Computer Assisted Cost Assessment of Intermodal Transportation Linkages, Phase II*

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I. Background

The most fundamental characteristic of economic society is trade. Transportation is inseparable from trade. Transportation, more than anything else, determines the "extent of the market." Economic progress would be virtually impossible without the ability to carry goods from place to place efficiently and cheaply. Distance has ceased to be an obstacle to trade or travel. Needless to say, the improvement in transportation, which has made possible the modern system of commerce, has brought about a vast improvement in the standard of living of all people. These improvements have provided a volume and a diversity of goods for individual consumption which were quite unattainable in former years, when the expense and the difficulty of transportation were such that nearly all trade was purely local in nature.

For the past few decades, very few studies have been done to compare the cost of the various transportation modes. Historically, comparisons have been based on the cost to transport a given unit of weight or volume per unit of distance traveled. Earlier studies have been done primarily to determine rates in the transportation industry. Virtually none of them address the societal costs of providing transportation services. Several government entities contribute to the nation's transportation infrastructure making it difficult to comparatively assess the true cost of different transportation modes.

The rail industry, for example, incurs costs to purchase right of ways, install and maintain track, and to construct bridges, tunnels, crossing signals, etc.. Railroad operators have most of the financial responsibility for maintaining the railroads' facilities, but the rates of rail transportation have long been regulated by the federal government. In contrast, trucking companies transport goods via the nation's highway system. The trucking companies are not responsible for the construction of their transportation network, but instead they pay an annual tax for each truck that uses the nation's interstate and local highway systems.

Waterway transportation has long been regarded as an economical way to transport bulk goods. It consists of the huge system of locks and dams of this nation's navigable inland waterways. The Army Corps of Engineers, a federal government agency, has financial responsibility for the waterways. A similar situation exists with air freight transportation. Air freight companies do not pay for the construction of the air fields and airports. These facilities are funded by the federal and state governments.

The expenditures by state and local governments include federal grant-in-aid funds while the federal expenditures are generally direct outlays. Table 1 presents the ratio of transportation expenditures that are “covered” or paid for directly by users and transportation-related collections.

Fiscal Year	Expenditures	User Revenues	Coverage Ratio
1981	60,350	34,018	56.37 %
1982	60,396	36,171	59.89 %
1983	63,098	40,020	63.43 %
1984	68,886	46,914	68.10 %
1985	74,539	52,038	69.81 %
1986	81,253	54,798	67.44 %
1987	85,345	58,399	68.43 %
1988	89,948	62,822	69.84 %
1989	94,006	67,579	71.89 %
1990	100,073	69,901	69.85 %
1991	107,953	77,410	71.71 %

Table 1: Federal, State and Local Government Transportation Finances (millions of dollars) [61]

II. Objectives

The investigators have developed a cost model to determine the societal cost associated with different transportation modes. The different transportation modes used in this analysis include rail, truck, barge and air transportation. The cost model considers the costs incurred by all activities associated with each transportation mode. These costs are amortized to result in a true (societal) weight/volume per unit distance cost for each transportation mode. These costs are generally not reflected in the transportation rates associated with each mode, even though they are a real and tangible burden to taxpayers. The obtained costs for each transportation mode from the developed cost model yield comparatively true values of weight/volume per unit distance costs. These obtained costs are representative of the societal costs of providing transportation services.

The developed model has been implemented in PC/Windows based software. The developed cost model has served as the basic structure for the software development effort completed in the second phase of this project. This software enables the user to determine the most effective transportation mode between a given origin and destination.

III. Regional Definition

The region selected for this analysis is primarily a rural area. The selected region includes five states, which are Alabama, Arkansas, Mississippi, Louisiana, and Tennessee. Four of these states were selected because they are contiguous with Arkansas. Alabama was added to the analysis region because of its ocean coastline associated with water transportation.

A. Truck Transportation Network

In order to keep the roadway transportation network of manageable size, only interstate highways within the region have been considered. This selection was also motivated by the availability of cost data for interstate highways as opposed to state and secondary roadways. The interstate highways in the selected region include I-40, I-20, I-55, I-59, I-10, and I-65.

B. Waterway Network

Most of the U.S. waterway networks are concentrated both on the Great Lakes and the Mississippi River Basin. The region selected for analysis has an extensive network of rivers and canals. The river systems included in this analysis are the Lower Mississippi River, the McClellan-Kerr Arkansas River, the Black Warrior-Tombigbee Rivers, the Tennessee River, and the Alabama-Coosa Rivers.

C. Railway Network

This selected analysis region is served by numerous railroad operators. These operators are nationwide providers of railroad freight services. These operators include Burlington Northern Railroad, CSX Rail Transport, Kansas City Southern Line, Norfolk Southern Corp., and Union Pacific Railroad. Only the current ICC Class I railroad companies are included in this analysis. This is an Interstate Commerce Commission (ICC) classification which includes railroads with average annual operating revenues of $50M or more.

D. Air Transportation Network

In Arkansas alone, there are over 100 airports and airfields of many kinds. To keep the size of the network to a manageable size, only airports that are classified as primary and commercial under the National Plan of Integrated Airport Systems are included. This reduces the number of airports in the entire region of analysis to about 40.

IV. Accomplishments

This project has been carried out in two phases as it has been proposed to the MBTC. Phase I was completed over an eighteen month period. Phase I consisted of the development of a societal transportation cost model, and implementation of the model in PC/Windows based software. We have focused on the development of a cost methodology to assess the various components of the societal costs associated with each transportation mode being analyzed. The methodology is common to all transportation modes. It permits each transportation mode to be accurately compared without the biases of federal/state contributions or intangible costs. We have also developed software to determine the true weight/volume per unit distance costs associated with different transportation modes.

The second project phase (Phase II) was completed over a a second period which began in August 1994. Phase II has focused on the application and use of the cost methodology and software developed in Phase I. In this phase, the software has been enhanced to provide the user with a method of selecting the least cost transportation mode for shipping from a selected origin to a desired destination within the analysis region. Our accomplishments since beginning of this project are summarized in the following sections.

A. Literature Search

An extensive literature search has been conducted to obtain any data and information that could be beneficial to this research. There are over sixty viable sources cited in the bibliography. We have noted that very little prior research has been conducted in recent years to address transportation cost allocation.

B. Cost Model Development

A general cost model has been developed to assess the true cost of transportation. Due to the different cost categories associated with different transportation modes, each model was tailored to fit each transportation mode. Each individual model was derived from a general cost model. Data collection proved to be the most difficult task in this research in terms of data availability. Data from the federal, state, and ICC regulated trucking companies were collected for the analysis of truck transportation. Data from ICC regulated railroad companies were collected for the analysis of railroad transportation. Data from the federal and state government, and data from the airlines compiled by Department of Transportation's Office of Aviation were collected for analyzing air transportation. Data needed for waterway transportation analysis were gathered through the Institute of Water Resources. For the purposes of consistency of analysis, cost data for fiscal years 1989, 1990, and 1991 were collected and used in our analysis, with the exception of waterway transportation.

C. Software Development

The software has been written and developed in Windows environment. It also provides a user-friendly interface to run and interact with the cost model. The software can evaluate single or multi-modal routes as well as evaluate alternate routings between an origin and destination. A sample session of the software will be provided in the final project report. A detailed description of the software is provided in Section VIII.

V. Literature Review

The goal in conducting the literature search has been to obtain data and information that could be used in assessing different transportation modes. To date, a bibliography in excess of sixty viable sources has been compiled. Perhaps the most striking results of this exercise is the almost complete absence of any consistent cost data for the different transportation modes. We have attempted to assess the federal and state contributions to the transportation infrastructure of each mode analyzed, and the operating costs incurred by each transportation carriers for each mode.

Cost related transportation studies have been devoted to rate setting by the transportation service providers, and determination of tax structures by state and federal government. Purchasers of transportation services usually consider the cost incurred to them rather than the cost incurred by the society in general.

A. Highway Transportation

Literature on this transportation mode is summarized in the subsections that follow.

1. Truck Usage and Truck-Miles of Travel

Approximately 44.6M private and commercial trucks were registered in the United States in 1987. Two-thirds of all trucks were used mainly for personal transportation. Alabama had about 894,000 trucks in use. The average miles per truck was 12,400, and the truck miles traveled was 11B in Alabama in 1987. There were about 521,000 trucks in Arkansas in the same year. The average miles per truck was 11,200, and the truck miles traveled totaled 5.8B. Louisiana had more than 926,000 trucks in service, and the average miles per truck traveled was 12,200. The truck miles driven in Louisiana was about 11.4B. Mississippi had the lowest number of trucks among the five states with slightly over 500,000. The average miles per truck is 11,900 and the truck miles driven totaled almost 6B. Tennessee had the largest number of trucks in these five states, 1.02M. It also had the highest number of average miles per truck, 12,500. The truck miles driven in Tennessee is 12.7B [51].

The average vehicle-miles of travel by all trucks on interstate rural highways was 69.4B, and 75.2B vehicle-miles on interstate urban in 1992 [51]. The total number of vehicle-miles by all trucks on all roads was 629B. Vehicle-miles is defined by Federal Highway Administration (FHWA) as the product of total mileage traveled by all trucks.

2. Highway Cost Allocation Studies

Highway cost allocation requires addressing the problem of how to raise revenues from selected groups of taxpayers so as to meet a given budget in a fair and equitable manner [33]. Efficiency and equity are the two fundamental standards against which to evaluate user charge instruments and rates [31]. Lee [28] noted that efficiency is not mentioned in the congressional mandate for the federal highway cost-allocation study now underway. The notion that vehicles should pay for the costs they generate is described as equitable, but it is also essential that they do so because it encourages them to reduce these costs and make sure that the benefits they derive are greater than the costs created. Efficiency can be divided into short term efficiency and long term efficiency. Short term efficiency deals with finding ways to maximize the utilization of the transportation facilities, while long term efficiency deals with finding the best program of investment in fixed facilities [28]. The concern addressed by equity is the distribution of costs and benefits among groups within society. Horizontal equity is not directly related to popular ideas of fairness; it urges that equals be treated equally. Vehicles in equal circumstances, from the standpoint of the highway provider, should therefore be charged equally.

The allocation of highway costs among the various classes of highway users is an area that has received an increasing amount of attention with the completion of the new Federal Highway Cost Allocation Study and several state studies [51]. Cost allocation distribution is a fair way to allocate costs among users. The amount of cost generated by a vehicle class can be determined by desegregating items of expenditure and assigning them to vehicle classes [28]. An algorithm known as the incremental cost method has been popular in recent studies, but there is very little professional consensus on which are the best methods for the practical determination of highway-user cost responsibilities. The incremental cost method takes as its starting point a basic highway, usually one designed for automobiles alone. Additional classes of vehicles cause additional increments of cost, and these increments are apportioned among the members of each class.

In addition to capital and maintenance expenditures, the following costs should be included [28].

Hidden costs: Some costs appear in public budgets but not in the budget of the agency responsible for highway expenditures. Vehicle code enforcement and traffic control may be hidden in police budgets, and payroll administration may be centralized rather than included in the transportation agency budget.

Negative: Negative externalities in the form of air pollution, noise, water pollution, and other unpriced effects on the physical, natural, and human environment constitute real costs to society. Even though we may never be able to place accurate dollar values on these costs, present policies can be improved on by a recognition of such costs.

Interference: Private costs in the form of delay time, vehicle wear, fuel, and accident costs are relevant to the correct pricing of highway services.

Tax expen-: ditures Exemption of fuel from general sales taxes and exemption of highway property from local property taxes result in a favorable treatment of highways in comparison with other activities that are not exempt. To the extent that these taxes pay for general government services, highway users are being subsidized by those engaged in other activities.

Interest: foregone The pay-as-you-go philosophy, in which each year's expenditures are matched with the same year's revenues, hides the fact that invested capital has an opportunity cost represented by the rate of return that the money would earn in another activity.

Theory tells us that the price charged for use of the highways should be equal to the marginal use cost. If less is charged, the user may not value the use as much as society values the resources consumed. If more is charged, some potential users are deterred, even though they would gain more from the travel than it costs society. However, this principle only applies to charges, such as a fuel tax or a weight-distance tax, that vary directly with usage. The design of practical mechanisms for imposing correct prices on highway users presents a major challenge.

Selection of a single budget for cost recovery from the many government agencies that participate in financing the highway system is highly arbitrary. The highway infrastructure lacks a single authority that can establish a complete user-charge structure. Without this institution, the only possible surrogate is a federal government initiative [3].

In allocating highway costs among vehicles, the two primary considerations are vehicle mileage and vehicle weight. Costs that are considered to be common to all vehicles are allocated to vehicles according to mileage [3]. Vehicle weight must also be taken into account when allocating cost responsibilities because the highway damage occasioned by a vehicle increases geometrically with the weight it carries on each axle. This means that highway costs are affected by the number of axles on a vehicle, the configuration of the vehicle's axle, and the distribution of its weight on the axle [3]. Data from the Federal Highway Cost Allocation Study [51] shows that the average passenger vehicle had a cost responsibility of $3.27 per thousand miles traveled, while a combination truck weighing over 75,000 pounds has a cost responsibility of $47.14 per thousand miles traveled [3].

A Highway Cost Allocation Study was conducted in 1981 by the Colorado State Highway Commission [51]. Two vehicle classes were utilized in the study, the two classes were defined as "basic vehicles" (weighing 10,000 lb. or less) and "heavy vehicles" (weighing over 10,000 lb.). In this analysis, cost responsibility is considered to represent the relative share of the Highway Users Tax Fund (HUTF) each of the vehicle classes should pay. The overall results show that heavy vehicles contribute 23% of the HUTF while being responsible for 37% of the HUTF expenditures.

In 1980, the Oregon Department of Transportation conducted a cost responsibility study on two groups of highway users, the basic vehicles and the heavy vehicles. The results indicated that basic vehicles (weighing 8,000 lb. or less) should contribute approximately 55% of the road user revenue, and heavy vehicles (weighing over 8,000 lb.) should contribute 45% [51].

Sinha and Fwa [43] indicated that in a cost allocation study of highway expenditures, allocation of highway pavement costs is the area that is most amenable to technical analysis. Consequently, a certain degree of subjective judgment is usually involved in allocating pavement costs to vehicle class. Over the years, several cost allocation studies have been performed for pavement cost responsibilities, and these studies can be categorized into three different approaches. These include the traditional incremental approach, the direct allocation approach , and the damage function approach. A unified approach for allocating pavement costs by Sinha was used in the 1983-1984 Indiana Cost Allocation study [43]. The latest Federal Cost Allocation Study [61] used a uniform removal technique in its analysis.

3. Cost Functions

A translog cost function presented by Harmatuck [18] was used to approximate the actual cost function of motor carrier related to service quality and marketing improvements. The basic cost model relates carrier operating cost less depreciation (C) to output levels and quality characteristics (Y), and input prices (P). This translog cost function has the following specification:

$$C_{it} + \alpha_0 + \Sigma_j \alpha_j Y_{ijt} + \Sigma_j \beta_j P_{ijt} + (1/2) \Sigma_j \Sigma_k \alpha_{jk} Y_{ijt} Y_{ikt} + (1/2) \Sigma_j \Sigma_k \beta_{jk} P_{ijt} P_{ikt} + \Sigma_j \Sigma_k \delta_{jk} Y_{ijt} P_{ikt} + \Sigma_j \mu_j D_{ijt} + \varepsilon_{it} \quad (1)$$

where,

C_{it} = natural log of operating expenses less depreciation of carrier I in period t

Y_{i1t} = natural log of TL shipments of carrier i in period t

Y_{i2t} = natural log of LTL shipments of carrier i in period t

Y_{i3t} = natural log of TL average shipment size (ton per shipment) of carrier i in period t

Y_{i4t} = natural log of LTL average shipment size (ton per shipment) of carrier i in period t

Y_{i5t} = natural log of average length of haul carrier i in period t

P_{i1t} = natural log of line haul activity price of carrier i in period t

P_{i2t} = natural log of pickup and delivery activity price of carrier i in period t

P_{i3t} = natural log of other prices of carrier i in period t

and α_j, β_j, β_{jk}, δ_{jk}, and μ_j are parameters. The cost function is specified in terms of activity prices rather than natural factor prices. This model was used to compare the service quality and price difference among motor carriers.

4. Current User Charge Structure

Annual user charge payments for automobiles have been decreasing. In contrast, these payments for trucks are increasing. This is primarily because the user charge structure relies heavily on fuel taxes, and auto fuel efficiencies are improving at a faster rate than truck fuel efficiencies. In addition, the truck sales taxes are ad-valorem taxes, and the receipts rise with inflation [61].

While the tax payments of all trucks as a class were found to be commensurate with the costs occasioned by trucks, lighter trucks were found to be overpaying by anywhere from 25 to 200% [3]. It is found that the heavier single unit trucks are found to significantly overpay relative to other vehicles. Combination trucks are found to underpay relative to other vehicles. Heavier combination trucks significantly underpay while the lighter combination trucks overpay.

The excise tax on new trucks is a flat 10 percent of the rate on all trucks greater than 10,000 pounds gross vehicle weight (GVW). The truck parts and accessories tax on all trucks is a flat 8 percent of the price. The highway use tax is a flat $3 per thousand pounds of GVW for all trucks over 26,000 pounds. The truck user charges are not graduated by weight, whereas cost assignments increase with weight due to the nature of the costs occasioned by increasing the size and weight of vehicles.

The federal government and the state governments collected almost $50B in a variety of transportation user taxes and fees in 1991 [47]. A significant portion of the user taxes are used for federal budget deficit reduction. In 1991, federal tax on the large truck use tax was $575M [47]. Taxes collected on trucks/buses/trailers amounted to $1.05 B[47].

B. Waterway Transportation

Literature on this transportation mode is summarized in the subsections that follow.

1. Inland Waterway System

Today some 170 major commercial ports on the nation's coastlines, river, lakes and canals serve as centers of commerce and growth. Every major metropolitan region either is a port or is closely linked by rail or highway with a port. Arkansas' major export is agricultural products. These products are transported by trucks or rail to the Mississippi , Arkansas, or White Rivers and are then barged to major export markets, such as the Port of New Orleans, for shipment overseas. The U.S. Inland Waterways have a total length of 25,543 miles [4].

The Mississippi River System alone has over 8,954 miles of navigable waterway. This mileage includes waterways improved by the Federal government, other agencies, and those that have not been improved but are usable for commercial navigation [4]. The Mississippi River System represents nearly 40% of the inland waterborne commerce in the United States [4]. The Mississippi River originates in northern Minnesota and flows in a southerly direction to the Gulf of Mexico. Total mileage on the river is 2,360 miles, and only 1,837 miles of it is navigable [66]. The annual cost of operation and maintenance of this system is $22M. The navigation season from Minneapolis to the mouth of the Missouri River is from the end of March to the first week of December. The navigation season is year round from the mouth of Missouri River to the head of Passes in Louisiana.

The McClellan-Kerr Arkansas River navigation system has a total navigation mileage of 448 miles [66]. It runs from the White River and the Arkansas River to the Verdigris River and to Catoosa, Oklahoma. The annual operation and maintenance cost is $5.3M. The navigation season is twelve months.

The Black Warrior-Tombigbee waterway lies wholly within the state of Alabama and is made up of the Black Warrior, Warrior, and Tombigbee Rivers. The total mileage on the waterway is 466 miles, with annual operation and maintenance costs of $2.5M [66]. The navigation season is 12 months per year.

The Tennessee River is formed at Knoxville by the junction of the Holston and French Rivers. It flows south and southwest into the Ohio river. It has a navigational mileage of 652 miles, and the annual cost for operation and maintenance cost is $1.8M [66]. The navigation season is 12 months.

The main streams of the Alabama-Coosa Rivers are Coosa, Tallapoosa, and the Alabama Rivers. The total mileage on the waterway is 305 miles [66]. The yearly operation and maintenance cost is $720,000, with a navigation season of 12 months.

2. Expenditures for Commercial Navigation

The total annual construction cost of waterways on the Mississippi River System is $223M. The Mississippi River and its tributaries are allocated $21.6M, advanced engineering and design are allocated $2.7M, channel improvements are allocated $ 27.5M, locks and dams are allocated $129.6M, and $41.5M is a multipurpose allocation. The total annual operation and maintenance cost on the system is $155.9M. Cost of operation and maintenance on the Mississippi River and tributaries is $10M, $45.2M goes to channel improvements, $87.7M to locks and dams, and $13M for multipurpose applications. This makes the total annual construction and operation / maintenance cost to $378.8M [68].

Annual operation and maintenance cost per ton-mile on Arkansas-Verdigris Waterway is $24.3M. The operation and maintenance cost is $1.04M on the Cumberland River, $0.27M on Gulf Intracoastal Waterway, $0.13M on Lower Mississippi River, $0.55M on Mobile-Tombigbee-Warrior Waterway, $16.2M on Ouachita-Black Rivers, and $0.58M on Tennessee River [66]. The levy per ton to recover 100% operation and maintenance cost on the Mississippi River is $0.1212 [34].

3. U.S. Ports

Traditionally, the U.S. port system has been developed on the basis of a partnership between local and state port authorities and the federal government. Landside cargo handling facilities and associated infrastructure including prescribed components of federal navigation projects, are provided by local, state and private interests. Navigational capabilities have been the responsibility of the federal government.

For their part, the local, state and private interests have responded to the dynamics of change. In its 1984 report on the status of U.S. public ports, the U.S. Maritime Administration states that local, state and private entities invested some $5B in terminal facilities in the period 1946-1980 and are likely to invest $5B more in this decade. All of this money has been and is being invested in a good-faith reliance upon the federal government to fulfill its traditional responsibility in providing appropriate development and adequate maintenance of the nation's deepcraft navigation system [50].

Federal expenditures for harbors and port development have been historically financed from general revenues. No user taxes or fees have been imposed for these specific expenditures. In June 1985, Reagan Administration announced an agreement with the Senate Republican leadership of a proposal for a 0.04 percent (4 mils, or 4 cents per $100) ad valorem excise tax on cargo loaded and unloaded at U.S. harbors to recover up to 40 percent of Corps of Engineers harbor operations and maintenance expenditures. Monies raised by this new tax would be deposited in a newly established trust fund for such expenditures. This tax would be in addition to certain cost sharing requirements for non-federal contributions to project costs [50].

In general, federal expenditures for construction, operation, and maintenance costs of U.S. waterways have been financed from general revenues, rather than from fees or taxes imposed on navigation users. In the Inland Waterways Revenue Act of 1978, however, Congress imposed an inland waterways fuel excise tax, and provided for transfer of these tax revenues to an Inland Waterways Trust Fund [50]. Amounts in the Trust Fund are available, as provided by Authorization and Appropriation Acts, for making construction and rehabilitation expenditures for navigation on the specified waterways the commercial use of which is subject to the fuel excise tax [50].

4. Costs Incurred by Travel on Waterways

Four types of costs are incurred during or prior to actual travel on the waterways: (1) public capital and operating-and-maintenance (O&M) costs of constructing and operating the waterway; (2) opportunity costs in terms of foregone alternative outputs of the multiple purpose waterway system (e.g. use of the water for power or irrigation); (3) private "straight-through" operating costs, which would be incurred by tows if no congestion were present (if barges could proceed without delay in carrying out their itineraries, that is all channels and locks were made ready to receive a tow upon arrival); (4) congestion costs [22].

5. Freight Traffic in Waterways

The following data was extracted according to each district from material published by the U.S. Army Corps. of Engineers Districts [52]. The data is summarized in the subsections that follow.

a. Vickburg, MS, District

The district includes the mouth of the Black River to Camden, Ark. (336 miles), from Mississippi River to the junction of Old and Yazoo Rivers (9.3 miles), from the Old River to the mouth of Yalobusha River (161 miles), and the mouth at the junction of Old and Atchafalaya Rivers, LA., to Fulton, Ark. (455.6 miles). Tons of freight transported by calendar year are listed below.

1982 -- 3,619,238 tons

1983 -- 3,572,416 tons

1984 -- 4,760,933 tons

1985 -- 5,518,947 tons

1986 -- 5,553,568 tons

b. Memphis, TN, District

The district includes the junction with the Arkansas Post Canal to Batesville, Ark.(285.5 miles), and mouth of the Wolf River to Mile 3 of the Wolf River. Freight volume, by calendar year is summarized below.

1982 -- 1,667,120 tons

1983 -- 1,396,566 tons

1984 -- 1,939,063 tons

1985 -- 2,117,009 tons

1986 -- 2,014,757 tons

c. Little Rock, AR, District

This district includes the lower 10 miles of the White River, the Arkansas Post Canal, the Arkansas River between Arkansas Post Canal and Muskogee, Okla., and the Verdigris River between Muskogee and Catoosa, Okla.(445 miles), and the lower 5 miles of Lake Langhofer, and the lower 10 miles of San Bois Creek (17 miles). Freight volumes are again listed below.

1982 -- 7,823,228 tons

1983 -- 7,567,986 tons

1984 -- 8,521,310 tons

1985 -- 7,725,468 tons

1986 -- 8,395,856 tons

d. Nashville, TN, District

This district includes the mouth of Cumberland River to Mile 552, the mouth of Tennessee River to Knoxville, Tenn. (652.2 miles), the Barkley Canal connecting the Barkley Reservoir and the Kentucky Reservoir, (1.75 miles), and the Clinch River (63 miles). Freight volumes for this district are listed below.

1982 -- 39,698,464 tons

1983 -- 42,983,396 tons

1984 -- 52,089,222 tons

1985 -- 57,502,620 tons

1986 -- 75,544,351 tons

e. Mobile, AL, District

This district includes the mouth of the Mobile River, bay, and river channels into Chickasaw and Three Mile Creeks, the mouth of the Alabama-Coosa River to Wetumpka, Ala., the mouth of the Black Warrior and Tombigbee Rivers on Chickasaw Creek to Mile

429.6 of the Chickasaw Creek, the Tennessee-Tombigbee Waterway (233.7 miles), the lower 4 miles of the Dog River and the lower 6.8 miles of the Pascagoula River. Freight volumes are listed below.

1982 -- 69,146,334 tons

1983 -- 67,300,393 tons

1984 -- 83,425,833 tons

1985 -- 81,800,546 tons

1986 -- 86,879,795 tons

f. New Orleans, LA, District

This district includes the river from New Orleans to the Gulf of Mexico (75.4 miles), the Gulf Intracoastal Waterway to Gulf of Mexico (40.2 miles), the Intersection of Gulf Intracoastal Waterway at Houma to Gulf of Mexico (36.6 miles), the Atchafalaya River from Morgan City, LA. to Gulf of Mexico, the Old River lock at Mississippi River through Old River to Morgan City, LA. (121 miles), the Gulf Intercoastal Waterway from Morgan City to Port Allen (64.1 miles), the Calcasieu River to the Sabine River (24.9 miles), and Port of New Orleans, LA. - from Mile 127 to the mouth of the Passes. Freight volumes, by year, are listed below.

1982 -- 205,081,030 tons

1983 -- 162,699,336 tons

1984 -- 166,261,389 tons

1985 -- 168,920,588 tons

1986 -- 177,233,374 tons

6. Waterway User Charges

For many years, developments in government policy have focused attention on the “free use” of U.S. inland waterways. This has culminated in various proposals for imposing a user charge on the nation’s towing industry. The four likely forms of user charges are (a) fuel taxes, (b) lockage fees, (c) segment tolls, and (d) licensing of floating equipment [34].

The fuel tax is imposed on diesel and other liquid fuels used by commercial cargo vessels on twenty-six designated inland or intracoastal waterways of the United States (Code sec.4042 of the Inland Waterways Revenue Act of 1978). Included among specified waterways are the Mississippi River upstream from Baton Rouge, the Mississippi's tributaries, and the Gulf and Atlantic Intracoastal Waterways. The tax does not apply to fuel used by deep-draft ocean-going vessels, recreational vessels, or noncargo vessels such as passenger vessels and fishing boats. The tax rate of 8 cents per gallon was increased to 10 cents per gallon on October 1, 1985 [50].

Certain aspects of the waterway user charge issue are relevant to any other alternatives. These include an assessment of Congressional intent in relation to the distinction among commercial, agricultural, flood control, power, and recreational use of the nation’s waterways. Another aspect deals with the proper definition of the U.S. inland waterway system. Much discussion by policy makers has centered on the attempt to establish a user charge program that would be equitable for all sections of the nation [34]. The ultimate objective of a waterway user charge is to shift the burden of navigational improvements from general tax revenues, or the taxpayer in general, to the direct users of navigable waterways. The implicit consequence for the public would be a change of roles in the financial support for waterways [34].

C. Rail Transportation

Literature on rail transportation is summarized in the following subsections.

1. Domestic Railroad Network

The railroad network of the U.S. consists of about 167,000 line miles. The operation of this industry is distributed by 18 Class I railroads [41]. It includes some 481 regional and local railroads. All U.S. railroad carriers are legally classified as common carriers, which means that the interstate activities of all railroads are regulated by the federal government. These organization’s intrastate activities are therefore subject to state regulation.

In 1929, railroads carried 74.9 percent of the total ton-miles of freight transported from one city to another. By 1979, the railroads transported only 36 percent of the intercity ton miles. Using the statistic of revenue ton-miles, nationwide the industry moved 858,105M revenue ton-miles of freight in 1978, which was 92 percent higher than the 447,332 carried in 1929 [70]. Revenue ton-miles are ton-miles of freight on which revenues are earned. They include most traffic carried. The example of non-revenue traffic would be a carload of railroad ties for the railroad's own use.

The railways of the United States are owned and operated by many different corporations. The Eastern District is owned and operated by Conrail, CSX Transportation, Florida East Coast, Grand Truck Western, Illinois Central and Norfolk Southern. The Western District ownership and operation is spread across Atchison Topeka & Santa Fe, Burlington Northern, Chicago & Northwestern, Denver & Rio Grande Western, Kansas City Southern, Soo Line, Southern Pacific and Union Pacific. All lines are connected and interconnected throughout the length and breadth of the country, forming one huge system. With a few minor exceptions, all the individual roads have the same gauge, and cars are permitted to move from one road to another. It is physically possible to convey a freight car between any two freight stations in the United States, however far apart they may be.

All railroads have all been built to accommodate prevailing currents of domestic trade. These currents or flows have developed because of the nature of the resources and industries of the different parts of the country. The internal trade of the United States, which the railroads were built to serve, has been based upon a sectional diversification of productive industry. The United States consists of three fairly well marked economic sections, a manufacturing and commercial East, an agricultural South with cotton as its outstanding product, and an agricultural West, the staples of which have been grain and livestock.

Railroad and motor carriers in the United States generally determine their rates, classifications, and other charges through group consideration. Several economic characteristics aid in explaining the prevalence of rate making in the railroad industry. First, as common carriers they have public utility status and thereby are subject to federal regulation. Secondly, internal economies of scale, external economies of scale, joint cost, unused capacity, or some combination of these are common. These sizable elements of cost, known as supplementary costs, cannot be specifically identified with any particular traffic movement and consequently must be allocated arbitrarily. Unused capacity on a round trip is usually the strongest cause of supplementary cost per unit of service [33].

In the railroad industry, the ratio of supplementary or fixed costs to variable costs has a propensity to be high because of heavy investments in railbeds, rolling stock, terminals, and other fixed facilities. An important dimension of the invariability of these costs is that costs per unit of traffic tend to decline as traffic volume and plant utilization increases [31]. So long as under utilization or excess capacity exists, increases in aggregate traffic volume will reduce unit costs, as much as constant costs are allocated over a larger volume of tonnage. This condition, in conjunction with an attendant inability to precisely identify common or joint movement costs, creates a situation which eventually could result in destructive pricing in the absence of federal or state rate regulation [41].

2. Freight Traffic and Cost Structure

Freight traffic volume trends in the railroad industry may be examined in various ways, including car loading, tonnage originated, and ton-miles carried. Because ton-miles reflect both weight and distance, they are normally considered the better indicator of actual service performed by a transportation mode compared to the other two ways. Revenue of freight in ton-miles generated by the railroad industry for 1990 was recorded at $1,034B.

The cost structure of the railroad industry is such that railroads can be very competitive in their short-term pricing policies and in the pricing of particular services [41]. Because of the very large investment in long-lived facilities such as track rights of way and terminals, a large portion of their costs are fixed or indirect in nature. During the life of these facilities, expenses of interest, depreciation, property taxation, maintenance, and similar costs do not vary with the amount of traffic handled. In the past, the cost structure has encouraged rate wars among railroads and between rails and other forms of carriage and the development of various kinds of discriminatory pricing policies [19].

Revenues of freight in ton-miles, operating cost, expenses and income generated by different rail operation organizations are shown in Tables 2 to 6.

The following are the Class I railroad companies reported on the Annual Report of *Transport Statistics in the United States* [24]:

- CR - Consolidated Rail
- CSX - CSX Transportation
- GTW - Grand Truck Western
- IC - Illinois Central
- NS - Norfolk Southern
- SL - Soo Line
- SP - Southern Pacific
- ATSF - Atchison Topeka & Santa Fe
- BN - Burlington Northern
- CNW - Chicago & North Western
- DRGW - Denver & Rio Grande Western
- KCS - Kansas City Southern
- UP - Union Pacific

District & Railroads	1992	1991	1990	1989
Eastern District				
CR	$3,133,262	$3,059,985	$3,206,437	$3,220,328
CSX	43,35,033	4,207,006	4,315,697	4,227,361
GTW	254,546	259,830	295,480	312,113
IC	504,503	509,419	511,773	517,727
NSC	3,655,251	3,530,134	3,663,222	3,580,008
Total Eastern District	$11,882,595	$11,566,374	$11,992,609	11,857,537
Western District				
ATSF	$2,212,848	$2,113,132	$2,067,573	2,155,240
BN	4,511,540	4,445,032	4,560,412	4,479,951
CNW	704,230	692,570	698,907	700,600
DRGW	329,782	315,426	326,312	323,347
KCS	318,366	305,158	302,255	296,396
SL	558,107	572,844	575,279	521,518
SP	2,286,247	2,226,570	2,302,582	1,843,369
UP	4,703,892	4,577,241	4,504,975	4,353,717
Total Western District	$15,625,012	$15,247,973	$15,338,295	14,674,138
Grand Total	$27,507,607	$26,814,347	$27,330,904	26,531,675

Table 2: Freight Revenues of Class I Railroads in The United States (thousands of dollars) [24]

District & Railroad	1992	1991	1990	1989
Eastern District				
CR	$3,207,663	$3,136,548	$3,292,856	$3,323,842
CSX	4,433,719	4,336,375	4,435,758	4,345,750
GTW	263,745	270,436	310,052	327,053
IC	547,436	549,728	544,174	547,043
NSC	3,776,987	3,653,971	3,785,987	3,694,082
Total Eastern District	$12,229,550	$11,947,058	$12,368,827	12,237,770
Western District				
ATSF	2,251,675	2,153,535	2,111,615	2,201,967
BN	4,629,843	4,558,650	4,674,408	4,606,286
CNW	816,456	803,033	809,954	812,184
DRGW	335,444	321,669	326,105	327,874
KCS	335,484	322,246	319,888	315,406
SL	576,788	589,246	593,955	539,210
SP	2,384,502	234,8602	2,025,503	1,943,110
UP	4,788,999	4,662,956	4,587,735	4,435,931
Total Western District	$16,119,191	$15,759,937	$15,449,163	14,788,396
Grand Total	$28,348,741	$27,706,995	$27,817,990	27,419,738

Table 3: Total Operating Revenues of Class I Railroads in The United States (thousands of dollars) [24]

District & Railroad	1992	1991	1990	1989
Eastern District				
CR	$2,701,613	$3,419,640	$2,877,546	$3,137,726
CSX	4,482,939	4,545,671	3,909,876	3,858,042
GTW	353,206	320,877	321,507	324,921
IC	397,092	404,631	410,321	461,794
NSC	2,850,839	3,345,470	2,969,395	2,864,431
Total Eastern District	$10,785,689	$12,036,289	$10,488,645	10,646,914
Western District				
ATSF	$2,268,459	$1,898,673	$1,922,554	2,416,046
BN	4,042,421	4,797,479	4,078,613	3,936,002
CNW	722,866	796,743	721,673	756,669
DRGW	324,984	305,031	291,762	294,274
KCS	276,182	267,473	264,305	253,018
SL	626,203	562,723	527,330	563,356
SP	2,407,026	2,701,890	2,063,318	2,024,602
UP	3,862,534	4,569,874	3,770,221	3,660,018
Total western District	$14,530,675	$15,899,886	$13,153,724	13,903,985
Grand Total	$25,316,364	$27,936,175	$2,412,842	24,550,899

Table 4: Total Operating Expenses of Class I Railroads in The United States (thousands of dollars) [24]

District & Railroad	1992	1991	1990	1989
Eastern District				
CR	$347,591	($130,978)	$295,265	$117,753
CSX	(9,390)	(129,816)	370,098	324,466
GTW	(76,191)	(40,687)	(8,839)	7,642
IC	112,573	114,331	111,324	81,142
NSC	616,878	222,577	502,551	525,575
Total Eastern District	$991,461	$35,427	$1,270,399	$1,056,578
Western District				
ATSF	(64,154)	$183,846	$278,203	(137,072)
BN	390,290	(110,900)	414,082	473,085
CNW	97,991	54,639	53,772	48,216
DRGW	7,218	13,312	25,207	20,919
KCS	41,464	37,672	36,730	38,326
SL	(34,161)	12,724	44,952	(19,936)
SP	(90,087)	(353,937)	(52,407)	(132,746)
UP	619,834	78,209	548,420	540,132
Total Western District	$968,092	($72,435)	$1,348,959	$824,259
Grand Total	$1,959,553	($37,008)	$2,619,358	$1,887,502

Table 5: Net Railway Operating Income of Class I Railroads in The United States (thousands of dollars) [24]

	Operating Revenue	Operating Expenses	Ordinary Income	Net Railway Operating Income	**Revenue Ton-miles**	**Capital Expenditure**
1983	26,729,392	24,106,254	1,777,916	1,837,854	828,275	2,760,909
1984	29,453,446	25,800,454	2,653,814	2,536,673	921,542	3,744,395
1985	27,586,441	25,225,295	1,788,151	1,746,386	876,984	4,422,903
1986	26,204,122	24,896,015	746,941	506,591	867,722	3,600,682
1987	26,6 22,482	23,878,116	1,965,475	1,756,460	943,747	2,970,805
1988	27,934,285	24,811,138	2,286,003	1,979,719	996,182	3,681,447
1989	27,955,969	25,037,666	2,009,094	1,894,315	1,013,821	3,708,662
1990[r]	28,369,803	24,651,542	1,961,127	2,648,258	1,033,969	3,639,838
1991[r]	27,845,206	28,061,187	(90,849)	(37,455)	1,038,875	3,437,363
1992	28,348,741	25,316,364	2 060,179	1,959,553	1,066,781	3,702,367

Table 6: Railway Revenue Ton-Miles and Expenses (millions of dollars) [24]

Railroads have variable costs of operation. These are costs that vary directly with volumes. Examples of railroad variable costs are: maintenance of equipment and rights-of-way based on usage; labor costs; fuel, and lubrication oil.

Prior to the 1940's, many transportation experts believed railroad fixed costs were as much as two-thirds of the total cost structure [41]. Today, it is generally believed that fixed costs are 40 to 50 percent of the total cost structure. The primary reason for this is that many railroads have greatly expanded their ton-mile production, using the same basic right-of-way and physical plant. When volume increases over time, the percentage of fixed costs compared to total cost decreases.

Because of the still relatively high fixed cost structure of railroads, economies-of-scale apply with increasing freight. As volume increases, the total cost of production decreases on a per unit basis [7]. The reason is that as volume increases, fixed costs stay constant and hence become less per unit of output. James C. Nelson [37], a noted railroad scholar, states: “Railroads, having a substantial investment in plant and equipment and relatively large fixed costs, cannot operate efficiently with low and irregular volumes of traffic. Either adequate traffic flows must be stimulated, or unprofitable operations and high rates will result.”

3. Cost Functions

According to Hasenkamp's model [16], the general term for a cost function is:

$h(y) = g(x)$, where,

(2)

y = vector of output (consists of passenger-miles, freight ton-miles),

x = vector of input (labor measured as man-hours, fuel measured as ton of coal & capital services measured as car-miles or train hours).

The analysis of cost function for railroad in this section is based on Translog Hedonic Cost Function [16]. The short-run variable cost function is

$$C = C(F(y, q), x, v, t) \quad (3)$$

where,

C = a short-run variable cost.

F = measure of effective ton-miles.

y = (1*N) vector of output.

q = (1*R) vector of shipment attributes associated with each output.

x = (1*H) vector of fixed factors.

v = (1*J) vector of prices of the variable factor.

t = (1*M) vector of technological variables.

N, R, H, J, M represent numbers of vectors in each different variable.

Studies show that this functional correlation has been inadequate in two respects. First, the equation fails to distinguish the effect way-and-structures capital has on cost from that of track (route-miles). Second, the equation ignores the effect on costs of such variables as traffic mix by commodity type, average length of haul, and low-density route-miles [16].

In specifying the rail cost function, Friedlaender & Spady [16] assume that way-and-structures capital such as track, bridge & building, signal, communication and others is fixed in the short run cost estimating calculation. This minimizes expenditures on the remaining factors given the exogenously determined quantity of the fixed factor, technological conditions, and outputs. It is appropriate to regard way-and-structure capital as fixed not only because its quantity is difficult to vary over short periods, but also because railroads are generally believed to have permitted this factor to decay rapidly in many instances. Since railroads are obligated by their status as common carriers to satisfy all shipper demands at fixed prices, both output and the technological conditions influenced by are exogenous [16]. Therefore, equation (3) has been modified as follows:

$C = C\ (y_p,\ y_{f,}\ x,\ v,\ t)$

(3a)

where,

y_p = passenger service output,

y_f = freight service output,

v = vector of prices of variable factors,

x = quantity of way-and-structure capital,

t = vector of technological conditions.

Passenger service output is measured by passenger-miles, y_p, which is then adjusted for another two quantities, passenger average travel length (PATL) and passenger miles per passenger route-mile (PDENS). Passenger service is defined as: $y_p = y_p * f(\text{PATL, PDENS})$, where f is the translog function. According to Friedlaender & Spady [16], one can expect that increases in passenger density will decrease the cost of producing a given amount of passenger-miles because of economies of utilization of equipment and centralization of ancillary service (ticket offices, terminal, etc.). Passenger service also requires that track be kept in better condition. Handling fewer passengers per passenger-mile lowers the cost associated with ticketing and boarding passengers. Increases in passenger average travel length are also associated with a shift in the type of passenger service provided from commuter to interstate. If the latter is more expensive than the former, we would expect $dy_p/d\text{PATL} < 0$ for larger values of PATL.

For freight service output, revenue ton-miles is used. Since average length of haul and traffic mix are liable to have a direct effect on factor shares, they have been included as technological conditions, which is a less restrictive condition than including them in the Hedonic function altering ton-miles.

The following five variables are used in estimating rail expenditures: equipment, general and maintenance labor, traffic and transportation labor (other than train), on-train labor, and fuel & material. According to Friedlaender & Spady [16], operating cost for railroad is equal to the sum of net way and structures, equipment depreciation, fringe benefit, labor taxes on employee compensation chargeable to operating expenses, net equipment rentals expenses, and imputed opportunity and depreciation cost on equipment capital.

D. Air Transportation

Literature on air transportation is summarized in the following subsections.

1. Domestic Air Transportation System

Aviation became an exciting form of transportation during the past century. The domestic airline industry began in the mid and late 1920's. The government provided subsidies to the airline companies to carry mail. Mail transport was the beginning of the airline industry. Passenger business developed as an afterthought to the carriage of mail. Passenger aircraft technology burgeoned during the 1930's. In the late 1930's there were many developments which improved the dependability and safety of the air navigation system - an essential step for air travel to become popular. Not only have there been developments in aircraft, there have also been parallel developments in airports and air navigation equipment which have accommodated the increased size, sophistication, and dependability of aircraft.

U.S. scheduled commercial airlines now operate some 3,400 jet aircraft. The domestic revenue ton-miles of freight by the air industry in 1990 totaled $9.2B. Air transportation is still primarily a passenger operation, which generates over 80% of their revenues [39]. Air cargo is defined by the airline industry to include freight, express, and mail. Freight represents the biggest portion of the air cargo. Most air freight is transported by combination (both passenger and cargo) carriers either in the belly of scheduled passenger aircraft or in aircraft used exclusively for cargo. Combination carriers usually find air freight service to be unprofitable, and all-cargo airlines have usually found it very difficult to be as profitable as common carriers of other modes [19]. Freight is often considered a byproduct of the passenger service in combination carriers, because the aircraft will be flown with or without the freight. Some carriers believe that only those costs specifically attributable to carrying freight should be assigned to freight traffic for pricing purposes, rather than assigning to freight traffic a share of all the costs incurred [19]. Airline cost structures are more comparable to trucking industry cost structures than to railroad costs. This is because airlines have a relatively high variable costs in proportion to fixed costs [39]. Airports and airways navigational aids are provided through federal and states funds. This has made cost allocation a very difficult problem.

There are about 200,000 general aviation aircraft in the U.S., compared with about 3,000 airline aircraft [69]. General aviation aircraft provide flight service to communities without scheduled airline service [69]. At present, more than 700 airports receive scheduled airline service. There are approximately 15,000 airports (although many are unpaved and unlighted). General aviation and commercial airlines compete with each other for air space and runway usage at major airports.

During 1989 there were 125 air traffic hubs in existence. They represented 25% of the 498 air traffic hubs and nonhubs in the 50 states, the District of Columbia, and other U.S. areas receiving air carrier service during the year. Air traffic hubs are not airports; they are the cities or twin cities requiring aviation services. The dominance of the hubs in air traffic patterns is underscored by the fact that 98% of passenger enplanements were recorded at these 125 hubs. Table 7 shows the number of hubs/nonhubs and the number of airports in those hubs. The nonhubs are the communities enplaning less than 0.05 percent of the total passengers.

Hub Classification	Numbers of Hubs/Nonhubs	Number of Airports	Enplaned Number	Passengers Percent
Large	28	53	313,779,281	73
Medium	34	39	76,097,543	18
Small	63	63	30,032,059	7
Nonhub	373	381	9,745,719	3
Total	498	544	429,654,602	100

Table 7: Numbers of hubs/nonhubs and the number of airports in those hubs [59]

In domestic aviation the aircraft are usually owned by private parties, either airlines or general aviation aircraft operators. The airports to and from which they operate are typically publicly owned, and the air navigation system they rely upon while airborne is provided by the federal government.

2. Airports and Airways

Airports provide the interface between air and ground transport as well as fulfilling the usual terminal functions. There are many types of airports, ranging from sophisticated airports found near major cities to small grass strips. Airports are classified by the Federal Aviation Administration as (1) local interest airports, (2) national system of airports, and (3) military airports [39]. Heliports, which can accommodate helicopters can be found on the tops of buildings in large cities. Seaplane bases service seaplanes and amphibious aircraft. These bases are found in areas where conventional landing strips are unavailable. Airports generally are developed with public funds -- federal, state, county, municipal, or a combination. Some airports are privately owned by either an industry or flight school. Airports used by commercial airlines are provided by government. Charges are levied against airlines in the form of landing fees and rental and lease fees of various kinds for their use of the landing field, terminal building and other physical facilities.

Land requirements are great, especially off the ends of the runways, where approach paths must be kept clear of obstacles to aircraft flight or the pilot's vision. Early airports were developed with private funds. The larger passenger-handling airports were owned by either airlines or aircraft manufacturing companies. The situation changed in the mid-1930's when communities used federal public works programs for airport construction. The *Federal Airport Act of 1946* established a federal aid program which matched construction funds supplied by local and state interest [36]. In 1970, the federal program was increased, with part of the increased funding coming from user fees paid by both airlines and general aviation.

Airports are not used exclusively by airlines; all airports used by the airlines are also used extensively by private flyers of various sorts, and by flying services of the armed forces [30]. Practically without exception, airport facilities have been provided by government expenditures, primarily by federal and municipal governments. The states have not been major players in the funding of airports. Since there are a variety of types of airport users, the problem of allocating proportionate costs for the use made of facilities becomes important. Public airports are owned and operated by city governments or special airport districts or boards. They attempt to recover their cost from the users of the airports. Principal revenue sources for them are landing fees and space rental to airlines and concessionaires in and around the terminal building. Each passenger who uses the airport is charged in a number of ways to raise funds to meet the airport's costs. Most public airports budgets have two components: an operating costs budget and a capital cost budget. Both usually cover a 12-month period. Operating costs include personnel costs, rent, supplies, and equipment with relatively short useful life. Capital costs are investments in land, buildings, and equipment with longer useful life.

Most air navigation facilities are provided by the federal government, operating through the Federal Aviation Administration (FAA). There are control towers at major airports; traffic control facilities controlling traffic above major metropolitan areas; and route navigation devices, which emit signals used by cross country flyers to determine their location. Although there are over 12,000 airports in the United States, only 600 have control towers. Only about 3,000 airports are both paved and lighted, meaning they are available for "round-the-clock" operations every day of the year [69]. Airports are funded by combinations of federal, state, county, municipal, and local money, and some of the costs are recovered through charges placed on aircraft using the airport and passengers moving through the terminal.

Commercial airlines are classified into four categories by the Department of Transportation [54]. The four carrier groups are:

- Major -- Operating Revenues of $1,000,000,000 and above.
- Nationals -- Operating Revenues of $100,000,000 to $1,000,000,000.
- Large Regional -- Operating Revenues of $10,000,000 to $99,999,999.
- Medium Regional -- Operating Revenues of $0 to $9,999,999.

3. Cost Structure

The cost structure for air transportation is comprised of three major fixed costs which are route, terminal, and vehicle [19]. Some other general costs and variable costs also apply. Unlike surface carriers, air transportation does not have a physical route in the sense of a fixed physical roadbed or right of way. However, aircraft do make use of traffic control facilities designed to prevent accidents, and part of the system involves assigning air space to aircraft over a designed route, as well as control of traffic into and out of airports. This airway system, as it is called, is used by all kinds of aircraft (for hire, general aviation, and military). The system is provided and operated by the federal government through the Federal Aviation Administration (FAA).

Because of the lack of an investment in physical routes, the airlines avoid the associated necessary return to investors, amortization or depreciation, maintenance costs, and property taxes. Instead, the user charges paid by aircraft operators to help pay for the airway system are in the nature of a variable cost because they tend to increase and decrease with the volume of traffic carried [39]. However, the route costs incurred by airlines are common in the sense that they are incurred in order to provide transportation of different passengers and/or different kinds of cargo traffic. Cost allocation to different segments is, therefore, difficult, particularly when the same aircraft carries both passenger and cargo traffic simultaneously.

Airline passenger terminal facilities are places where passengers purchase tickets, transfer between aircraft and airlines, and board and depart from aircraft. Air cargo terminals are places where cargo is collected after local pickup and prior to line-haul by air. However, airports used by commercial airlines are provided by government. Charges are levied against airlines in the form of landing fees and rental and lease fees of various kinds for their use of the landing field, terminal building, and other physical facilities. Airline terminal costs are consequently a blend of fixed and variable costs, the proportions varying with the nature of the particular airline's operation and the length of the lease or rental agreements and the amount of actual investment an airline makes. In some cases, air carriers initially fund construction and modifications of the facilities [27]. An analysis of comparative cargo transportation costs by Douglas Aircraft Company showed that the terminal cost is one important reason why air costs are substantially greater than truck or rail costs [45].

Aircraft expense is a large cost item for an airline company. A wide-bodied jet aircraft can cost well over 20 million dollars, including spare parts. Most aircraft are provided by the carriers through ownership or leasing (sometimes joint between two or more carriers). The costs associated with ownership and operation of aircraft are both fixed and variable The wear and tear on the aircraft and the fuel and labor expense associated with their operation may be considered variable because they are incurred in relation to the volume of traffic carried, to the extent that traffic volume dictates the number of flights made. For a given number of flights, however, the costs associated with operating the aircraft may be considered fixed, as long as the number of flights do not change [45]. Other general expenses incurred by airlines include the costs of operating and maintaining office space, wages of administrative personnel not involved in the operation of aircraft and terminal operation and maintenance.

Airlines have a large proportion of variable costs. The degree of variability is affected by the ability of the carrier to adjust the aircraft fleet to meet changes in demand for airline services.

Airline costs can be reduced or increased as service is reduced or increased. A major contributor to the large variable costs is the large amount of and high price of labor used in airline operations, a cost that tends to be variable. Air cargo has been expensive to handle because of the methods used, and the odd-shaped cargo (especially in combination carriers).

Historically, the total operating costs of an airline have consisted of two major components: the direct operating costs and the indirect operating costs. The direct operating costs are those incurred as a necessary result of, and directly related to, flying the aircraft. The indirect operating costs are not directly related to the operation of the aircraft but are incurred as a result of operating services on the ground [45]. Direct operating costs of flying passengers or freight do not differ materially and, as a result, the elements and variations in direct costs for most operations are identifiable within the framework of the airline accounting structure [9]. The allocation of these costs in combination aircraft is still a matter of discussion and controversy.

4. Air Cargo Joint Cost Allocation.

When the airplane consumes fuel and oil to carry both passengers and cargo, this incurred cost is referred to as joint cost [10]. Any attempt at allocating these costs is always based upon an individual value judgment, not upon an underlying, self-evident truth. Brewer and DeCoster [9] indicated that all methods of allocating joint costs result in allocation either by physical attributes or the ability to carry costs. The allocation of costs by physical attributes is often done on the basis of the services rendered. Ton-miles, for example, implies that the costs incurred vary in direct proportion with variations in these physical attributes. Also, all physical units are treated as homogeneous in nature, which may not be true.

The allocation of costs to the services on the basis of their ability to absorb costs results in costs for each service that are proportional to the sales value. This can be considered primarily as a way of allocating the costs among the products [45]. Changes in the market value of one or more of the products automatically causes a change in the cost allocation basis. Both of these methods fall short of the desired results of truly accurate and reliable costing. Unfortunately, the air cargo industry has joint costs and there is no way of eliminating them.

5. Allocation of Airway Costs.

A civil airway may be defined as a path through the navigable airspace (above the minimum altitudes of flight prescribed by regulations) [30]. These airways are designated by naming points on the earth and connecting them with straight lines. The width of the airway extends five miles on either side of the center line.

If the cost of the airways is to be allocated among the various users, a decision must be made as to what costs should be covered and by whom. The determination of the portion of total costs to be met by the different users is part of this problem as is also the determination of the treatment to be given to historical costs or costs that have already occurred. Because of the nature of the reasons for expenditures upon airways, i.e., national defense requirements, rapid development of feeder airways, etc., the federal government should not attempt to collect total allocated airways costs. Only current costs of the government in the maintenance and improvement of the airways should be considered [30].

It would be inequitable for the airline passenger and shipper to be required to absorb a portion of the cost of general aviation, since vast majority of such passengers and shippers could not afford to own and operate an aircraft of their own.

The airways system is wholly owned and operated by the federal government. The cost of the federal airways system, and the allocation of that cost among users, can be determined on a national basis. No fair determination can be made of airport costs on a national basis, and one certainly could not allocate airport costs among users on a national basis. This must be done airport by airport. Any allocation of the airways system costs must be based on an appraisal of actual utilization of the airways corridor by each type of users. It is apparent that some users make greater use of the airways system than others. For example, on the basis of total number of aircraft using the system, general aviation makes more use of the airways (98%) then either the airlines or military aviation. It can also be measured on the basis of flying hours. In terms of flying hours, the airlines have 18% of flying hours on the system [49].

A 1966 FAA [49] report on "User Charges for the Domestic Federal Airways System", analyzed the extent of actual aircraft activity by type of operations involved under each of the thirteen major categories of airways facility groups. These includes air traffic control towers, approach control facilities, radar, instrument landing service systems, approach lighting, VORTAC, air route traffic control centers, flight service stations, and others. This FAA analysis shows that different classes of users are dominant in the use of different airways facilities [49]. The total aircraft operations on different categories of airways facilities are presented below:

FAA air traffic control towers :

Air carrier	20.6%
General aviation	70.3%
Military	9.1%

Flight service stations :

Air carrier	9.0%
General aviation	73.5%
Military	17.5%

Surveillance radar instrument :

Air carrier	62.9%
General aviation	23.3%
Military	13.8%

The over-all weighted average use of the airways facilities in the 1966 report [49] shows the distribution of user percentage as :

Air carrier	44.6%
General aviation	29.3%
Military	26.1%

However, there is a shortcoming in the FAA report. It fails to assign sufficient weight to the paramount claim of the military on the airways system. The military use of the airways has some extraordinary characteristics. There are special services provided to military users of the airways by FAA. Among these special services are the “Restricted Airspace” for military activities, which are prohibited to civil aviation users, and the “priority” in the use of the airways [49].

All the government uses of the airways were classified under military uses. Many of them are either government users or non-public users, such as VIP flights and flights by the FAA, which owned over 100 aircraft. Many of these operations have been lumped, improperly, into the general aviation category.

VI. Method of Analysis

A base cost model has been adopted from Hay [20] for modal cost assessment. Modification to this base cost model have been made, where required, for the different modes of transportation that have been analyzed. The base cost model is described as:

Total Transportation Cost = Capital Costs + Operating Costs

(4)

where,

Capital Costs = Facilities Costs + Equipment Costs

(5)

Operating Costs = Facilities Maintenance Costs + Equipment Maintenance Costs + Transport Costs + Traffic Costs + General Costs

(6)

The definition of each cost component is described in greater detail below.

Capital Cost -- Costs of providing initial plant and equipment and additions to or betterment of those facilities, such as initial roads construction, railroad track construction, port construction, etc.

Operating Cost -- Costs of providing transportation services.

Facilities Cost -- Investment in routes, structures, and terminals.

Equipment Cost -- Investment in vehicles.

Facilities Maintenance Cost -- Costs of maintaining roadway and track, pavement and subgrade, rivers and harbors, channels and dams, etc..

Equipment Maintenance Cost -- Costs of maintaining motive power and rolling stock, such as cars, locomotive, trucks, airplanes, tow boats, etc..

Transport Cost -- Costs of conducting transportation, such as power and fuel, wages of vehicle crew, wages of those directing vehicle movements.

Traffic Cost -- Costs of traffic solicitation, wages of highway safety officers, advertising, publishing rates and tariffs, and administration.

General Cost -- Costs of general office expenses, legal advice, accounting, and salaries of general officers and staffs.

A. Truck Transportation

There has been a great deal of research conducted over the years in determining and allocating costs of highway transportation. The method of cost allocation is based on several cost allocation studies that have been conducted over the years.

The method divides highway transportation costs or expenditures into two kinds of costs. These two kinds of costs are attributable and non-attributable costs. Cost allocation methodology by the FHA [62] has been utilized for our analysis. The FHA analysis uses an improved incremental method of cost allocation for its analysis. Using the result of that analysis, all cost components in both capital costs and operating costs are carefully divided into attributable and non-attributable costs. Attributable costs are costs associated with vehicle weight, while non-attributable costs are costs associated with vehicle mileage.

This cost allocation method uses the American Association of State Highway and Transportation Officials (AASHTO) recommendation [47]. According to this organization, the minimum thickness of a new pavement structure is considered a residual or non-attributable cost shared by all vehicle classes. The extra thickness to accommodate traffic loading is assigned to all vehicle classes by the AASHTO design parameter, equivalent single axle load (ESAL). ESAL is a factor used by highway agencies to determine the overall pavement thickness required for a new roadway. This improved method eliminates the problem of the unfair assignment of the economies of scale in pavement cost/thickness that exists in the incremental method. Vehicle Miles of Travel (VMT) was used in that study to determine non-attributable costs.

Truck transportation in our analysis considers the use of interstate highways only. This simplifying assumption has been adopted because of the limited availability of cost data for secondary, state, and local highways. The tables below show the shares of attributable and non-attributable costs by each vehicle class. They are obtained from the study discussed above. Attributable costs can be allocated to vehicles based on the percentage distribution presented in Table 8 [47].

Vehicle Class	Percent Share
Autos/Motorcycles	21.5 %
Buses	2.4 %
Pickups/Vans	9.1 %
Other single unit trucks	11.9 %
Combination trucks	55.1 %

Table 8: Shares of Attributable Costs

Non-attributable costs can be allocated to vehicles in accordance with the percentage distribution in Table 9 [47].

Vehicle Class	Percent Share
Autos/Motorcycles	74.1 %
Buses	0.4 %
Pickups/Vans	16.4 %
Other single unit trucks	3.8 %
Combination trucks	5.3 %

Table 9: Shares of Non-Attributable Costs

Three major cost components considered in our analysis of truck transportation are federal costs, state costs, and truck operating costs. The analysis, factors such as ratio of interstate truck mile to total highway system truck mile, ratio of number of bridges on interstate to total number of bridges on federal-aid highway system, and ratio of number of interstate vehicle miles to total number of federal-aid highway system vehicle miles are used to factor out cost responsibilities of truck on interstate.

1. Truck Transportation Cost Model

A set of modified cost models have been developed for the analysis of truck transportation. These cost models were derived from the base cost model (equations (4) - (6)) with the addition of several allocation factors. The cost models are defined as:

$TTC_t = CC_t + OC_t$

(7)

where,

$CC_t = FC_t + EC_t$

(8)

$OC_t = FMC_t + EMC_t + TC_t + TRC_t + GC_t$

(9)

where,

$FC_t =$ $a * b *$ (Federal Expenditures on Facilities + State Expenditures on Facilities) + $c * h *$ (Trucking Co. Expenditures on Facilities)

(10)

$EC_t = c * h *$ (Trucking Co. Expenditures on Equipment)
(11)

$FMC_t = a * b *$ (Federal Expenditures on Facilities Maintenance + State Expenditures on Facilities Maintenance) + $a * b * d *$ (Federal Expenditures on Bridge Maintenance)
(12)

$EMC_t = c * h *$ (Trucking Co. Expenditures on Equipment Maintenance)

(13)

$TC_t = c * h *$ (Trucking Co. Expenditures on Transport)

(14)

$TRC_t = e * b * f *$ (Federal Expenditures on Traffic) + * $e * b * g *$ (State Expenditures on Traffic)
(15)

$GC_t = e * b * f *$ (Federal Expenditures on General Costs) + $e * b * g *$ (State Expenditures on General Costs) + $c * h *$ (Trucking Co. Expenditures on General Costs) (16)

where,

a = % of attributable cost responsibilities for truck
(Percent share of cost responsibility of single trucks and combination trucks from Table 8)

b = % of ton-miles carried by ICC regulated truck
(Ton-miles carried by ICC regulated truck over the total ton-miles carried by ICC and Non-ICC regulated trucks)

c = % of interstate truck miles on total highway system
(Truck-miles traveled on interstate highways over total truck-miles traveled on all highways)

d = % of number of interstate highway bridges on total federal-aid highway system
(The number of bridges on interstate highways over the total number of bridges on federal-aid highways.)

e = % of non-attributable cost responsibilities for truck
(Percent share of cost responsibility of single trucks and combination trucks from Table 9)

f = % of interstate vehicle miles on federal-aid highway system
(The number of vehicle-miles traveled on interstate highways over the total vehicle-miles traveled on federal-aid highways.)

g = % of interstate vehicle miles on all road systems
(The number of vehicle-miles traveled on interstae highways over the total number of vehicle-miles traveled on all road systems.)

h = % of trucking cost allocated per state
(The amount of public road mileage in each state over the total amount of public raod mileage in the nation.)

Note: Allocation factor *c* is used to factor out the truck-miles traveled on interstate highways from the total truck-miles traveled on total highway system.

Allocation factor *g* is used to factor out the vehicle-miles traveled on interstate highways from the total vehicle-miles traveled on all road system, including local roads.

also,

CC_t (Capital Cost) -- Costs of providing initial plant and equipment and additions to or betterment of those facilities in highway transportation, such as initial roads construction.

OC_t (Operating Cost) -- Costs of providing transportation services in highway transportation.

FC_t (Facilities Cost) -- Investment in routes, structures, and terminals in highway transportation.

EC_t (Equipment Cost) -- Investment in vehicles, such as trucks in highway transportation.

FMC_t (Facilities Maintenance Cost) -- Costs of maintaining roadway, pavement and subgrade in highway transportation.

EMC_t (Equipment Maintenance Cost) -- Costs of maintaining motive power and rolling stock, such as trucks in highway transportation.

TC_t (Transport Cost) -- Costs of conducting transportation, such as power and fuel, wages of vehicle crew, wages of those directing vehicle movements in highway transportation.

TRC_t (Traffic Cost) -- Costs of traffic solicitation, wages of highway safety officers, advertising, publishing rates and tariffs, and administration.

GC_t (General Cost) -- Costs of general office expenses, legal advice, accounting, and salaries of general officers and staffs in highway transportation.

Detailed descriptions of equations (10) to (16) are presented here. In equation (10), allocation factor *a* is used to factor the attributable cost responsibility of trucks from governments' expenditures (facilities costs) on interstate highways. Since the analysis is only dealing with cost data from ICC regulated trucking companies, it is appropriate to factor the portion of governments' expenditures (facilities costs) to ICC regulated trucks. Allocation factor *b* is used for this purpose. Allocation factor *c* is used to factor the protion of trucking companies' expenditures (facilities costs) on interstate highways. Allocation factor *h* is used to factor the portion of trucking companies' expenditures on facilities costs for each state.

In equation (11), allocation factor *c* is used to factor the portion of trucking companies' expenditures on equipment on interstate highways. Allocation factor *h* is used to factor the portion of trucking companies' expenditures (equipment costs) for each state.

In equation (12), allocation factor *a* is used to factor the attributable cost responsibility of trucks from governments' expenditures (facilities maintenance costs) on interstate highways. Allocation factor *b* is used to factor the portion of governments' expenditures (facilities maintenance costs) to ICC regulated trucks. Allocation factor *d* is used to factor the portion fo governments' expenditures on interstate bridge maintenance.

The reason for the use of allocation factors in eqations (13) and (14) is the same as equation (11). In equation (15), allocation factor *e* is used to factor the portion of non-attributable costs of trucks on governments' expenditures (traffic costs) on interstate highways. Allocation factor *b* is used to factor the portion of governments' expenditures (traffic costs) to ICC regulated trucks. Allocation factor *f* is used to factor the portion of federal government's expenditures (traffic costs) on interstate highways. Allocation factor *g* is used to factor the portion of state government's expenditures (traffic costs) on interstate highways.

The reason for the use of allocation factors in equation (16) is the same as equations (11) and (15).

2. Truck Transportation Cost Data

The tables on the following pages represent the expenditures by the federal government and the respective state governments, and trucking companies. Information from Table 8 and Table 9 is utilized to factor out the costs attributable to truck transportation.

The following are the United States Department of Transportation's classification of highway expenditures. Specific costs by state are shown in Tables 11 to 20 [62]. The following cost categories apply:

Capital Outlay --   Costs associated with highway improvements, including land acquisition and other right-of-way costs, preliminary and restorationcosts of roadway and structure.

Maintenance -- Costs required to keep the highways in usable condition, such as routine patching repairs, bridge painting, and other maintenance of condition costs.

Traffic Service -- Costs associated with snow and ice removal, pavement markings, signs, signals, litter cleaning, and toll collection expenses.

Administration -- Costs for general overhead and engineering, and research costs.

Highway Safety -- Highway law enforcement and safety expenditures.

Bond Interest -- Interest on the trust funds and bonds.

Bond Retirement -- Retirement of trust funds and bonds.

Intergovernmental -- Grants-in-aid to local government.

Interstate Payments -- Costs associated with the development of interstate highway systems, including purchase of right-of-way and highway construction.

Interstate Resurfacing -- Costs associated with highway repairs and pavement maintenance.

Planning & Research -- Costs for highway research and administrative planning.

Bridge Replacement -- Costs associated with replacing and restoring highway bridges.

Emergency Relief -- Costs associated with relief efforts during emergency period.

Others -- Costs associated with other categorial programs, beautification, interstate substitute, and other miscellaneous funds administered directly by FHWA.

Cost categories for equations (11) through (17) are described in Table 10 below.

Cost Components	**Cost Categories**
Facilities Costs	Interstate Capital Outlays
Facilities Maintenance Costs	Interstate Resurfacing Maintenance

Traffic Costs	Highway Safety Emergency Relief Traffic Service Administration and Police
General Costs	Planning & Research Others Bond Interest Grant-in-aid Bond Retirement

Table 10: Cost Components for Cost Equations

Federal and state highway expenditures are presented in Tables 11 through 20. The data presented are for the fiscal years of 1989-1991.

In Tables 11, 13, 15, 17 and 19, the figures in all cost categories include the funds for other road systems, such as primary and secondary roads, with the exception of interstate and interstate resurfacing. The interstate portion of bridge replacement, is factored out using the ratio of the number of bridges on interstate system to the total number of bridges on federal-aid highway system. The interstate highway portion for rest of the cost categories is determined by using the ratio of vehicle-miles of travel. The factor is the number of interstate vehicle-miles over the total number of vehicle-miles on federal-aid system.

A different factor is used in Tables 12, 14, 16, 18, and 20 to determine the interstate highway portion on each cost category. All the cost categories with the exception of capital outlays and maintenance, include funds for other road systems, such as freeways and arterial roads. The factor used is the number of interstate vehicle-miles over the total vehicle-miles on all systems. Two of the three cases above use vehicle-miles traveled as the main factor, as this factor is a good representation of the traffic volume. This allocation factor was discussed in the cost-estimation techniques by Wohl [70].

Cost data for trucking companies were abstracted from the *Blue Book* [5]. The variable is used to factor out the interstate mileage is the total number of interstate truck-miles traveled over the total number of truck-miles traveled on all systems. In order to calculate the cost for each state, the public road mileage for that state over the total public road mileage for the nation is used as the proration factor. The data on trucking companies' expenditures is presented in Table 21.

	1989	1990	1991
Interstate	$119,314	$96,434	$79,359
Interstate Resurfacing	$56,676	$66,359	$53,136
Planning & Research	$4,120	$3,143	$4,171
Highway Safety	$6,802	$6,367	$3,781
Bridge Replacement	$49,516	$53,004	$22,604
Emergency Relief	$--	$1,315	$13,322
Others	$751	$18,600	$1,157

Table 11: Expenditure of Federal Funds Administered by FHWA in Alabama [63] [64] [65] (thousands of dollars)

	1989	1990	1991
Capital Outlays	$198,349	$182,679	$151,505
Maintenance	$23,573	$11,576	$12,719
Traffic Service	$111,707	$104,800	$110,441
Admin. & Police	$84,070	$98,573	$105,313
Bond Interest	$13,829	$5,933	$4,945
Grant-in-aid	$180,232	$149,810	$147,860
Bond Retirement	$93,875	$21,415	$19,605

Table 12: State Disbursements for Highway in Alabama [63] [64] [65] (thousands of dollars)

	1989	1990	1991
Interstate	$15,135	$15,433	$11,126
Interstate Resurfacing	$10,170	$22,225	$27,683
Planning & Research	$1,836	$1,743	$1,709
Highway Safety	$3,538	$3,520	$4,702
Bridge Replacement	$20,131	$19,631	$17,456
Emergency Relief	$249	$80	$974
Others	$10,484	$11,419	$14,944

Table 13: Expenditure of Federal Funds Administered by FHWA in Arkansas [63] [64] [65] (thousands of dollars)

	1989	1990	1991
Capital Outlays	$49,749	$23,479	$28,017
Maintenance	$10,205	$13,487	$12,542
Traffic Service	$87,336	$83,365	$83,275
Admin. & Police	$43,305	$48,666	$46,813
Bond Interest	$--	$--	$--
Grant-in-aid	$92,267	$85,467	$85,152
Bond Retirement	$--	$--	$--

Table 14: State Disbursements for Highway in Arkansas [63] [64] [65] (thousands of dollars)

	1989	1990	1991
Interstate	$143,917	$152,050	$146,946
Interstate Resurfacing	$44,649	$50,717	$55,671
Planning & Research	$4,586	$5,063	$4,814
Highway Safety	$7,705	$8,585	$8,901
Bridge Replacement	$24,470	$22,132	$25,305
Emergency Relief	$296	$--	$--
Others	$778	$3,128	$2,495

Table 15: Expenditure of Federal Funds Administered by FHWA in Louisiana [63] [64] [65] (thousands of dollars)

	1989	1990	1991
Capital Outlays	$242,693	$201,340	$220,604
Maintenance	$1,091	$2,338	$18,642
Traffic Service	$47,367	$54,617	$42,602
Admin. & Police	$139,953	$143,666	$135,266
Bond Interest	$72,402	$62,892	$88,189
Grant-in-aid	$47,863	$43,641	$32,845
Bond Retirement	$340,396	$49,691	$66,390

Table 16: State Disbursements for Highway in Louisiana [63] [64] [65] (thousands of dollars)

	1989	1990	1991
Interstate	$6,494	$8,202	$15,766
Interstate Resurfacing	$22,807	$33,306	$29,978
Planning & Research	$2,110	$1,751	$2,100
Highway Safety	$3,955	$5,752	$5,300
Bridge Replacement	$20,705	$21,225	$23,994
Emergency Relief	$4	$12	$--
Others	$8,990	$15,550	$7,134

Table 17: Expenditure of Federal Funds Administered by FHWA in Mississippi [63] [64] [65] (thousands of dollars)

	1989	1990	1991
Capital Outlays	$42,454	$--	$61,481
Maintenance	$6,365	$--	$5,369
Traffic Service	$47,570	$51,396	$42,615
Admin. & Police	$64,831	$59,529	$62,255
Bond Interest	$16,772	$15,444	$15,100
Grant-in-aid	$54,745	$57,905	$60,399
Bond Retirement	$15,850	$17,796	$30,149

Table 18: State Disbursements for Highway in Mississippi [63] [64] [65] (thousands of dollars)

	1989	1990	1991
Interstate	$25,933	$33,970	$13,777
Interstate Resurfacing	$77,187	$65,101	$82,827
Planning & Research	$3,889	$3,319	$3,796
Highway Safety	$6,219	$5,764	$11,924
Bridge Replacement	$54,581	$48,404	$40,890
Emergency Relief	$498	$1,871	$1,984
Others	$15,185	$23,325	$11,974

Table 19: Expenditure of Federal Funds Administered by FHWA in Tennessee [63] [64] [65] (thousands of dollars)

	1989	1990	1991
Capital Outlays	$154,342	$160,627	$95,691
Maintenance	$44,149	$51,042	$48,140
Traffic Service	$132,793	$153,489	$144,440
Admin. & Police	$135,465	$132,271	$126,296
Bond Interest	$2,055	$1,642	$1,237
Grant-in-aid	$216,017	$228,538	$223,624
Bond Retirement	$8,820	$8,820	$8,820

Table 20: State Disbursements for Highway in Tennessee [63] [64] [65] (thousands of dollars)

All the costs from the tables are next used to obtain the necessary cost data for equations (10) through (16). This yields a value for TTC_t as specified by equation (7). The determined TTC_t represents the total transportation cost for the individual state.

The determined TTC_t is then divided by the total ton-miles traveled per year by the trucking companies on the interstate highway system to obtain the true cost of transportation per ton-mile. In a mathematical representation, the true cost of transportation per ton-mile is, TTC_t / total ton-miles traveled per year. Given the weight of the commodity and the distance traveled, one can determine the true effective cost to transport goods.

Cost data for trucking companies is available only from 1989 to 1991. These data are used to determine TTC_t and true cost per ton-mile for these three years. The true cost per ton-mile for the remaining years of 1992 and 1993 was projected by using the least squares method suggested in Riggs [40]. The projected figures for the years 1992 and 1993 are summed with the figures for 1989, 1990 and 1991. Mean values over the five year period were determined. The reader should refer to Appendix A of reference [10a] for detailed computations.

	1989	1990	1991
Facilities Costs	$2,699,065	$2,978,628	$3,262,338
Equipment Costs	$8,293,777	$9,189,012	$11,127,110
Equip. Maint. Costs	$1,871,146	$1,491,724	$2,128,070
Transport Costs	$17,020,764	$16,844,705	$20,047,439
General Costs	$13,504,473	$13,920,462	$16,595,170
Ton-Miles Carried	$3.01 * 10^{11}$	$3.11 * 10^{11}$	$3.20 * 10^{11}$

Table 21: Trucking Companies' Expenditures (thousands of dollars) [5]

3. Truck Transportation Cost Computation (A Numerical Example)

This section illustrates the truck cost calculation procedure. An example is used to show how the equations work, and how data and information is extracted from Tables 8 through 21. As mentioned earlier, the calculation procedure is performed for each state for a given year. This example illustrates the analysis for the State of Alabama for 1989.

The first step of this calculation procedure is to determine all the allocation factors for the State of Alabama for 1989. As mentioned earlier, a is the allocation factor for the attributable cost for trucks. This is obtained by summing up the percent share of other single unit trucks (11.9%) and combination trucks (55.1%) in Table 8. This allocation factor remains the same for all three years in the analysis. The calculation for a is as follows:

$$a = 0.119 + 0.551 = 0.67$$

Allocation factor b is defined as the percentage of ton-miles carried by ICC regulated trucks. This is obtained by dividing the ton-miles carried by ICC regulated trucks by the total ton-miles carried by ICC and non-ICC regulated trucks. These numbers are published in *Transportation in America*, by Eno Transportation Foundation [48]. This allocation factor changes every year. The calculation is as follows:

$$b = 302 \text{ billion ton-miles} \div 716 \text{ billion ton-miles} = 0.422$$

Allocation factor c is defined as the percentage of interstate truck miles on total highway system. This is obtained by dividing the total truck miles traveled on interstate highway by the total truck miles traveled on all highways. These numbers are obtained from the publication, *Highway Statistics* [63]. This allocation factor also changes every year because the truck miles traveled changes every year. The calculation for this factor is as follows:

$$c = (67{,}628 \text{ million} + 67{,}078 \text{ million}) \div 605{,}456 \text{ million} = 0.223$$

Note: 67,628 million represents the truck miles traveled on urban interstate highways.
67,078 million represents the truck miles traveled on rural interstate highways.

Allocation factor *d* is defined as the percentage of interstate highway bridges on the total federal-aid highway systems. This allocation factor changes every year and varies from state to state. This is obtained by dividing the number of bridges on interstate highways by the total number of bridges on the federal-aid highways. These numbers are also obtained from the publication, *Highway Statistics* [63]. The calculation for this factor is as follows:

$$d = (604 + 554) \div 15437 = 0.075$$

Note: 604 represents the number of bridges on urban interstate highways.
554 represents the number of bridges on rural interstate highways.

Allocation factor *e* is defined as the percentage of non-attributable cost for trucks. This allocation factor is obtained by summing up the percent share of other single unit trucks (3.8%) and combination trucks (5.3%) from Table 9. This factor remains unchanged over the three years of this analysis (same as the allocation factor *a*). The calculation for this factor is as follows:

$$e = 0.038 + 0.053 = 0.091$$

Allocation factor *f* is defined as the percentage of interstate vehicle miles on federal-aid highway system. This allocation factor is obtained by dividing the vehicle miles traveled on interstate highways over the total vehicle miles traveled on federal-aid highway system. This allocation factor allocates federal expenditures to interstate highways. These numbers are obtained from the publication, *Highway Statistics* [63]. This factor changes every year and varies from state to state. The calculation for f is as follows:

$$f = 7{,}594 \text{ million miles} \div 30{,}842 \text{ million miles} = 0.246$$

Allocation factor g is defined as the percentage of interstate vehicle miles of all road systems. This allocation factor is obtained by dividing the vehicle miles traveled on interstate highways by the total vehicle miles traveled on all road system. This factor allocates some state expenditures to interstate highways. The numerical values are obtained from the publication *Highway Statistics* [63]. This factor changes every year and varies from state to state. The calculation for g is as follows:

$$g = 7{,}594 \text{ million miles} \div 40{,}765 \text{ million miles} = 0.186$$

The difference between allocation factor f and allocation factor g is the denominator in both allocation factors. The denominator in allocation factor f is the total vehicle miles traveled on federal-aid highway systems. The denominator in allocation factor g is the total vehicle miles traveled on all road systems, which includes all federal-aid road systems and state funded road systems.

Allocation factor h is defined as the percentage of trucking companies' cost allocated per state. This allocation factor is obtained by dividing the total public road mileage in each state by the total public road mileage in the nation. These numbers are again obtained from the publication *Highway Statistics* [63]. This allocation factor changes every year and varies from state to state. The calculation for h is as follows:

$$h = 90{,}672 \text{ miles} \div 3{,}880{,}151 \text{ miles} = 0.0234$$

The data presented in Table 20 represents the figures for the entire nation's ICC regulated trucking companies. The second step of this calculation procedure is to apply these allocation factors to equations (7) through (16). The data used in this calculation is extracted from Tables 11, 12, and 20. The following are the calculation examples for equations (7) through (16).

FC_t = 0.67 * 0.422 * ($119,314,000 + $198,349,000) + 0.223 * 0.0234 * ($2,699,065,000)
= $104,325,970

$119,314,000 is federal expenditures on facilities on Alabama's interstate highways in 1989, and $198,349,000 is state expenditures on facilities on Alabama's highway systems in 1989. Both these numbers are extracted from Table 11 and Table 12 according to the classification in Table 10. $2,699,065,000 is the trucking companies' expenditures on facilities in 1989, and this number is extracted from Table 21.

EC_t = 0.223 * 0.0234 * ($8,293,777,000)
= $43,278,590

$8,293,777,000 is the trucking companies' expenditures on equipment in 1989. This number is extracted from Table 21.

FMC_t = 0.67 * 0.422 * ($56,676,000 + $23,573,000) + 0.67 * 0.422 * 0.075 * ($49,516,000)
= $23,852,130

$56,676,000 is the federal expenditures on facilities maintenance on Alabama's interstate highway in 1989, and $23,573,000 is state expenditures on facilities maintenance on Alabama's highway systems in 1989. Both these numbers are extracted from Table 11 and Table 12 according to the classification in Table 10. $49,516,000 is the federal expenditures on bridge maintenance on Alabama's interstate highway in 1989. This number is extracted from Table 11.

EMC_t = 0.223 * 0.0234 * ($1,871,146,000)
= $9,764,010

$1,871,146,000 is the trucking companies' expenditures on equipment maintenance in 1989. This number is extracted from Table 21.

TC_t = 0.223 * 0.0234 * ($17,020,764,000)
= $88,817,750

$17,020,764,000 is the trucking companies' expenditures on transport costs in 1989. This number is extracted from Table 21.

TRC_t = 0.091 * 0.424 * 0.246 * ($6,802,000) + 0.091 * 0.424 * 0.186 * ($111,707,000 + $84,707,000)
= $1,469,570

$6,802,000 is federal expenditures on traffic on Alabama's highway systems in 1989. This number is extracted from Table 11 according to classification in Table 10. $111,707,000 and $84,707,000 are state expenditures on traffic on Alabama's highway systems in 1989. Both these numbers are extracted from Table 12 according to classification in Table 10.

GC_t = 0.091 * 0.424 * 0.246 * ($4,120,000 + $751,000) + 0.091 * 0.424 * 0.186 * ($13,829,000 + $180,232,000 + $93,875,000) + 0.223 * 0.0234 * ($13,504,473,000)
= $72,579,770

$4,120,000 and $751,000 are federal expenditures on general costs on Alabama's highway systems in 1989. These numbers are extracted from Table 11 according to classification in Table 10. $13,829,000, $180,232,000 and $93,875,000 are state expenditures on general costs on Alabama's highway systems in 1989. All these numbers are extracted from Table 12 according to classification in Table 10. $13,504,473,000 is the trucking companies' expenditures on general costs in 1989. This number is extracted from Table 21.

$$
\begin{aligned}
TTC_t &= CC_t + OC_t \\
&= FC_t + EC_t + FMC_t + EMC_t + T_{Ct} + TRC_t + GC_t \\
&= \$104{,}324{,}970 + \$43{,}278{,}590 + \$23{,}852{,}130 + \$9{,}764{,}010 + \$88{,}817{,}750 + \\
&\qquad \$1{,}469{,}570 + \$72{,}579{,}770 \\
&= \$334{,}086{,}790
\end{aligned}
$$

The third step of the calculation is to determine the portion of ton-miles carried for Alabama in 1989. The data used in this calculation is obtained from Table 21. Below is the procedure and equation for this calculation.

$$\text{Ton-Miles Carried for each state} = c * h * \text{Ton-Miles Carried}$$

(17)

$$
\begin{aligned}
\text{Ton-Miles Carried for Alabama in 1989} &= 0.223 * 0.0234 * 3.01 * 10^{11} \\
&= 1{,}570{,}678{,}200
\end{aligned}
$$

$$
\begin{aligned}
\text{Cost per ton-mile} &= TTC_t \div \text{Ton-Miles Carried} \\
&= \$334{,}086{,}790 \div 1{,}570{,}678{,}200 \\
&= \$0.213
\end{aligned}
$$

$3.01 * 10^{11}$ is the ton-miles of freight carried by ICC trucking companies in 1989. This number is extracted from Table 21.

B. Barge Transportation

There is probably no field of transportation that has a greater dearth of data and studies of economic analysis than barge transportation. In order for a waterway to be navigable, facilities such as canals, lock and dams, and ports are needed. The funds to develop these facilities come from both the federal and state government and also from private businesses. The functions of waterways and canals are not solely for freight navigation purposes, they are also used for flood control, drinking water, power generation, and recreation.

1. Barge Transportation Cost Model

The cost equations for barge transportation are:

$$TTC_b = CC_b + OC_b \tag{18}$$

$$CC_b = FC_b + EC_b \tag{19}$$

$$OC_b = FMC_b + EMC_b + TC_b + TRC_b + GC_b \tag{20}$$

where,

CC_b (Capital Cost) -- Costs of providing initial plant and equipment and additions to or betterment of those facilities in waterway transportation, such as ports construction and canal construction.

OC_b (Operating Cost) -- Costs of providing transportation services in waterway transportation.

FC_b (Facilities Cost) -- Investment in routes, structures, and terminals in waterway transportation.

EC_b (Equipment Cost) -- Investment in vehicles in waterway transportation, such as tow boats and barges.

FMC_b (Facilities Maintenance Cost) -- Costs of maintaining rivers and harbors, channels and dams, etc.

EMC_b (Equipment Maintenance Cost) -- Costs of maintaining motive power and rolling stock, such as tow boats.

TC_b (Transport Cost) -- Costs of conducting transportation, such as power and fuel, wages of vehicle crew, wages of those directing vehicle movements in waterway transportation.

TRC_b (Traffic Cost) -- Costs of traffic solicitation, advertising, publishing rates and tariffs, and administration in waterway transportation.

GC_b (General Cost) -- Costs of general office expenses, legal advice, accounting, and salaries of general officers and staffs in waterway transportation.

The focus of this analysis is on cost allocation on multiple purpose projects for rivers and other inland waterways. The cost distribution guideline defined in the Water Resources Development Act of 1985 [50] has been used to prorate these projects. In the guideline, 35% of costs on irrigation/navigation projects are allocated to navigation. The same cost allocation factor applies to flood control/navigation projects. The cost distribution for recreation/navigation projects is 50/50. Under the same guideline, 100% of the costs for hydroelectric and water supply projects are solely for their own purposes.

2. Barge Transportation Cost Data

Cost information for the categories previously defined has been extremely difficult to extract from the literature, to date. The investigators have worked closely with the Arkansas Waterways Commission to identify sources of cost information that have been published by the Army Corps of Engineers. All the cost information used in this analysis has been provided by the Institute of Water Resources, Water Resources Support Center of The U.S. Army Corps of Engineers [14,15].

The resultant cost model for barge transportation is similar to the other cost models. As mentioned earlier, the allocation factors separate the commercial navigation users' cost responsibilities from other users. This task was found to be unnecessary as the cost data provided by the Institute of Water Resources [14] on the waterways had been separated by user category. The data used is solely for navigation purposes. The data provided by the Institute of Water Resources applies only for fiscal year 1994.

Table 22 shows all the cost data used in this analysis to determine the true cost of water freight transportation. Note that in Table 22, Facilities Costs and Facilities Maintenance Costs are combined into one cost category. These costs are the government contributions to the waterway infrastructures. The data in Table 22 is for 1994.

Facilities Costs & Facilities Maint. Costs	$152,937.4
Equipment Costs	$1,379,755.92
Equipment Maintenance Costs	$305,468.7
Transport Costs & Traffic Costs	$1,438,004.2
General Costs	$345,117.58
Ton-Miles Carried	$239 * 10^9$

Table 22: Total Costs for Tow-Boats, Barges, and Government Expenditures on Waterways for 1994 (thousands of dollars) [14] [15]

3. Barge Transportation Cost Computation (A Numerical Example)

This section illustrates the waterway cost calculation procedure. An example is used to show how the equations work, and how cost information is extracted from Table 22. As mentioned earlier, the data provided by the Institute of Water Resources are data compiled for the entire Mississippi River and its tributaries, and Gulf Intracoastal Waterways. It is virtually impossible to factor them out on a per state basis. Therefore, this analysis calculates the cost on the system wide basis.

No allocation factor is required in this calculation as the cost data provided is solely attributable to navigation. The first step in this calculation is to extract the cost data from Table 22 and insert the data into equations (18) through (20). The calculation for equations (18) through (20) are presented as follows:

$$TTC_b = CC_b + OC_b$$

$$= FC_b + EC_b + FMC_b + EMC_b + TC_b + TRC_b + GC_b$$

$$= \$152,937.4 + \$1,379,755.92 + \$305,468.7 + \$1,438,004.2 + \$345,117.58$$

$$= \$3,621,283.8 * 10^3$$

The second step of the calculation is to determine the cost per ton-mile for water transportation. The data used in this step came from Table 22 and the previous calculation.

Ton-Miles Carried = $239 * 10^9$ (from last row in Table 22)

Cost per ton-mile = $TTC_b \div$ Ton-Miles Carried

$$= \$3,621,283,800 \div 239 * 10^9$$

$$= \$0.015$$

C. Rail Transportation

The construction and maintenance of railroad transportation routes are carried out solely by the respective operators. Costs involved in the operation include roadbeds, bridges, crossing, right of ways, etc. There are no government contributions to the railway infrastructures for freight services. The federal government's contribution to railroads is mainly for Amtrak and Northeast Corridor Project. Since our analysis addresses costs only for the transportation of freight, it can be assumed that the total cost incurred by the operators in providing the service has a direct indication of the true cost of transportation in rail services. Therefore, the method of analysis is the most straightforward of the four transportation modes being analyzed.

1. Rail Transportation Cost Model

The cost model for rail services derived from the base cost model is defined as:

$TTC_r = CC_r + OC_r$

(21)

where,

$CC_r = a * (FC_r + EC_r)$

(22)

$OC_r = a * (FMC_r + EMC_r + TC_r + TRC_r + GC_r)$

(23)

a = % of track miles per state

CC_r (Capital Cost) -- Costs of providing initial plant and equipment and additions to or betterment of those facilities in rail transportation, such as railroad track construction.

OC_r (Operating Cost) -- Costs of providing transportation services in rail transportation.

FC_r (Facilities Cost) -- Investment in routes, structures, and terminals in rail transportation.

EC_r (Equipment Cost) -- Investment in vehicles in rail transportation, such as locomotives, box cars, etc.

FMC_r (Facilities Maintenance Cost) -- Costs of maintaining railroad track, etc.

EMC_r (Equipment Maintenance Cost) -- Costs of maintaining motive power and rolling stock, such as locomotive and box cars.

TC_r (Transport Cost) -- Costs of conducting transportation, such as power and fuel, wages of vehicle crew, wages of those directing vehicle movements in rail transportation.

TRC_r (Traffic Cost) -- Costs of traffic solicitation, advertising, publishing rates and tariffs, and administration in rail transportation.

GC_r (General Cost) -- Costs of general office expenses, legal advice, accounting, and salaries of general officers and staff in rail transportation.

The only cost allocation question in our analysis is the share of passenger service compared to the share of freight service. The unit of measurement in the railway cost allocation analysis is the amount of cost attributable to each type of service. Traditional units like ton-miles or passenger-miles are not an appropriate allocation factors. Both units reflect only the attributes of one type of service. Ton-miles reflects the freight service while passenger-miles reflects the passenger service.

2. Rail Transportation Cost Data and Allocation Procedure

Tables 23 shows the data used in the analysis of rail transportation cost. The source of the data is the annual report of the Interstate Commerce Commission [24]. The annual report shows both freight expenditures and passenger expenditures. Therefore, it is only necessary to include the freight expenditures in this analysis. Each cost category in the railroad companies' operating data is fitted into the base cost model to determine the actual cost of providing rail services. Mean values of a five year period are again determined. The reader should refer to Appendix A of reference [10a] for detailed computations. Table 23 below represents the data used in the calculations of true transportation cost for railways.

	1989	1990	1991
Total Passenger Expenditures	$125,735,000	$127,328,000	$140,105,000
Total Freight Expenditures	$24,911,931,000	$24,524,214,000	$27,921,082,000
Total Operating Expenditures	$25,037,666,000	$24,651,542,000	$28,061,187,000
Total Ton-Miles Carried	2,128,275,904,000	2,185,006,708,000	2,150,235,017,000
Total Track Miles Operated	138,006	133,189	129,672

Table 23: Railway Expenditures and Traffic Data [24,25,26]

3. Rail Transportation Cost Computation (A Numerical Example)

An illustration of the railway cost calculation procedure is presented in this section. It shows how data and information is extracted from Table 23, and how the equations work. As mentioned earlier, the method of analysis for railway is the most straightforward of the four transportation modes being analyzed. The illustration below demonstrates the procedure for the analysis for the State of Arkansas in 1989.

The first step of this calculation is to determine all the allocation factors for the State of Arkansas in 1989. Allocation factor a is defined as the percentage of track miles per state. This is obtained by dividing the number of track miles in each state by the total number of track miles in the nation. The number of track miles for each state in this analysis is obtained from

MapInfo, the mapping software used in this project. Table 24 shows the track miles operated in each state. The calculation for *a* is as follows:

$$a = 3{,}195.48 \text{ miles} \div 138{,}006 \text{ miles} = 0.0232$$

	Alabama	Arkansas	Louisiana	Mississippi	Tennessee
Track Miles Operated	3548.29	3195.48	3194.69	3091.4	2340.03

Table 24: Track Miles Operated in Each State

The next step in the calculation procedure is to apply the allocation factor to equations (21) through (23). All cost components in the equations have the same allocation factors. Therefore, they are combined into equation (21). The calculation for total transportation cost for railroads is as follows:

$$TTC_r = a * (FC_r + EC_r + FMC_r + EM_{Cr} + TC_r + TRC_r + GC_r)$$

$$= 0.0232 * (\$24{,}911{,}931{,}000)$$

$$= \$576{,}826{,}929.8$$

$24,911,931,000 represents the total freight expenditures incurred by railroad companies in 1989. This number is extracted from Table 23 under total freight expenditures.

The third step in this calculation is to determine the portion of ton-miles carried for Arkansas in 1989. The data used in this calculation is obtained from Table 23. Below is the procedure and equation for this calculation.

$$\text{Ton-Miles Carried for each state} = a * \text{Ton-Miles Carried}$$

$$\text{Ton-Miles Carried for Arkansas in 1989} = 0.0232 * 2{,}128{,}275{,}904{,}000 \text{ ton-miles}$$
$$= 49{,}376{,}000{,}970 \text{ ton-miles}$$

Cost per ton-mile = TTC_r ÷ Ton-Miles Carried

= \$576,826,929.8 ÷ 49,376,000,970 ton-miles

= \$0.0117 per ton-mile

Note that in this analysis, allocation factor *a* is used in both numerator and denominator of cost per ton-mile calculation. Both allocation factors cancel out each other. Therefore, cost per ton-miles can be calculated directly from dividing the total freight expenditures by the total ton-miles carried. Because of the lack of information on ton-miles for freight carried by each state, every state will have the same cost per ton-mile.

D. Air Transportation

The cost responsibilities of air freight are distributed to all cargo carriers and combination carriers. This procedure presented in this section determines the portions of cost to be attributed to all cargo carriers and combination carriers. In 1966, Civil Aeronautics Board (CAB) implemented Form 242 in an attempt to determine cost of all-cargo operations for combination and all-cargo carriers [11]. The cost formulas from this form were applied by the Civil Aeronautics Board (CAB) to the airlines' annual reports to the Board. All carriers are required to submit their operating expenses and other financial statistics in accordance with the Board's Uniform System of Accounts and Reports (Form 41).

1. Cost Allocation Procedure

In reference to the cost formulas of Form 242, we have applied the following allocation factors to the cost items reported in the *Air Carrier Financial Statistics* [54,55]. The allocation factor was generated from the information and data provided in the *Air Carrier Traffic Statistics* [56,57].

Cost Items	Allocation Factor
Aircraft & Traffic Servicing Transport Related Promotion & Sales General & Administration Depreciation and Amortization Maintenance Flying Operation	# of revenue ton-miles of freight / # of total revenue ton-miles

Table 25: Allocation Factor for Air Carriers

Only the primary and commercial service airports reported in *National Plan of Integrated Airport Systems* [67] are considered in our analysis. The Air Transport Association's (ATA) adjusted relative percentage of use by the different groups is used in this analysis instead of the finding from the 1966 FAA report [49]. The comparative percentages from each report are compared below.

	ATA's Report	FAA's Report
Air carrier	35.4%	44.6%
General aviation	23.2%	29.3%
Military	41.4%	26.1%

The reason for not choosing the FAA report is because it fails to assign sufficient weight to the paramount claim of the military on the airways system. The military use of the airways has some extraordinary characteristics. There are special services provided to military users of the airways by FAA. Among these special services are the "Restricted Airspace" for military activities, which are prohibited to civil aviation users, and the "priority" in the use of the airways. All the government uses of the airways were classified under military uses. Many of them are either government users or non-public users, such as VIP flights and flights by the FAA, which owns over 100 aircraft. Many of these operations have been lumped, improperly, into the general aviation category.

2. Air Transportation Cost Model

The modified cost model for air transportation is defined as:

$TTC_a = CC_a + OC_a$

(24)

where,

$CC_a = FC_a + EC_a$

(25)

$OC_a = FMC_a + EMC_a + TC_a + TRC_a + GC_a$

(26)

where,

$FC_a = a * b * c *$ (Government Expenditures)

(27)

$EC_a = a * d *$ (Air Carrier Expenditures)

(28)

FMC_a = embedded in FC

$EMC_a = a * d *$ (Air Carrier Expenditures)

(29)

$TC_a = a * d *$ (Air Carrier Expenditures)

(30)

$TRC_a = a * d *$ (Air Carrier Expenditures)

(31)

$GC_a = a * d *$ (Air Carrier Expenditures)

(32)

where,

a = % of freight revenue ton-miles over total revenue ton-miles (Amount of freight revenue ton- miles carried over the total amount of revenue ton-miles carried.)

b = % of aircraft activity per state (airport traffic control towers) (Amount of flights in each state over the total amount of flights in the nation.)

c = % of air carrier traffic at FAA facilities (Airport traffic control towers. Amount of air carrier flights over the total amount of flights in the nation.)

d = % of freight activity per state (Amount of freight tonnage enplaned in each state over the total amount of freight tonnage enplaned in the nation.)

where,

CC_a (Capital Cost) -- Costs of providing initial plant and equipment and additions to or betterment of those facilities, such as airports, airways, aircraft, etc.

OC_a (Operating Cost) -- Costs of providing transportation services.

FC_a (Facilities Cost) -- Investment in routes, structures, and terminals in air transportation.

EC_a (Equipment Cost) -- Investment in vehicles in air transportation.

FMC_a (Facilities Maintenance Cost) -- Costs of maintaining runways and lighting in airports, airways, etc.

EMC_a (Equipment Maintenance Cost) -- Costs of maintaining motive power and rolling stock, such as airplanes in air transportation.

TC_a (Transport Cost) -- Costs of conducting transportation, such as power and fuel, wages of vehicle crew, wages of those directing vehicle movements in air transportation.

TRC_a (Traffic Cost) -- Costs of traffic solicitation, advertising, and publishing rates and tariffs in air transportation.

GC_a (General Cost) -- Costs of general office expenses, legal advice, accounting, and salaries of general officers and staffs in air transportation.

The allocation factor to determine the portion of government expenditures on airports and airways per state is expressed as the ratio of the amount of air traffic activity for each state over the total amount of air traffic activity in the nation. The allocation factor to determine the portion of commercial activity in airports and airways is the ratio of number of commercial air carrier traffic activity at FAA facilities in a given state over the total number of air traffic activity at FAA facilities. It is realized that this allocation factor may not accurately reflect the actual cost responsibility of commercial carriers on airport costs. However, we feel that this is the best approximation possible due to the difficulty in obtaining more detailed cost data and information from the existing publications.

The allocation factor for determining the freight cost from the total commercial carriers costs is the ratio of number of freight revenue ton-miles enplaned over the total revenue ton-miles enplaned. Percentage of tonnage of freight enplaned in each state over the total tonnage of freight enplaned in the nation is the allocation factor used to prorate each state's portion of air carrier expenditures and ton-miles traveled.

As a general rule in this analysis, all the data has been collected for a five year period. In the event where data was not available for all five years, data from the most recent three years was collected. A linear regression model is used to determine the missing figures for the remaining two years. The true cost of air transportation is determined by averaging the annual TTC_a per ton-miles over the five year period. The annual TTC_a per ton-mile is calculated by the diving the annual TTC_a by the annual ton-miles of freight carried. See Appendix A of reference [10a] for detailed computations.

3. Air Transportation Cost Data

Table 26 shows the data used in analyzing and estimating the air transportation cost. The data sources are *Air Carrier Financial Statistics* [54,55] and *Air Carrier Traffic Statistics* [56,57].

	1989	1990	1991
Air Carrier Operating Expenditures	$52,260,462	$58,983,238	$56,691,260
Government Expenditures on Airways and Airports	$11,017,000	$13,007,000	$14,570,000
Freight Revenue Ton-Miles Carried	7,526,736	7,581,718	7,372,445
Total Revenue Ton-Miles Carried	42,456,749	43,654,404	42,536,364

Table 26: Financial and Traffic Data for Air Transportation [54,55,56,57] (amounts in thousands)

4. Air Transportation Cost Computation (A Numerical Example)

Following is an example to illustrate how equations (24) through (32) work and how the data in Table 26 were extracted for the analysis. The calculation procedure here is similar to analyses for other transportation modes. It is performed for each state and for individual year. This example illustrates the analysis for the State of Tennessee for 1989.

The first step of this calculation procedure is to determine all the allocation factors for the State of Tennessee for the year 1989. As mentioned earlier, a is defined as the percentage of freight revenue ton-miles carried. This is obtained by dividing the freight revenue ton-miles carried by the total revenue ton-miles carried shown on Table 26. This allocation factor is the same for all the states but varies from year to year. See Appendix C of Reference [10a] for allocation factors for 1990 and 1991. The calculation for a is as follows:

$$a = 7{,}526{,}736 \text{ revenue ton-miles} \div 42{,}456{,}749 \text{ revenue ton-miles}$$
$$= 0.177$$

Allocation factor b is defined as the percentage of air traffic activity per state. This is obtained by dividing the amount of air traffic in each state by the total amount of air traffic in the nation. These numbers are obtained from the *FAA Statistical HandBook of Aviation* [60]. This factors vary every year and from state to state. See Appendix C of Reference [10a] for allocation factors for 1990 and 1991. The calculation for b is as follows:

$$b = 961{,}716 \text{ flights} \div 61{,}345{,}173 \text{ flights} = 0.016$$

The allocation factor c is defined as the percentage of air carrier traffic at FAA facilities. This is obtained by dividing the amount of air carrier traffic by the total amount of aircraft traffic. These values are obtained from the *FAA Statistical HandBook of Aviation* [60]. This factor varies only from year to year. See Appendix C of Reference [10a] for allocation factors for 1990 and 1991. The calculation for c is as follows;

c = 20,816,616 flights ÷ 61,299,017 flights = 0.3393

The allocation factor d is defined as the percentage of freight activity for each state. This is obtained by dividing the freight tonnage enplaned for each state by the total freight tonnage enplaned in the nation. These parameters are obtained from the *FAA Statistical HandBook of Aviation* [60]. This factor varies annually and from state to state. See Appendix C of Reference [10a] for allocation factors for 1990 and 1991. The calculation for d is as follows:

d = 601703.12 tons ÷ 3967009.7 tons = 0.1517

The next step is to calculate the true cost of transportation using equations (27) through (32) by applying these allocation factors with data extracted from Table 26. Note that equations (28) through (32) have the same allocation factors and cost components. Therefore they are combined with equation (27) into equation (24). Following are the examples of the calculation for equation (24).

TTC_a = 0.177 * 0.016 * 0.3393 * ($11,017,000,000) + 0.177 * 0.1517 * ($52,260,462,000) = $1,413,826,648

The next procedure in the calculation is to determine the ton-miles carried in the State of Tennessee in 1989. The data used in this calculation is obtained from Table 26.

Ton-Miles Carried for each state = d * Ton-Miles Carried

(33)

Ton-Miles Carried for Tennessee in 1989 = 0.1517 * 7,526,736,000 ton-miles
= 1,141,805,851 ton-miles

Cost per Ton-Miles = TTC_a ÷ Ton-Miles Carried

= $1,413,826,648 ÷ 1,141,805,851

$= \$1.238$ per ton-mile

VII. Results of Cost Analysis

A. Data Collection

An interim report on this project was submitted to the grantor in the Spring of 1994. Since then, data collection has been successful, considering the limited of number of viable literature sources available. All data needed were gathered by the investigators for a complete analysis.

For highway/truck transportation, the data include the expenditures by federal and state government on interstate highway system, and operating data from ICC regulated trucking companies for the period 1989 to 1991. Data collection for barge transportation has proven to be a very formidable task. A great deal of effort has been expended in trying to aggregate government expenditures on inland waterways system. There are no federal regulatory agency such as the ICC for truck and rail transportation. Data for waterway analysis were gathered from the Institute of Water Resources.

The data collection for rail transportation has focused only on ICC Class I railroad company. Data has been aggregated for twelve Class I railroad companies over a period from 1989 to 1991. This data has been published by ICC on its annual report [24]. Operating data for commercial air carriers was compiled from literature published by the Department of Transportation's Research and Special Programs Administration [54]. These carriers include all-cargo carriers and combination carriers from the carrier groups classified as majors, nationals, large regional, and medium regional. The applicable period is from 1989 to 1991. Annual government expenditures on the entire national airways are available. Unfortunately, this information is not tabulated on a state-by-state basis. Government allocation for expenditures on airports are available only on an airport-by-airport basis.

Transportation cost analysis software (described later) is now available. This software allows the user to estimate and input the required cost parameters. The software contains complete data for all transportation modes.

B. True Transportation Costs Generated from Analysis

The true transportation costs in terms of cost per ton-mile for truck, barge, rail, and air transportation are summarized in this section.

1. Truck Transportation

The true (societal) cost of providing truck transportation service determined from the developed methodology is presented in Table 27. Values presented are averages for the five states obtained from the data in Appendix A of Reference [10a].

State	**True Cost of Transportation**
Alabama	$0.215 per ton-mile
Arkansas	$0.177 per ton-mile
Louisiana	$0.278 per ton-mile
Mississippi	$0.183 per ton-mile
Tennessee	$0.211 per ton-mile

Table 27: Societal Costs of Truck Transportation by State

2. Barge Transportation

Barge transportation costs are indicated for all states and are summarized below.

State	True Cost of Transportation
Alabama	$0.015 per ton-mile
Arkansas	$0.015 per ton-mile
Louisiana	$0.015 per ton-mile
Mississippi	$0.015 per ton-mile
Tennessee	$0.015 per ton-mile

Table 28: Societal Costs of Barge Transportation by State

3. Rail Transportation

The true cost of providing rail transportation service in terms of cost per ton-mile using our methodology are summarized in Table 29. Values are averages for all states as previously described.

State	True Cost of Transportation
Alabama	$0.0115 per ton-mile
Arkansas	$0.0115 per ton-mile
Louisiana	$0.0115 per ton-mile
Mississippi	$0.0115 per ton-mile
Tennessee	$0.0115 per ton-mile

Table 29: Societal Costs of Rail Transportation by State

4. Air Transportation

The true cost air freight transportation in terms of cost per ton-mile determined by the analysis are presented in Table 30. Entries shown are averages over the five states obtained from the data in Appendix A of Reference [10a].

State	True Cost of Transportation
Alabama	$1.813 per ton-mile
Arkansas	$4.812 per ton-mile
Louisiana	$1.785 per ton-mile
Mississippi	$6.712 per ton-mile
Tennessee	$1.367 per ton-mile

Table 30: Societal Costs of Truck Transportation by State

VIII. Software Development

A. Introduction

The following sections present a detailed description of the development of interactive cost analysis software for different transportation modes. The Cost Assessment of Intermodal Transportation Linkages software (CAITL) has been written in a Windows environment. The Windows environment was chosen because of the growing popularity of Windows.   The CAITL software has been loosely tied to MapInfo [32], a commercial software package for creating maps. MapInfo serves as the graphical representation of the transportation networks and as a useful tool for extracting the distance between two cities or places.

The Cost Assessment of Intermodal Transportation Linkages (CAITL) software serves as the fundamental tool for the user to determine both the published and societal costs for each of the transportation modes. The ultimate goal of the CAITL software is to offer the user the option of combining and evaluating the different combinations of transportation modes in order to determine the minimum transportation cost between two points.

B. Tools Used in CAITL Software Development

The tools used in the development of the CAITL software are as follows: MapInfo – for the visualization of the maps, Visual BASIC – for the development of the cost analysis software, and MapBasic – for the automation of some cumbersome MapInfo procedures.   These tools are described in more detail in the subsections that follow.

1. MapInfo

MapInfo [32], a powerful analytical resource, offers a variety of digital maps. These maps contain data for streets, railroads, waterways, and airports for most of the seven continents. One of the digital maps available for MapInfo is StreetInfo™. StreetInfo™ includes streets, street names, highways, highway names, and water boundaries for the U.S.. Another digital map, Airports-Basic, is available for MapInfo and contains information on over 17,000 airports in the U.S. and outlying territories.

MapInfo also includes data files containing the facility name, type of facilities (airport, heliport, seaplane port, etc.) and field coordinates. Railroad-Map is a file contained in MapInfo which includes U.S. railroads for the 48 contiguous states.

There is a technical software package called American Digital Cartography (ADC) WorldMap available for MapInfo. ADC WorldMap is a digital chart of the entire world and is considered to be the most detailed set of world-wide data available as well as the most comprehensive seamless set of data for North America. There are 17 primary layers of information and a MapBasic application which assists the user in loading the information. These layers include roads, railroads, utilities (pipelines, power lines), airports, rivers and lakes, bridges, tunnels, etc.. MapInfo allows a user to zoom in to see the areas of interest and also allows an attachment of a user data to any object on a map. MapInfo's drawing tools enable the user to draw delivery routes, defined regions, etc..

MapInfo can directly read and query on dBASE, delimited ASCII, Lotus, and Excel files. MapInfo has other tools that might be very useful to the user. These include:

- MapCode - A programming language for DOS.

- MapBasic - A programming language for windows, Macintosh, Sun and HP.

- Real Time MapInfo - a direct serial communication with DOS applications to track many objects and monitor changing status at remote sites.

Many MapInfo users have concluded that this software is a very powerful and useful tool in handling data visualization and analysis. It has received high ratings by publications such as *PC Magazine*, *Windows Magazine, MacUser* and *American Demographics Magazine*.

2. Visual Basic

Visual BASIC could be considered the pioneer of the visual programming language group. The idea behind the visual programming move was to take the programmer away from the detail of developing interface. Furthermore, the visual languages in general cause more standardized interfaces to be developed by the programmer.

The standardized interfaces come about because the visual programming languages offer a tool kit filled with standard Windows tools. Some of the standard tools available for Visual Basic are text boxes, list boxes, combination boxes, windows, buttons, and even pull-down menus. The items contained in the tool bar can be placed on the screen by simply double clicking the item on the tool bar.

Visual BASIC also offers a set of very powerful Windows commands or utilities. For example, the Dynamic Data Exchange (DDE) command can be used for transferring data from one Windows application to another.

3. MapBasic

MapInfo has its own programming language called MapBasic [32]. MapBasic is designed to work with MapInfo. It is a structured, BASIC-like language that enables both seasoned and novice programmers alike to create powerful new desktop mapping applications. MapInfo concepts are embedded in this language. MapBasic contains a set of Structured Query Language (SQL) functions that can be used to access MapInfo data or Data Sets. Other useful applications that MapBasic offers to the user are as follows:

- Create custom MapInfo applications
- Perform sophisticated geographic SQL queries.
- Create custom menus and dialog boxes with Title Option, Buttons, Pop-up menus, etc..
- Automate repetitive operations, and much more.

MapBasic is a complete programming language built around the MapInfo Graphical User Interface (GUI) products (Windows, Macintosh, Sun, HP, and Intergraph). It is a fundamental software design that significantly enhances productivity when creating custom desktop mapping applications. Compiled MapBasic applications are completely portable across all GUI platforms, while protecting the original source code. With MapBasic, applications can be created on one platform and run on all other GUI platforms without changes to the original program. SQL commands can be incorporated into MapBasic programs to automate powerful new geographic extensions such as Within, Intersects, and Contains. MapBasic contains complex relational database queries that can be performed with just one command. For example, queries can be made to select all states that intersect a specific highway. MapBasic has a geographic analysis tool that enables the user to add graphical objects to maps, create buffers, find perimeters and distances.

In the Microsoft Windows environment, both MapBasic and MapInfo support Dynamic Data Exchange (DDE) conversations, which allow other Windows programs to communicate with MapInfo and also enable MapBasic applications to communicate directly with other Windows applications. For example, an Excel macro can send a ZIP Code taken from a spreadsheet cell to MapInfo to determine which territory the ZIP Code resides in. The territory can be read back to Excel.

C. System Requirements

This section presents the requirements for executing the developed software. The software has been designed to be executed on a personal computer. The hardware requirements for executing the software include:

- A hard disk with at least 150 megabytes
- A mouse or pointing device compatible with mouse or supported by Microsoft Windows
- A graphics quality super VGA monitor
- Microsoft (MS) - or PC-DOS, version 3.1 or higher
- Microsoft Windows 3.1 or higher, running in standard or enhanced mode
- At least 8 MB of RAM (Random Access Memory)
- A CD ROM disk device

D. Software Architecture

The CAITL software has been designed to interface transparently with MapInfo. Data exchanges are accomplished with MapInfo without any physical modification of the MapInfo software. The architecture of CAITL is overviewed in the subsections that follow.

1. Data Files

CAITL requires the initial structuring of two separate data files. These are described in the subsections that follow.

a. Time constraints Data File

The time constraints data file contains the time constants associated with each transportation mode. The data file contains four fields. These fields include transportation mode, time traveled per day, average velocity, and distance traveled per day. There are four transportation modes included in the study. These transportation modes are airplane, barge, rail, and truck.

The other three fields in the data file are very much related because the user enters the time traveled per day and the average velocity. Once these two parameters have been entered, the program calculates the distance traveled per day. The reader should note that the program does not do any dimensional checking. Therefore, the user should enter the same units for all related items. For example, if the user enters the velocity in miles per hour, then all distance related items should be entered in miles.

The parameters currently residing in the time constraints data file are reasonable estimates made by the authors. The parameter values are presented in Table 31.

Mode	Traveled Time / Day in Hours	Average Velocity in Miles / Hour.	Distance Traveled/ Day in Miles
Air Traffic	6	300	1800
Highway	10	60	600
Railroad	20	40	800
Water Way	20	5	100

Table 31: Time Constraints

The discussion of how to enter, change, and delete data in the time constraints data file is presented later in this report when the software execution procedure is described.

b. Transportation Rates Data File

The transportation rates data file contains both commercially published and societal cost data. The data file contains an identification field and four numbers. The identification field is the name of the state being analyzed (Arkansas, Louisiana, etc.) for the societal cost data and the word "published" for the published cost data. The four numerical values correspond to the four transportation modes included in the study. These transportation modes are airplane, barge, rail, and truck.

The cost data currently residing in the rates data file can be obtained from various tables: Table 27 which contains the societal cost data for truck, Table 28 which contains the societal cost data for barge transportation, Table 29 which contains the societal cost data for rail transportation, and Table 30 which contains the societal cost data for air transportation. The societal cost is the amortization of all costs associated with each transportation mode. These cost are amortized to result in a true (societal) weight/volume per unit distance for each transportation mode. The procedure for societal cost determination for each mode has been described earlier in this report.

If published cost data records are present, they are always the first record in the file. The societal cost data is in alphabetical order by state following the published cost data. A discussion of how to enter, change, and delete data in the transportation rates data file is presented later in this report when software execution procedures are described.

2. Distance Calculation

The procedure for calculating the distance between two cities or places requires the use and software interface with MapInfo. MapInfo serves as the graphical representation of the geographic region as well as providing a methodology for calculating distances. The study has defined the geographic region to include Alabama, Arkansas, Mississippi, Louisiana, and Tennessee.

The distance can be calculated by performing either an SQL-select command or a Simaut.mbx command. The specifics of how to use these commands is discussed in the MapInfo tutorial presented later in this report. The Simaut.mbx is an automation of the SQL-select command. The Simaut.mbx is a MapBasic function which has the SQL-select command embedded in the code.

Once the distance has been obtained from MapInfo, the software interface transfers the data to the CAITL software. A design decision was made not to hard link MapInfo with the CAITL. This was primarily to avoid copyright and royalty complications in the event the finished package has widespread use among transportation practitioners. The developed interface is thus completely transparent and will allow future users to use CAITL directly with MapInfo as it is purchased from commercial sources.

3. Cost Calculation

The cost calculation section of the CAITL software could be considered the heart of the software. The cost calculation procedure takes information from both the data files described above, and the distance from MapInfo to produce both the societal cost, published cost, and time associated with the travel arrangements.

The following screens make up the functional model for the cost calculation procedure. A functional Model consists of multiple data flow diagrams which specify the meaning of operations and constraints. A data flow diagram shows the functional relationships of the values computed by a system, including input values, output values, and internal data stores.

Figure 1 is not a data flow diagram of the cost calculation procedure; rather, it is a data flow diagram (DFD) of the CAITL software. The DFD contains three data stores: transportation rates, time constraints, and summary. Furthermore, there are seven procedures depicted on the diagram. These procedures are as follows: clear link variables, request transportation information, calculate societal and published cost, request action, setup next route, and exit.

Figure 1: Data Flow Diagram for the CAITL software

The data store contains a variety of information. Although two of the data stores perform similar tasks, the other data store performs an entirely different task. The transportation rates and time constraints data stores shows what procedure extracts the information from the data files, while the summary data store contains all the resulting calculations information.

The procedures are combined with the data stores to produce the end result. Most of these procedures are quite involved and have their own data flow diagram (DFD). Both of the request functions do not have corresponding DFDs because the procedures are merely inputs from the user. Furthermore, the exit procedure does not have a data flow diagram because the exit procedure does not handle any data. The clear link variables, calculate societal and published cost, and setup next route procedures do have corresponding DFDs.

The first step of any good software package is to ensure that all values have been set to ensure that the program functions properly. Consequently, the first procedure depicted in Figure 1 is the clear links procedure. The purpose of the clear links (Figure 2) procedure is to set all the values associated with a link to zero.

A link is defined by the software as all elements associated with a particular mode of transportation. Furthermore, a transportation route, which is the combination of all combined transportation linkages that connect the two cities, could be made up of one link or multiple links. A multiple link or multiple modal route is defined any time the user attempts to switch modes after a value has been assigned to another transportation mode. For example, a transportation route could be the combination of railroad and road connecting two cities, or the route could be made up of only road.

The clear links procedure (Figure 2) merely loops through all the defined links in the program setting all the values to zero. The link variable depicted in the Figure 2 is of the linkages type which is a user defined type variable. The linkages type variable contains the distance, mode, societal cost, and published cost Figure 1 associated with a transportation mode. Once the clear links procedure has set the all the links to zero, the procedure sets the number of links variable to zero signifying that the transportation route is complete.

Figure 2: Data Flow Diagram for Clear Links Module

The next procedure in Figure 1 is the request transportation information which is an input function which does not have a data flow diagram (DFD). The method for entering data is discussed in some detail in the software execution section of this report.

After the request transportation information function is the calculate societal and published cost procedure. This procedure does much more than simply calculate the different cost. For example, the calculate procedure also calculates the time associated with the transportation method. Figure 3 is a data flow diagram (DFD) of the calculation procedure.

The diagram shows that the calculation procedure starts with the user. The diagram demonstrates that the user is responsible for entering the state percentages, transportation mode, travel distance. The state percentages are only valid when a transportation route crosses the state boundary. If the transportation route crosses the state boundary, MapInfo will not necessarily break the line into line segments. For example, HWY 71 may or may not be broken at the Missouri Arkansas border. The state percentages allow the user proportion the distance traveled in each state by assigning it a percentage based on their visual observation. If the line is either segmented around the state boundary or the source and destination points are in the same state, the user should simply enter one hundred in the percentages box.

The first procedure depicted in Figure 3 is the total percentages procedure which loops through all the states accumulating the total percentage. If the percentage is between ninety five and one hundred six percent, the program will calculate a percentage adjustment and move on; otherwise, the program will present the user with an error message. After the percentage adjustment is calculated, it is applied to cause the percentages to equal one hundred. After the percentage has been adjusted to equal one hundred, the calculation proceeds to calculate the societal, published cost, and time.

The societal cost is calculated by retrieving the rate from the transportation rates data file and looping through all the states until all the cost have been added to the societal cost (Figure 3). The internal societal calculation procedure multiplies the transportation rate times the weight of the commodity times the transportation distance times the state percentage and adds the result of the multiplication to a societal cost accumulator. Once the procedure has looped through all the states accumulating a societal cost, the published cost is then calculated.

The published cost (Figure 3) is calculated by retrieving the published cost rate if it exists and multiplying it by the distance traveled and the weight of the commodity. If the published cost data does not exist, the procedure is halted.

Figure 3: Data Flow Diagram for the Calculation Module

All of the above described procedures are performed every time the add button is depressed

allowing for multiple links or multiple modes.

4. Time Calculation

In Figure 3, there is a section in the upper right hand corner that depicts how the software retrieves the time from the time constraints data file and calculates the time associated with the mode of transportation. Before the procedure can be executed, it must verify that a time constant exists for the transportation method that has been chosen. If the constraint does not exist, the procedure moves on to the next state which will only exists if a line segment is split across a state boundary. If the constraint exists, the procedure adds to the time associated with the transportation methodology.

5. Summary Information

The summary information is depicted by a data store on the two of the previous diagrams Figure 1 and Figure 3. The summary screen is where the program stores all the information associated with each of the transportation routes formed during a software session. The three data flow diagrams show where and when the summary information is updated.

6. Conclusion

The above described procedures collectively comprise the developed CAITL software. The software combines the distance calculating power of MapInfo with the cost calculation procedure to produce a useful model for comparing the cost of different transportation methods. The transportation modes can either be composed of a single transportation mode or multiple transportation modes. The reader should recall that a mode is synonymous with rail, barge, truck, or air transportation.

Figure 4 presents an object modal diagram for the CAITL software. The purpose of an object model is to describe the structure of the objects in a system – their identity, their relationships to other objects, their attributes, and their operation. The object model presented in Figure 4 shows how the major sections of CAITL software interact.

The object model shows that the cost calculation portion of the program is the center piece or hub of the software. The cost calculation section draws information from the time constraints and transportation rates section while adding information to the summary section.

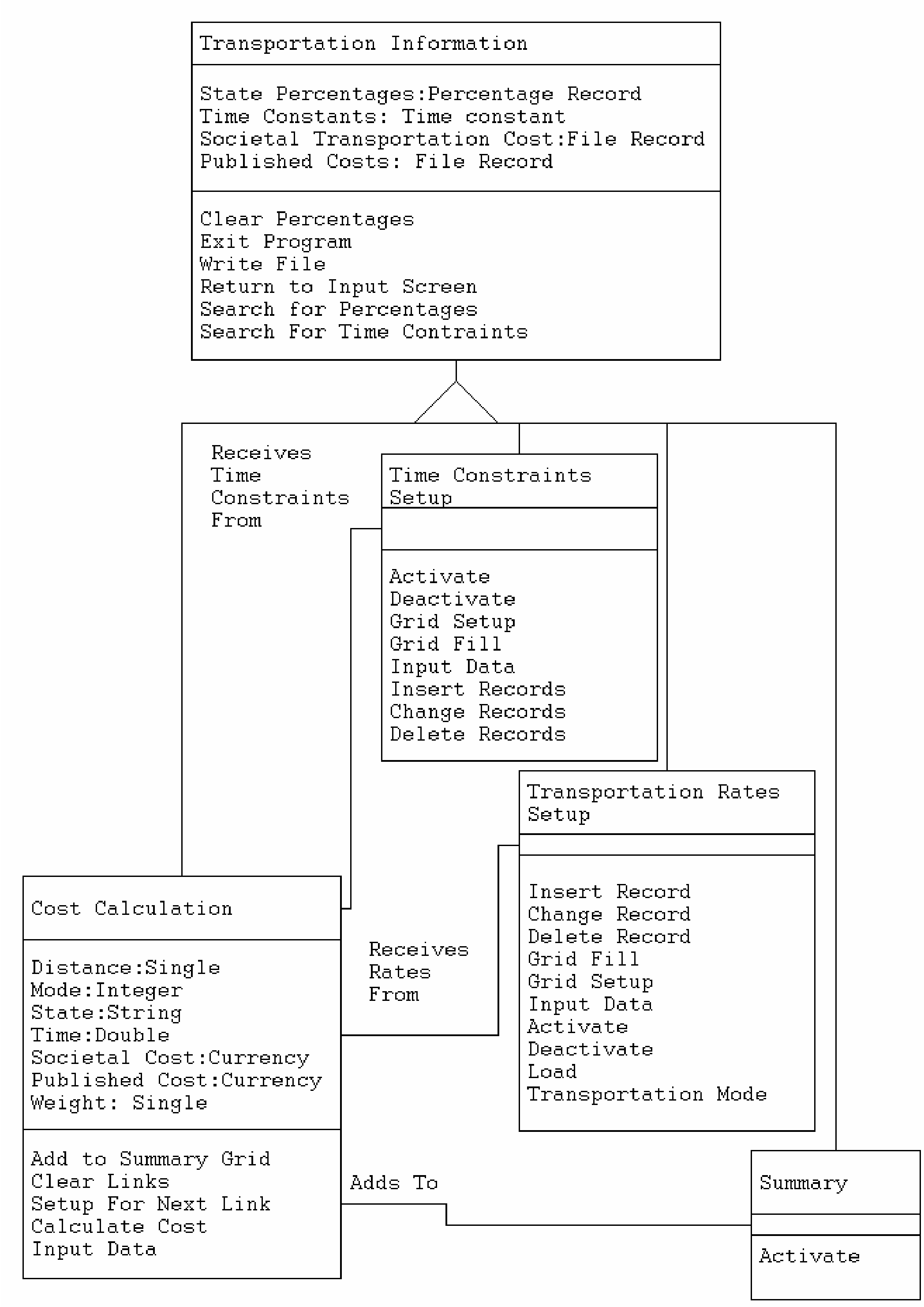

Figure 4: Object Modal Diagram for the CAITL Software

IX. Software Execution

An example software execution session of the transportation cost software is presented in this section. Since MapInfo is an integral part of the software, a brief tutorial of MapInfo will be provided first. The tutorial contains only those features of MapInfo that are necessary for interfacing with the developed cost analysis software package. A complete example that illustrates the developed software's operation is presented after the MapInfo tutorial.

A. MapInfo Tutorial

An overview of the commercially available MapInfo software is presented in the subsections that follow.

1. MapInfo Introductory Screens

When the user begins a MapInfo session, the first screen which appears is the quick start screen which is illustrated in Figure 5. This screen provides the user with several operation modes. The operation modes are Restore Previous Session, Open Last Used Workspace, Open A Workspace, and Open A Table. Each of these operations will change the way in which MapInfo will function. The first operation will cause MapInfo to restore the information which was present on the screen when the user quit the last session.

If the user chooses to the "Open Last Used Workspace" option, the user must redefine the area of interest on the map as well as the zooming level. By choosing the "Open a Workspace" option, the user can change the maps. For example, the user could exchange the North American workspace with an Asian workspace. The "Open A Table" option allows the user the capability of overlaying additional information such as layers onto the current screen. For example, one can overlay the streets of San Francisco onto a map of the Bay area.

Figure 5: MapInfo Quick Start Screen

The authors suggest the user define an initial MapInfo session and from then on simply use the “Restore Previous Session” option. (The procedure for defining an initial session will be discussed later when the layer control screen is presented.) This procedure will reduce the required startup time associated with operating the software. By selecting the “Open Last Used Workspace” option, the user spends more time rezooming the image as well as locating the area of interest. The “Open A Workspace” option could alternately be used because the user can define and save workspaces allowing thus allowing the flexibility to easily locate multiple areas on a map.

MapInfo does not allow the use of scroll bars on user defined workspaces. Since only a small geographic region can be viewed on the screen, the user must use the scroll bars to move around the region in order to select the entire path between the two points.

The Layer Control screen (Figure 6) allows the user to customize the workspace. The information is contained on many different layers which can be turned on and off. For example, the North American workspace contains an abundance of information, but only twenty layers are necessary for the cost analysis application. The twenty required layers consist of the following:

- trans_str_text -- transportation label structure
- ocean_fea_text -- ocean feature labels
- drainage_text -- river and shore labels
- railroad_text -- railroad annotation
- road_text -- road annotation
- populated_text -- city and town names
- pol_ocean_text -- country and ocean labels

- trans_str_pnts -- small transportation structures
- ocean_fea_pnts -- small ocean features
- drainage_pnts -- small inland lakes and islands
- airports -- airports
- populated_pnts -- populated places (cities, towns, villages)
- trans_str_line -- transportation structure and lines
- ocean_fea_line -- ocean feature lines
- railroad_line -- railroad lines
- roads -- road lines
- drainage_line -- drainage lines (rivers and shores)
- pol_ocean_line -- political boundary lines
- populated_area -- populated areas (cities and towns)
- drainage_area. -- inland water bodies

All twenty of these layers have an X placed on the visible, selectable, and zoom layered columns. By placing an X in these columns, the layers will remain visible. The user can place an X in these columns on the layer control popup-window by clicking the mouse directly on the actual words or by clicking the mouse on the boxes directly to the left of the words.

All the layers that do not have an X in three columns are no longer visible. The significance of eliminating layers is to increase the drawing speed of the map. The reason that the drawing speed is increased is because it takes time to draw each layer on the screen.

Figure 6: MapInfo Layer Control Screen

Figure 7 shows how the map would look if the default layers are used. The default layers are all the available layers provided with the ADC (American Digital Cartography) World Map of North America. Figure 8 depicts how the map will appear after the user has eliminated the unnecessary layers. This illustration map shows the use of the twenty layers previously described.

Also contained on this screen shown in Figure 7 are the tool bars. Some features available on the tool bars are zooming tools, selection tools, and measurement tools. Only those tools necessary to execute the cost analysis software are described. These tools are addressed in the subsection that follows.

2. *Description of Tool Bar Icons*

There are two zooming tools present on the tool bar; one for zooming in on the object and one for zooming out away the object. The two zooming tools are very much alike in appearance. The tool for zooming in is a magnifying glass with a plus sign whereas the tool for zooming out is a magnifying glass with a minus sign. To use the zooming in tool, the user simply selects one corner of the object and drags the mouse at a diagonal until the rectangle completely encompasses the objects desired for expansion. The tool for zooming out away from an object works in a slightly different manner. To use the zooming out tool, the user simply places the magnifying glass in the center of the object and clicks the right mouse button.

The selection tool is depicted by an arrow icon. It is used for informing MapInfo of an object of interest. For example, the selection tool can be used to select the various line segments between two cities. To select an object, the mouse cursor is placed over the object, and the right mouse button is clicked. MapInfo will correspondingly highlight the object with red hash marks.

The measurement tool is the ruler icon. The ruler tool is used to retrieve the distance between two points on the MapInfo screen. It is necessary to use this tool when the distance between two points is not already defined by road or rail segments on the map. To use the measurement tool, the user anchors the end of the ruler on the first object by clicking the right mouse button. The user then drags the mouse to destination point and double clicks the right mouse button. MapInfo will place the resulting distance in a browser window in the upper left hand corner of the screen.

Figure 7: MapInfo Screen Containing All Layers of Information

Figure 8: MapInfo Screen Containing the Twenty Layers

3. *MapInfo Distance Calculation Screens*

Figure 9 shows a selected path from Fayetteville to Fort Smith, Arkansas which is marked or highlighted by the crossed lines. The path was selected by clicking the left mouse button on the line segments while the selection tool is activated.

Figure 9: MapInfo Screen With Selected Line Segment From Fayetteville to Fort Smith

Figure 10 illustrates the next screen, the SQL-select pop-up window. This window demonstrates the method which MapInfo provides for aggregating distances of line segments. This screen can be activated by choosing the Query pull-down menu. Inside the query menu the user needs to select the SQL-select command. The method used by MapInfo is an SQL-select statement. The appropriate parameters for the SQL-select statement are provided with the screen.

The SQL-select statement works as follows. The ObjectLen function returns the distance of any one line segment. The aggregate function, "Sum", loops through adding up all the highlighted line segments. The "From Table" informs the software where to retrieve the information. To sum the distance of a selected line segment, the user must enter the word "Selection" into the "From Table" slot. The final option necessary to perform a proper SQL-select is the "Into Table Named" option which simply tells the software where to replace the results of the SQL-Select statement. This is illustrated in Figure 11.

Figure 10: MapInfo SQL Select Screen

Figure 13 presents the results of the SQL-select command which is the distance from Fayetteville to Fort Smith. The distance is provided in a browser window in the upper left hand corner of the screen. If the user uses the maximize option on the map screen, the map screen will be reduced greatly.   The windows feature that causes this phenomenon is the Minimize On Execution option. This option is set by the SQL-select command. To adapt for this problem, the user can drag the map to the desired size increasing the minimized size of the window.   As is common with most Windows applications, the user can click on the bottom corner of the map and drag the map to the desired size.

Figure 11: MapInfo Screen Showing Result of SQL-Select Command

4. Distance Summing Methodology

Figure 12 shows the Run MapBasic Program pop up window which was invoked by selecting the File pull-down menu. After choosing the File option, the user selects Run MapBasic (Figure 12) from the File pull-down menu. The user will probably wish to use the MapBasic command entitled Simaut.mbx, which automates all the cumbersome SQL-select statement. Consequently, all the user must do is highlight the Simaut.mbx (Figure 12) command and hit the enter key.

Obviously, the easier of the two distance summing methods is the Simaut.mbx command. The SQL-select command has also been presented because it is the MapInfo standard procedure for the calculation of the distance between two points.

Figure 12: MapInfo Run MapBasic Program Screen

The next screen (Figure 13) shows the result of the Simaut.mbx command which is the distance from Fayetteville to Fort Smith in a browser window. The Simaut.mbx is the simplest option available to the user because the user no longer needs to consider the placement of parameters in the SQL-select statement. The reader can verify the results of this program or command by comparing Figure 11 with Figure 13 since the selected path was exactly the same.

Figure 13: MapInfo Screen Presenting the Results From the MapBasic Program

B. Transportation Cost Software

The software has been divided into three logical areas. These include setup, input, and summary. These three areas are described in detail in the subsections that follow.

1. Setup Screen

The setup area is divided into two subcategories which include transportation rates and time constraints. The setup area can be activated in two ways. The software will automatically bring up the transportation rates setup screen as shown in Figure 14. This will occur only if the files *truecst.dat* and *time.dat* do not already exist. The time constraints setup screen corresponding to the *time.dat* file is illustrated in Figure 15. The procedure for the actual data entry into the files is discussed in the following sections.

a. Transportation Rates and Time Constraints

If both files exist, then the user will be presented with the input screen (Figure 16). To activate the setup screen, the user selects the File pull-down menu. Under the File pull-down menu the user will be presented with two options:

- Setup
    - Transportation Rates
    - Time Constraints
- Exit.

If the transportation rates option is selected chosen, the user will be presented with the transportation rates screen shown in Figure 14. If the user selects the time constraints option, the time constraints setup screen (Figure 15) will be the active screen. Of course, if the user selects the exit option, the program will terminate execution.

Figure 14: Transportation Rates Setup Screen

Figure 15: Time Constraints Setup Screen

Although the two setup screens deal with different sets of data, the functionality of both screens is exactly the same. Both screens have two pull-down menus.

- File
    - Return to Input screen
- Exit
- Edit
    - Insert
    - Change
    - Delete

Both screens are subdivided into two areas: an inputting area and an editing/output area.

The inputting area enables the user to type the data into the textboxes. The user depresses the return key after the data is entered to move to the next textbox. When the data is entered into the last textbox, the insert button will be highlighted, and the user can enter the data in the textboxes by simply clicking the left mouse button or hitting the enter key. (Refer to Figure 16 and Figure 17.) The process for entering the data can be repeated for up to fifty states for the transportation rates and up to ten modes for the time constants. The user should be aware that the program is not unit specific, but the end result will be affected by the velocity units that the user enters.

Figure 16: Time Constraints Screen Before Insertion

Figure 17: Time Constraints Screen After Insertion

After the data has been entered, the user can make changes to as many rows as desired at once. The method to use when changing rows is to simply type the new values into the cells of the grid shown in Figure 18. After the user has changed all the desired cells, the user should select all the rows where changes were made as shown in Figure 19.

b. Change Option

The user should next click the change option under the edit pull-down menu as shown in Figure 20.

Figure 18: Time Constraints Screen Depicting a Highlighted Cell

Figure 19: Time Constraints Screen After Cell has been Modified But Before The Change Option Has Been SelectedOption Has Been Selected

Figure 20: Time Constraints Screen After The Change Option

The user can also delete as many rows as he/she desires by selecting the corresponding rows shown in Figure 21and Figure 22 and clicking on the delete option under the edit pull-down menu. Even though the software will caution the user about of the pending danger associated with deleting items, the user should still be careful because useful data could easily be deleted. The data restoration could take longer because the user would have to reinsert all the data. (See Figure 23 and Figure 24.)

Figure 21: Time Constraints Screen Prior To Deletion Showing One Highlighted Row

Figure 22: Time Constraints Screen After Deletion

Figure 23: Time Constraints Screen Prior To Deletion Depicting Multiple Highlighted Rows

Figure 24: Time Constraints Screen After Deletion

After the desired data has been entered into the program, the user can proceed with some calculations. The user should click the return to input screen under the file pull-down menu. By clicking on this option, the user will be at the input screen.

2. Input Screen

Figure 25 illustrates the input screen. The user provides the program with the following information:

- Multiple Mode or Single Mode
- Transportation mode - highway, waterway, airway, and railroad.
- The state of interest - Arkansas, Alabama, Louisiana, Mississippi, and Tennessee
- The percentage of distance traveled in the state.
- The distance in miles
- Weight of commodity in tons

The user provides the aforementioned information by following the steps below.

- The user can click the multiple mode button to place the program in multiple modes (See Figure 25). A multiple mode operation is a combination of any of the four modes included in the study: airplane, barge, rail, and road. Once the user clicks the multiple mode button, it will toggle to be the single mode button. The program assumes that user is doing single mode (See Figure 26) operations until the multiple mode button is clicked or the user attempts to perform a multiple mode operation. If the user attempts to change modes and add more cost to the already existing cost without clicking the next route button, the program will automatically switch to multiple modes.

- To select the proper transportation mode, the user must move the mouse cursor directly over the white dot to the right of the appropriate transportation mode and click the left mouse button. (See Figure 27.)

- To enter the state, the user must click the left mouse button on the arrow just to the left of the state combo box. Then the user must highlight the appropriate state and click the left mouse button. There were only five states included in the study: Alabama, Arkansas, Louisiana, Mississippi, and Tennessee. (See Figure 27.)

- To enter the distance, weight, and percentage, the user must select the text box and type the appropriate values. (See Figure 28.)

- The user must next click the left mouse button on the add button. After the user clicks the add button the program will calculate both the societal and published cost.

The user can continue this process by adding more transportation linkages or just more cost for traveling on the same mode across multiple states until the next route button is clicked. Once the next route button is clicked, the existing route is added to the summary screen (Figure 29), and the summary screen is prepared for another route. A route is defined as the combination of all the transportation linkages between the two cities. A transportation linkage is synonymous with a mode.

3. Summary Screen

To view the summary screen, the user must click the left mouse button on the summary button. The summary screen presents the results of all the previous routes. The two options on the summary screen can be assessed via under the file pull-down menu.

- File

- Return to Input Screen
- Exit

Figure 25: Input Screen In Multiple Modes

Figure 26: Input Screen In Single Mode

Figure 27: Sample Cost Analysis Software Screen

Figure 28 shows a sample cost calculation. The example in this screen is totally fictional. The number of miles and the weight were arbitrarily assigned for the sole purpose of illustrating how the software presents the results to the user.

Figure 28: Sample Input Screen Containing Calculation Results

Figure 29 is the summary screen associated with the above input screen. The information presented on the summary screen includes the link number, the mode, the time, the distance, the true cost, and the published cost. This information will be presented for every link of each route as well as a total of all links.

Figure 29: Summary Screen

C. Calculation of Societal Cost -- An Example

This example illustrates how the developed software can be used to compare the cost associated with each of the transportation modes analyzed in this study. For this example it is assumed five tons of a commodity is to be shipped from Fort Smith to Russellville, Arkansas. The first step in the cost calculation process is to retrieve the distance by selecting the transportation linkages between these two cities in MapInfo and performing the SQL-select command or the simaut.mbx as previously described. This process is illustrated for three different transportation modes which include truck, rail, and air transportation.

1. Truck Transportation

For truck transportation, the linkages are selected by moving the mouse pointer over the first line segment and clicking the right mouse button. After the first line segment has been selected, the user selects the rest of the line segments by depressing the shift key and the right mouse button while the mouse cursor is located directly above the line segment. This process is continued until the entire path is selected from Fort Smith to Russellville as illustrated in Figure 30. Line segments are usually defined by MapInfo individually as described between crossing points. Such points may include bridges, intersections with other map parameters, etc. This makes it necessary for the user to separately define several individual line segments between a selected transportation origin and its destination. For example, there may be as many as seven or eight line segments between Fort Smith and Russellville, Arkansas.

Figure 30: A MapInfo Screen Depicting the Selected Line Segment of I40 Between Fort Smith and Russellville

The result of the SQL-select or simaut.mbx command is then input into the distance text box. Figure 31 shows the results of the simaut.mbx command. The distance from Fort Smith to Russellville, approximately seventy miles, is presented in the distance browser window as shown in Figure 31.

Reviewing the distance summing methodology, the user should select the Run MapBasic Program pop-up window which is an option of the File pull-down menu. After selecting the Run MapBasic Program option, the user should highlight the simaut.mbx command and hit the enter key.

Figure 31: A MapInfo Screen presenting the Distance by Road Between Fort Smith and Russellville

For example purposes, suppose it is desired to ship five tons of commodity by truck from Fort Smith to Russellville Arkansas. The user must enter the following parameters into the transportation cost analysis software.

- The user must select the desired mode of transportation to be road. The selection can be made by clicking the left mouse button just to the left of the word "Road".
- The user must choose the state to be Arkansas. The user is able to choose the state by clicking the arrow just to the left of the state combo box. Then the user should highlight Arkansas and click the left mouse button.

- The obtained distance can then be placed in the distance text box of the Transportation Cost Analysis Software. The distance can be entered in the distance text box by selecting the text box with the mouse cursor and then typing the appropriate distance which is approximately seventy miles.

- Since the weight was determined to be five tons, the user should place a five in the weight text box.

- The last step is to click the left mouse button on the add button.

Figure 32 shows the results of entering the above parameters into the transportation cost analysis software.

Figure 32: A Cost Development Screen Showing the Cost of Traveling From Fort Smith to Russellville by Road

2. Rail Transportation

The next set of MapInfo Screens shows the selected railroad region between the two cities along with the associated distance. The path by railroad is selected exactly the same as the selection procedure for roads. Also shown is the calculation screen which presents the societal cost associated with railroad transportation. Figure 33 shows the highlighted railroad path between Fort Smith and Russellville.

Figure 33: A MapInfo Screen Depicting the Selected Line Segment of Railroad Between Fort Smith and Russellville

The result of the SQL-select or simaut.mbx command is then input into the distance text box in the developed program. Figure 34 shows the results of the SQL-select command. The distance from Fort Smith to Russellville, approximately seventy eight miles, is presented in the distance browser window.

Figure 34: A MapInfo Screen presenting the Distance by Railroad Between Fort Smith And Russellville

For the example, we wish to ship five tons of a commodity by rail from Fort Smith to Russellville Arkansas. Therefore, the user must enter the following parameters into the transportation cost analysis software:

- The user must select the desired mode of transportation mode to be railroad. The selection can be made by clicking the left mouse button just to left of the word "Railroad".
- The user must choose the state to be Arkansas. The user is able to choose the state by clicking the arrow just to the left of the state combo box. Then the user should highlight Arkansas and click the left mouse button.
- The obtained distance can then be placed in the distance text box of the Transportation Cost Analysis Software. The distance can be entered in the distance text box by selecting the text box with the mouse cursor and then typing the appropriate distance which is approximately seventy eight miles.
- Since the weight was determined to be five tons, the user places a five in the weight text box.
- The last step is to click the left mouse button on the add button.

Figure 35 shows the results of entering the above parameters into the transportation cost analysis software.

Figure 35: A Cost Development Screen Showing the Cost of Traveling From Ft. Smith to Russellville by Rail

3. Barge Transportation

The next set of MapInfo Screens shows the selected river region between the two cities along with the associated distance. The path by river is selected exactly the same as the selection procedure for road. Also shown is the calculation screen which presents the societal cost associated with the river transportation. Figure 36 shows the highlighted river path between Fort Smith and Russellville.

Figure 36: A MapInfo Screen Depicting the Selected Segment of River Between Fort Smith and Russellville

The result of the SQL-select or simaut.mbx command is then input into the distance text box in the developed program. Figure 37 shows the results of the SQL-select command. The distance from Fort Smith to Russellville, approximately one hundred twenty three miles, is presented in the distance browser window.

Figure 37: A MapInfo Screen presenting the Distance by River Between Fort Smith And Russellville

For the example, we wish to ship five tons of a commodity by barge from Fort Smith to Russellville Arkansas. Therefore, the user must enter the following parameters into the transportation cost analysis software:

- The user must select the desired mode of transportation mode to be barge. The selection can be made by clicking the left mouse button just to left of the words "Waterway".
- The user must choose the state to be Arkansas. The user is able to choose the state by clicking the arrow just to the left of the state combo box. Then the user should highlight Arkansas and click the left mouse button.

- The obtained distance can then be placed in the distance text box of the Transportation Cost Analysis Software. The distance can be entered in the distance text box by selecting the text box with the mouse cursor and then typing the appropriate distance which is approximately one hundred twenty three miles.

- Since the weight was determined to be five tons, the user places a five in the weight text box.

- The last step is to click the left mouse button on the add button.

Figure 38 shows the results of entering the above parameters into the transportation cost analysis software.

Figure 38: A Cost Development Screen Showing the Cost of Traveling From Fort Smith to Russellville via River

4. Air Transportation

The next MapInfo screen (Figure 39) shows the resulting distance from the ruler tool. The ruler tool has to be used to calculate the distance between airports because MapInfo does not provide any line segments connecting the airports. MapInfo indicates the airports by small airplane as shown in Figure 39. The ruler tool is rather simple to use. All one has to do is select the white ruler from the tool box and drag the mouse between two points. In order to make the ruler tool bend, the user should click the right mouse button once. To anchor the ruler, the user clicks the right mouse button twice. After the distance is retrieved using the ruler tool, the program is used to calculate the societal cost associated with shipping five tons of commodity via air transportation.

Figure 39: A MapInfo Screen Depicting the Distance Between by Airplane Between Fort Smith and Russellville

For the example, we wish to ship five tons of commodity by airplane from Fort Smith to Arkansas. The user must therefore enter the following parameters into the transportation cost analysis software:

- The user must select the desired mode of transportation to be air. The selection can be made by clicking the left mouse button just to left of the word "Air Traffic".
- The user must choose the state to be Arkansas. The user is able to choose the state by clicking the arrow just to the left of the state combo box. Then the user should highlight Arkansas and click the left mouse button.

- The obtained distance can then be placed in the distance text box of the transportation cost analysis software. The distance can be entered in the distance text box by selecting the text box with the mouse cursor and then typing the appropriate distance which is approximately seventy three miles.
- Since the weight was determined to be five tons, the user places a five in the weight text box.
- The last step is to click the left mouse button on the add button.

Figure 40 shows the results of entering the above parameters into the transportation cost analysis software.

Figure 40: A Cost Development Screen Showing the Cost of Traveling From Fort Smith to Russellville by Airplane

5. Summary of All Single Mode Operations

Figure 41 and Figure 42 present the resulting summary screen from the above performed operations. The reader should note that the purpose of the summary screen is merely to present summarize the results of the transportation cost analysis to the user. Once the user has reviewed the information, the user can click the "Return to Input Screen" option under the File pull-down menu. After this option has been invoked, the user will be promptly returned to the input screen.

Figure 41 : Summary Screen Comparing All The Single Modes

Figure 42: Summary Screen Comparing All The Single Mode Operations

6. Multiple Mode Transportation Analysis

The next example is a multiple modal example which is a transportation route that involves more than one of the transportation mode. The following set of screens depicts an example of shipping five tons of a commodity from Fort Smith to Russellville by combination rail and truck transportation.

The first portion of the trip is traveled by railroad, and the second leg of the trip is traveled by truck. Figure 43 depicts the selected line segment of railroad between Clarksville and

Russellville. The distance retrieved from MapInfo is shown in Figure 44, and the results of entering the distance, weight, and percentage are shown in Figure 47.

The user should remember that there are two ways to place the program in multiple modal operation. The first is to change the mode of transportation without clicking the next route button. The second method is to click the multiple mode button.

Once the program is in multiple mode, one can simply retrieve another distance from MapInfo (Figure 46). The selected segment of road that results in the distance depicted in Figure 46 is presented in Figure 45. Figure 48 is a captured screen after the user entered all the data but before the "Add Link" button is clicked. After clicking the "Add Link" button, the new results will be combined with the original results (Figure 49).

Figure 43: A MapInfo Screen Depicting the Selected Segment of Railroad Between Fort Smith and Clarksville

Figure 44: A MapInfo Screen Presenting the Distance by Railroad Between Fort Smith And Clarksville

Figure 45: A MapInfo Screen Depicting the Selected Segment of Road Between Clarksville and Russellville

Figure 46: A MapInfo Screen Presenting the Distance by Road Between Clarksville and Russellville

Figure 47: A Cost Development Screen Showing the Cost of Traveling From Fort Smith to Clarksville by Railroad

Figure 48: A Cost Development Screen After the Information for Road Transportation Has Been Entered, But Before The "Add Link" Button Has Been Pressed

Figure 49: A Cost Development Screen Presenting the Cost of Traveling From Clarksville to Russellville via Road

7. Final Summary Screen

Figure 50 and Figure 51 present the resulting summary screen from the above performed operations included the multiple mode example. The reader should recall that the purpose of the summary screen is merely to summarize the results of the transportation cost analysis for the user. Once the user has looked at the information, the user can click the "Return to Input Screen" option under the File pull-down menu. After this option has been invoked, the user will be promptly returned to the input screen.

Figure 50: Summary Screen Presenting All Modes of Transportation Between Fort Smith and Russellville

Figure 51: Summary Screen Presenting All the Aforementioned Methods of Transportation Between Fort Smith and Russellville Continued

X. Summary

This section summarizes the contents of this report. Separate subsections address the developed cost assessment methodology and the subsequent software development.

A. Analysis Summary

The cost of providing transportation services has always been viewed by the public as the amount of dollars paid to the carrier to transport the goods. The money paid includes the margin of profits to the transportation carrier and the physical costs of performing the task. The physical costs consist of all the capital costs, operating costs, etc.. A fraction of these physical costs are used for private, non-commercial use by the public rather than the transport of goods. Another portion is attributed to recreation and, in the case of waterways, drinking water and flood control.

The purpose of the developed cost assessment methodology has been to determine these costs and attribute them to the appropriate "users". Several researchers have addressed the question of attributing the cost responsibilities, but most of them have concentrated only on highway transportation. Virtually no previous research has addressed this problem for other modes of transportation. This research has developed a means to factor out those cost not associated with freight transportation. The result has been the most accurate determination of societal transportation costs completed to date.

The developed model performs an economic analysis for the user. The analysis incorporates all the viable tangible and intangible cost entities to perform the true cost assessment. The developed methodology operates in conjunction with Cost Assessment of Intermodal Transportation Linkages (CAITL) software to determine the true least cost of freight transportation. The interface of the software and a graphical user display provides the user the capability of a visual display of the transportation mode being analyzed and the cost associated with that particular mode of transportation.

The developed model allows for an individual cost assessment for all the modes. It provides the user the mode or modal combination with the least cost. The methodology is designed to permit the expansion of the region of analysis. The region of analysis for this research is limited to only a five states region of Alabama, Arkansas, Mississippi, Louisiana, and Tennessee.

The results of the analysis are acceptable in that the obtained societal costs for truck and air transportation are higher than the published revenue per ton-mile. This is due to substantial government contributions to the infrastructure associated with these transportation modes. The societal costs for rail transportation is lower than the published revenue per ton-mile. This is because the government makes no contribution to the infrastructure of this transportation mode. Furthermore, many of the large assets associated with rail transportation have previously been depreciated by these transportation carriers.

B. Software Summary

All events carried out by the user, MapInfo and cost software are presented in Table 31.

Event	User	Cost Assessment Program

User enters MapInfo (selects Region)	Loads MapInfo and opens file INTMOD.WOR	No action required
Selecting path of transportation	User selects the segment of transportation route from MapInfo	No action required
Starting Program	User "clicks" program icon, which appears on screen to start the program	Program checks to see if a valid data set is currently selected. If not, return to first level. If yes, proceed to the next level
Enter data	User enters data to specify what he/she wants	Program gives user a dialog box to fill in correct data the program required for calculations
Calculation	User clicks the add button.	Program uses various formulas to calculate cost for each mode
Return Results	User clicks the summary button.	Program returns a comparative output in a Summary to the user indicating the costs for each transportation mode.
Alternatives path	Choose new path from MapInfo	No action required
Exit Program	User clicks "Quit"	Program terminates applications

Table 31: Summary of All Procedures between MapInfo, Main Program and the User

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