	210	257	2 I-20US165US-82
278	97	96	70	76	4 I-71
279	98	62	178	293	4 I-55
280	98	97	313	396	2 I-10US-71
281	99	67	127	138	4 I-75
282	100	95	258	280	4 I-40
283	100	101	358	390	4US287
284	100	102	419	559	2US-70US-54
285	100	104	516	688	2US-87
286	101	95	206	224	4 I-35
287	101	96	175	190	4 I-30
288	101	97	185	201	4 I-20
289	102	101	620	674	4 I-20
290	102	104	574	624	4 I-10
291	103	97	309	388	2 I-35 S-31 I-20
292	103	101	193	210	4 I-35
293	103	105	164	201	2US183 I-10
294	104	103	77	83	4 I-35
295	104	105	197	214	4 I-10
296	105	97	234	262	2US-59US-79
297	105	98	356	387	4 I-10
298	105	101	243	264	4 I-45
299	106	93	551	654	4 I-15 I-90
300	106	94	504	548	4 I-80 I-25
301	106	117	780	848	4I-80N
302	107	108	432	490	4 I-17 I-40
303	107	102	443	482	4 I-10
304	108	100	284	308	4 I-40
305	108	102	266	289	4 I-25
306	109	93	845	918	4 I-90
307	109	106	871	947	4 I-90 I-82I-80N
308	110	106	752	817	4 I-80
309	110	111	379	412	4 I-5
310	111	94	1059	1151	4 I-15 I-70
311	111	106	715	777	4 I-15
312	111	107	389	423	4 I-10
313	112	41	106	115	2US-17 I-95
314	112	42	139	185	2US-78US-28
315	112	80	255	277	2US-52 I-95
316	112	82	113	123	4 I-26
317	113	92	153	166	4 I-35
318	113	118	251	334	2 US-2ST200ST-34US-10
319	114	50	100	109	4 I-55
320	114	51	127	169	4US-36
321	114	54	326	354	4 I-55 I-74 I-80
322	114	89	193	260	2US-36
323	114	90	189	205	4 I-55
324	115	86	155	168	4 I-75
325	115	87	111	120	4 I-90
326	115	88	61	66	4 I-75
327	115	89	219	245	4 I-69US-24
328	115	90	232	252	4I-90
329	115	116	133	180	2US-23
330	116	75	182	198	4 I-70
331	116	84	164	219	2US-33
332	116	85	108	117	4 I-71
333	116	86	65	71	4 I-70
334	116	87	139	151	4 I-71
335	117	119	172	187	4 I-5
336	117	110	640	695	4 I-5
337	118	92	234	254	4 I-94
338	118	93	611	664	4 I-94
339	119	88	147	160	4 I-96
340	119	89	241	321	4US131US-31
341	119	90	168	183	4I-196 I-94
342	120	78	90	98	4 I-64
343	120	80	168	225	2US-58 I-95

RAIL ARCS

Arc.	Orig.	Dest.	Dist.	Speed	Cap.	RRCo.				
345	1	2	87	35	40	23				
346	1	4	48	12	10	23				
347	1	7	176	12	10	23				
348	2	67	70	45	100	23				
349	2	68	366	45	40	11				
350	2	99	210	35	24	23				
351	3	6	181	12	10	24				
352	3	7	112	12	10	24				
353	3	42	54	12	10	24				
354	4	2	76	35	40	23				
355	4	6	61	12	10	23				
356	4	8	108	35	40	23				
357	4	9	112	12	10	23				
358	5	7	54	12	10	23				
359	6	2	110	28	24	24				
360	6	8	86	28	24	24				
361	6	15	134	12	10	23				
362	6	67	108	12	10	24				
363	7	8	62	28	24	24				
364	7	11	101	28	24	24				
365	7	43	33	12	10	12				
366	7	44	88	35	40	24	24			
367	8	9	36	12	10	24				
368	8	10	123	35	20	23				
369	8	11	95	12	10	23				
370	8	13	170	12	10	23				
371	8	41	168	12	10	23				
372	8	44	138	35	20	23				
373	9	7	106	28	24	24				
374	9	11	77	28	24	24				
375	9	15	72	12	10	24				
376	9	66	99	12	10	23				
377	10	12	114	35	40	23				
378	10	44	69	12	10	2				
379	11	17	171	28	24	24				
380	11	44	120	12	20	24	24			
381	11	66	163	12	10	23				
382	12	17	64	35	80	16	24(4)	23	24	23
383	12	44	99	35	40	24	24			
384	12	45	122	12	10	24				
385	13	10	104	12	10	31				
386	13	14	51	12	10	23				
387	13	17	97	35	40	16	24			
388	13	19	104	12	10	13				

Arc	Orig.	Dest.	Dist.	Speed	Cap.	RRCo.			
389	13	63	171	12	10	16			
390	13	64	178	35	40	16	24		
391	13	65	158	12	10	16			
392	14	11	84	12	10	24			
393	14	15	68	12	10	23			
394	16	17	85	35	40	16			
395	16	18	43	28	24	24			
396	16	46	24	28	24	24			
397	16	47	121	35	40	16	16		
398	17	18	129	12	10	24			
399	17	19	56	35	40	24	16		
400	17	20	148	28	24	13			
401	17	21	138	35	40	27			
402	17	22	118	12	10	24			
403	17	45	143	28	24	24			
404	18	20	54	28	24	24			
405	18	47	126	12	10	16			
406	19	22	60	12	10	13			
407	19	63	96	35	40	24			
408	20	21	50	12	20	13	13		
409	20	25	57	35	40	13			
410	20	26	94	28	24	24	13		
411	21	22	65	12	20	13	13		
412	21	63	104	35	40	27			
413	22	61	169	12	20	13	13		
414	22	63	99	12	20	13	13		
415	22	65	60	12	10	27			
416	23	26	76	12	20	13	13		
417	23	61	63	12	30	13	13	13	
418	24	49	124	35	80	13	13	13	13
419	25	24	48	28	24	13	13	13	
420	25	47	153	35	40	16	16		
421	26	24	78	28	24	13			
422	26	25	89	12	10	16			
423	26	60	135	28	24	28			
424	26	62	214	28	24	13			
425	27	26	68	35	40	27			
426	27	28	90	35	40	27	19		
427	27	31	82	35	40	19			
428	27	32	105	35	40	27			
429	27	96	304	35	40	28			
430	28	26	90	28	24	19			
431	28	60	51	35	40	19			
432	30	26	142	35	40	27			

Arc.	Orig.	Dest.	Dist.	Speed	Cap.	RRCo.		
433	30	49	29	35	80	28	27	
434	31	30	44	35	40	19		
435	31	50	130	35	40	19		
436	32	36	113	35	40	27		
437	33	50	182	35	40	27		
438	34	51	155	35	40	1		
439	34	52	55	35	40	19	20	13
440	35	52	60	28	48	18	19	8
441	36	33	57	35	40	27		
442	36	39	83	28	24	27		
443	36	40	65	35	40	27		
444	37	54	170	28	24	3	7	
445	37	55	127	12	10	3		
446	38	34	80	45	50	13	19	3,20, 1
447	38	35	94	28	24	19	8	
448	38	36	184	12	10	27		
449	38	37	60	35	80	3	19	
450	38	39	103	35	40	27	14	19
451	38	53	87	45	100	17	8	
452	38	56	65	35	72	30	1	
453	38	57	227	45	100	1		
454	38	58	195	28	72	18	1	19
455	39	35	92	12	10	18		
456	40	28	310	12	10	19		
457	40	39	63	35	40	27	14	19
458	40	58	115	35	40	27		
459	40	59	175	28	24	14	27	
460	41	1	78	35	40	23		
461	41	3	75	12	10	24		
462	41	4	97	35	40	23		
463	41	5	118	12	10	23		
464	41	80	361	35	40	23		
465	41	82	141	35	40	23		
466	42	43	93	12	5	12		
467	42	44	159	28	24	12		
468	42	81	128	12	10	23		
469	42	82	82	12	10	24		
470	44	45	136	35	80	16	16	24
471	45	46	98	28	24	16	24	
472	47	45	151	35	40	16		
473	47	48	160	35	40	16		
474	48	50	166	28	24	16		
475	48	90	289	35	40	16		
476	49	50	130	40	72	27	19	
477	51	50	129	28	24	3		
478	52	50	130	45	100	8,3,	19,13,18 ,	20

Arc	Orig.	Dest.	Dist.	Speed	Cap.	RRCo.			
479	52	51	88	35	80	20	3		
480	53	37	75	28	24	3	1		
481	53	52	83	28	24	3	20		
482	53	54	161	28	24	8			
483	53	90	412	35	40	8			
484	54	55	135	35	192	7	17	8	3
485	55	93	896	12	10	3			
486	55	94	560	35	40	3	30		
487	56	57	160	28	24	8			
488	57	94	580	28	24	1			
489	57	100	348	28	48	1	8		
490	58	59	124	28	24	19			
491	58	95	119	28	24	27			
492	58	101	318	28	24	18			
493	59	60	160	28	24	19			
494	59	95	210	12	10	8			
495	59	96	190	35	40	14			
496	60	96	144	35	40	19			
497	60	98	484	35	40	19			
498	62	61	138	12	10	13	13		
499	62	63	97	12	20	13	13		
500	62	64	179	12	10	13			
501	62	98	183	35	72	13	13	13	
502	63	64	137	12	20	13	27		
503	63	98	202	28	24	24			
504	64	65	96	12	10	16			
505	64	98	140	35	40	16			
506	65	66	202	12	10	16			
507	66	67	160	12	10	23			
508	67	99	141	35	40	23			
509	69	70	201	35	112	6	6		
510	69	72	230	35	72	6			
511	70	71	298	45	100	6			
512	70	73	190	35	40	6			
513	71	87	184	45	100	20	21		
514	71	88	252	35	40	6			
515	72	70	142	35	112	6	6		
516	72	73	134	35	72	6			
517	72	74	183	35	144	6	6		
518	72	76	225	35	112	6	5		
519	73	71	262	35	40	6			
520	73	74	136	35	40	6			
521	73	75	310	12	10	6			
522	74	75	245	45	100	21			
523	74	76	112	35	72	6			
524	75	76	296	35	72	5			

Arc	Orig.	Dest.	Dist.	Speed	Cap.	RRCo.			
525	75	87	131	35	216	21	5	6	
526	75	116	191	35	72	21			
527	76	77	227	35	40	20			
528	76	78	117	45	200	24	22		
529	77	84	225	35	72	20			
530	78	77	174	35	80	20			
531	78	79	279	35	40	24			
532	78	80	159	35	40	23			
533	78	84	369	35	40	5			
534	79	80	156	35	40	23			
535	79	81	98	45	100	23	24		
536	80	41	375	35	40	23			
537	81	44	154	145	100	24	23		
538	82	79	108	28	24	24			
539	82	80	203	35	40	23			
540	82	81	111	12	20	24	23		
541	83	44	197	28	24	16			
542	83	45	111	35	80	24	24	16	
543	83	47	216	12	10	16	24		
544	83	79	269	28	24	24			
545	84	85	204	45	100	5			
546	85	48	229	28	48	16	24		
547	85	50	338	28	24	5			
548	85	83	292	35	80	24	16		
549	85	90	281	35	40	5			
550	86	85	55	45	100	21			
551	86	87	109	35	144	21	21		
552	86	90	248	35	40	5			
553	87	90	340	35	256	20	5	21	6
554	88	90	272	35	72	21	20		
555	89	47	298	12	10	6	16		
556	89	50	240	35	40	6			
557	89	85	109	35	40	5			
558	89	90	184	35	40	21	16		
559	89	114	197	35	40	20			
560	90	49	364	35	72	13			
561	90	50	284	35	40	33			
562	90	51	272	45	100	3	1		
563	90	54	358	35	184	7	17	8	3
564	90	91	86	45	100	7	7	17	
565	90	92	396	35	40	3			
566	92	91	327	45	72	25	17		
567	93	109	903	35	40	3	3	17	
568	94	106	570	35	112	9	30		
569	95	57	172	35	80	8	1		
570	95	100	274	12	10	8			
571	96	101	182	45	30	29	26		
572	96	103	460	28	24	19			
573	97	62	218	12	10	13			

Arc	Orig.	Dest.	Dist.	Speed	Cap.	RRCo.			
574	97	96	73	28	24	14	26		
575	97	101	194	45	20	29			
576	97	105	232	35	40	26	14		
577	98	97	315	12	10	15			
578	98	105	363	12	10	26			
579	99	68	261	35	40	23			
580	100	108	374	35	40	1			
581	101	103	209	28	24	18			
582	101	105	264	35	40	1			
583	101	95	236	35	40	22	1		
584	102	100	446	28	24	26			
585	102	101	646	35	40	29			
586	102	104	610	35	40	26			
587	102	107	434	35	40	26			
588	102	108	255	28	24	1			
589	103	104	82	24	19				
590	105	103	174	35	40	1	26		
591	105	104	210	28	24	26			
592	106	110	821	35	72	26	32		
593	106	111	783	35	40	30			
594	107	111	425	35	112	1	26		
595	108	107	576	35	72	1			
596	110	117	742	35	40	26	32		
597	111	110	470	35	80	26	26	1	
598	112	41	111	35	40	23			
599	112	80	204	35	40	23			
600	112	82	129	12	10	24			
601	113	92	145	28	24	3			
602	114	50	99	35	72	13	13	20	
603	114	51	123	35	40	20			
604	114	90	185	35	40	13	13		
605	115	75	261	35	40	21			
606	115	86	160	35	40	5			
607	115	87	107	45	100	21			
608	115	88	56	35	184	10	21	20	
609	115	90	243	45	100	21			
610	115	116	135	45	100	20	21		
611	116	86	71	35	224	21	21	21	21
612	116	87	138	45	100	21			
613	116	84	204	45	100	20	5		
614	117	106	836	35	40	30			
615	117	109	183	45	100	3			
616	118	92	231	35	72	3	3		
617	118	93	640	35	40	3	3		
618	119	88	152	35	40	6			
619	119	90	184	35	40	6			
620	120	77	258	35	40	20			
621	120	78	109	45	100	6	20		

WATER ARCS

Arc	Orig.	Dest.	Dist.	Speed	Lock	Chan	Sys.
623	62	98	337	7	0	11	12
624	61	62	101	7	0	11	12
625	23	61	80	7	0	11	12
626	26	23	120	7	0	11	12
627	24	26	115	7	0	11	12
628	49	24	168	7	0	11	12
629	50	49	128	7	2	9	12
630	51	50	147	7	7	9	12
631	92	51	526	7	22	9	12
632	58	59	182	7	5		2
633	59	60	230	7	6		2
634	60	61	154	7	6		2
635	52	50	179	7	0	8	13
636	34	52	78	7	0	8	13
637	38	34	109	7	0	8	13
638	37	38	82	7	0	8	13
639	55	37	168	7	0	8	13
640	25	49	222	7	6	11	18
641	20	25	60	7	1	11	18
642	18	20	50	7	0	11	18
643	16	18	48	7	4	11	18
644	46	16	19	7	0	11	18
645	45	46	141	7	2	11	18
646	83	45	184	7	3	11	18
647	47	49	304	7	7	11	6
648	48	49	241	7	9	11	15
649	85	48	322	7	4	11	15
650	75	85	470	7	6	11	15
651	84	85	263	7	4		11
652	90	50	365	7	9		10
653	19	64	215	7	4		19
654	22	19	125	7	2		19
655	21	22	75	7	4		19

Arc	Orig.	Dest.	Dist.	Speed	Lock	Chan	Sys.
656	20	21	55	7	4		19
657	17	19	224	7	2		4
658	13	64	334	7	3		1
659	15	65	100	7	1		5
660	11	15	200	7	2		5
661	42	41	150	7	0		17
662	70	72	180	7	0	12	9
663	71	70	342	7	35	20	14
664	69	72	265	10	-1	-1	3
665	72	120	440	10	-1	-1	3
666	120	76	197	10	-1	-1	3
667	120	112	460	10	-1	-1	3
668	112	41	121	10	-1	-1	3
669	41	1	90	10	-1	-1	3
670	1	2	90	10	-1	-1	3
671	2	68	371	10	-1	-1	3
672	68	99	369	10	-1	-1	3
673	99	66	220	10	-1	-1	8
674	66	65	253	10	-1	-1	8
675	65	64	81	10	-1	-1	8
676	64	98	166	10	-1	-1	8
677	98	105	417	10	-1	-1	8
678	111	110	351	10	-1	-1	16
679	110	117	635	10	-1	-1	16
680	117	109	361	10	-1	-1	16
681	71	87	176	10	-1	-1	7
682	87	88	108	10	-1	-1	7
683	88	91	568	10	-1	-1	7
684	88	113	726	10	-1	-1	7
685	113	91	743	10	-1	-1	7
686	91	90	85	10	-1	-1	7
687	115	88	54	10	-1	-1	7
688	87	115	96	10	-1	-1	7
689	72	76	270	10	-1	-1	3

APPENDIX D

MANUFACTURING INDUSTRY DATA

INDUSTRY DATA

	COMMODITY			GROUP			
	201	202	203	204	205	206	207
COMPANIES	3,944	3,557	1,923	2,223	3,044	1,043	
ESTABLISHMENTS	4,437	4,590	2,557	3,080	3,633	1,249	
MEAN DIRECT LABOR WAGE/HR.	$ 3.78	$3.88	$3.09	$3.94	$3.94	$ 3.48	$3.76
INPUT PER TON SHIPPED							
DIRECT LABOR,HRS.	16.1	18.7	11.5	2.7	120.	114.	1.9
INDIRECT LABOR	$20.0	$85.5	$10.6	$ 5.5	$ 385.	$ 147.	$ 3.7
CAPITAL INVESTMENT	$85.5	$267.	$940.	$49.4	$ 974	$ 1552.	$40.3
ENERGY, KWH EQ.	1246		932	678		25.250.	189.
RAW MATERIALS, TONS COMMODITY/TONS	021/0.87 025/0.38 201/0.16	024/0.09 202/0.40	013/0.84 341/	011/ 207/0.18	204/2.71	013/30.3 017/0.19 206/1.88	013/0.79 207/0.01

COMMODITY GROUP

	208	209	210	220	230	240	250
COMPANIES	2,980	3,486	177	5,611	21,949	31,935	8,482
ESTABLISHMENTS	3,624	4,153	272	7,203	24,438	33,948	9,232
MEAN DIRECT LABOR WAGE/HR.	$4.44	$3.26	$3.75	$2.79	$2.53	$3.37	$3.08
INPUT PER TON SHIPPED							
DIRECT LABOR HOURS	4.3	15.0	73.5	143	372	9.8	134
INDIRECT LABOR	$22.0	$31.0	$69.6	$103	$303	$ 8.9	$ 155
CAPITAL INVESTMENT	105.	$162	$ 666	$775	$475	$ 35	$2550
ENERGY, KWH EQUIV.	706	3,910	3,780	6,110	3,140	170	1250
RAW MATERIALS, TONS COMMODITY/TONS	208/0.04	209/0.25 091/0.09	013.25 210/0.47	202/0.37 282/0.24	220/1.63	240/	220/0.01 240/1.08 285/0.003 331/0.38 333/0.01 342/0.15

	C O M M O D I T Y			G R O U P			
	260	270	281	282	283	284	285,9
COMPANIES	3,956	39,894	345	265	922	2,308	3,361
ESTABLISHMENTS	6,038	42,102	1,049	461	1,078	2,573	4,204
MEAN DIRECT LABOR WAGE/HR.	$4.15	$4.62	$4.94	$4.50	$4.41	$4.04	$4.10
INPUT PER TON SHIPPED							
DIRECT LABOR HRS.	1.18	211	2.5	9.7	88.6	12.1	13.1
INDIRECT LABOR	$ 19.0	$ 782	$ 8.9	$24.8	$ 556	$ 43.8	$54.1
CAPITAL INVESTMENT	$ 220	$1760	$56.	$214.	$2,040	$ 124.	$98.3
ENERGY, KWH EQUIV.	4,370	5,370	13,620		13,050	1,370	2,970
RAW MATERIAL, TONS COMMODITY/TONS	240/2.00	260/3.89	102/0.25		203/	207/0.05	207/0.01
	260/0.84	289/0.06	140/0.09			281/0.18	281/0.11
		390/0.02	281/0.08			284/0.05	282/0.05
			331/0.01				286/0.05
							287/0.02

	COMMODITY GROUP						
	286	287	290	301	302	310	321
COMPANIES	557	795	1,236	136	7,799	2,699	13,170
ESTABLISHMENTS	827	1,233	2,016	206	9,031	3,201	15,817
MEAN DIRECT LABOR WAGE/HR	$5.27	$3.94	$5.31	$5.37	$3.37	$2.74	$3.95
INPUT PER TON SHIPPED							
DIRECT LABOR, HRS.	5.8	2.9	0.3	29.7	70.7	409.	8.7
INDIRECT LABOR	$ 22.1	$8.6	$0.9	$53.7	$111.	$294.	$ 13.1
CAPITAL INVESTMENT	$387.	29.	$20.	$496	$343.	$265	$ 88
ENERGY, KWH EQUIV.	10,770	171.	749	4,160	1,590	8,034	2,260
RAW MATERIALS, TONS COMMODITY/TONS	140/0.02	140/2.67	130/1.20	220/0.06	281/0.04	201/0.54	140/2.79
	281/0.18	281/0.06	140/0.08	281/0.05	282/0.52	310/0.07	281/0.03
	287/0.04	287/0.02	290/0.02	282/0.14	286/0.03		282/0.001
	290/0.53		321/0.004	286/0.38	289/0.02		324/0.08
				289/0.16	302/0.05		331/0.0001
				302/0.05	321/0.01		
				331/0.02			

	C O M M O D I T Y			G R O U P			
	324	331	333	341	342	358	350
COMPANIES	75	1,855	3,745	223	26,150	1,566	36,519
ESTABLISHMENTS	198	2,370	4,422	553	28,972	1,769	39,023
MEAN DIRECT LABOR WAGE/HR.	$5.54	$ 5.05	$ 4.30	$4.86	$ 4.10	$ 4.27	$ 4.50
INPUT PER TON SHIPPED							
DIRECT LABOR, HRS.	0.83	9.9	18.8	33.9	60.6	127.2	154.5
INDIRECT LABOR	$ 1.24	$ 15.6	$ 31.3	$37.9	$115.	$293	$447
CAPITAL INVESTMENT	$64.3	$242.	$482.	$445.	$295.	$145	$1,213.
ENERGY, KWH EQUIV.	2,255.	3,896.	7,054.	603.	2,166	5300	1,604
RAW MATERIALS, TONS COMMODITY/TONS	140/	101/10.45	102/0.26	331/1.63	282/0.002	331/1.04	110/0.01
	260/	102/0.01	140/0.004	333/0.12	331/1.04	333/0.01	331/0.79
		110/0.68	281/0.25		333/0.06	342/0.01	342/0.05
		140/0.07	282/0.04		342/0.003		
		321/0.29	331/0.001				
		331/0.27	335/0.32				
		333/0.01					

	COMMODITY GROUP					
	361	362	371	372	380	390
COMPANIES	8,742	1,289	2,817	4,731	5,269	14,560
ESTABLISHMENTS	10,763	1,511	3,391	5,411	5,987	15,188
MEAN DIRECT LABOR WAGE/HR.	$ 3.88	$3.85	$5.35	$4.76	$ 3.90	$3.20
INPUT PER TON SHIPPED						
DIRECT LABOR, HRS.	156.8	131.	35.9	19.3	398	148.
INDIRECT LABOR	$449.	$306	$52.8	$84.5	$1440	$244
CAPITAL INVESTMENT	$1,024.	$1,034.	$320.	$95.2	$2760	$600
ENERGY, KWH EQUIV.	4,210	6,930	1,890.	694	1406	4100
RAW MATERIALS, TONS COMMODITY/TONS	282/0.03	282/0.004	282/	331/0.07	207/0.004	282/0.08
	331/0.29	331/0.74	331/0.40	333/0.09	331/0.10	310/0.003
	340/0.002	333/0.35	333/0.07	342/0.003	342/0.003	331/0.12
		342/0.001	342/0.03			333/0.01

APPENDIX E
TRANSPORTATION COSTS
FOR COMMODITIES

Line haul and loading and unloading costs are presented in this appendix for the rail and highway modes. The material is divided into four tables whose contents are as follows:

1. Railroad line haul costs per ton mile by commodity for each of three rail carrier cost areas. The first 53 entries are ordered by commodity for RCCA-1; the next 53 for RCCA-2 and the final 53 for RCCA-3.
2. Railroad loading and unloading costs per ton. Each entry includes loading plus unloading cost. These costs are listed by commodity for each of the three RCCAs as above.
3. Highway Line haul costs per ton mile by commodity for each of the eight motor carrier cost areas. The first 53 entries are ordered by commodity for MCCA-1, etc.
4. Highway loading and unloading costs per ton. These are listed by commodity for each MCCA.

RAILROAD LINE HAUL COSTS -- DOLLARS PER TON MILE

.0127	.0133	.0176	.0118	.0219	.0140	.0155	.0102	.0097	.010
.0103	.0106	.0150	.0154	.0123	.0130	.0282	.0107	.0106	.01
.0119	.0154	.0205	.0205	.0124	.0391	.0131	.0167	.0105	.0104
.0150	.0178	.0121	.0105	.0108	.0118	.0124	.0205	.0198	.0216
.0103	.0116	.0113	.0110	.0306	.0150	.0203	.0122	.0272	.0197
.0195	.0201	.0254	.0102	.0107	.0139	.0095	.0169	.0110	.0121
.0083	.0079	.0081	.0083	.0085	.0122	.0121	.0099	.0104	.0233
.0087	.0086	.0099	.0097	.0123	.0161	.0161	.0099	.0303	.0105
.0134	.0085	.0085	.0119	.0145	.0097	.0085	.0087	.0095	.0099
.0161	.0156	.0172	.0084	.0094	.0091	.0089	.0237	.0118	.0158
.0098	.0211	.0154	.0151	.0159	.0198	.0107	.0110	.0143	.0102
.0180	.0114	.0130	.0089	.0084	.0087	.0089	.0091	.0129	.0128
.0103	.0108	.0246	.0091	.0091	.0103	.0101	.0128	.0166	.0166
.0104	.0312	.0109	.0139	.0090	.0088	.0123	.0152	.0102	.0090
.0093	.0100	.0106	.0166	.0160	.0178	.0089	.0098	.0097	.0092
.0244	.0127	.0166	.0101	.0217	.0159	.0156	.0164	.0204	

RAILROAD LOADING & UNLOADING COSTS -- DOLLARS PER TON

3.1118	3.9694	6.6905	2.6843	4.1794	3.4134	2.1742	2.0860	1.9078	2.0265
2.2763	2.2067	7.5860	3.1489	3.5357	3.7337	19.1913	2.9263	2.7651	4.1704
3.8947	7.9560	6.1007	6.1807	2.9430	16.4659	3.6521	6.8314	2.3647	3.3589
4.0667	8.2582	2.9137	2.3868	2.3871	3.0320	2.9712	6.8496	6.5915	8.4724
2.2618	2.7460	2.5358	2.5273	9.7305	4.0556	7.0952	4.8117	10.3201	9.8178
5.2701	6.3826	7.9477	2.0622	2.7591	4.9131	1.7333	2.6228	2.2399	1.3582
1.3378	1.2221	1.2987	1.5210	1.4115	5.7284	2.1423	2.4604	2.5728	13.0864
2.0727	1.9429	2.9411	2.7058	6.2484	4.0034	4.0084	1.9114	11.4729	2.4356
4.7649	1.5537	2.4762	2.6348	5.5224	1.8986	1.5677	1.5615	1.9903	1.9186
4.6773	4.5132	5.5657	1.4877	1.7946	1.6480	1.6485	6.2275	2.7106	5.0787
3.7678	7.2819	7.8417	3.4277	4.1490	5.1173	3.0218	3.8337	6.4225	2.6019
4.0394	3.2770	2.1946	2.0528	1.8898	1.9983	2.2414	2.1625	7.3669	3.1056
3.4314	3.6095	10.2312	2.8727	2.7168	4.0501	3.7830	7.7286	5.8206	5.8206
2.8441	15.4341	3.5195	6.5407	2.3204	3.3073	3.8793	7.8678	2.8203	2.3405
2.3355	2.9402	2.8687	6.4895	6.2533	8.0059	2.2237	2.6680	2.4676	2.4675
9.0583	3.8790	6.7593	4.7141	9.7557	9.4962	4.9720	6.0204	7.4341	

HIGHWAY LINE HAUL COSTS -- DOLLARS PER TON MILE

.1282	.1005	.1608	.2010	.2876	.1005	.1105	.2010	.2010	.2010
.2010	.1960	.1427	.1065	.1005	.1005	.1507	.1156	.1507	.1005
.1005	.1608	.1105	.2613	.1417	.2010	.1005	.1005	.1688	.1166
.1005	.1045	.1407	.1608	.1940	.1357	.1859	.1507	.1608	.1608
.1759	.1216	.1849	.1146	.2914	.1779	.1437	.1105	.1608	.2713
.2578	.1105	.1306	.0709	.0556	.0890	.1112	.1591	.0556	.0612
.1112	.1112	.1112	.1112	.1084	.0790	.0589	.0556	.0556	.0834
.0639	.0834	.0556	.0556	.0890	.0612	.1446	.0784	.1112	.0556
.0556	.0934	.0645	.0556	.0578	.0778	.0934	.1073	.0751	.1029
.0834	.0890	.0890	.0973	.0673	.1023	.0634	.1612	.0984	.0795
.0612	.0890	.1501	.1426	.0712	.0723	.0725	.0568	.0909	.1136
.1626	.0568	.0625	.1136	.1136	.1136	.1136	.1108	.0807	.0602
.0568	.0568	.0852	.0653	.0852	.0568	.0568	.0909	.0625	.1477
.0801	.1136	.0568	.0568	.0954	.0659	.0568	.0591	.0795	.0954
.1096	.0767	.1051	.0852	.0909	.0909	.0994	.0687	.1045	.0648
.1647	.1005	.0812	.0625	.0909	.1534	.1457	.0625	.0738	.0567
.0444	.0710	.0839	.1271	.0444	.0488	.0888	.0888	.0888	.0888
.0966	.0650	.0471	.0444	.0444	.0666	.0511	.0666	.0444	.0444
.0710	.0488	.1154	.0626	.0888	.0444	.0444	.0746	.0515	.0444
.0462	.0622	.0746	.0857	.0599	.0821	.0666	.0710	.0710	.0777
.0537	.0817	.0506	.1288	.0786	.0635	.0488	.0710	.1199	.1139
.0488	.0577	.0601	.0471	.0754	.0942	.1348	.0471	.0518	.0942
.0942	.0942	.0942	.0918	.0669	.0499	.0471	.0471	.0706	.0542
.0706	.0471	.0471	.0754	.0518	.1225	.0664	.0942	.0471	.0471
.0791	.0546	.0471	.0490	.0659	.0791	.0909	.0636	.0871	.0706
.0754	.0754	.0824	.0570	.0867	.0537	.1366	.0834	.0674	.0518
.0754	.1272	.1208	.0518	.0612	.0521	.0408	.0653	.0816	.1168
.0408	.0449	.0816	.0816	.0816	.0816	.0796	.0579	.0432	.0408
.0408	.0612	.0469	.0612	.0408	.0408	.0653	.0449	.1061	.0575
.0816	.0408	.0408	.0685	.0473	.0408	.0424	.0571	.0685	.0787
.0551	.0755	.0612	.0653	.0653	.0714	.0494	.0751	.0465	.1183
.0722	.0583	.0469	.0653	.1102	.1047	.0449	.0530	.0561	.0440
.0704	.0880	.1259	.0440	.0484	.0880	.0880	.0890	.0880	.0858
.0625	.0466	.0440	.0440	.0660	.0506	.0660	.0440	.0440	.0704
.0484	.1144	.0620	.0880	.0440	.0440	.0739	.0510	.0440	.0458
.0616	.0739	.0849	.0594	.0814	.0660	.0704	.0704	.0770	.0532
.0810	.0502	.1276	.0779	.0629	.0484	.0704	.1188	.1129	.0484
.0572	.0749	.0587	.0939	.1174	.1680	.0587	.0646	.1174	.1174
.1174	.1174	.1145	.0634	.0622	.0587	.0587	.0880	.0675	.0880
.0587	.0587	.0939	.0646	.1526	.0828	.1174	.0587	.0587	.0986
.0681	.0587	.0610	.0822	.0986	.1133	.0792	.1086	.0880	.0939
.0939	.1027	.0710	.1080	.0669	.1702	.1039	.0839	.0646	.0939
.1585	.1506	.0646	.0763	.0883	.0692	.1107	.1384	.1981	.0692
.0761	.1384	.1384	.1384	.1384	.1349	.0983	.0734	.0692	.0692
.1038	.0796	.1038	.0692	.0692	.1107	.0761	.1799	.0976	.1384
.0692	.0692	.1163	.0803	.0692	.0720	.0969	.1163	.1336	.0934
.1280	.1038	.1107	.1107	.1211	.0837	.1273	.0789	.2007	.1225
.0990	.0761	.1107	.1868	.1775	.0761	.0900	.0537	.0421	.0674
.0842	.1205	.0421	.0463	.0842	.0842	.0842	.0842	.0821	.0598
.0446	.0421	.0421	.0631	.0494	.0631	.0421	.0421	.0674	.0463
.1095	.0594	.0842	.0421	.0421	.0707	.0488	.0421	.0438	.0589
.0707	.0813	.0568	.0779	.0631	.0674	.0674	.0737	.0509	.0775
.0480	.1221	.0745	.0602	.0463	.0674	.1137	.1080	.0463	.0547
.0531	.0416	.0666	.0832	.1191	.0416	.0458	.0832	.0832	.0832
.0832	.0811	.0591	.0441	.0416	.0416	.0624	.0478	.0624	.0416
.0416	.0666	.0458	.1082	.0587	.0832	.0416	.0416	.0699	.0483
.0416	.0433	.0582	.0699	.0803	.0562	.0770	.0624	.0666	.0666
.0728	.0503	.0765	.0474	.1206	.0736	.0595	.0458	.0666	.1123
.1067	.0458	.0541	.0559	.0438	.0701	.0876	.1254	.0438	.0482
.0876	.0876	.0876	.0876	.0854	.0622	.0464	.0438	.0438	.0657
.0504	.0657	.0438	.0438	.0701	.0482	.1139	.0618	.0876	.0438

HIGHWAY LINE HAUL COSTS (CONT.)

.0438	.0736	.0508	.0438	.0456	.0613	.0736	.0845	.0591	.0810
.0557	.0701	.0701	.0766	.0530	.0806	.0499	.1270	.0775	.0626
.0482	.0701	.1183	.1123	.0482	.0569	.0467	.0366	.0586	.0732
.1047	.0766	.0403	.0732	.0732	.0732	.0732	.0714	.0520	.0388
.0366	.0366	.0549	.0421	.0549	.0366	.0366	.0586	.0403	.0952
.0516	.0732	.0366	.0366	.0615	.0425	.0366	.0381	.0512	.0615
.0706	.0494	.0677	.0549	.0586	.0586	.0640	.0443	.0673	.0417
.1061	.0648	.0523	.0403	.0586	.0988	.0939	.0403	.0476	.0664
.0520	.0832	.1040	.1488	.0520	.0572	.1040	.1040	.1040	.1040
.1014	.0738	.0551	.0520	.0520	.0780	.0598	.0780	.0520	.0520
.0832	.0572	.1352	.0733	.1040	.0570	.0520	.0874	.0603	.0520
.0541	.0728	.0874	.1004	.0762	.0962	.0780	.0832	.0832	.0910
.0629	.0957	.0593	.1508	.0920	.0744	.0572	.0832	.1404	.1334
.0572	.0676	.0584	.0458	.0733	.0916	.1311	.0458	.0504	.0916
.0916	.0916	.0916	.0893	.0650	.0485	.0458	.0458	.0687	.0527
.0687	.0458	.0458	.0733	.0504	.1191	.0646	.0916	.0458	.0458
.0769	.0531	.0458	.0476	.0641	.0769	.0884	.0618	.0847	.0687
.0733	.0733	.0801	.0554	.0843	.0522	.1328	.0911	.0655	.0504
.0733	.1237	.1175	.0504	.0595	.0623	.0488	.0781	.0976	.1397
.0488	.0537	.0976	.0976	.0976	.0976	.0952	.0693	.0517	.0488
.0488	.0732	.0561	.0732	.0488	.0488	.0781	.0537	.1269	.0688
.0976	.0488	.0488	.0820	.0566	.0488	.0508	.0683	.0820	.0942
.0659	.0903	.0732	.0781	.0781	.0854	.0590	.0898	.0556	.1415
.0864	.0698	.0537	.0781	.1318	.1252	.0537	.0634	.0544	.0426
.0682	.0852	.1219	.0426	.0469	.0852	.0852	.0852	.0852	.0831
.0605	.0452	.0426	.0426	.0639	.0490	.0639	.0426	.0426	.0682
.0469	.1108	.0601	.0852	.0424	.0426	.0716	.0494	.0426	.0443
.0596	.0716	.0822	.0575	.0788	.0639	.0682	.0682	.0745	.0515
.0784	.0486	.1235	.0754	.0609	.0469	.0682	.1150	.1093	.0469
.0554	.0561	.0440	.0704	.0880	.1259	.0440	.0484	.0880	.0880
.0880	.0860	.0858	.0625	.0466	.0440	.0440	.0660	.0506	.0660
.0440	.0440	.0704	.0484	.1144	.0620	.0880	.0440	.0440	.0739
.0510	.0440	.0458	.0616	.0739	.0849	.0594	.0814	.0660	.0704
.0704	.0770	.0532	.0810	.0502	.1276	.0779	.0629	.0484	.0704
.1188	.1129	.0484	.0572	.0582	.0456	.0730	.0912	.1305	.0456
.0502	.0912	.0912	.0912	.0912	.0889	.0648	.0483	.0456	.0456
.0684	.0524	.0684	.0456	.0456	.0730	.0502	.1186	.0643	.0912
.0456	.0456	.0766	.0529	.0456	.0474	.0638	.0766	.0880	.0616
.0844	.0684	.0730	.0730	.0798	.0552	.0839	.0520	.1322	.0807
.0652	.0502	.0730	.1231	.1170	.0502	.0593	.0541	.0424	.0678
.0848	.1213	.0424	.0466	.0848	.0848	.0848	.0848	.0827	.0602
.0449	.0424	.0424	.0636	.0488	.0636	.0424	.0424	.0678	.0466
.1102	.0598	.0548	.0424	.0424	.0712	.0492	.0424	.0441	.0594
.0712	.0818	.0572	.0784	.0636	.0678	.0678	.0742	.0513	.0780
.0483	.1230	.0750	.0606	.0466	.0678	.1145	.1088	.0466	.0551
.0675	.0529	.0846	.1058	.1514	.0529	.0582	.1058	.1058	.1058
.1058	.1032	.0751	.0561	.0529	.0529	.0793	.0608	.0793	.0529
.0529	.0846	.0582	.1375	.0746	.1058	.0529	.0529	.0889	.0614
.0529	.0550	.0741	.0889	.1021	.0714	.0979	.0793	.0846	.0846
.0926	.0640	.0973	.0603	.1534	.0936	.0756	.0582	.0846	.1428
.1357	.0582	.0688	.0635	.0498	.0797	.0996	.1425	.0498	.0548
.0996	.0996	.0996	.0996	.0971	.0707	.0528	.0498	.0498	.0747
.0573	.0747	.0498	.0498	.0797	.0548	.1295	.0702	.0996	.0498
.0498	.0837	.0528	.0498	.0518	.0697	.0837	.0961	.0672	.0921
.0747	.0797	.0797	.0871	.0603	.0916	.0568	.1444	.0881	.0712
.0548	.0797	.1345	.1277	.0548	.0647	.0656	.0514	.0822	.1028
.1471	.0514	.0565	.1028	.1028	.1028	.1028	.1002	.0730	.0545
.0514	.0514	.0771	.0591	.0771	.0514	.0514	.0822	.0565	.1336
.0725	.1028	.0514	.0514	.0864	.0596	.0514	.0535	.0720	.0864
.0992	.0694	.0951	.0771	.0822	.0822	.0899	.0622	.0946	.0586
.1491	.0910	.0735	.0565	.0822	.1388	.1318	.0565	.0668	

HIGHWAY LOADING & UNLOADING COSTS -- DOLLARS PER TON

5.9402	6.8200	10.9120	3.4100	19.5188	6.8200	7.5020	3.4100	3.4100	3.4100
3.4100	3.5805	5.5924	7.2092	6.8200	6.8200	10.2300	6.3085	5.1150	6.8200
6.8200	10.9120	7.5020	17.7380	5.4219	13.6400	6.8200	6.8200	4.5012	6.2744
6.8200	6.6836	5.4560	4.5012	3.6487	5.6265	3.9215	10.2300	10.9120	10.9120
4.2625	6.1039	3.9556	6.3426	19.7780	4.1943	6.3767	7.5020	10.9120	15.4140
17.4933	7.5020	8.6660	6.6593	7.6800	12.2880	3.8400	21.9801	7.6800	8.4480
3.8400	3.8400	3.8400	3.8400	4.0320	6.2976	8.1408	7.6800	7.6800	11.5200
7.1040	5.7600	7.6800	7.6800	12.2880	8.4480	19.9680	6.1056	15.3600	7.6800
7.6800	5.0688	7.0656	7.6800	7.5264	6.1440	5.0688	4.1088	6.3360	4.4160
11.5200	12.2880	12.2880	4.8000	6.8736	4.4544	7.1424	22.2720	4.7232	7.1808
8.4480	12.2880	20.7360	19.6992	8.4480	9.9840	8.1787	9.3900	15.0240	4.6950
26.8742	9.3900	10.3290	4.6950	4.6950	4.6950	4.6950	4.9297	7.6993	9.9534
9.3900	9.3900	14.0850	8.6857	7.0425	9.3900	9.3900	15.0240	10.3290	24.4140
7.4650	18.7800	9.3900	9.3900	6.1974	8.6388	9.3900	9.2022	7.5120	6.1974
5.0236	7.7467	5.3992	14.0850	15.0240	15.0240	5.8687	8.4040	5.4462	8.7327
27.2310	5.7748	8.7796	10.3290	15.0240	25.3530	24.0853	10.3290	12.2070	7.7867
8.9400	14.3040	4.4700	25.5863	8.9400	9.8340	4.4700	4.4700	4.4700	4.4700
4.6935	7.3308	9.4764	8.9400	8.9400	13.4100	8.2695	6.7050	8.9400	8.9400
14.3040	9.8340	23.2440	7.1073	17.8800	8.9400	8.9400	5.9004	8.2248	8.9400
8.7612	7.1520	5.9004	4.7829	7.3755	5.1405	13.4100	14.3040	14.3040	5.5875
8.0013	5.1352	8.3142	25.9260	5.4981	8.3589	9.8340	14.3040	24.1380	22.9311
9.8340	11.6220	9.1716	10.5300	16.8480	5.2650	30.1369	10.5300	11.5830	5.2650
5.2650	5.2650	5.2650	5.5282	8.6346	11.1618	10.5300	10.5300	15.7950	9.7402
7.8975	10.5300	10.5300	16.8480	11.5830	27.3780	8.3713	21.0600	10.5300	10.5300
6.9498	9.6876	10.5300	10.3194	8.4240	6.9498	5.6335	8.6872	6.0547	15.7950
16.8480	16.8480	6.5812	9.4263	6.1074	9.7929	30.5370	6.4759	9.8456	11.5830
16.8480	28.4310	27.0094	11.5830	13.6890	13.3873	15.3700	24.5920	7.6850	43.9889
15.3700	16.9070	7.6850	7.6850	7.6850	7.6850	8.0692	12.6034	16.2922	15.3700
15.3700	23.0550	14.2172	11.5275	15.3700	15.3700	24.5920	16.9070	39.9620	12.2191
30.7400	15.3700	15.3700	10.1442	14.1404	15.3700	13.0626	12.2960	10.1442	8.2229
12.6802	8.8377	23.0550	24.5920	24.5920	9.6062	13.7561	8.9146	14.2241	44.5730
9.4525	14.3710	16.9070	24.5920	41.4990	39.4240	16.9070	19.9810	9.6681	11.1000
17.7600	5.5500	31.7682	11.1000	12.2100	5.5500	5.5500	5.5500	5.5500	5.8275
9.1020	11.7660	11.1000	11.1000	16.6500	10.2675	8.3250	11.1000	11.1000	17.7600
12.2100	28.8600	8.8245	22.2000	11.1000	11.1000	7.3260	10.2120	11.1000	10.8780
8.8800	7.3260	5.9385	9.1575	6.3825	16.6500	17.7600	17.7600	6.9375	9.9345
6.4380	10.3230	32.1900	6.8265	10.3785	12.2100	17.7600	29.9700	28.4715	12.2100
14.4300	9.4678	10.8700	17.3920	5.4350	31.1099	10.8700	11.9570	5.4350	5.4350
5.4350	5.4350	5.7067	8.9134	11.5222	10.8700	10.8700	16.3050	10.0547	8.1525
10.8700	10.8700	17.3920	11.9570	28.2620	8.6416	21.7400	10.8700	10.8700	7.1742
10.0004	10.8700	10.6526	8.6960	7.1742	5.8154	8.9677	6.2502	16.3050	17.3920
17.3920	6.7937	9.7286	6.3046	10.1091	31.5230	6.6850	10.1635	11.9570	17.3920
29.3490	27.8815	11.9570	14.1310	8.4661	9.7200	15.5520	4.8600	27.8186	9.7200
10.6920	4.8600	4.8600	4.8600	4.8600	5.1030	7.9704	10.3032	9.7200	9.7200
14.5800	8.9910	7.2900	9.7200	9.7200	15.5520	10.6920	25.2720	7.7274	19.4400
9.7200	9.7200	6.4152	8.9424	9.7200	9.5256	7.7760	6.4152	5.2002	8.0190
5.5890	14.5800	15.5520	15.5520	6.0750	8.6994	5.6376	9.0396	28.1880	5.9779
9.0882	10.6920	15.5520	26.2440	24.9318	10.6920	12.6360	8.7361	10.0300	16.0480
5.0150	28.7059	10.0300	11.0330	5.0150	5.0150	5.0150	5.0150	5.2657	8.2246
10.6318	10.0300	10.0300	15.0450	9.2777	7.5225	10.0300	10.0300	16.0480	11.0330
26.0780	7.9738	20.0600	10.0300	10.0300	6.6198	9.2276	10.0300	9.8294	8.0240
6.6198	5.3660	8.2747	5.7672	15.0450	16.0480	16.0480	6.2687	8.9768	5.8174
9.3279	29.0870	6.1684	9.3780	11.0330	16.0480	27.0810	25.7269	11.0330	13.0390
13.9708	16.0400	25.6640	8.0200	45.9064	16.0400	17.6440	8.0200	8.0200	8.0200
8.0200	8.4210	13.1578	17.0024	16.0400	16.0400	24.0600	14.8370	12.0300	16.0400
16.0400	25.6640	17.6440	41.7040	12.7518	32.0800	16.0400	16.0400	10.5864	14.7568
16.0400	15.7192	12.8320	10.5864	8.5814	13.2330	9.2230	24.0600	25.6640	25.6640
10.0250	14.3558	9.3032	14.9172	46.5160	9.8646	14.9974	17.6440	25.6640	43.3080
41.1425	17.6440	20.8520	7.0638	8.1100	12.9760	4.0550	23.2108	8.1100	8.9210
4.0550	4.0550	4.0550	4.0550	4.2577	6.6502	8.5966	8.1100	8.1100	12.1650
7.5017	6.0825	8.1100	8.1100	12.9760	8.9210	21.0860	6.4474	16.2200	8.1100
8.1100	5.3526	7.4612	8.1100	7.9478	6.4880	5.3526	4.3388	6.6907	4.6632

HIGHWAY LOADING & UNLOADING COSTS (CONT.)

12.1600	12.9760	12.9760	5.0687	7.2584	4.7038	7.5423	23.5190	4.9876	7.5828
8.9210	12.9760	21.8970	20.8021	8.9210	10.5430	7.4383	8.5400	13.6640	4.2700
24.4415	8.5400	9.3940	4.2700	4.2700	4.2700	4.2700	4.4835	7.0028	9.0524
8.5400	8.5400	12.8100	7.8995	6.4050	8.5400	8.5400	13.6640	9.3940	22.2040
6.7893	17.0800	8.5400	8.5400	5.6364	7.8568	8.5400	8.3692	6.8320	5.6364
4.5689	7.0455	4.9105	12.8100	13.6640	13.6640	5.3375	7.6433	4.9532	7.9422
24.7660	5.2521	7.9849	9.3940	13.6640	23.0580	21.9051	9.3940	11.1020	6.8635
7.8800	12.6060	3.9400	22.5526	7.8800	8.6680	3.9400	3.9400	3.9400	3.9400
4.1370	6.4616	8.5528	7.8800	7.8800	11.8200	7.2890	5.9100	7.8800	7.8800
12.6080	8.6680	20.4860	6.2646	15.7600	7.8800	7.8800	5.2008	7.2496	7.8800
7.7224	6.3040	5.2008	4.2158	6.5010	4.5310	11.8200	12.6080	12.6080	4.9250
7.0526	4.5701	7.3284	22.8620	4.8462	7.3678	8.6680	12.6080	21.2760	20.2122
8.6680	10.2440	7.2580	8.3100	13.2960	4.1550	23.7832	8.3100	9.1410	4.1550
4.1550	4.1550	4.1550	4.3627	6.8142	8.8036	8.3100	8.3100	12.4650	7.6867
6.2325	8.3100	8.3100	13.2960	9.1410	21.6060	6.6064	16.6200	8.3100	8.3100
5.4846	7.6452	8.3100	8.1438	6.6480	5.4846	4.4458	6.8557	4.7782	12.4650
13.2960	13.2960	5.1937	7.4374	4.8198	7.7283	24.0990	5.1106	7.7698	9.1410
13.2960	22.4370	21.3150	9.1410	10.8030	7.9871	9.1700	14.6720	4.5850	26.2445
9.1700	10.0870	4.5850	4.5850	4.5850	4.5850	4.8142	7.5194	9.7202	9.1700
9.1700	13.7550	8.4822	6.8775	9.1700	9.1700	14.6720	10.0870	23.8420	7.2901
18.3400	9.1700	9.1700	6.0522	8.4364	9.1700	8.9866	7.3360	6.0522	4.9059
7.5652	5.2727	13.7550	14.6720	14.6720	5.7312	8.2071	5.3186	8.5281	26.5930
5.6395	8.5739	10.0870	14.6720	24.7590	23.5210	10.0870	11.9210	8.6752	9.9600
15.9360	4.9800	28.5055	9.9600	10.9560	4.9800	4.9800	4.9800	4.9800	5.2290
8.1672	10.5576	9.9600	9.9600	14.9400	9.2130	7.4700	9.9600	9.9600	15.9360
10.9560	25.8960	7.9182	19.9200	9.9600	9.9600	6.5736	9.1632	9.9600	9.7608
7.9680	6.5736	5.3286	8.2170	5.7270	14.9400	15.9360	15.9360	6.2250	8.9142
5.7768	9.2628	28.8840	6.1254	9.3126	10.9560	15.9360	26.8720	25.5474	10.9560
12.9480	8.4835	9.7400	15.5840	4.8700	27.8759	9.7400	10.7140	4.8700	4.8700
4.8700	4.8700	5.1135	7.9860	10.3244	9.7400	9.7400	14.6100	9.0075	7.3050
9.7400	9.7400	15.5840	10.7140	25.3240	7.7433	19.4800	9.7400	9.7400	6.4284
8.9608	9.7400	9.5452	7.7920	6.4284	5.2109	8.0355	5.6005	14.6100	15.5840
15.5840	6.0875	8.7173	5.6492	9.0582	28.2460	5.9901	9.1069	10.7140	15.5840
26.2900	24.9831	10.7140	12.6620	10.7830	12.3800	19.8080	6.1900	35.4315	12.3800
13.6190	6.1900	6.1900	6.1900	6.1900	6.4995	10.1516	13.1228	12.3800	12.3800
18.5700	11.4515	9.2850	12.3800	12.3800	19.8080	13.6180	32.1880	9.8421	24.7600
12.3800	12.3800	8.1708	11.3896	12.3800	12.1324	9.9040	8.1708	6.6233	10.2135
7.1185	18.5700	19.8080	19.8080	7.7375	11.0301	7.1804	11.5134	35.9020	7.6137
11.5753	13.6180	19.8080	33.4260	31.7547	13.6180	16.0940	10.5914	12.1600	19.4560
6.0800	34.8019	12.1600	13.3760	6.0800	6.0800	6.0800	6.0800	6.3840	9.9712
12.8896	12.1600	12.1600	18.2400	11.2480	9.1200	12.1600	12.1600	19.4560	13.3760
31.6160	9.6672	24.3200	12.1600	12.1600	8.0256	11.1872	12.1600	11.9168	9.7280
8.0256	6.5056	10.0320	6.9920	18.2400	19.4560	19.4560	7.6000	10.8832	7.0528
11.3088	35.2640	7.4784	11.5696	13.3760	19.4560	32.8320	31.1904	13.3760	15.8080
11.2794	12.9500	20.7200	6.4750	37.0629	12.9500	14.2450	6.4750	6.4750	6.4750
6.4750	6.7787	10.3190	13.7270	12.9500	12.9500	19.4250	11.9787	9.7125	12.9500
12.9500	20.7200	14.2450	33.6700	10.2952	25.9000	12.9500	12.9500	8.5470	11.9140
12.9500	12.6910	10.3600	8.5470	6.9282	10.6837	7.4462	19.4250	20.7200	20.7200
8.0937	11.5902	7.5110	12.0435	37.5550	7.9642	12.1082	14.2450	20.7200	34.9650
33.2167	14.2450	14.8350	8.6132	9.2000	14.7200	4.6000	26.3304	9.2000	10.1200
4.6000	4.6000	4.6000	4.6000	4.8300	7.5440	9.7520	9.2000	9.2000	13.8000
8.5100	6.9000	9.2000	9.2000	14.7200	10.1200	23.9200	7.3140	18.4000	9.2000
9.2000	6.0720	8.4640	9.2000	9.0160	7.3600	6.0720	4.9220	7.5900	5.2900
13.8000	14.7200	14.7200	5.7500	8.2340	5.3360	8.5560	26.6800	5.6580	8.6020
10.1200	14.7200	23.8400	23.5980	10.1200	11.9600	8.9539	10.2800	16.4480	5.1400
29.4214	10.2800	11.3080	5.1400	5.1400	5.1400	5.1400	5.3970	8.4296	10.8968
10.2800	10.2800	15.4200	9.5690	7.7100	10.2800	10.2800	16.4480	11.3080	26.7280
8.1726	20.5600	10.2800	10.2800	6.7848	9.4576	10.2800	10.0744	8.2240	6.7848
5.4990	8.4810	5.9110	15.4200	16.4480	16.4490	6.4250	9.2006	5.9624	9.5604
29.8120	6.3222	9.6118	11.3080	16.4480	27.7560	26.3692	11.3080	13.3640	

APPENDIX F

EVALUATION CRITERIA SCREENING

CRITERION	MAXIMIZE	MINIMIZE	QUALITATIVE	QUANTITATIVE	UNITS	RANK IMPORTANCE WITH REGARD TO THE STAGE OF INVESTIG. 1-highest 5-lowest: 1	2	3	4	5	DATA READILY AVAILABLE	DATA READILY MEASURABLE	ESTIMABLE OR FORECASTING MODELS AVAILABLE	ANALYSIS: NATIONAL	REGIONAL	CORRIDOR	LOCAL
I. SOCIAL																	
A. Land Use Changes				o	Acres			o			NO		Limited				o
B. Community Forms				o	Pop.Dens					o	NO	NO	Limited				o
C. Quality of Life	o		o		Subject.			o			NO	NO	NO	o	o	o	o
D. Political Feasibility	o		o				o				NO	NO	NO	o	o	o	o
E. Population Shift																	
1. Internal (Redistribution)		o		o	People			o			NO	YES	Limited				o
2. External (Inward Migration)	o			o	People			o			NO	YES	Limited				o
H																	
I. Service to Urban Renewal	o		o		Subject.					o	NO	NO	NO				o
J. Degree Community Goals are Served	o		o		Subject.					o	NO	NO	NO				o
K. Degree Corridor Goals are Served								o			NO	NO	NO				
L. Acres of Park Land Taken		o		o	Acres					o	YES	YES	YES			o	
M. Acres of Cemeteries or Number Graves Rem.		o		o	Acres					o						o	
N. Acres of Business or Industrial Land Taken		o		o	Acres					o						o	
O. Number of Families Displaced		o		o	Families					o						o	
P. Number of Churches Moved		o		o	Churches					o						o	
Q. Number of Schools Moved		o		o	Schools					o						o	
R. Number of Public Buildings Taken		o		o	Building					o						o	
S. Number of Jobs Eliminated or Relocated		o		o	Jobs					o						o	
T. Creation of Open Space	o			o	Acres					o	YES	YES	NO				
U. Services to Adjacent Land	o		o		Subject.				o		NO	NO	NO		o	o	o
V. Enhance the Provision for Nat Defense	o		o		Subject.			o			NO	NO	NO	o			
II. ECONOMICAL																	
A. Direct Revenues From																	
1. Taxes				o			o				NO	YES	Limited		o		
2. Tolls				o				o							o		
3. Fares				o			o								o		
4. Shipping Fees				o	$		o								o		
B. Market Share Changes				o	$	o						NO				o	
C. Tax Base Changes				o	$	o						YES			o		
D. Changing Pattern Producer-Consumer Relations			o			o						NO					o
E. Overall Industrial Development	o			o		o						YES			o	o	
F. Personal Income Changes				o	$		o									o	
G. Influence on Property Values (Residential)				o	$			o								o	
H. Infuence on Property Values (Industrial)				o	$			o								o	
I. Employment Change due to NewLand Use Devel.	o			o	Jobs	o										o	

CRITERION	MAXIMIZE	MINIMIZE	QUALITATIVE	QUANTITATIVE	UNITS	WITH REGARD TO THE STAGE OF INVESTIGATION 1-Highest 5-Lowest					DATA READILY AVAILABLE	DATA READILY MEASURABLE	ESTIMABLE OR FORECASTING MODELS AVAILABLE	ANALYSIS			
						1	2	3	4	5				NATIONAL	REGIONAL	CORRIDOR	LOCAL
II. ECONOMICAL (cont.)																	
J. Employement Change due to Dislocation & Rel.		o		o	Jobs						NO	NO	NO			o	
K. Value of Commodities Flow	o			o	$						NO	YES	Limited			o	
L. Effects on Construction Industry	o			o	Jobs						YES	YES	YES			o	o
M. Availability of Aternative Mode Transport.	o		o												o		
N																	
O. Commercial Sales Receipts & Income	o			o	$						NO		NO			o	
1. Change Due to Dislocation		o		o	$											o	
2. Change Due to Barrier		o		o	$												o
3. Change Due to Population Change	o			o	$											o	
4. Change Due to Income Change	o			o	$										o	o	
5. Change Due to Bypass Effect		o		o	$											o	
6. Change Due to Accessibility	o			o	$										o	o	
7. Change Due to price change (Resul.Trans.	o			o	$										o		
III. PHYSICAL																	
A. Level of Service Provided	o			o	Subj.		o				YES	YES	YES			o	
1. Peak Hour Capacity	o			o	Tph/Vph		o									o	
2. Off Hour Volume				o	Tph/Vph			o								o	
3. Vehicle Size	o			o	ft/Tons		o									o	
4. Vehicle Speed	o			o	mph		o									o	
5. Travel Time -Distance		o		o	hrs/mi		o									o	
6. Shipped Time		o		o	Hrs.	o										o	
A. Line Haul		o		o	Hrs.	o										o	
B. Terminal		o		o	Hrs.	o											o
7. Average Daily Volume				o	Tons	o											
8. Congestion		o		o	V/C		o									o	
B. Resource Utilization	o			o	Tons		o				NO	NO	Limited		o		
C. Energy Consumption		o		o		o					YES	YES			o		
1. Travel Modes		o		o	Btu/TM	o					YES		YES			o	
2. Terminals		o		o	Btu/Ton	o					NO		NO				o
3. Industry along the Corridor		o		o	Btu/Ton	o					YES		Limited			o	
D. Operations																	
1. Continuity	o		o					o			NO	NO	Limited			o	
2. Flexibility	0		o					o								o	
A. Mode Interchanges	o		o													o	
B. Shipment Sizes	o			o			o								o		
C. Commodity Type	o			o	SIC		o								o		
D. Time Scheduling				o			o									o	o

CRITERION	MAXIMIZE	MINIMIZE	QUALITATIVE	QUANTITATIVE	UNITS	TO THE STAGE OF INVESTIGATION (1-highest 5-lowest) 1	2	3	4	5	DATA READILY AVAILABLE	DATA READILY MEASURABLE	ESTIMABLE OR FORECASTING MODELS AVAILABLE	ANALYSIS NATIONAL	REGIONAL	CORRIDOR	LOCAL
C. Operations (cont.)																	
3. System Flexibility -Short Term	o		o				o									o	
4. System Adaptibility-Long Term	o		o				o									o	
5. Requirement for Auxiliary System		o						o			NO	NO	NO			o	
6. Reliability Inclement Weather Operations	o						o									o	
7. Reliability Schedule Dependability	o						o										o
8. Safety: Freedom from Damage/Theft	o			o	$ Lost		o									o	
9. Safety to Non-Users	o				Accident			o								o	
10. Freedom from Repairs	o							o								o	
11. Operator Requirements		o						o								o	
D. Right of Way Needs							o				YES	YES	YES				
1. Continuous R-O-W Characteristics			o		Ft^2		o									o	
2. Natural Path Capability of R-O-W			o				o								o		
3. Required R-O-W width				o	Ft	o										o	
4. Required Overhead Clearences				o	Ft		o									o	
5. Allowable Curvature, Grades				o	Degrees%		o										o
6. Mileage		o		o	Miles	o										o	
E. Terminal Requirements																	
1. Convenience Loading & Unloading	o			o				o			NO	NO	Limited				o
2. Accessibility	o			o			o									o	
a. Requirement for Distribution System		o		o			o										o
b. Requirement for Collection System		o		o			o										o
3. Model Interchange	o			o			o										
4. Required Vehicle Storage				o	Spaces		o				NO	YES	YES				o
5. Repair Freight Storage				o	Ft^3/Tons		o										o
6. Terminal Spacing Requirements		o		o	Miles		o									o	
7. Terminal Size Requirement		o		o	Ft^3			o									o
8. Connectivity: Ease of Transfers	o			o			o					NO	NO				o
IV. FISAL																	
A. Construction Costs		o		o	$	o					YES	YES	YES			o	
B. Maintenance Costs		o		o	$	o										o	
1. Line Haul		o		o	$	o										o	
2. Terminal		o		o	$		o									o	
C. Administrative Costs		o		o	$		o									o	
D. Operation Costs		o		o	$	o										o	
1. Line Haul		o		o	$	o										o	
2. Terminal		o		o	$		o				NO	NO	NO			o	

CRITERION	MAXIMIZE	MINIMIZE	QUALITATIVE	QUANTITATIVE	UNITS	RANK IMPORTANCE WITH REGARD TO THE STAGE OF INVESTIGATION 1-highest 5-lowest: 1	2	3	4	5	DATA READILY AVAILABLE	DATA READILY MEASURABLE	ESTIMABLE OR FORECASTING MODELS AVAILABLE	LEVEL OF ANALYSIS: NATIONAL	REGIONAL	CORRIDOR	LOCAL
D. (cont.)																	
a) Inter-Modal		o		o	$		o				NO	NO	NO			o	
b) Intra-Modal		o		o	$	o					YES	YES	YES			o	
E. User's Costs (Out-of-Pocket)																	
1. Line Haul Costs		o		o	$	o					YES	YES	YES			o	
2. Terminal Transfer Costs		o		o	$						YES	YES	YES			o	
3. Terminal Storage Costs		o		o	$			o			NO	YES	YES				o
4. Terminal Parking Costs		o		o	$			o			NO	YES	YES				o
F. Accident Costs		o		o	$		o				YES	YES	YES			o	
G. Cost/Effectiveness Ratio					$	o					NO	NO	Limited				
V. AESTHETIC																	
1. Right-of-Way Aesthetics	o		o							o	NO	NO	NO			o	
2. Terminal Aesthetics	o		o							o							o
3. Preservation of Value System	o		o						o								
4. Noise-Air Pollution to System		o		o	dBA,mg/l							YES	Limited			o	
a) Line Haul		o		o	dBA,mg/l		o									o	
b) Terminal		o		o	Dba,mg/l		o										o
5. Noise-Air-Pollution due to Industry that Dev. along Corridor		o		o	dBA,mg/l		o									o	
6. Beauty of Structures	o		o							o		NO	NO			o	o
7. Vibration		o						o				YES	YES			o	o
8. Drainage Patterns Water Pollution	o			o			o					YES	YES			o	o
9. Lighting				o						o		YES	YES				o
10. Advertising (R-O-W)				o						o		NO	NO			o	

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