EVALUATING THE FEASIBILITY OF AN INTERMODAL TRANSPORTATION FACILITY IN CHATTANOOGA

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I am submitting a thesis written by Murugan Auruvankulam-Palani entitled "Evaluating the feasibility of an Intermodal transportation facility in Chattanooga". I have examined the final copy of this thesis and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a concentration in industrial engineering.

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DEDICATION

This thesis is dedicated to

my beloved mother

Mrs. P. Thilagavathy

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ABSTRACT

This research develops a mathematical model based on linear programming techniques to evaluate the feasibility of developing an intermodal transportation facility in Chattanooga. Transportation resources in and around Chattanooga were studied, and the opportunities available for developing business by a transportation facility are analyzed. Large quantities of goods are shipped in and out of Chattanooga by trucks in either trailers or containers. In order to transfer goods in container or trailer from one mode of transportation to another, specific handling equipment is needed. Mobile cranes present in some transportation terminals in Chattanooga can transfer goods in small units only, but transferring cargo in whole a unit such as a container or a trailer from one mode to another requires heavy handling equipment such as a gantry crane. An intermodal facility is one which handles transfer of goods from one mode to the other.

Another problem in the region is the lack of a facility to store bulk quantities of goods and to do debulking into smaller units which could then be distributed to different places is not present in Chattanooga. This research is intended to evaluate the feasibility of developing such facilities. Different levels of requirements for such a facility such as a ramp, triple crown, bulk transfer, container storage depot, distribution center, handling facility and depot, and bulk to packaging are discussed. Data collected from various sources for river shipments and rail shipments are also presented and analyzed. Also an intermodal facility in Hunstville, a river terminal in Chattanooga, Shaw industries in Dalton, Department of Transportation of Georgia, UTK Transportation center, and Norfolk Southern rail yard in Chattanooga were visited and the information gathered from these places are also presented. These data and information help to understand the resources available regarding transportation, various steps involved in development of an intermodal facility, operation of a intermodal facility, and also the necessity of a facility.

The siting requirements for designing a facility and also a potential site are also discussed. A layout for the facility with respect to Volunteer Army Ammunition Plant site is designed and the infrastructures in the layout are analyzed including the capacities of the facility, construction and operating costs, and equipment costs. To obtain an evaluation of the feasibility of a facility and to understand the functions of the different elements in the facility, a linear programming model which characterizes the operations and activities of the facility is developed. The objective of the model is to optimize the flow in the facility and to maximize the profit to the facility. The different constraints involved in the model and the constraint equations are presented. Also in order to utilize the LP model, and to understand the behavior of the model for different situations, seven different cases were run for the LP model. The results obtained from these cases were analyzed and certain conclusions were reached. Recommendations were made for further work using the LP model.

CONTENTS

CHAPTER **PAGE**

LIST OF TABLES

LIST OF FIGURES

FIGURE **PAGE**

CHAPTER 1

INTRODUCTION

1.1 Transportation resources in and around Chattanooga.

Chattanooga and the surrounding regions are served by four different modes of transportation. These are rail, water, road, and air. These resources are discussed in detail below.

Rail

According to the Association of American Railroads, Railroad Facts, 1989 edition, about 2,475 railroad miles are operated in the state of Tennessee. Chattanooga is currently served by two of the nation's largest rail networks, CSX Transportation Inc., and Norfolk Southern Corporation (NS). Maps showing NS and CSX rail networks in the southeast of the country are shown (Figure 1.1, Appendix M, and Figure 1.2, Appendix N). These rail companies serve the area through extensive freight movement.

Rail-highway, piggyback and container services were previously provided in Chattanooga by Norfolk Southern Corporation. In 1991, the Chattanooga rail terminal had a capacity of 19 rail cars and parking facilities for 200 wheeled units.

Joint rail-truck distribution facilities for dry bulk commodities are available on both the Norfolk Southern (NS) and CSX rail systems. NS operates in partnership with Matlack, Inc. CSX operates in partnership with Fleet Transport Company, Inc.

The Chattanooga area has about 16 river terminals presently along the Tennessee river, and eight of these are served by rail. NS serves North Chattanooga and the areas of

Jersey Pike (Bonnie Oaks), Riverport (Amnicola), downtown, and south Chattanooga. CSX also serves downtown, as well as Tyner Spur (Chickamauga), Wauhatchie and South Chattanooga.

Water

The Tennessee River provides Chattanooga with water transportation access to major places around the country and world through the Inland Waterway System. Due to its location on the Tennessee River, Chattanooga has good access to these markets. Chattanooga is 185 river miles from Knoxville, 55 river miles from Charleston, TN, and 167 river miles from Clinton, TN. Chattanooga and the vicinity are served by 16 barge terminals along the Tennessee river. A map showing the barge terminals is shown (Figure 1.3, Appendix O).

These facilities are located within a 17-mile corridor along the Tennessee River, stretching from Creek Road upstream to the Chickamauga lock. Because of their locations, these terminals are able to ship in or out of east and central Tennessee, and also to northern Georgia.

Road

Chattanooga is located in the junction of Interstates 24 and 75. It is approximately 110 miles from Atlanta and Knoxville, 140 miles from Birmingham, and 125 miles from Nashville. Chattanooga is served by 7 federal highways, 4 primary state highways, and 12 secondary state roads. There are 26 motor freight terminals located in Chattanooga Hamilton County, (International Thomson Transport Press, American Motor Carrier

Directory). Figure 1.4, Appendix P shows the highway system through Chattanooga.

Air

Chattanooga Municipal Airport, called Lovell Field, is located in northeast Chattanooga, and provides commercial airline services. The Cherokee warehouse located on Amnicola Highway is currently being certified as a Foreign Trade Zone, which could be used as a trade zone for receiving goods through the airport. Highway 153 and Interstate 75 provide access to the airport.

1.2 Volume and type of commodities.

The following section discusses the volume of goods transported in the region by the different modes. The type of commodities handled by each mode are also discussed below.

Rail

There are approximately 25 different commodities that move in and out of Chattanooga. The majority of this traffic consists of chemicals, scrap metal, grains, and steel. These goods are transported in bulk, containers, trailers, liquid bulk, and in small quantities. A list containing the quantity of goods transported in the region from the year 1988 to 1992 is shown in Appendix A. The annual tons of goods transported out of Chattanooga has constantly been around 16,000 tons, except for the year 1990. In 1990, the total weight of goods transported from Chattanooga was about 92,305 tons. The primary goods transported from Chattanooga are cement, scrap metals, caustic soda, asphalt, and power components. Also in all the years from 1988 to 1992 the largest volume of goods was transported to Atlanta.

The quantity of goods transported into Chattanooga was analyzed for the five year period of 1988 to 1992. The total weight of goods in 1988 was about 610,000 tons, but dropped to 146,000 tons in 1989. During the years from 1990 to 1992, the total weight of goods transported fluctuated from 140,000 tons to 195,000 tons. Most of the commodities inbound, consisted of chemicals, scrap metals, paper, steel, grain, appliances, soybeans, liquid and solid sweeteners, beer, newsprint, sand, propane, building materials, and frozen foods.

Siskin Steel and Southern Foundry Supply are two companies that use both the networks NSC and CSX for importing scrap steel to their warehouses. Other companies use only one of the rail networks, depending upon the network that services their location. Appendix B lists names of companies, types of business, types of shipment, and the commodity shipped for the two rail networks.

Water

By serving as a regional distribution and collection center, Chattanooga's geographic location on the Tennessee river provides business to river terminal operators. Chattanooga is ranked as the second most active port in the Tennessee River, handling about 2.49 million tons of cargo. In 1988 there were about 30 different commodities moving in and out of Chattanooga by river. A list of these commodities is included in Appendix C. The majority of this traffic occurred in sand and gravel, chemicals, petroleum and grains. Sand, gravel, and salt accounted for about 49.1 percent Chemicals and petroleum products accounted for about 22.8 percent Grains and grain products accounted for about 20.1 percent and other products accounted for about 8 percent of the total traffic handled in Chattanooga river terminals in the year 1988. [2]

Road and Air

Sufficient data regarding road and air freight could not be obtained, due to unavailability of published data and also due to confidential matters of releasing such data by motor freight carriers.

1.3 Opportunities for developing business.

With four major transportation resources in Chattanooga, a significant quanties of goods move into and out of the region and, as well as pass through the region. The region defined here includes Catoosa, Dade, and Walker counties in Georgia, and Hamilton, Marion, and Sequatchie counties in Tennessee. In spite of the existing transportation resources in the region, the region continues to lack certain facilities for modern transportation, storage and distribution. These missing facilities are an intermodal transportation facility, bulk storage sites, and repackaging and distribution centers. The availability of such facilities could provide opportunities to develop new businesses.

Intermodal transportation

Intermodal transportation involves the transfer of cargo units between vehicles of different modes of transportation. The existing barge facilities, rail network services, trucking terminals and the airport provide facilities for shipments in their respective modes. Some of these facilities are identified as intermodal terminals by the Metropolitan Planning Organization of Chattanooga Urban Area. A list of these terminals is e shown in Appendix D. While some of these facilities provide intermodal transfer operations, a significant quantity of intermodal shipments is not provided in the region. The reason for this might be that the terminals are not properly equipped to handle intermodal transfer, especially in the case of handling containerized cargo. There is no terminal in the region that has been declared as intermodal, although a few terminals (shown in Appendix D) are identified as potential intermodal terminals.

In 1991, Congress passed an act called the Intermodal Surface Transportation Efficiency Act (ISTEA). In passing the legislation, Congress declared that its purpose is "to develop a National Intermodal Transportation System that is economically efficient, environmentally sound, provides the foundation for the Nation to compete in the global economy and will move people and goods in an energy efficient manner." ISTEA provides for local and state incentives to promote use of passenger and freight intermodalism. ISTEA also established the Office of Intermodalism. It is responsible for assisting the Department of Transportation (DOT) in developing policies and programs designed to encourage and support intermodal programs and projects. ISTEA also created the Bureau of Transportation Statistics within the DOT to enhance data collection, analysis and reporting, and to ensure the most cost-effective use of transportation resources. [1]

Bulk storage and distribution

Storage facilities are provided for the region in barge terminals and rail network warehouses. The type of storage facilities available are enclosed shed, open storage area, grain elevators, and liquid storage tanks. Due to lack of proper facilities and equipment, however, these facilities do not provide large quantities of bulk storage; neither are the types of storage mentioned above present in all facilities. Moreover, almost none of the terminals provide debulking and packaging or repackaging facilities. A repackaging center could provide a facility for companies to unload their goods and package then into smaller quantities or add value to the goods as a new product. The repackaged goods could be warehoused and then distributed to different places as desired.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction.

Literature involving intermodal transportation equipment, facilities, and the benefits of intermodal transportation facilities was reviewed from recent publications. Since linear programming is intended to be used for evaluating the feasibility of a facility, literature involving linear programming was also reviewed. Some of the literature reviewed is discussed briefly below.

2.2 Literature survey

Muller [1] discusses in detail the development of intermodal, container revolution, government regulation, intermodal movements by rail, motor carrier, air, water and bridge services, intermodal equipment, intermodal containers, information technologies, competition, and the future of intermodalism. Different types of intermodal movements such as road to rail, rail to water, road to air, road to water, water to air and vice-versa are presented by Muller. This book also discusses the different types of intermodal shipments or services by rail, such as trailer on flat car (TOFC), container on flat car (COFC), and double stack trains (DST). TOFC, also known as piggy back, refers to the movement of highway trailers on flatcars. A trailer off loaded from a rail car can be driven to a location by road. When transferred from a rail car, containers on flatcars have to be loaded on to a frame attached to a truck. Double-stack trains consist of containers loaded with one container placed on top of another in a rail car. Double-stack trains have advantages such as reduced train lengths and reduced capital costs payload per ton carried. The book discusses various sizes of containers and trailers. Containers and trailers sizes range from 89 feet to 20 feet long.

An intermodal terminal design, as presented by Muller, is influenced by the type of cargo it is expected to handle. The different types of cargo include bulk cargo, containerized cargo, trailer, and break bulk. Bulk cargo-handling equipment or facilities are usually located in a separate area from facilities for containerized, trailer, and break bulk transfers. Muller also discusses terminal characteristics such as location, access, infrastructure, and density of the terminal placement. In earlier years, trucks and rail terminals were situated near large population areas or where the geography easily accommodated the interface of two or more modes. Now intermodal terminals are located outside large cities in order to escape the relatively high cost of real estate and labor that prevails in these areas.

Intermodal terminals should provide clear and easy access for coordinating the interface of two or more different transportation systems. Infrastructure considerations of a terminal must meet scheduling and performance standards of each mode. The placement of a terminal with respect to other terminals in the region is important for its performance. Muller also discusses the different handling equipment that can be used in a facility and also personnel requirements for a typical intermodal terminal.

Wong [4] discusses the growth of intermodalism and logistics management. He points out that manufacturers and distributors have three basic transportation goals, which are to move the freight when needed, to move freight at the least cost, and to move it so it arrives at its destination on time. This goal is not always possible to achieve using only one mode of transportation. Companies are now relying on more than one mode of transportation to minimize their freight costs. Wong also suggests that to make intermodalism successful, coordination between modes, single-invoice shipping, differentiated train service, and modal exchanges that are transparent to the customer have to be considered.

Chandler[5] discusses the cost benefits of using combination of transportation modes for manufacturers. He points out that certain companies take smaller loads and consolidate them with goods from other businesses going to the same destination. This considerably reduces the shipment cost of the manufacture. Chandler also lists different companies' savings in using intermodal transportation facilities. Certain companies provide services with refrigerated containers, which can be lifted onto trucks, ships or railroad cars. For rail shipment the containers are often double-stacked on flat cars. Double-stacked rail shipments are priced as much as 30 percent below comparable truck load shipments. Chandler also points out that on less than truck-load services the customer pays one price regardless of whether the shipment goes by truck or intermodal. Savings in freight costs in intermodal also depend on the cost of pick up-from and delivery-to rail terminals at the points of origin and destination. The article also discusses Triple Crown, which ships freight for its clients on revolutionary transport vehicles called Road Railers. Road Railers are 48-foot and 53-foot long truck trailers equipped with running gear for movement by both highway and rail. It takes only five minutes to convert a highway trailer into a rail car, and this also provides a good savings for manufacturers and distributors in freight costs.

Hillier and Lieberman [6] present the details of linear programming, simplex method, sensitivity analysis, transportation and assignment problems, dynamic programming, integer programming, nonlinear programming and more. This literature is reviewed to understand linear programming and sensitivity analysis. Hillier and Lieberman present an example for developing a linear programming model, and also discuss methods and software that could be used to solve a linear programming model. The use of sensitivity analysis in finding the range of values for the constraints formulated in the problem is also considered. Case studies and examples provide information on formulating a problem into a linear programming model.

2.3 Summary.

The literature reviewed has sufficient information regarding the design of an intermodal facility, determining its location, projecting cost benefits, and the infrastructure and handling equipment needed. The literature reviewed for linear programming could also be applied in formulating the problem into a linear programming model. The literature reviewed does not, however, provide a situation similar to the problem of evaluating the feasibility of an intermodal facility by use of linear programming. The problem could nevertheless be formulated using the basic concepts of the linear programming model and the literature reviewed regarding an intermodal terminal.

CHAPTER 3

PROBLEM STATEMENT

3.1. Introduction.

Chattanooga and surrounding cities have several manufacturing industries, warehouses, retail and dealership stores, and other business organizations that utilize one or more modes for transporting goods in and out of the region. Large quantities of goods are shipped in and out of Chattanooga by trucks in either trailers or containers. A significant quantity of cargo is shipped by rail and also by barge, while relatively less quantities are shipped by air.

In order to transfer the goods from one mode to the other, specific handling equipment is needed depending upon the type, nature, and packaging of the goods. Terminals such as JIT Terminal Inc., Mid-South Terminal Inc., Combustion Engineering Co., Southern Electric Fleeting Co., and Concrete Service Co. are equipped with mobile cranes to handle bulk material and/or terminal facilities with pipelines to transfer liquids and gases. The mobile cranes present in these terminals facilitates the transfer of goods in small units (less than a truck load) from one mode to another. Pipelines present in the terminals transfer chemicals and gases arriving in the facility to storage tanks. From there they find their final destination via different modes of transport, whether truck, rail or pipeline. Transferring cargo from one mode to another in whole units (such as a container or a trailer) requires heavy handling equipment such as gantry crane.

Intermodal transport involves the transfer of a single cargo between vehicles of different modes. An intermodal facility is one which handles the transfer of goods from one mode to the other. A common form of goods transfer within an intermodal facility is freight stored in containers (similar to trailers without wheels). Unfortunately, the facilities in Chattanooga and the surrounding region are not equipped to handle the transfer of containers or trailers from or to rail. For instance, the absence of a railroad ramp facility in the region slows the process of transferring goods from one place to another. The lack of facilities is addressed in two ways. First, containers and trailers are transported by trucks to nearby cities like Atlanta, where they are transloaded to another mode. Secondly, the containers or trailers can be transported by one mode only, either truck or rail, to their final destination without doing an intermodal transfer. The same is true in the case of receiving goods from other places to Chattanooga.

This lack of facilities can present problems for organizations transporting goods in and around Chattanooga. Organizations must choose an alternate shipping method which may be more expensive and time-consuming, depending upon the distance and need of shipments. Furthermore, organizations must adjust their operation since there may be less effective distribution planning, and/or improper or unnecessary material handling.

Though focused on one aspect of transport transfer, an intermodal facility could significantly contribute to business overall growth opportunities. An intermodal facility not only provides a better, quicker, more and economical, means of handling goods, it also provides an opportunity to expand an organization's operations. The types of handling equipment present in an intermodal facility might provide an opportunity for industries to produce and ship their products in a larger size or quantity. These facts provide an opportunity to evaluate the feasibility, use, and necessity of having an intermodal facility in Chattanooga. However, such a facility must meet several criteria to address the problems that Chattanooga businesses face today.

Another aspect of this region's problem is the storage of large bulk quantities of goods for further processing or distribution. Chattanooga lacks a facility to store bulk quantities of goods and to do debulking into small units which could be then distributed to different places. Absence of such facilities could reduce opportunities for the growth of business, since industries in and around Chattanooga could make use of such a facility to improve their operations. Problems that might arise due to the lack of such facilities are higher transportation costs, increased transit time, a reduction in the growth of existing businesses, and fewer new businesses.

In designing and developing an appropriate intermodal facility for this region, several factors have to be considered in order to evaluate the feasibility of such a facility. The problem statement of this topic deals with the level of shipments and the requirements for a facility.

3.2 Level of shipments.

In Chattanooga, different levels of shipments are currently done depending upon the nature of goods to be transported. Containers, trailers, tanks, pallets, bundles, rolls, small packages, corrugated boxes, and rail cars are used for shipping cargo. Table 3.1 shows the different kinds of goods for which transportation is done in this region.

Table 3.1 Different kinds of goods transported in Chattanooga

Paper and allied products	Stoneand stone products	Industrial machinery
Printing and publishing	Salt	Electronic and electrical equipment
Chemicals and allied products	Clay	Transportation equipment
Rubber and plastic products	Glass products	Instruments and related products
Grain and grain products	Iron, steel scraps	Gas products and petroleum
Leather products	Fabricated metal products	Raw materials for manufacturing

Some goods are transported in open vessels and others are moved in closed containers, depending upon the type of material. Materials like sand, gravel, salt, scrap material, and coal are shipped in open vessels in rail cars or by barge. Since these materials are usually transported in large bulk quantities, it is easy and economical to transport them in open vessels. Petroleum products, chemicals, and gas products (like cooking gas) are shipped in special tanks in rail or by trucks. Materials that need to be kept at low temperatures are shipped in refrigerated containers.

3.3 Requirements for a facility.

In this section, the conceptual requirement for a facility is presented.

1. Rail-Trailer Ramp

The economics involved in operating the ramp and the imbalance of freight movement were among the reasons that Norfolk Southern's Chattanooga ramp facility was closed. CSX's Chattanooga ramp was also closed. One solution to the problem might be a single ramp at a site which can be accessed by both the railroads. The requirement for such a ramp is a site which has a rail line or spur to both major rail networks' sites. Sufficient length and an adequate number of rail tracks on the site must be allowed in order to switch rail cars, do repairs and maintenance, and transload to another mode of transportation.

2. Triple Crown Facility

In the Intermodal freight workshop held in Chattanooga on June 18, 1996, Mr. Dan Clark of Norfolk Southern Corp., stated that Norfolk Southern is considering the possibility of opening a Triple Crown facility in Chattanooga. Norfolk Southern has already opened Trip Crown Facilities in different parts of the country, allowing shipments to travel in trailers that ride on rail for long-haul, then on the highway for local deliveries. Triple Crown facilities use the RoadRailer, a semi-trailer that can run on the road as well as on rails. The first RoadRailers had a pair of train wheels always on the trailer that dropped down to allow them to run on rails. In newer models, the rear ends of the trailer can be raised. A special bogie is put underneath to allow trailers to run as one long train car. These RoadRailers are also called bimodal vehicles. A Triple Crown Facility is one which is equipped to handle such vehicles and transfers. The requirement for such a facility will again be either a site which has access to NS rail lines and enough area to put sufficient length of rail tracks, or a site which has pre-existing rail tracks.

3. Bulk Transfer-- River to Rail

Given the nature of goods movement by river in Chattanooga , the transfer of both liquid and dry goods (such as chemicals, coal, sand, etc.) from the river to other modes (especially rail) has to be done in a facility with both a barge terminal and rail access. This basic provision alone could provide an intermodal bulk transfer facility, transloading both liquid and dry bulk.

4. Container storage

The facility should provide enough space for container storage, for intermediate storage during transfers and also for extended storage. Almost all containers that currently come by truck or rail to Chattanooga are from steamshipline companies located in Atlanta or other cities. A steamshipline company working in or through a Chattanooga facility might be willing to have a site for its container storage. The demand for such a storage location would depend on regional businesses and to some extent on the volume of the intermodal facility.

5. Handling facility and depot

Chattanooga lacks a ramp for the major rail networks and for handling specifically containerized goods. This absence provides a business opportunity. Companies could store their goods in advance at a local facility and direct their shipments later. Such a handling facility should be able to provide rail to truck, truck to rail, rail to barge, truck to barge, barge to rail, and barge to truck transfer operations. An ideal site would take advantage of existing rail lines, yard facilities and access to major rail networks. It would be located between major highways and thus be easily accessed by trucks. It would be located along the Tennessee river and within few miles of the airport. Such a site would be ideal for such a facility.

6. Distribution Center

A distribution center located on site could be used by companies to distribute the goods received by rail or other modes. These goods would then be shipped to various parts of the city and to places around Chattanooga in smaller allotments. Such a center should be located within a facility that has a ramp or handling transfer facilities.

7. Bulk to Packaging

Such a facility would greatly benefit from the ability to handle packaging or repackaging. Two types of packaging operations could be done. Bulk cargo could be broken down, packaged into small packages, and distributed in needed quantity to different companies or retail stores. Bulk cargo could also be repackaged for transloading into another mode of transportation. A site with the proper infrastructure and equipment and an intermodal facility could provide an excellent facility for repackaging and distribution.

Conclusion

In order to evaluate the feasibility of a facility with the different levels discussed above, one must consider design and layout, economics, and the optimal flow in such a facility, determine the volume of operation required for profitability and selecting proper site.

CHAPTER 4

DATA COLLECTION

Various data regarding rail, river, road and air shipments were collected for the study. These data are used to develop a perspective for the volume and type of shipments through the region. The data is also an indicator of the potential for such a facility in the region.

4.1 Rail transportation statistics.

This section discusses about the quantity, types of material and destinations of rail shipments in Chattanooga. The necessary statistical information was obtained from 'Rail Waybill Data' [4]. 'Rail Waybill Data' is provided by the Bureau of Transportation Statistics (BTS), Department of Transportation. It contains rail shipment data such as origin and destination regions of the shipments, types of commodities, weight of shipment, revenue from the shipments, interchange states, and mode (all rail or intermodal). The data are based on the Carload Waybill Sample, which is a proprietary sample of freight waybills submitted by Class 1 railroads to the Interstate Commerce Commission.

The data provided is for the years 1988-1992. Shipments are reported at the multi-county Bureau of Economic Analysis Areas (BEA) to BEA level. The BEA for the Chattanooga area contains the following Georgia counties: Catoosa, Dade, Walker, Chattoga, Murray, and Whitfield. In Tennessee it includes Hamilton, Marion, Sequatchie, Bledsoe, Bradley, Grundy, McMinn, Meigs, Monroe, Polk and Rhea counties. De Kalb and Jackson counties, Alabama, are also included in the BEA for the Chattanooga area.

The type of commodity shipped is denoted by means of a code called Standard Transportation Commodity Code (STCC). A list of the major commodities and their STCC codes that are transported in and out of Chattanooga is given in Appendix E.

For the purpose of this study, the huge Rail Waybill database was analyzed to understand the nature of rail shipments in and out of Chattanooga. For each year from 1988 to 1992, the data were sorted and separated into the two categories of goods transported into Chattanooga and goods transported from Chattanooga. For each year and for the goods transported into Chattanooga, the data were furthermore sorted and separated by the type of commodity and also by the origin BEA area. The data were likewise sorted for the goods transported out of Chattanooga by the type of commodity and the destination BEA areas.

4.2 Analysis of the goods transported in and out of Chattanooga by rail.

Appendix F summarizes the segregations of each year's shipments as described above. For the year 1991, the total weight of goods transported from Chattanooga (BEA 051) was about 14,710 tons. The goods were transported to 33 different BEA areas and also within the Chattanooga BEA area. About 4000 tons of goods were transported to Atlanta (BEA area 036), which was the highest quantity of goods transported for the year. About 1400 tons of goods were also transported within the Chattanooga BEA area. Goods transported to other BEA areas ranged from 20 to 800 tons. The number of commodities that were transported from Chattanooga was about 5. The principal commodities and their Standard Transportation Commodity Codes (STCC) are as follows: 20412 bran; 01137 wheat; 26311 fiber, paper, and pulp board; 28211 plastic materials and synthetic resins; 40211 iron or steel scrap; and 40241 paper waste or scrap. Out of the 5 commodities, iron and steel scrap were the major commodity transported out of Chattanooga.

About 139,198 tons of goods were transported into Chattanooga in the year 1991, from about 65 BEA areas. The highest quantity of goods was transported from Evansville, IN (BEA 80), which was about 15,000 tons. Other BEA Areas ranged from as low as 25 to 12,000 tons. About 20 different commodities were transported into Chattanooga in the year 1991, out of which wheat and corn, with 59,000 and 37,000 tons respectively, were the commodities with highest quantity.

In 1992, about 171,481 tons of goods were transported into Chattanooga. About 22 different commodities from about 72 BEA areas were transported into Chattanooga. Out of the 22 commodities, wheat (57,267 tons) and corn (58,640 tons) constitute the major portion of the commodities transported into Chattanooga. The next major commodity is plastic materials (10,334 tons). The remaining commodities ranges from 400 to 6000 tons. Evansville, IN (approximately 35,000 tons) was the largest shipping BEA.

In 1992, about 16,322 tons of goods were transported from Chattanooga to 40 different BEA areas. Five different commodities were transported. The highest quantity transported out of Chattanooga was about 3500 tons to Atlanta (BEA area 36). About 1500 tons of goods were transported within the Chattanooga BEA area. Out of the 5 commodities transported from Chattanooga, fiber and paper board, with approximately

8200 tons, was the major commodity transported out of Chattanooga. About 2500 tons of wheat, plastic materials, and iron or steel scrap were also transported out of Chattanooga. Paper waste, which was the only other commodity transported out, was about 700 tons.

About 55 establishments, including industries, retail stores, and transfer facilities, use rail for the shipment of goods. Out of this, the number of manufacturing companies that use rail for receiving raw materials and also for the shipment of finished products is approximately 31. The companies, retail stores, dealers and distributors that use rail for shipment have about 11 warehouses. There are also about 12 terminals around Chattanooga that use rail for shipment of goods. Most establishments use the rail terminals available near their location. Norfolk and CSX do not serve all places, however, and both networks' terminals are present only in the downtown and south Chattanooga areas. Siskin Steel and Southern Foundry Supply are the only two companies that use both railways for transportation. Some manufacturing industries (such as Wheland Foundry and BASF) have two locations from which to ship their goods.

Almost all of the 55 establishments (51) receive goods (inbound), and about 10 of them ship out goods (outbound). About 4 manufacturing companies (such as Rock Tenn, ABB CE, Wheland Foundry and Combustion) and 3 river terminals (such as Commercial Metals, Southern Foundry Supply, JIT terminal) transport inbound and outbound goods.

Companies such as Cargill Flour, Foodliner, and Sovex use the railway to ship in wheat and corn. Wheat and corn are the two largest commodities that are transported into Chattanooga by rail. For the year 1991, Cargill Flour, Foodliner and Sovex transported about 37,000 tons of corn and 58,500 tons of wheat into Chattanooga by rail. In the year 1992, 57,000 tons of corn and 59,000 tons of wheat were shipped in. All other commodities transported into Chattanooga during those years amounted to less than 12,000 tons. Next to wheat and corn, the largest commodities transported into Chattanooga were plastic materials (synthetic resins) and soybean by-products. About 8,000 tons of plastic materials and 7,000 tons of soybean by-products were transported in 1991, and about 10,000 tons of plastic materials and 6,500 tons of soybean by-products were transported in 1992. Companies such as Ringcan Corp., NA Industries and Hamilton Plastics deal with plastic materials. ADM ships in soybean by-products.

Rock-Tenn is a company that ships in scrap paper and ships out fiber, paper or pulp board. Between 1989 and 1992, this was the largest shipment out of Chattanooga. In the years 1991 and 1992, the quantity of paper, fiber, or pulp board transported out of Chattanooga was about 7,000 and 8,000 tons, respectively. The next largest commodity that is transported out of Chattanooga is iron or steel scrap. Companies such as Commercial Metals, Southern Foundry Supply, Wheland Foundry, and Siskin Steel Co. ship in and ship out scrap metals.

4.3 River transportation.

"The Economic Impact of Commercial Navigation on the Chattanooga Metropolitan Statistical Area," a study conducted in 1991 by the Tennessee Valley Authority (TVA) and by the Metropolitan Planning Organization of the Chattanooga Urban Area, was consulted to obtain the following data.

Chattanooga is the second most active port on the Tennessee River. In 1988 it handled about 2.49 million tons of cargo. There were approximately 30 different commodities moving in and out of Chattanooga at that time. About 92 percent of this traffic occurred in transporting sand and gravel, chemicals, petroleum and grains. Of these, the principal commodity handled at the port was sand and gravel, which accounted for fifty percent of the total traffic. Grains and chemicals and petroleum products accounted for 20 and 23 percent. The majority of this traffic was inbound in 1988, and consisted mostly of limestone flux, sand and gravel, residual fuel oil and asphalt. Only three percent of the traffic was outbound, and the majority of these shipments was of grain and animal seeds. Appendix G the compares commercial river traffic of stone, grain and other products from the years 1970 to 1988. A list of the 30 different commodities handled in the port of Chattanooga is shown in Appendix C.

4.4 Information gathered from people visited

In order to fully understand shipping aspects, the importance and necessity of an intermodal facility in Chattanooga, the services that could be provided in such a facility, and to identify possible potential intermodal shippers, several people were visited in this study. The findings of the discussions are abstracted below.

1. Shaw Industries

Shaw Industries, located in Dalton, GA, ships most of their carpets to the western part of the country via trains. Shaw could be a major beneficiary of an intermodal facility or a ramp in Chattanooga. The following information was obtained from an interview with Mr. Ron McIlvene, Corporate Manager, Shaw Industries. Shaw Industries transports their goods by truck to Atlanta. From Atlanta their goods are transported by rail to different parts of the country. Almost all of their carpets are transported by trailers and containers. They use both 53-foot and 40-foot containers. In 1995, Shaw Industries domestically shipped about 2,731 of carpet out of Dalton via truck or truck/rail. (One load equals a trailer or container.) Also in the year 1995, 1200 loads of carpets were shipped internationally. Ninety percent of these loads were in 40-foot containers. Shaw is opening company-owned retail stores across the nation, projecting a 40 percent increase in carpet sales and shipments for the years 1996 and 1997. Shaw also anticipates increased international sales and shipments for 1996 and beyond.

Because they lack a ramp facility in Chattanooga or Dalton, Shaw has to transport their goods in truck to Atlanta to get them to rail. It costs them between about $200 and $300 for a truck load to travel from Dalton to Atlanta. A ramp would permit Shaw to save on transport costs, and a ramp facility in Chattanooga would also save time in their shipping process. Mr. Ran Mcllvene expressed great interest in opening a ramp or an intermodal facility in Chattanooga.

2. Georgia Department of Transportation

Mr. Richard Drake, an engineer with The Georgia Department of Transportation, was contacted about their intermodal study for the port of Savannah and for Chattem county. The Georgia Department of Transportation is currently conducting a study of all Intermodal requirements, both for new facilities and for consolidation of facilities. The study involves three phases: Data Collection and Analysis, Postulation of Scenarios and Alternatives, and Identification and Development. (The study is currently behind schedule by approximately a year, and is over budget.)

The objective of the study is to identify current users and providers of intermodal services, quantify the capacity and movement of freight, and develop future scenarios with alternate facilities. The consultant doing the study will present their findings to The GaDOT, including an analysis of the alternate scenarios based on computer simulation. The GaDOT is currently at Phase 2 of their study. Due to the scheduled budget issues, the study scope may be more limited than was indicated in the initial work statement.

3. Chickamauga Lock

A seminar about 'Intermodal Freight Workshop' was held in Chattanooga on June 18, 1996, and the possibility of closing the Chickamauga lock and building a new one was discussed. The need for closing results from structural and foundation problems. Closing the lock will abandon 290 miles of commercial and recreational navigation upstream of Chickamauga. The traffic through Chickamauga lock is approximately 2.1 to 2.2 million tons. The current plans are close to the lock and build a new lock within the next ten years. This would cost approximately 288 million dollars. Two companies that will be seriously affected in their transportation if the lock is closed are Bowater's and Sailey.

4. International Intermodal Center, Huntsville

The International Intermodal Center at Huntsville was visited to understand the functioning and operation of an intermodal facility. It has been operated for approximately 10 years. It has only recently begun to return a profit.

The facility has about 34 acres of land. It serves as an intermodal facility and as a depot for container storage. The intermodal handling facility has four parallel railroad tracks, with a capacity to accommodate forty-four 100-foot rail cars each. The facility has a parking capacity of 500 wheeled units of Trailer On Flat Cars (TOFC), or a combination of 450 stacked units containers referred to as Container On Flat Cars (COFC) with 250 wheeled units. There are separately-controlled gates for entry and exit. The facility is also equipped with two-way audio, video and pneumatic communication between the driver at the gate and the personnel inside the facility. Video cameras record pictures of the driver and containers' conditions as they come in and go out.

Frequent yard checks are done to control inventory in the facility. The center is located close to the airport, and it is a trade-free zone. The facility also rents office space to International Cargo Customs Office, which is an added attraction. Computers are linked with the Norfolk Southern mainframe. This facilitates the monitoring of arrival and departure of trains and plans container loadings and shipments.

The facility has Electric-Electronic Gantry crane, which has a capacity of 45 tons. The crane can perform both conventional and double stack operations. The original cost of the crane was about $2.4 million dollars. The facility also has a 40-foot fork lift and a 20-foot fork lift. Nine people currently work in the facility. Four operate the crane from the ground, and supervise loading and unloading, and five work in the office, communicate with truck drivers, control data, and manage the operation. The facility has a maximum capacity to handle 88 lifts per day, or about 20,000 lifts per year. Currently, it is operating at 8,000 - 10,000 lifts/yr.

Revenue for the facility comes from various services such as lifting (loaded or empty), container storage, renting containers, use of the facility as a depot, and maintenance on equipment and trailers. At present, the average revenue of the facility is about $1.3 million. $1 million is from rail/truck transfer, and $300,000 is from other depot operations. The center is also trying to expand its land area to accommodate more storage of containers.

5. JIT Terminal

A field visit to the JIT Terminal located on the Manufacturers Road in Chattanooga beside the Tennessee river was done. The details of the visit and the information gathered are discussed under Existing Facilities in the Siting Needs section.

6. UTK Transportation Center

The Transportation Center at the University of Tennessee at Knoxville has research and service activities in all modes of transportation, including highway, rail, air, water, public transit, ride-sharing and pedestrian travel. Dr. Dave Clark, Assistant. Director of the transportation center and Mr. Barton Jennings were visited to discuss the center's research and activities. The center indicated that they had not done significant work in rail shipments or with the rail industry, although this area is of interest to Dr. Clark. He indicated that the center was beginning to look at getting more involved with the rail industry, facility conditions, rail shipments, etc. The center has provided some training for the railroad industry.

The individuals did not indicate that they provide free services to clients or small businesses. It is understood that the transportation center would be do research for a fee for their services. Dr. Clark took a very brief walk over some of tracks at Volunteer site and made a brief assessment of that site. Also Mr. Jennings was involved in the study for a similar army site at Indiana.

7. Norfolk Southern Debutts Yard - Chattanooga

To understand its infrastructure and operations, the Norfolk Southern Debutts Yard located on Amnicola highway was visited,. The yard handles an average of about 4000 rail cars and 85 trains per day. The classification yard has about 60 tracks. Rail cars are classified by their destination cities. The biggest track in the yard is about 8000 feet in length. Local car loadings to the yard are either picked up by NS rail engines or dropped off by the company's own engine. The yard, which used to operate on schedule basis, currently operates on a signal basis. The Volunteer site rail lines extend to this classification yard. The yard's crane for intermodal transfers from truck to rail or rail to truck is currently not in operation.

Conclusion

Data collected and information gathered are useful in developing an understanding of the region's freight movement, the organizations involved in freight movement, the types of commodities shipped, and the modes of transportation that are used. In-depth data concerning each organization's volume of freight were unavailable, as most of this information is kept confidential. The data gathered about rail freight and river freight were a few years old, but they still provided valuable information about the region's freight movement. The information gathered by visiting many people helps to understand the resources available regarding transportation, the various steps involved in the development of an intermodal facility, the operation of an intermodal facility, and also the necessity of a facility.

CHAPTER 5

SITING NEEDS

This section lists the siting requirements for the design and layout of an intermodal facility, bulk storage and distribution center.

5.1. Siting needs

The siting requirements for an intermodal facility with a bulk storage and distribution center are listed below. These were developed on the basis of information and research conducted previously.

1. Sufficient land area to handle bulk storage, to build an infrastructure, to allow an easy traffic flow, and room for parking, container storage, intermediate storage of goods during transfer, etc.
2. Presence of regional industries and other business organizations requiring shipments.
3. Access to major rail networks.
4. Classification yards for the rail.
5. Access to major highways and interstate highways.
6. Rate of road traffic near or through the site.
7. Number, extension, and strength of the roads within the site.
8. Access to or adjacent to airport.
9. Access to river or barge terminals.
10. Volume of goods movement in the region where the site is developed.

11. Volume of existing or potential intermodal movement in the region.

5.2. Potential Sites

In investigation of potential sites in and around Chattanooga the Volunteer Army Ammunition Plant (VAAP) in Chattanooga could be considered as a potential site for developing an intermodal facility. VAAP is an inactive U.S. Army facility for the production of TNT. It encompasses approximately 7000 acres including both developed and reasonably undeveloped land areas.

The site has 23 miles of rail tracks within its boundaries. Two classification yards are also present in the site. As it is located near the Tennessee river, a barge facility is also available in the region. The site is also situated within 2 miles of major interstate highways, and the Chattanooga Metropolitan Airport is located within 6 miles of the site. Many industries and other business organizations surround the area. These factors make the VAAP site an ideal location for developing an intermodal facility. The strength's and weaknesses of the facility are tabulated and shown in Table 5.1.

Other possible sites in Chattanooga such as Lovell field and River port though has access to different modes of transportation, lack in some areas in terms of facilities available in the site. The VAAP site has two classification yards with access to both the rail networks, which the Lovell field and River port does not have. Also the VAAP site is about two miles from the interstate which is in much close proximity than the other two sites.

Table 5.1 Strength and weakness of the VAAP site

STRENGTH	WEAKNESS
1. Access by two major rail networks	1. Rails not ready for service. Lot of clearing and Preparing has to be done
2. Two classification yards	2. Limited to Class I rail
3. Strategic distribution location in all four directions	3. Connection between CSX and NF rails poor
4. Rail lines reach most part of the site	4. Rail washouts incoming and on site
5. Good use of rail by companies around VAAP	5. No handling and loading equipments or limited loading facility
6. Proximity of river, air and highway is good	6. Bridge strength in access to CSX rail line from VAAP
7. Enough land area to handle large quantities of storage	7. Adequacy of roads on site for truck traffic
8. Significant amount of road traffic through Chattanooga	8. Ability of the roads inside the facility to withstand heavy truck traffic
9. Infrastructure for warehouse	9. Both rail ramps were closed in Chattanooga because of service inbalance
10. Different types of manufacturing companies in Chattanooga	10. Already established intermodal facilities in Chattanooga
11. Rail can be put into service with minimum amount of repair	
12. Has all requirements for an intermodal facility and other similar services.	
13. Rails inside the site owned by VAAP	

5.3 Existing facilities

A detailed list of existing terminals, the type of the facility, the commodity handled, the types of handling and storage facilities available, and the terminal's connections to other modes of transportation are shown in Appendix H. One of the existing terminals which was visited in order to study its operations is discussed below.

JIT Terminal

The JIT Terminal located on Manufacturers Road in Chattanooga beside the Tennessee river, was visited. Mr. John Bennett of JIT led the visit. The visit provided an opportunity to understand JIT's operations, capacity, and infrastructure. The JIT Terminal is an intermodal facility which has the capacity to transfer loads from barge to truck or rail. JIT receives goods such as roll steel, and chemicals like sodium hydroxide and LPG in barge. The facility has tank storage for chemicals. Each of the four tanks hold about one half million gallon capacity. One load of chemical barge shipment is less than 1/2 million. Chemicals received from barge are pumped to the storage tank through pipelines.

The facility has a 25 ton crane to transload or unload goods from barge to truck. Eleven propane storage tanks are located in the terminal, with two loading platforms to pump the propane to trucks. The two platforms combined together have a capacity of 60 trucks per day.

JIT receives approximately 60 truck loads of roll steel in one barge load. One truck carries one roll of steel weighing 40,000 pounds (trucking limit). JIT also cuts steel rolls into smaller sizes and weights. These are repackaged and transported by rail or truck. JIT owns 6 trucks and averages 3 barge-loads of steel per week and 3 rail and gas loads per week.

CHAPTER 6

PROBLEM FORMULATION

6.1. Layout

The design of an intermodal facility can consider the factors listed in the section titled 'Requirements of the facility'. The layout will be quite different depending on the level of the facility. A facility can have a simple ramp for trailers or provide equipment for sophisticated handling of goods. The layout of an intermodal facility with a depot for container storage is shown in Figure 6.1, Appendix Q. The main components of the facility are a container storage area, frame storage area, loading and unloading zone, gantry crane, inflow and outflow lanes, a pathway, and a rail yard. The layout is designed with respect to the Volunteer site Classification yard on the southern side of the site and land area available.

Depot

The container storage area is to be used for storing containers loaded with goods and also to store empty containers. These containers are staged in the storage area for several different purposes. Full containers stored in the depot will be transferred to a railcar, which will later leave the facility and be transported to a particular destination. Also, full containers coming into the facility by rail will be transferred onto a truck with an empty frame and might be stored in the depot. Then truck leaves the facility for a particular destination.

Similarly, empty containers coming into the facility by truck will be stored in the depot. If a company needs these empty containers to transport their goods, these containers might leave the facility by truck or might be transferred to rail and will leave by rail. Due to the time limits in operating the crane, which are discussed later, the containers may have to wait for a significant period of time. After one set of transfers is made, the area near the crane has to be cleared by the truck or rail which stayed in the area for a transfer, before the next set of transfer will take place. Sometimes the loaded containers might have to be stored overnight. These factors necessitate a storage area for the containers. The size of the storage area, also has to be large enough to hold a substantial amount of containers. The calculations for the size of the depot and the volume of container storage possible are discussed later.

Frame storage area

Empty frames come into the facility to receive full or empty containers when they are transferred from a railcar. A transfer of a full or empty container from a truck to a railcar also results in an empty frame. These frames have to be stored in a place until they are used to carry a container. The frame storage area serves this purpose. The calculations done in determining the size of the frame storage area are discussed later.

Gantry crane

The gantry crane transfers an empty or loaded container from one mode of transportation to another. In our case the gantry crane transfers a container from a truck to railcar or from a railcar to a truck. The crane is capable of lifting a container from a vehicle and placing it on top of another container. The crane could also be used to transfer a container from one truck to another truck or from one railcar to another. The crane is also capable of lifting two stacked containers at the same time. The crane plays a vital role in the intermodal operations of the facility. Each transfer of the crane is called a lift. The number of lifts the crane can perform in a day influences the other operations of the facility. The crane could be placed over a rail line by the side of pathway or road where a truck could be parked, or by the side of rail line on top of pathway. The crane has guide rails so that it can move back and forth to lift or drop. The railcars underneath the container can also be moved to receive a lift or to be picked up. The calculations done in determining the capacity of the crane are discussed later.

Loading and unloading zone

If gantry crane is to perform a transfer, trucks to receive transfers or to transfer containers and trailers must be in close proximity to the crane. A loading and unloading zone as shown in the layout is provided, so that the crane will be able to reach the container. The railcars also have to be under the crane or by the side of it. The size of the zone has to be reasonable, so that the crane does not have to wait for a truck to clear the way before it can perform a lift. The length of the zone has to be equal or greater than the length of the guide rails of the crane, which will be the maximum distance the crane will be able to move and lift a container.

Inflow and outflow lanes

A certain number of inflow and outflow lanes has to be provided for the trucks to come in and leave the facility. The lanes have entry and exit gates where the trucks coming in or going out will be inspected and documents will be checked and cleared.

The gates at these lanes will have communication links with the office in the facility. These activities take a certain period of time, this delay might restrict the number of trucks that can come in or leave the facility.

Pathway

A concrete pathway have to be provided between the depot, the frame storage area and the loading and unloading zone. These pathway facilitate easy movement of trucks with loaded containers within the facility.

Railyard

Containers coming into or leaving the facility by rail require a railyard with connecting rail tracks to major rail lines nearby. The number of tracks and the length of the tracks available in the yard determine the operating capacity and the parking capacity of the railyard. The Volunteer site has about 23 miles of rail tracks within its boundaries. The VAAP also has two classification yards, one served by CSX and one by NS. The number of tracks and the length of the tracks is important in determining the layout of the facility. The southern classification yard in the VAAP site is considered in designing the layout. This yard has a static capacity of 170 railcars. The operating capacity of the railyard is based on the maximum number of railcars the yard can handle without significantly reducing switching efficiency. The operating capacity of the yard can be calculated as 60 percent of the static capacity. Therefore the operating capacity of the yard with 170 static capacity is about 100 railcars. This classification yard has about 10 tracks of length approximately 1050 feet running parallel.

Calculations for capacity and area required of the facility

Given below are the calculations for operating crane capacity, the volume of inflow and outflow of trucks possible, the area required for all the storage areas, the pathway, and the loading and unloading zone.

Capacity of the facility

Maximum number of containers that could be handled in an intermodal facility with a 45 Ton Gantry Crane

Time required to transfer a container(either TOFC or COFC) from a truck to rail or from a rail to truck (for one lift) is estimated at 20 minutes.

At 20 min/lift for one day maximum number of lifts possible in single stack operation will be 75 lifts or 75 containers which can be transferred or transloaded.

At 25 min/lift for one day maximum number of lifts possible in double stack operation will be 115 lifts or 115 containers can be transferred or transloaded.

Inflow of Trucks

Assuming it takes ten minutes for a truck from the point of entry at the gate to enter the facility after clearing documents.

At 10 minutes the maximum number of trucks that could possibly to enter the facility in one day is 145

The total storage capacity of the depot is assumed to be 300, and the maximum number of lifts that can take place in a day for a double stack operation is about 115. Therefore the total number of containers in trucks that come into the facility should be more than or equal to 300+115=415. In order to do this the number of incoming lanes to the facility has to be at least 3.

Therefore with 3 drive-in lanes 145 * 3 = 435 trucks

Outflow of Trucks

Assuming it takes 15 minutes for a truck to clear documents, have its contents inspected, and to exit the facility at the gate.

The maximum number of trucks that could possibly exit the facility at 15 minutes intervals, with one exit lane in one day will be 95 trucks. With the same reasoning given for the number of incoming lanes, the optimal number for the number of outgoing lanes will be three. With three exit lanes the maximum number of trucks that leave the facility will be 285.

Calculations for land area required

In order to calculate the land area required, the area occupied by one container for a maximum size is considered. The land area for the depot, loading and unloading zone, pathway, frame storage are defined in terms of the number of containers needed to be stored. Area occupied by one container of size 85 feet length and 10 feet width will be 850 square feet. The maximum size of a container or a trailer currently available is about 89 feet in length and 10 feet in width [1]. Adding a foot on the length and on either side of the width for better spacing between the containers, gives a size of 90 feet length and 12 feet width. Area needed for a size 90ft X 12ft = 1080 sqft.

1. Area required for the loading and unloading area near the gantry crane

The land for the loading and unloading zone has to be near the classification yard over which the gantry crane will be placed. The guide rails of the gantry crane will be approximately equal to the length of the yard's rail tracks, which is about 1050 ft. This is the length the crane will travel, and the length of the loading and unloading has to be greater than or equal to this length. Therefore the length of the area for loading and unloading zone was chosen to be 1200 ft. The width of the area should be able to accommodate the length of a trailer or a container. So the width of the area was chosen to be 110 feet given the necessary clearances.

Length 1200 ft and width 110 ft = 132,000 sqft or 3.03 acres

2. Area required for storage or depot

   Assuming a storage capacity of 300 containers in single stack.

   Area required for one container of size 90ft X 12ft = 1080 sqft.

   For 300 containers, 300 * 1080 sqft = 324,000 sqft or 7.43 acres

   Size of the depot -- 360ft X 900 ft

3. Area required for the pathway

   For a pathway of size 100ft and 1800 ft length, area required =

   100ft * 1800 ft = 180,000 sqft or 4.13 acre

4. Area required for the office building and entry, exit gates approximately 0.5acres

5. Area required for frame storage area with a capacity of 100 containers (or frames) could be 180 * 600 sqft/container = 108,000 sqft or 2.48 acres.

Total area required for the facility

1. Loading and unloading area	=	3.03 acres
2. Depot	=	7.43 acres
3. Pathway	=	4.13 acres
4. Office and other buildings	=	0.50 acres
5. Frame storage area	=	2.48 acres
TOTAL	=	17.58 acres

6.2 Equipment and Costs

Under this section the cost of equipment needed to run the facility and other cost factors associated in developing a site into facility are caluculated. Possible expenses in the facility for a day are also calculated.

1. Estimate cost of equipment for the facility, land, and building

A. Estimate equipment cost

The cost of a Gantry crane of capacity 45 tons, as is currently used in the Huntsville intermodal facility is about 3 million dollars. A similar capacity crane is considered for the estimate here.

Cost of Yard Gantry Crane = $3,000,000

Support Equipment required for a gantry crane will be one or two mobile cranes, five tractors and chassis. [1]

B. Estimate labors.

The minimum number of personnel required in a facility for operating one gantry crane operation are listed below. [1]

supervisor -- 1

clerks -- 2 to 4

crane operators -- 2

load operators -- 2

tractor drivers -- 2

maintanence personnel -- 1

C. Estimate revenue based on Huntsville intermodal facility data.

The following cost figures are the costs currently charged by the Huntsville intermodal facility. These cost figures are used as a basis to calculate revenue.

Revenue from lifts

At $25 per lift

Revenue obtained by performing 75 lifts per day in single stock operation will be 75 * $25 = $1,825/day.

Revenue obtained by performing 150 lifts per day in double stock operation will be 150* $25 = 3,750/day.

Revenue from storing containers at the Depot

Assuming $6 for one day storage for a container

Assuming a storage capacity 300 single stack containers of maximum size 90ft X 12ft in the depot.

For a storage capacity of 300 containers, the maximum revenue possible from the depot in one day will be 300 * $6 = $1,800/day

2. Calculations for civil construction, land preparation, and filling.

A. Calculations for depot, frame storage area, pathway, loading and unloading zone concrete flooring.

The cost figures mentioned below were obtained from a construction company in Chattanooga as a rough estimate for calculation purposes.

1. Land preparation cost for an area of 744,688 sqft or 17.08 acres	
17.08 acres X $2,000 per acre	= $ 34,200
2. Cut and fill at 4 ft X 4 ft for 17.08 acres	
109,738 cubic yards X $3 per cubic yard	= $ 329,200
3. Concrete flooring at 8 inch thickness for 744,688 sqft area	
744,688 sqft X $3.40 per sqft	= $2,532,000
4. Hardener topping	
744,688 sqft X $0.65 per sqft	= $ 484,000
Total	= $3,379,400

B. Calculations for office building of area 0.50 acres

1. Land preparation

0.50 acres X $2000 per acre	= $ 1,000

2. Cut and Fill

3335 cubic yard X $3 per cubic yard	= $ 10,000

3. Concrete slab and footings

22,185 sqft X $2.50 per sqft	= $ 55,462

4. Construction cost for a 2 storey office building

22,185 sqft X $60 per sqft	= $1,331,100
Total	= $1,397,562

3. Production costs

Fixed costs

1. Assuming an average salary of $50,000/year for one person working in the facility.

$50,000 / year =- $140 / day, For 3 persons salary = $140 * 3 = $420

2. Interest

Amount invested by Industrial bonds - $8,000,000 Current average Interest rate for long term Industrial Bonds is 6% / year.

For $8,000,000 interest will be $480,000

Interest to be paid per day - $1,335

Variable costs

1. Utilities

Electricity - \$700 / day - Obtained from the Huntsville intermodal facility.

Water -- \$ 50 / day - Obtained from the Huntsville intermodal facility.

Telephone - \$ 100 / day - a rough estimate.

2. Maintanence --- gantry crane, rail yard, roads, tractors, mobile crane, trailers, depot

Approximately - \$ 200 / day - a rough estimate.

3. Assuming a labor cost of \$10/hour.

Labor cost for 5 persons with \$10 / hour, operating 16 hours per day will be \$ 800 / day

Total production cost = \$3,350 / day

B. Capital recovery

Total Investment = \$8,000,000

If the capital invested is desired to be recovered at a 10% rate of return, then the return at 10% / year for \$8,000,000 will be \$800,000 / year at 10 years.

Recovery per day = \$2,200

Total cost per day

\$3,350 + \$2,200 = \$5,550 / day

6.3. Analytical Model

To obtain an evaluation of the feasibility of a facility and to understand the functions of its different elements, a model which characterizes the facility's operations and activities is developed. This model is designed to estimate the activities of the facility such as container storage, inflow and outflow, and transfers. From this model, the levels of activities can be examined to define the various economic levels needed for operation. Information was obtained and developed from visiting intermodal facilities, interviewing existing users & potential users, transportation authorities, and studying the requirements of the region, and the facilities available on the site under consideration.

The facility's capabilities and functions considered for the model initially are an intermodal facility and a depot including container storage. The facility is fully described in Chapter 3.3 under 'Requirements of a facility.' The layout for this model is shown in Figure 6.1. Using the available data and information, it is intended to investigate aspects of flow and various activities of the facility, and to optimize possible operations of the facility. One possible way to optimize such a problem is by formulating them as a linear programming model.

The facility's potential can be evaluated by formulating its activities as a linear programming problem and by analyzing the results of that problem. In order to formulate the problem, the capacities of the facility's different storage and equipment components were calculated. The inflow and outflow and different possible activities for the facility were also calculated.

The objective of formulating this linear programming model is to optimize the flow in the facility and to maximize the profit to the facility. The facility has two types of vehicles moving in and out of the facility with or without goods. The two types of vehicles are railcars and trucks. The trucks can have a frame or just the cab for pickup, and carry either a full (loaded) container or an empty container to the facility. Also, trucks can have trailers with wheels to be shipped as a unit. Railcars moving in and out of the facility carry loaded containers, empty containers and trailers. A crane present in the facility could transfer containers and trailers from truck to railcar or from railcar to truck. A container in a truck or in a railcar coming into the facility could be either stored in the storage area or transferred to another mode and would leave the facility to a particular destination.

Formulation

In order to formulate these activities into a linear programming model the decision variables in the problem have to be identified first. If a truck comes into the facility with a full container, the container could be either stored or transferred to a railcar for shipment or temporary storage. So when a truck with a full container enters the facility three activities are possible, a truck with a full container coming into the facility, storage of a full container in the storage area and transfer of a full container from truck to a railcar by a crane. In this way all the variables for all possible activities of the facility are identified by determining the flow of containers, frames, and trailers within the facility. A sample of activity and the corresponding decision variables are shown in a tabular form in Table 6.1.

The objective function of the LP model is given below

Maximize Z = X1 + X2 + X3 + ---------------------------------+ X58 + X59 + X60 – X61

where X1 = Full container coming in by truck in day 1

X2 = Empty container coming in by truck in day 1

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X60 = Empty railcars coming in by rail carried over to day 4

X61 = Total cost for three day operations

Table 6.2 contain a complete list of decision variables. These variables form the decision variables of the objective function of the linear programming model. Each of the decision variables is associated with a cost coefficient depending upon its function in the model. The transfer of a container from one mode to another and storage of containers, frames and railcars are the primary sources of revenue to the facility. The objective function of the model, with the decision variables and the cost coefficients is shown in Appendix I.

Formulation of the constraints

From the discussion of the layout of the facility, it can be observed that a group of activities are associated with one operation in the facility. These activities influence the decision variables associated with the operation. In order to get the optimal quantity of a

Table 6.1 List of activities and corresponding decision variables

Activity	Decision Variables
1. Truck coming into the facility with full container.	1. Number of Truck coming into the facility with full container 2. Number of Transfer of full container to a Railcar by the crane and out of the facility by railcar.
2. Truck coming into the facility with an empty container	3. Number of Trucks with empty container coming into the facility 4. Number of transfer of empty containers from truck to a railcar and out of the facility by railcar.
3. Truck coming into the facility with an empty frame	5. Number of Trucks coming into the facility with an empty frame
4. Truck leaving the facility with an empty container	6. Number of Trucks with empty container leaving the facility
5. Truck leaving the facility with an empty frame	7. Number of Trucks leaving the facility with an empty frame
6. Railar coming into the facility with full container.	8. Number of Railcars coming into the facility with full container 9. Number of Transfer of full container to a Truck by the crane and out of the facility by truck.
7. Railcar coming into the facility with an empty container	10. Railcar coming into the facility with an empty container 11. Number of transfer of empty container into a truck by crane and out of the facility by truck.
8. Railcar coming into the facility empty	12. Number of railcars coming into the facility empty
9. Railcar leaving the facility with an empty container	13. Number of railcars with empty container leaving the facility
10. Railcar leaving the facility empty	14. Number of railcars leaving the facility empty

Table 6.2 List of decision variables

X1 = Full container coming in by Truck in day 1	X29 = Empty container in by Truck and out by Rail in day 2
X1T = Trailers coming in by Road in day 1	X30 = Empty container in by Rail and out by Truck in day 2
X2 = Empty container coming in by Truck in day 1	X31 = Empty frame in by Truck in day 2
X3 = Full container coming in by Rail in day 1	X32 = Empty frame out by Truck. in day 2
X3T = Trailers coming in by Rail in day 1	X33 = Empty railcar in by rail. in day 2
X4 = Empty container in by Rail in day 1	X34 = Empty railcar out by rail. in day 2
X5 = Empty container out by Truck in day 1	X35 = Full containers by Truck carried over today3
X6 = Empty container out by Rail in day 1	X35T = Trailers by Road carried over to day 3
X7 = Full container in by Truck and out by Rail in day 1	X36 = Empty containers by Truck carried over to day 3
X7T = Trailers in by Road and out by Rail in day 1	X37= Empty Frame by Truck carried over to day 3
X8 = Full container by Rail and out by Truck in day1	X38= Full containers by Rail carried over to day 3
X8T = Trailers by Rail and out by road in day 1	X38T= Trailers by Rail carried over to day 3
X9 = Empty container in by Truck and out by Rail in day 1	X39= Empty containers by Rail carried over to day 3
X10 = Empty container in by Rail and out by Truck in day 1	X40= Empty Railcars by Rail carried over to day 3.
X11 = Empty frame in by Truck in day 1	X41 = Full container coming in by Truck in day 3
X12 = Empty frame out by Truck. in day 1	X41T = Trailers coming in by Road in day 3
X13 = Empty railcar in by rail. in day 1	X42 = Empty container coming in by Truck in day3
X14 = Empty railcar out by rail. in day 1	X43 = Full container coming in by Rail in day 3
X15 = Full containers by Truck carried over to day 2	X43T = Trailers coming in by Rail in day 3
X15T = Trailers by Road carried over to day 2	X44 = Empty container in by Rail in day 3
X16 = Empty containers by Truck carried over to 2	X45 =Empty container out by Truck in day 3
X17= Empty Frame by Truck carried over to day 2	X46 = Empty container out by Rail in day 3
X18= Full containers by Rail carried over to day 2	X47 = Full container in by Truck and out by Rail in day 3
X18T= Trailers by Rail carried over to day 2	X47T = Trailers in by Road and out by Rail inday 3
X19= Empty containers by Rail carried over to day 2	X48 = Full container by Rail and out by Truck in day 3
X20= Empty Railcars by Rail carried over to day 2	X48T = Trailers by Rail and out by road in day 3
X21 = Full container coming in by Truck in day 2	X49 = Empty container in by Truck and out by Rail in day 3
X21T = Trailers coming in by Road in day 2	X50 = Empty container in by Rail and out by Truck in day 3
X22 = Empty container coming in by Truck in day 2	X51 = Empty frame in by Truck in day 3
X23 = Full container coming in by Rail in day 2	X52 = Empty frame out by Truck. in day 3
X23T = Trailers coming in by Rail in day 2	X53 = Empty railcar in by rail. in day 3
X23T = Trailers coming in by Rail in day 2	X54 = Empty railcar out by rail. in day 3
X24 = Empty container in by Rail in day 2	X55 = Full containers by Truck carried over today4
X25 = Empty container out by Truck in day 2	X55T = Trailers by Road carried over to day 4
X26 = Empty container out by Rail in day 2	X56 = Empty containers by Truck carried over to day 4
X27 = Full container in by Truck and out by Rail in	X57= Empty Frame by Truck carried over to day 4
X27T = Trailers in by Road and out by Rail in day 2	X58= Full containers by Rail carried over to day 4
X28= Full container by Rail and out by Truck inday2	X58T= Trailers by Rail carried over to day 4
X28T = Trailers by Rail and out by road in day 2	X59= Empty containers by Rail carried over today4
	X60= Empty Railcars by Rail carried over to day 4

particular decision variable, decision variables have to satisfy certain constraints. The individual activities may influence more than one decision variable. The group of activities and its constraints are discussed below.

1. Storage capacity of the facility (depot)

The facility has different storage areas for the containers, frames, trailers, and railcars. Each of these storage areas has a physical limit for the maximum storage possible. The maximum number of containers (full or empty) that can be stored in the depot is 300. This container storage area is used by full and empty containers coming into the facility by truck, and by containers transferred from railcar to truck. While containers coming into the facility by truck and containers transferred from railcar to truck increase the number of stored containers in the facility, containers leaving the facility and containers transferred to railcar from truck decrease the number of containers stored in the facility's container storage area. The maximum storage possible influences the number of containers coming in and leaving and also affects the transfers made from one mode to another. In order to optimize and to balance the container storage, the following constraint equation is necessary.

$$X1 + X1T + X2 + X10 - X7 - X7T - X9 <= 300 \quad \text{(Constraint 1)}$$

where X1 = Full containers coming in by truck in day 1.
X1T = Trailers coming in by road in day 1.
X2 = Empty containers coming by truck in day 1.
Table 6.2 contains a listing and description of the decision variables.

The maximum number of frames that can be stored in the frame storage area is 100. The frame storage area is necessary since containers transferred from a railcar to a truck requires an empty frame. When a container is transferred from truck to railcar, the resulting empty frame has to be stored. The frame storage area is used by the empty frames coming into the facility, and frames resulting out of a transfer from truck to railcar. While the empty frames coming into the facility and the transfer of containers from truck to railcar increases the number of frames stored, empty frames leaving the facility and transfer of containers from railcar to truck decreases the number of frames stored in the frame storage area. These activities result in the following constraint equation.

$X7 - X8 + X9 - X10 + X11 - X12 <= 100$ (Constraint 2)

The maximum number of railcars that can be stored in the rail yard is 100. The rail lines in the rail yard are used for the storage of full and empty containers coming into the facility in railcars, and also by empty railcars. The maximum number of railcars that can be stored without hindering the inflow and outflow of other railcars is 100. Containers and empty railcars coming in by rail and containers transferred from truck increase the quantity of railcars stored in the facility. Containers transferred from railcar to truck and empty railcars leaving the facility decrease the quantity stored. These activities are put together to optimize and balance the storage of railcars as shown below.

$X3 + X3T + X4 + X7 + X9 + X13 - X8 - X8T - X10 - X14 <= 100$ (Constraint 3)

2. Inflow and outflow of the facility

The maximum number of trucks that comes into the facility in a day due to the number of incoming lanes available and the time required between one truck to another to enter the facility as discussed in the layout for one day is 400. This limit restricts the number of full and empty containers coming into the facility by truck and the number of empty frames coming into the facility by truck.

These activities are represented by the following constraint.

X1 + X1T + X2 + X11 <= 400 (Constraint 4)

The maximum number of trucks that can leave the facility due to the number of exit lanes available and the time interval between each truck leaving in one day, is about 285. The possible exits from the facility through road are empty container by truck, full container coming in by rail and transferred to truck will leave the facility, empty container that came in by rail transferred to truck might leave the facility, and empty frame might leave the facility. The sum of these activities should be less than or equal to the number of possible exits in one day, which shown by the following constraint equation.

X5 + X8 + X8T + X10 + X12 <= 285 (Constraint 5)

The maximum number of railcars that can come into the facility rail yard in one day will be 316. This restricts the number of railcars coming into the facility with full containers, railcars with empty containers and empty railcars. This restriction is shown by the following constraint equation.

X3 + X3T + X4 + X13 <= 316 (Constraint 6)

The maximum number of railcars that can leave the facility is also restricted to 316. Therefore the total number of empty containers leaving the facility by rail, empty railcars leaving the facility, the transfer of full containers from a truck to railcar which leaves the facility, and the transfer of empty containers from truck to rail which might leave facility should be less than or equal 316, which is shown by the following equation.

X6 + X7 + X7T + X9 + X14 <= 316 (Constraint 7)

3. Operating capacity of the Gantry crane

The gantry crane due to the time it takes to transfer a container empty or full, from one mode one of transportation to another, the number of possible transfers is restricted to 75 per day. In order to transfer a full or an empty container from truck to rail or from rail to truck, the gantry crane has to be used. Therefore the total possible number of such transfers in one day is restricted to 75, which is represented by the following constraint equation.

X7 + X7T + X8 + X8T + X9 + X10 <= 75 (Constraint 8)

4. Dependence of one activity on another

Some activities in the facility depend on the number of transactions of another activity. Sometimes one activity has to occurr before another occurs because one activity may be proportional to the number of another activity. These activities and there corresponding constraint equations are given below.

The number of full containers transferred from truck to rail should not be more than the number of full containers that came into the facility by Truck.

X1 - X7 >= 0 (Constraint 9)

The number of empty containers transferred from truck to rail should not be more than the number of empty containers that come into the facility by truck.

X2 - X9 >= 0 (Constraint 10)

The number of full containers transferred from rail to truck should not be more than the number of full containers that come into the facility by rail.

X3 - X8 >= 0 (Constraint 11)

The number of empty containers transferred from rail to truck should not be more than the number of empty containers that come into the facility by rail.

X4 - X10 >= 0 (Constraint 12)

The number of empty containers going out by truck should not be more than the number of empty containers that came in by truck.

X2 - X5 >= 0 (Constraint 13)

The number of empty containers going out by rail should not be more than the number of empty containers that came in by rail.

X4 - X6 >= 0 (Constraint 14)

The number of full container transfers from truck to rail should not be more than the number of empty railcars that come in.

X13 - X7 >= 0 (Constraint 15)

The number of empty railcars that leave should be less than the number of empty railcar that came in, plus the number of empty railcars that resulted out of a transfer to truck.

X8 + X13 - X14 >= 0 (Constraint 16)

The number of transfers from truck to rail should be equal to or less than the number of empty railcars that came, plus the number of empty railcars that resulted from a transfer to truck.

X13 + X8 - X7 >= 0 (Constraint 17)

The number of transfers from rail to truck should be equal to or less than the number of empty frames that came in by truck, plus the number of empty frames that resulted out of a transfer to rail.

X11 + X7 - X8 >= 0 (Constraint 18)

The linear programming (LP) model thus obtained was run by using a LP optimization software called LINDO. The results obtained for the initial case were questionable results as the total number of trucks or railcars that came in exited the same day. The model did not appear to account for possible carry over of the system's state to the next day. This neccessiated a modification of the model to include constraints that would carry over the state of certain variables such as the full or empty containers, frames, and railcars to be used in the analysis of the following day. Since LP are usually static models, a method had to be derived to address the carryover state of the system from one period to the next. This led to the development of a multiperiod formulation of the LP. It expands the number of variables but provided the necessary coupling.

Carryover constraints

The carrying over of an activity from one day to the next is formulated as shown below, with a decision variable assigned for the activity. For example, the full containers that come in by truck are transferred to rail by the crane, but the containers that are not transferred to rail has to be carried over to next day. The next day these containers will possibly be transferred to rail. This shown by the following constraint.

X1 - X7 = X15 (Full containers that come in by truck - transferred to rail = full containers stored or carried over to next day in container storage.) (Constraint 20)

This is also true for empty containers which, leads to the following constraint.

X2 - X9 - X5 = X16 (Empty containers that come in by truck - transferred to rail - empty containers that leave by Truck = Empty containers stored or carried over to next day in container storage.) (Constraint 21)

The empty frames coming into the facility leave the facility with a container recieved from a rail transfer or has to be carried over to next day. Also, the frame might leave the facility empty. This is shown by the following constraint.

X11 - X8 - X12 = X17 (Empty frame that came in by truck - frame that leaves with containers (full or empty) - Empty frame that leaves by truck = Empty frame stored or carried over to next day in frame storage.) (Constraint 22)

As in the case of containers by truck, the same is true for containers coming in and leaving by rail, as shown by the following constraint equations.

X3 - X8 = X18 (Full containers that come in by rail- full containers that are transferred to truck = full containers stored or carried over to the next day in railcar storage.)Constraint 23)

X4 - X10 - X6 = X19 (Empty containers that come in by rail - empty containers transferred to truck - empty containers that leave by rail = Empty containers stored or carried over to next day in railcar storage.) (Constraint 24)

X13 - X7 - X14 = X20 (Empty railcars that come in by rail - railcars that leave with containers (full or empty) - Empty railcars that leave by rail = Empty railcars stored or carried over to next day in railcar storage) (Constraint 25)

The final linear programming model with the objective function and constraint equations are shown in Appendix K.

CHAPTER 7

RESULTS

7.1 Introduction

The LP model which was developed was executed in LINDO optimization software to optimize operations at the proposed intermodal facility, and the results were then analyzed. Based on a test case to verify its operations, it was observed that the LP model gave acceptable results. The model reached an optimum, giving a maximum profit amount by making the maximum possible transfers or lifts. Due to computational limits in the optimization software (number of variables and constraint equations permitted) used only three days of operation in the facility are considered in formulating the objective function and the constraint equations. The results obtained from the model were also analyzed to see if the constraint conditions were met properly.

Some of the values of the decision variables were in decimals or fractions. The results of the model are expected to be a whole number, since a fraction of a container or a railcar cannot enter the facility nor can be transferred. The divisibility assumption of the linear programming implies that fractional answers are acceptable. A linear programming in which the decision variables must be nonnegative integers could be solved using Integer programming. In this LP model the divisibility assumption is not satisfied. For this situation, rounding off each variable in the optimal LP solution yields a reasonable solution, so decision variables with a fractional value are rounded off.

To understand the behavior of the model for different cases or situations, and to utilize the LP model for investigating operational levels for facility profitability, seven different cases were run. These cases help to evaluate the feasibility of the facility by analyzing the quantity of activities needed in the facility for a desired state of operation. A description of the cases run are listed in table 7.1.

Table 7.1 Description of cases run for the LP model.

NAME	DESCRIPTION
CASE A : To find the level of activities needed to Break Even	This case is set to find the level of activities needed when cost is set equal to the revenue.
CASE B: Cost assigned only for lifts and container storage	This case is to understand the behavior of the model when cost coefficients are varied.
CASE C: Cost assigned only for the lifts	This case is again helpful to understand the model's behavior when a cost is assigned for few variables, especially lifts.
CASE D: Maximum profit possible with normal lift capacity	A cost is assigned for all the decision variables. The maximum profit generated for the model with respect to the level of activities will be helpful in analyzing its feasibility.
CASE E: Maximum profit possible with lift capacity increased from 75 to 100	Adding additional capability to the facility (such as a ramp) will increase lift capacity. Results obtained by increasing the lift capacity will be helpful in analyzing the effects of additional capability.
CASE F: Maximum profit with lift capacity decreased from 75 to 50.	This case helps to understand the opposite effect of reducing current capacities.
CASE G: Maximum profit possible with total cost reduced from $5,550/day to $4,705 / day	This case demonstrates the effect on the profit and the different activities involved by having a reduced total cost. A reduced total cost is possible by having a lesser capital recovery or by some other means.

A sensitivity analysis is done, for each case examined using the LP model. The results obtained are analyzed below. A summary of the results obtained for each of the cases is shown in Table 7.2. The LP model and the results obtained from sensitivity analysis for each case is given in Appendix K. The results of the LP for each case were analyzed to see if there is a balance at the end of the day between the number of incoming containers and trailers, the number of transfers made to another mode, the number of containers and trailers that leave the facility, and the number of containers and trailers carried over to the next day operations. The results of these analysis are given in Appendix L.

7.2 Case Analysis

Case A:

Case A is designed to establish the level of activities needed for revenues to equal cost plus capital recovery for the given facility design. This particular case is obtained by adding a constraint equation in which the values of all the decision variables multiplied by its cost coefficient were set equal to the total operation cost, plus the capital recovery for three days of facility operation. A cost coefficients is assigned for each of the decision variables in the LP. This cost will be the fee charged by the facility to its customers. For example, a $19 fee will be charged by the facility to its customers for transferring a container from truck to rail.

Table 7.2 summary of the results obtained for each case

SUMMARY OF THE RESULTS OBTAINED FROM DIFFERENT CASES OF THE LINEAR PROGRAMMING MODEL

CASES	DAY OF OPERATION	LIFTS	FULL CONTAINER STORAGE IN DEPOT	EMPTY CONTAINER STORAGE IN DEPOT	FULL CONTAINER STORAGE IN RAILYARD	EMPTY CONTAINER STORAGE IN RAILYARD	EMPTY FRAME STORAGE IN DEPOT	EMPTY RAILCAR STORAGE IN RAILYARD	TRAILER STORAGE IN DEPOT	TRAILER STORAGE IN RAIL YARD	FORECASTED GAIN IN REVENUE
CASE A TO FIND THE LEVEL OF ACTIVITIES NEEDED FOR BREAK EVEN	1	75	0	0	100	0	100	0	0	0	$0 (Break Even)
	2	75	0	300	100	0	100	0	0	0	
	3	75	0	300	75	0	50	0	0	0	
CASE B A COST WAS ASSIGNED FOR ONLY LIFTS AND CONTAINER STORAGE	1	75	300	0	0	0	100	100	0	0	$96.00
	2	75	300	0	0	0	100	100	0	0	
	3	75	300	0	100	0	100	0	0	0	
CASE C A COST WAS ASSIGNED ONLY FOR LIFTS	1	75	0	150	0	0	0	100	0	0	($6,944.00)
	2	75	0	150	0	0	0	75	0	25	
	3	75	0	150	0	0	100	0	150	100	
CASE D MAX PROFIT POSSIBLE WITH NORMAL LIFT CAPACITY	1	75	0	150	0	0	0	100	0	0	$8,073.00
	2	75	0	150	0	0	0	100	0	0	
	3	75	0	150	0	0	100	0	150	100	

Table 7.2 summary of the results obtained for each case

CASES	DAY OF OPERATION	LIFTS	FULL CONTAINER STORAGE IN DEPOT	EMPTY CONTAINER STORAGE IN DEPOT	FULL CONTAINER STORAGE IN RAILYARD	EMPTY CONTAINER STORAGE IN RAILYARD	EMPTY FRAME STORAGE IN DEPOT	EMPTY RAILCAR STORAGE IN RAILYARD	TRAILER STORAGE IN DEPOT	TRAILER STORAGE IN RAILYA	FORE-CASTED GAIN IN REVENUE
CASE E											
MAX PROFIT	1	100	0	150	0	0	0	100	0	0	
POSSIBLE											
WITH LIFT	2	100	0	150	0	0	0	100	0	0	$9,348.00
CAPACITY											
INCREASED	3	100	0	300	0	100	100	0	0	0	
FROM 75 TO 100											
CASE F											
MAX PROFIT	1	50	0	100	0	0	0	0	0	0	
POSSIBLE											
WITH LIFT	2	50	0	100	0	0	0	0	0	0	$2,538.00
CAPACITY											
DECREASED	3	50	0	100	0	0	50	0	0	0	
FROM 75 TO 50											
CASE G											
MAX PROFIT	1	75	0	150	0	0	0	100	0	0	
POSSIBLE											
WITH REDUCED	2	75	0	150	0	0	0	100	0	0	$10,608.00
TOTAL COST											
	3	75	0	150	0	0	100	0	150	100	

The results obtained were analyzed to find which constraint equations were binding. The constraint equation for maximum possible lifts or transfers for each day's operation was observed to be binding. This means that the maximum capacity of the crane was used to reach the break even point. The constraint equations were not binding for maximum storage possible for containers and trailers in the depot, maximum storage possible in the frame storage area, maximum storage possible for railcars in the yard, maximum possible number of trucks that can come in, or maximum possible number of trucks that can leave the facility, maximum possible number of railcars that can come in, maximum possible number of railcars that can leave the facility. This situation indicates that the maximum storage capacity in the depot, frame storage area, and the railyard was not used to reach the break even point. So more storage and more revenue can be generated from the facility. Since the maximum number of vehicles that can come in and leave in a single day is not reached, it is possible that more vehicles could enter or leave the facility in a single day.

A sensitivity analysis was done on the cost coefficients of the decision variables for the lifts. This analysis gives a range of values for which the current basis will remain unchanged. The cost for some of the variables whose results were equal to zero can be decreased to infinity and the basis will not change. When the basis does not change, the same solution set will be obtained. The sensitivity analysis indicates that for all the cost coefficients of the lifts, the amount by which it can be increased is zero. This might indicate that the costs for the lift decision variables is critical of the cost coefficient and that increasing the costs on these will lead to a different set of solutions. Since the objective in this case is to break even, increasing the cost for a decision variable might reduce the amount of that activity in the solution for that decision variable to reduce the revenue obtained. Reducing the amount of that activity will equal the revenue to the total cost. For the variables which had results greater than zero, the range by which the cost can be increased or decreased is zero.

Shadow prices for the constraint equations were obtained by doing the sensitivity analysis. The shadow price of a constraint is the amount by which the objective function value will increase, if we increase the value of the constraint by one unit. Shadow price will help to understand the effect of increasing the lift and storage capacities of the facility on the result of the objective function.

Except for two constraint equations, all the shadow prices in this case are zero. The constraint equation (equation number 83 in the LP model for case A), in which the value of all the decision variables was set equal to the total operation cost plus the capital recovery for three days of operation of the facility, the shadow price was $1. Also for the constraint equation (equation number 84 in the model), in which a decision variable is set equal to the total operating cost plus the capital recovery for three days of operation, the shadow price was -$1. The shadow price $1 indicates that increasing the right hand side by $1 will increase the revenue $1 more than the cost, thereby increasing the objective function value by $1. Shadow price of -$1 indicates that increasing the total cost by $1 will reduce the value of the objective function by $1.

A sensitivity analysis on the right hand side values of the constraint equations was done. For the depot storage capacity value 300, no increase or decrease is possible. An increase or decrease in the value will give different set of solutions for the LP. Thus the storage capacity is a critical value in the model for this case. The railyard storage capacity cannot be increased, but can be decreased by as much as 35 without affecting the solution set. This indicates that to break even in the facility lesser railyard storage space will be sufficient. If the lift capacity of the crane is increased by 54 and decreased by 10 the set of solutions for the LP will not change. Increasing or decreasing the lift capacity will result in an increase or decrease from the number of lifts obtained in the previous solution for a lift decision variable.

CASE B:

CASE B is designed to understand the behavior of the facility when cost is assigned for only variables such as lifts and storage. A fee of $25 is assigned for full container and trailer transfers, $16 for empty container transfers, and $6 for storage.

The case gave a result of $32 per day as the profit or gain in revenue. The results were checked to see which of the constraint equations were binding. It is observed that the constraint equations for lifts, container, trailer storage in the depot, frame storage, and railyard storage were all binding. Constraint equations for the maximum possible number of trucks, trailers that can come in and leave, and the maximum possible number of railcars that can come in and leave, however were not binding. This might indicate that when the importance is given for lifts and storage in the LP by assigning costs only for those variables, the optimum is obtained by utilizing the full capacities.

A sensitivity analysis on the cost coefficients of the lift decision variables indicates that the variables which had a result greater than zero cannot be increased or decreased. The variables which had result of zero could be increased to a set of ranges. This is also true in case of storage.

Shadow prices in this case are very sensitive towards the constraint equations for lifts or crane capacity. An increase in the lift capacity by 1 unit increases the objective function value by $24. Shadow prices for storage in the depot, railyard, and frame have shadow prices of $4, $5, and $4 respectively. An increase in the storage capacities by one unit increases the profit obtained by the dollar value given above. Shadow prices reflect the costs assigned for the decision variables in the objective function.

Sensitivity analysis on the constraint values indicate that in this case the depot storage, railyard storage, frame storage, and maximum possible inflow of trucks cannot be increased or decreased. But the maximum possible inflow of railcars can be decreased by 141 and will not affect the current result of this case.

CASE C:

This case similar to case B, but a cost is assigned only for the lifts. A fee of $25 for full container and trailer and $16 for empty containers is assigned. The model for this case is expected to behave very sensitively towards lift capacity.

This case gave the result of negative $2,315 per day as gain in revenue. The constraint equations for depot storage, for the maximum inflow and outflow in a railyard and in depot, and for frame storage were not binding. But the constraint equations for railyard storage and crane capacity are binding, indicating that the full storage capacities of railyard storage were used.

Sensitivity analysis on the cost coefficients of the decision variables indicates results similar to case B. The cost coefficients for lift variables with a result greater than zero cannot be increased or decreased. Shadow prices of the constraint equations for lift capacities indicate that the increase in lift capacity will increase the value of the objective by \$23. A sensitivity analysis on the depot storage constraint indicates that storage can be decreased by 75, and will not affect the set of solutions obtained for this case. Railyard storage capacity cannot be increased or decreased.

CASE D:

This case is set to find the maximum profit that can be generated with the normal lift capacity and with a cost assigned for all the variables. A fee of \$19 for a full container and trailer lifts and \$6 for the incoming container and trailer is assigned. The fee of \$25 for a lift is divided between the lift and the incoming containers and trailers. The same is done for empty containers also. The model generated a \$2,691 per day profit for this case.

The results of the LP model is analyzed to find binding and non binding constraints. The constraint equations for depot storage, the maximum number of trucks that can come in and leave, maximum number of railcars that can come in and leave, and frame storage were not binding. This means these capacities were not used in full in order to optimize the model for this case. The constraint equations for railyard storage, and crane capacity were binding. This means the full capacity of the railyard and crane were utilized.

Sensitivity analysis on the cost coefficients of the decision variables of the LP indicate that the cost for the rail to truck full container transfer or lift variable which had a result greater than zero can be increased by \$3, and the same solution set will be obtained. For rail to truck trailer transfer, the variable which had a result greater than zero can be decreased by $3 and the results of the LP will not change. Whereas for other lift variables which had a result of zero can be decreased to infinity, and the results of the LP for this case will not change.

The shadow prices for the crane capacity constraint are $16. An increase in the crane capacity by one dollar will increase the value of the objective function or will increase the profit by $16. The shadow prices for depot storage, railyard storage, and frame storage are all zero. So increasing the storage capacity will not increase the value of the objective in this case. The shadow price of incoming railcars is $6, indicating that increasing the incoming railcar's capacity will increase the profit of the facility.

A sensitivity analysis on the value of the constraint equations was done. If the storage capacity of the depot if decreased by 75 units, the solution set for the model will not change. Also the storage capacity of the railyard if decreased by 75 units, the solution set for the model will not change. This indicates that a lesser storage capacity in the railyard and depot could still achieve the same profit for this particular case. If the crane capacity is increased or decreased by 40 units also, the solution set for the model will not change.

CASE E:

This case is set to find the outcome of the LP if the lift capacity is increased from 75 units per day to 100 units per day. When additional transfer capacity is added such as a ramp or triple crown it will increase the number of transfers possible. So this case is helpful in understanding the feasibility of the facility with increased transfers. This case generated a profit of $3,116 per day.

The results of the case were analyzed for binding and non-binding constraint equations. The constraint equations for depot storage and frame storage were not binding, but the constraint equations for railyard storage, and lift capacity were binding. A sensitivity analysis on the cost coefficients of the lift decision variables indicates that variables which had a result greater than zero cannot be increased or decreased. The variables which had a zero result could be increased to a set of ranges. This is true in the case of storage as well.

Shadow price for the lift capacity constraint is $16, indicating that an increase in the lift capacity will increase the profit by $16. Shadow prices for depot storage, the maximum possible number of incoming trucks, frame storage, and railyard storage have zero shadow prices. The shadow price for incoming railcars is $6, indicating a profit with the increase of railcars. A sensitivity analysis on the constraint equation values shows that if the depot storage capacity is decreased by 150 units the solution set for the model will not change. If the railyard capacity is decreased by 35 units also the solution set for the model will not change.

CASE F:

In this case the lift capacity is decreased by 25 units. This case will help to understand more about the role of the lift capacity. This case can also indicate a situation where the crane is not operated in one shift of a three shift day operation. A cost for all the decision variables is set in the objective function equation of the LP. This case generated a profit of $846 per day.

When analyzed for binding and non binding constraint equations, the results indicate that the constraint equations except for the crane capacity were not binding. This situation indicates that except for the crane capacity the storage facilities were not used to their full capacity. A sensitivity analysis on the cost coefficients of the decision variables in the objective function indicate that the cost for the transfer of trailer from rail to truck which had a result greater than zero, if decreased by $1 will not change the result of this LP. The cost coefficients of other lift variables, if decreased to infinity, will not change the result of this LP.

Shadow price for the lift constraint equation is $19. But the shadow price for all the other variables is zero. For this model only, increasing the lift capacity increases the profit of the facility. A sensitivity analysis on the constraint equation value indicates that if the depot storage capacity is increased to infinity or decreased by 200 units, will not change the solution set of this LP. Also if the storage capacity of the railyard is increased to infinity or decreased by 100 will have no impact on the solution set of this LP. But if the lift capacity is increased more than 35 or decreased more than 50 will give a new set of solutions.

CASE G:

This case is set to find the outcome of the LP if the total cost for the three days of operation of the facility is reduced by some amount. In this case the total cost is reduced by reducing the expected percentage of capital recovery from 10 percent to 5 percent A cost is assigned for all the decision variables, and the lift capacity is set to normal capacity of 75 units per day as in case D. All the constraint equations and the objective values in this case are similar to case D, except for the total cost. The total cost, which was $5,550 per day in case D, is reduced to $4,705 per day. This case generated a profit of $3,536 per day.

The results of the case analyzed for binding and non-binding constraints indicate that the depot storage, maximum possible trucks and railcars that can come in and leave, and frame storage constraint equations were not binding. But the crane capacity equations and railyard storage were binding. A sensitivity analysis on the cost coefficients of the objective function was done. The cost coefficients of the lift variables which had result greater than zero cannot be increased or decreased. But the cost coefficients of other lift variables can be decreased to infinity.

The shadow prices for the crane capacity constraint is $16, indicating an increase of $16 in profit with an increase in lift capacity. Shadow prices for depot storage and railyard storage are zero. The shadow price for railyard incoming capacity is $6, but the shadow price for the outgoing railyard capacity is zero dollars. A sensitivity analysis is done to find the range of values in which the constraint equation values can be changed. If the depot storage capacity is changed by decreasing 75 units, the set of solutions obtained for the LP will in this case be affected. Also if the railyard storage capacity is reduced by 75 units will affect the solution set. The crane capacity value can be increased or decreased by 40 units, and the set of solutions will not change.

CHAPTER 8

CONCLUSIONS AND FURTHER WORKS

8.1 Conclusions

By analyzing the results of the operational needs of the intermodal facilities with respect to the different cases, certain conclusions can be reached. These conclusions are discussed below.

It could be observed that from the results of the different cases that the given facility design would be able to recover operating and fixed costs, at a level of operation within the facility design. From case A (the break even case), the activities needed to reach the break even point in the facility indicate that the facility does not have to operate at full capacities. For each of the cases except for case C, results gave a positive number for the gain in revenue. The break even is achieved by operating at 100% of crane capacity, 91.5% of railyard storage capacity, 83% of frame storage capacity, and 67% of container and trailer storage capacity in the depot.

Some of the activities in the intermodal facility are critical factors for optimizing the model. All the case results indicate that the crane capacity is a critical factor in optimizing the activities of the facility. The number of transfers or lifts in all the cases were set at the maximum allowable for the crane. This means that the crane would have to be operated in all the shifts or 24 hours a day. In the pricing scheme used, the fee charged for crane transfer is critical. This is indicated by the various shadow prices for the crane operation. The shadow prices from different cases indicate that the increase in crane capacity increases the value of the objective function or the profit of the facility by a minimum of $15. This provides a good reason to increase the crane capacity by adding a ramp to the facility. Adding a ramp will share the transfers done by the crane and thereby increase the total number of transfers per day. The case where the lift capacity is increased from 75 to 100 also provides an indication of the effect of increasing the lift capacity on the facility's profit. In most of the cases analyzed, railyard storage is mostly operated to its full capacity. So increasing the railyard storage by additional raillines will increase the revenue generated from the facility. It is important to note that rail networks set the pricing scheme and the scheme can fluctuate depending on the nature of goods, size, and distance and the desire of the rail networks to use a facility. This practice might influence storage at the railyard and the transfers done from truck to rail for rail shipments.

The storage capacities of the depot and the number of incoming lanes provided are not critical factors in optimizing the operations of the intermodal facility. From the results of the different cases, the storage capacity of the depot is not always used to its fullest capacity. This provides room for reducing this aspect of the depot to the current level of operations, which would in turn reduce the land costs and construction costs, and thereby reducing the total operating costs per day. The number of incoming lanes provided for truck entry provides a possibility of 400 trucks entering in a single day, which from the analyses of the results were never used to their fullest capacity. Reducing the number of incoming lanes also reduces land, construction, and operating costs.

If the capital required for the construction and operation of the facility is reduced, the facility can experience a significant impact on the profit. Case G indicates that reducing the total cost of operations per day increases the profit for the facility considerably. The total cost can also be reduced by achieving lower construction costs, as is suggested in the estimate.

From the different case results, a level of the daily activities needed for running the facility profitably can be obtained. These figures indicate the daily requirement such as full containers coming into facility by rail or trucks, trailers coming in by rail or road, and empty containers coming in by rail or truck, which gives the volume of freight movement required for the facility to operate successfully.

8.2 Further works

The following recommendations are suggested to expand the model for further research.

The LP model did not include double stack operations due to size limit in the optimization software used. Decision variables for double stack operations can be included and new constraint equations can be formulated to solve the LP. This will increase the revenue generated by the facility.

If actual data on container and trailer shipments in the region for all the modes of transportation in the region were obtained, that could be used as resources available in the LP model. The constraint equations could be modified to fit these resources. Furthermore, if a contract would be established with nearby ports and steamshipline companies to ship goods through the facility, these shipments would further increase the resources available.

The LP model could be expanded for other levels of the facility by finding the respective cost of construction, equipment, and operation for all the levels. The LP model would involve decision variables for transfer of freight to other facilities such as bulk storage and repackaging and distribution.

The model would be further expanded to find the activities needed for a week or a month of operation. This model considered only 3 days of operation due to computational limitations. The impact of integer programming on the results of the model could also be examined. These areas should enhance the use of the model and its applicability for investigation of an intermodal facility.

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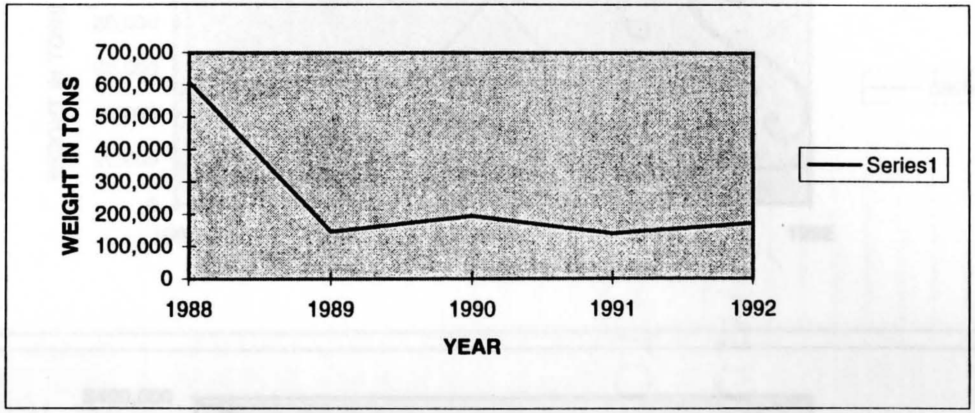
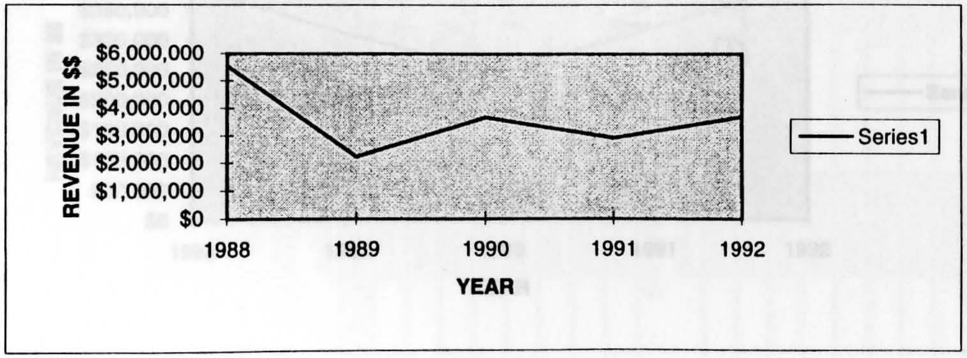
APPENDIX A

SUMMARY OF GOODS TRANSPORTED IN AND OUT OF CHATTANOOGA FROM 1988 TO 1992

Summary of goods transported into Chattanooga 1988 to 1992

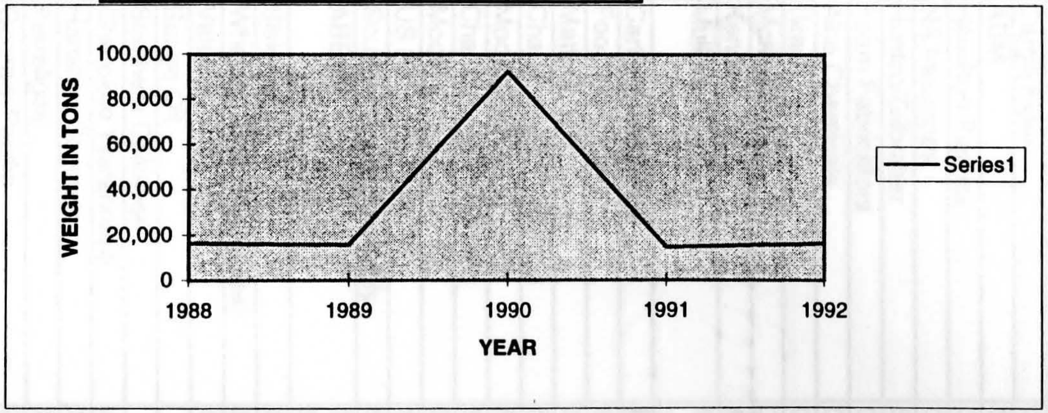
YEAR	BILLED WEIGHT IN TONNE	FRIEGHT REVENUE IN $ DOLLARS
1988	609,514	$5,547,999
1989	146,034	$2,232,265
1990	193,246	$3,671,667
1991	139,198	$2,923,129
1992	171,481	$3,680,035

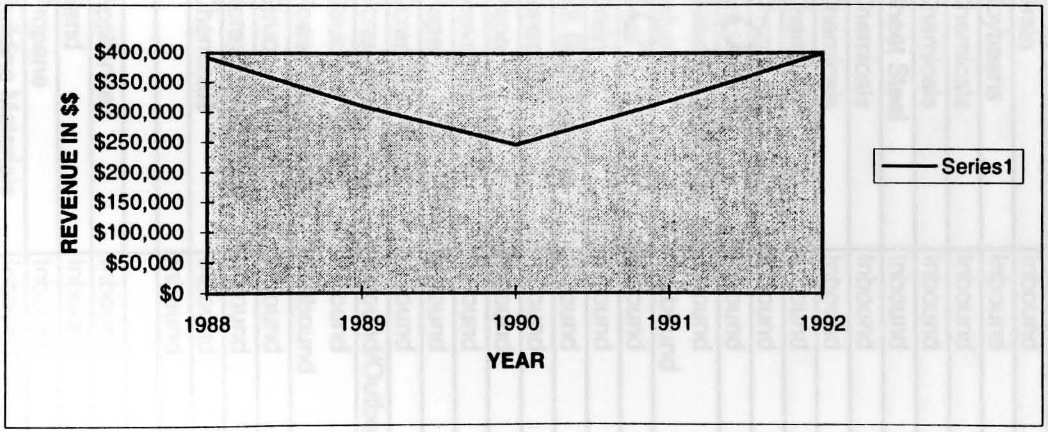




Summary of goods transported from Chattanooga 1988 to 1992

YEAR	BILLED WEIGHT IN TONNE	FRIEGHT REVENUE IN $ DOLLARS
1988	16,442	$391,314
1989	15,674	$310,641
1990	92,305	$246,746
1991	14,710	$320,180
1992	16,322	$398,251





APPENDIX B

List of names of the companies, types of their shipments, and commodities shipped for the rail networks

NORFOLK SOUTHERN

AREA	COMPANY	COMMODITY	DIRECTION
North Chattanooga	Dupont	Chemicals	Inbound
	Signal Mtn Cement	Cement	outbound
	Commercial Metals	Scrap Metal	Inbound/Outbound
	Rock Tenn	Scrap paper Fibre board	Inbound Outbound
	JIT terminal	Propane/ sheet steel Caustic soda	Inbound Outbound
	Siskin Steel	Structural Steel	Outbound
	Amoco	Asphalt	Outbound
Jersey Pike/ Bonnie Oaks	Fleet Transfer	Chemicals/Liquid Sweetners	Inbound Inbound
Riverport/ Amnicola	BASF	Chemicals	Inbound
	Cargill Flour	Grain	Inbound
	ADM	Soybeans	Inbound
	Hamilton Plastics	Chemicals	Inbound
	NA Industries	Chemicals	Inbound
	Huntco/Gilbralter	Sheet Steel	Inbound
	Foam Fabricators	Chemicals	Inbound
	Alco Chemicals	Chemicals	Inbound
	Grace	Chemicals	Inbound
	McKesson	Chemicals	Inbound
	Kenco	Appliances	Inbound
	Mulleur	Metal/metal scrap valves	Inbound Outbound
Downtown	Carter Distributors	Beer	Inbound
	Foodliner(Flour)	Grain	Inbound
	Matlock TBT	NS Bulk Transfer	Inbound
	Chattanooga Publishing	Newsprint	Inbound
	Model Box	Paper	Inbound
	Chattanooga Publishing	Newsprint	Inbound
	Model Box	Paper	Inbound
	US Pipe and Foundry	Scrap Iron, Sand	Inbound
	Southern Foundry Supply	Scrap steel	Inbound/Outbound
	ABB/CE	Structural Steel Power Components	Inbound Outbound
	Siskin steel	Structural Steel	Inbound
	Wheland Foundry(2 sities)	Scrap Steel, Sand	Inbound
South Chattanooga	Velsicol	Chemicals	Inbound
	Bunge Oil		Inbound
	Southern Cellulose		
	Cherokee Warehouse	Appliances	Inbound
	Hamilton Concrete	Sand	Inbound
	Ferrellgas	Propane	Inbound
	Georgia Pacific	Building Materials	Inbound

APPENDIX B

CSX RAILROAD

AREA	COMPANY	COMMODITY	DIRECTION
Downtown	Bids Terminal	CSX Bulk Transfer	Inbound
	US Pipe and Foundry	Scrap Steel, Sand	Inbound
	Siskin	Scrap Steel	Inbound/Outbound
	ABB/CE	Plate Steel	Inbound
		Power Components	Outbound
Tyner Spur/ Chickamauga	Synthetic Industries	Chemicals	Inbound
	Stone Container	Paper	Inbound
	Lookout Beverage	Wine	Inbound
	Nutrative Sweetners	Solid Sweetners	Inbound
	BASF (2 sites)	Chemicals	Inbound
	BiLo Warehouse	Frozen Foods	Inbound
	Brach & Brock	Solid sweetners	Inbound
South Chattanooga	Porter Warner	Sand	Inbound
	Ringcan	Plastic pellets	Inbound
		Plastic bottles	Outbound
	Sovex	Sweetner (Sugar)	Inbound
	American Manufacturing	Steel	Inbound
	McKee Foods	Sweetner (Sugar)	Inbound
	Eureka Foundry	Scrap Metal	Inbound
		Castings	Outbound

APPENDIX C

List of Commodity movements at port of Chattanooga

	Name of Commodity
1	Farm Products
2	Forest Products
3	Fish and other marine products
4	Metallic ores
5	Crude Petroleum
6	Minerals, Nonmetallic
7	Ordnance and Accessories
8	Food and Kindered products
9	Tobacco Products
10	Basic Textiles
11	Apparel and other finished textile
12	Lumber and Wood products
13	Furniture and Fixtures
14	Pulp, Paper and other allied products
15	Printed matter
16	Chemicals and other products
17	Petroleum and other products
18	Rubber and misc plastic products
19	Leather and Leather products
20	Stone, Clay, and Glass
21	Primary metal products
22	Fabricated metal products
23	Machinery, except electrical
24	Electrical machinery, Equipment, and Supplies
25	Transportation equipment
26	Photographic goods
27	Optical goods, Watches and Clocks
28	Miscillaneous products of manufacture
29	Waste and Scrap materials
30	Special items

APPENDIX D

List of terminals identified as potential intermodal terminals by The Metropolitan Planning Organization of the Chattanooga Urban Area

TERMINAL	CRITERIA FOR INTERMODAL
Colonial Pipeline	Truck/Pipeline terminal- Approximately 320 Trucks per day
Chattanooga Metropolitan Airport	Airport - 300,000 Annual enplanements
Mid South Terminals, Ergon incorporated, General Oils Company Star enterprises, Amoco Oil Company	Port terminal - 187 Trucks per day
JIT Terminals	Port terminal - 115 trucks per day
Vulcan Materials Company	Port terminal - 105 trucks per day
Southern Foundry Supply Company	Port terminal - 120 trucks per day

APPENDIX E
List of major commodities and STCC codes

STCC Code	Name of the Commodity
1132	Corn
1137	Wheat
10513	Calcined or activated Bauxite ores
14413	Industrial sand, crude, ground or pulverized
20412	Wheat Bran Middlings or shorts
20461	Corn syrup
20621	Sugar, Granulated or powdered, Sugar cubes or Tablets
20821	Beer, Ale, porter, stout or other fermented malt liquiors
20923	Soybean cake flour grits meal or other by products
24211	Lumber, Rough or dressed or softwood
26311	Fibre board, Paper board or Pulp board
28122	Sodium alkalines
28123	Sodium compounds
28128	Chlorine
28185	Glycols or Glycerines
28211	Plastic materials or Synthetic resins
29119	Petroleum refinning products
29121	Liquified gases Coal or petroleum
32952	Light weight aggregates, clays or slags ground or treated
33123	Iron or steel sheet or strip
40211	Iron or steel scrap, waste or tailings
40241	Paper waste or scrap

APPENDIX F

Summary of shipments segregated by commodity and BEA area for the years 1989 to 1992, along with BEA codes for cities mentioned

SUMMARY -- 1992

Goods transported into Chattanooga by type of commodity--1992

Destinatio BEA Area	Commodit STCC Code	Billed Weight in Tons	Frieght Revenue in $ dollars
51	1132	57,267	$825,330
51	1137	58,640	$1,246,050
51	10513	1,195	$38,840
51	14413	6,390	$128,587
51	20461	1,372	$40,593
51	20621	3,366	$119,382
51	20821	474	$12,641
51	20923	7,463	$97,763
51	20939	343	$6,853
51	24211	1,671	$66,428
51	26311	3,978	$115,142
51	28122	1,390	$33,228
51	28123	1,895	$116,755
51	28128	593	$7,320
51	28185	496	$30,151
51	28211	10,334	$468,516
51	29119	1,059	$33,395
51	29121	432	$13,959
51	32952	2,135	$47,866
51	33123	3,894	$126,438
51	40211	2,547	$33,267
51	40241	4,547	$71,531
TOTAL		**171,481**	**$3,680,035**

SUMMARY-1992

Goods transported from Chattanooga by destination BEA Area-1992

Origin BEA Area	Billed Weight in Tons	Revenue in $ Dollar	Destnation BEA Area
51	2,909	$79,985	0
51	45	$2,835	6
51	131	$5,253	7
51	45	$2,385	9
51	51	$2,313	17
51	49	$2,467	18
51	308	$14,652	19
51	425	$8,297	21
51	301	$8,902	28
51	267	$6,137	29
51	289	$6,381	31
51	3,416	$49,546	36
51	126	$4,080	39
51	458	$18,156	41
51	219	$9,955	43
51	723	$27,503	44
51	991	$11,779	49
51	50	$470	50
51	1,511	$6,298	51
51	357	$4,547	53
51	900	$12,914	54
51	103	$2,170	55
51	104	$2,079	57
51	249	$9,705	65
51	101	$3,672	66
51	44	$1,188	67
51	166	$7,145	71
51	47	$1,468	79
51	195	$8,085	83
51	148	$7,152	96
51	61	$2,523	105
51	52	$1,477	112
51	367	$11,819	113
51	45	$1,737	117
51	200	$9,322	122
51	196	$8,911	125
51	354	$16,689	129
51	135	$6,930	131
51	92	$3,799	138
51	92	$5,494	157
TOTAL	**16,322**	**$398,251**	

SUMMARY 1992

Goods Transported from Chattanooga by type of commodity-1992

Origin BEA Area	Commodit STCC Code	Billed Weight in Tons	Frieght Revenue in $ dollars
51	20412	2,859	$54,519
51	26311	8,140	$260,682
51	28211	2,185	$37,636
51	40211	2,479	$30,002
51	40241	659	$15,412
Total		16,322	$398,251

SUMMARY -1992

Goods transported into Chattanooga by type of origin BEA Area--1992

Destinatio BEA Area	Billed Weight in Tons	Frieght Revenue in $ dollars	Origin BEA Area	Origin City or Place
51	35184	$835,175	0	Unknown or not provided
51	934	$33,696	16	Pittsburg, PA
51	742	$25,042	18	Philadelphia, PA
51	126	$1,940	19	Baltimore, MD
51	345	$5,700	20	Washington, DC
51	878	$29,046	21	Roanoke-Lynchburgh,LA
51	65	$1,767	23	Norfolk Virgina beach, VA
51	265	$6,864	24	Rocky mount-Wilson, NC
51	62	$1,264	28	Greensboro, NC
51	151	$2,334	29	Charlotte, NC
51	138	$2,251	30	Asheville, NC
51	124	$1,590	31	Greensville, SC
51	95	$1,905	32	Columbia, SC
51	1197	$19,435	35	Augusta, GA
51	459	$5,925	36	Atlanta, GA
51	54	$898	37	Columbus, GA
51	455	$8,563	38	Macon, GA
51	173	$4,298	39	Savannah, GA
51	427	$7,800	40	Albany, GA
51	303	$3,920	41	Jacksonville, FL
51	179	$2,880	44	Tampa-ST, FL
51	150	$2,984	47	Mobile, AL
51	921	$9,759	49	Birmingham, AL
51	46	$546	50	Huntsville, AL
51	1511	$6,298	51	Chattanooga, TN
51	475	$6,379	52	Johnsoncity, TN
51	1699	$20,015	53	Knoxville, TN
51	3222	$30,901	54	Nashville, TN
51	267	$4,060	55	Memphis, TN
51	146	$2,167	57	Louisville, KY

Destinatio BEA Area	Billed Weight in Tons	Frieght Revenue in $ dollars	Origin BEA Area	Origin City or Place	
51	483	$7,499	58	Lexington, KY	
51	70	$2,674	62	Parkersburg, WV	
51	180	$6,582	64	Youngstown, OH	
51	80	$2,288	65	Cleveland, OH	
51	421	$6,723	66	Columbus, OH	
51	11122	$146,290	67	Cincinnatti, OH	
51	279	$5,059	69	Lima, OH	
51	887	$16,860	76	Fortwayne, IN	
51	99	$1,862	77	Kokomo, IN	
51	4214	$64,137	78	Anderson, IN	
51	1504	$25,638	79	Indianapolis, IN	
51	33378	$486,631	80	Evansville, IN	
51	1481	$18,781	81	Terre, In	
51	601	$9,870	82	Lafayette, In	
51	15670	$261,460	83	Chicago, IL	
51	1732	$29,995	84	Urbana Champaign, IL	
51	570	$11,056	85	Spring Filed, IL	
51	2450	$33,825	96	Minneapolis, MN	
51	5670	$139,219	105	Kansas City, MO	
51	1355	$23,158	107	St.Louis, MO	
51	43	$1,086	111	Little Rock, AR	
51	84	$1,528	112	Jackson, MS	
51	3086	$104,529	113	New Orleans, LA	
51	1033	$31,797	114	Baton Rouge, LA	
51	297	$8,637	116	Lake Charles, LA	
51	96	$2,638	117	Shreve POrt, LA	
51	165	$5,264	118	Monore, LA	
51	285	$9,291	120	Tyler, TX	
51	5852	$344,240	122	Houston, TX	
51	70	$344,240	139	Wichita, KS	
51	6002	$41,657	140	Salina, KS	
51	4934	$40,022	141	Topeka, KS	
51	3381	$212,996	148	Aberdeen, SD	
51	7255	$226,130	149	Fargo, ND	
51	3052	$100,905	150	Grand Forks, ND	
51	497	$18,030	151	Bismarck, ND	
51	1205	$73,170	165	Salt Lake City, UT	
51	46	$3,435	172	Portland, OR	
51	24	$1,080	177	Sacramento, CA	
51	23	$1,235	180	Los Angeles, CA	
51	108	$6,742	190		
51	598	$44,605	191		
TOTAL	**171,481**	**$3,680,035**			

List of BEA Area codes and respective cities

Origin BEA Area	Origin City or Place
0	Unknown or not provided
16	Pittsburg, PA
18	Philadelphia, PA
19	Baltimore, MD
20	Washington, DC
21	Roanoke-Lynchburgh,LA
23	Norfolk Virgina beach, VA
24	Rocky mount-Wilson, NC
28	Greensboro, NC
29	Charlotte, NC
30	Asheville, NC
31	Greensville, SC
32	Columbia, SC
35	Augusta, GA
36	Atlanta, GA
37	Columbus, GA
38	Macon, GA
39	Savannah, GA
40	Albany, GA
41	Jacksonville, FL
44	Tampa-ST, FL
47	Mobile, AL
49	Birmingham, AL
50	Huntsville, AL
51	Chattanooga, TN
52	Johnsoncity, TN
53	Knoxville, TN
54	Nashville, TN
55	Memphis, TN
57	Louisville, KY
58	Lexington, KY
62	Parkersburg, WV

Origin BEA Area	Origin City or Place
64	Youngstown, OH
65	Cleveland, OH
66	Columbus, OH
67	Cincinnatti, OH
69	Lima, OH
76	Fortwayne, IN
77	Kokomo, IN
78	Anderson, IN
79	Indianapolis, IN
80	Evansville, IN
81	Terre, In
82	Lafayette, In
83	Chicago, IL
84	Urbana Champaign, IL
85	Spring Filed, IL
96	Minneapolis, MN
105	Kansas City, MO
107	St.Louis, MO
111	Little Rock, AR
112	Jackson, MS
113	New Orleans, LA
114	Baton Rouge, LA
116	Lake Charles, LA
117	Shreve POrt, LA
118	Monore, LA
120	Tyler, TX
122	Houston, TX
139	Wichita, KS
140	Salina, KS
141	Topeka, KS
148	Aberdeen, SD
149	Fargo, ND
150	Grand Forks, ND
151	Bismarck, ND
165	Salt Lake City, UT
172	Portland, OR
177	Sacramento, CA
180	Los Angeles, CA

APPENDIX G

Comparision of Stone, Grain and other products transported by river from 1970 to 1988

Year	Stone in Million Tons	Grain in Million Tons	Other products in Million Tons
1970	1.25	1.25	0.6
1971	1.3	1.2	0.6
1972	1.25	0.75	0.7
1973	1.25	0.9	0.6
1974	1.25	0.85	0.6
1975	0.9	0.8	0.4
1976	1.1	0.8	0.8
1977	1.1	0.8	0.7
1978	1.2	0.8	0.8
1979	1.25	0.6	0.6
1980	1.2	0.7	0.6
1981	1.25	0.8	0.5
1982	0.9	1	0.6
1983	1.1	1	0.65
1984	1.2	1.4	0.6
1985	1.25	1.4	0.6
1986	1.25	1	0.8
1987	1.3	0.45	0.7
1988	1.25	0.45	0.65

APPENDIX H

LIST OF TERMINALS, FACILITIES AND CONNECTIONS

NAME	TYPE & COMMODITY HANDLED	FACILITIES	CONNECTIONS
1. Central Soya CO Chattanooga TN	Barge - Private Grain products transfer	Dock, mooring cells marine leg, conveyor and storage elevators	Plant connects with Norfolk Southern railway
2. Seaboard Cargill Milling Corp Chattanooga, TN	Barge - private Manuf - Grain products transfer	Mooring cells, marine leg, conveyor and storage elevators	Plant connects with Norfolk Southern railway
3. JIT Terminal Inc Chattanooga, TN	Barge, Truck and Rail - public Liquid product transfer by barge - truck Rail transfer of iron & steel Public and proprietary warehousing	Docking barge, mooring cells, 150-ton crane, two 25-ton gantry cranes, pipelines, storage tanks steam, and 50,000 sq.ft warehouse with inside rail siding.	Norfolk Southern rail connection Port terminal primary Connection to National Highways by Trucks -- 115 Trucks per day
4. Rock-Tenn Mill Division Chattanooga , TN	Barge -- private Petroleum products transfer	Floating dock, mooring cells, derrick, and pipelines	Plant connects with Norfolk Southern railway
5. Amoco Oil CO Chattanooga, TN	Barge, Truck, and Rail -- private Petroleum products transfer	Floating dock, mooring cells, pipelines, and storage tanks	Plant connects with Norfolk Southern railway Connection to National Highways by Trucks -- 187 Trucks per day
6. Dixie Sand and Gravel Corp Chattanooga, TN	Barge, Truck, and Rail -- private Sand and Gravel transfer	Grounded barge dock with concrete bulkhead mooring cells, storage bin, fixed crane, clam bucket, rail and truck scales and bulk hopper	Norfolk Southern rail connection Port terminal primary Connection to National Highways by Trucks
7. Dixie Portland Flour Mills Inc Chattanooga, TN	Barge, Truck -- private Grains product transfer	Derrick, marine leg, conveyor and loading bins	No rail connection but Norfolk Southern nearby

APPENDIX H

NAME	TYPE & COMMODITY HANDLED	FACILITIES	CONNECTIONS
8. Southern Foundry Supply Inc Chattanooga, TN	Barge, Truck, and Rail -- private Iron, steel, and scrap metal transfer	Dock, mooring cells, and dolphins, derrick, lifting magnet, and truck scales	Norfolk Southern and CSX rail connections Barge -- primary Connection to National Highways
9. ABB Combustion Engineering Systems Chattanooga, TN	Barge, Truck, and Rail -- public General freight and heavy manufactured products transfer	Dock, mooring cells and 1,200 ton gantry crane	Norfolk Southern and CSX rail connections Barge -- primary Connection to National Highways
10. Ergon, Inc Chattanooga, TN	Barge, Truck, and Rail -- private Petroleum products transfer	Docking cells, mooring dolphins, pipelines, derrick, and on-shore storage tanks	Norfolk Southern railway derrick and on-shore connection with terminal in rear Connections to National Highways by trucks -- 187 Trucks per day
11. Mid-South Terminals Chattanooga, TN	Barge, Truck, and Rail -- Public General freight transfer	Loading docks, mooring cells, and crane	No rail connection but CSX and Norfolk Southern nearby
12. Missouri Portland Cement Chattanooga, TN	Barge -- private Cement transfer	Unloading dock, mooring cells, pipelines, and storage bins	No rail connection but CSX and Norfolk Southern nearby
13. Signal mountain cement CO Signal mountain, TN	Barge -- private Manufacturing - limestone	Dock, conveyor, crane and storage area	Norfolk Southern connects with plant
14. Colonial Pipeline Chattanooga, TN	Truck, Pipeline		Truck - Pipeline terminal Connection to National Highway by Trucks -- 320 Trucks per day

APPENDIX I

Objective function of the model

MAX 6 X1 + 6 X1T + 6 X2 + 6 X3 + 6 X3T + 6 X4 + 6 X5 + 6 X6 + 19 X7
+ 19 X7T + 19 X8 + 19 X8T + 10 X9 + 10 X10 + 6 X11 + 3 X12 + 3 X13
+ 3 X14 + 6 X15 + 6 X15T + 6 X16 + 6 X17 + 6 X18 + 6 X18T + 6 X19
+ 6 X20 + 6 X21 + 6 X21T + 6 X22 + 6 X23 + 6 X23T + 6 X24 + 6 X25
+ 6 X26 + 19 X27 + 19 X27T + 19 X28 + 19 X28T + 10 X29 + 10 X30
+ 6 X31 + 3 X32 + 3 X33 + 3 X34 + 6 X35 + 6 X35T + 6 X36 + 6 X37
+ 6 X38 + 6 X38T + 6 X39 + 6 X40 + 6 X41 + 6 X41T + 6 X42 + 6 X43
+ 6 X43T + 6 X44 + 6 X45 + 6 X46 + 19 X47 + 19 X47T + 19 X48
+ 19 X48T + 10 X49 + 10 X50 + 6 X51 + 3 X52 + 3 X53 + 3 X54 + 6 X55
+ 6 X55T + 6 X56 + 6 X57 + 6 X58 + 6 X58T + 6 X59 + 6 X60 - X61

APPENDIX J

FINAL LINEAR PROGRAMMING MODEL

Objective Function:

MAX 6 X1 + 6 X1T + 6 X2 + 6 X3 + 6 X3T + 6 X4 + 6 X5 + 6 X6 + 19 X7
+ 19 X7T + 19 X8 + 19 X8T + 10 X9 + 10 X10 + 6 X11 + 3 X12 + 3 X13
+ 3 X14 + 6 X15 + 6 X15T + 6 X16 + 6 X17 + 6 X18 + 6 X18T + 6 X19
+ 6 X20 + 6 X21 + 6 X21T + 6 X22 + 6 X23 + 6 X23T + 6 X24 + 6 X25
+ 6 X26 + 19 X27 + 19 X27T + 19 X28 + 19 X28T + 10 X29 + 10 X30
+ 6 X31 + 3 X32 + 3 X33 + 3 X34 + 6 X35 + 6 X35T + 6 X36 + 6 X37
+ 6 X38 + 6 X38T + 6 X39 + 6 X40 + 6 X41 + 6 X41T + 6 X42 + 6 X43
+ 6 X43T + 6 X44 + 6 X45 + 6 X46 + 19 X47 + 19 X47T + 19 X48
+ 19 X48T + 10 X49 + 10 X50 + 6 X51 + 3 X52 + 3 X53 + 3 X54 + 6 X55
+ 6 X55T + 6 X56 + 6 X57 + 6 X58 + 6 X58T + 6 X59 + 6 X60 - X61

Constraint Equations:

SUBJECT TO
2) X1 + X1T + X2 - X7 - X7T - X9 + X10 <= 300
3) X7 - X8 + X9 - X10 + X11 - X12 <= 100
4) X3 + X3T + X4 + X7 - X8 - X8T + X9 - X10 + X13 - X14 <= 100
5) X1 + X1T + X2 + X11 <= 400
6) X5 + X8 + X8T + X10 + X12 <= 285
7) X3 + X3T + X4 + X13 <= 316
8) X6 + X7 + X7T + X9 + X14 <= 316
9) X7 + X7T + X8 + X8T + X9 + X10 <= 75
11) X1 - X7 >= 0
12) X2 - X9 >= 0
13) X3 - X8 >= 0
14) X11 <= 100
15) X4 - X10 >= 0
16) X2 - X5 >= 0
17) X4 - X6 >= 0
18) - X7 + X13 >= 0
19) X8 + X13 - X14 >= 0
20) - X7 - X7T + X8 + X13 >= 0
21) X7 - X8 + X11 >= 0
22) X15 + X15T + X16 + X21 + X21T + X22 - X27 - X27T - X29 + X30 <= 300
23) X17 + X27 - X28 + X29 - X30 + X31 - X32 <= 100
24) X18 + X18T + X19 + X23 + X23T + X24 + X27 - X28 - X28T + X29 - X30 + X33 - X34 <= 100
25) X21 + X21T + X22 + X31 <= 400
26) X25 + X28 + X28T + X30 + X32 <= 285
27) X19 + X24 - X30 >= 0
28) X17 + X31 <= 100
29) X16 + X22 - X25 >= 0
30) X19 + X24 - X26 >= 0
31) X20 - X27 + X33 >= 0
32) X20 + X28 + X33 - X34 >= 0
33) X20 - X27 - X27T + X28 + X33 >= 0
34) X17 + X27 - X28 + X31 >= 0
35) X23 + X23T + X24 + X33 <= 316

36) X26 + X27 + X27T + X29 + X34 <= 316
37) X27 + X27T + X28 + X28T + X29 + X30 <= 75
39) X15 + X21 - X27 >= 0
40) X16 + X22 - X29 >= 0
41) X18 + X23 - X28 >= 0
42) X1 - X7 - X15 = 0
43) X2 - X5 - X9 - X16 = 0
44) - X8 + X11 - X12 - X17 = 0
45) X3 - X8 - X18 = 0
46) X4 - X6 - X10 - X19 = 0
47) - X7 - X7T + X13 - X14 - X20 = 0
48) X15 + X21 - X27 - X35 = 0
49) X16 + X22 - X25 - X29 - X36 = 0
50) X17 - X28 + X31 - X32 - X37 = 0
51) X18 + X23 - X28 - X38 = 0
52) X19 + X24 - X26 - X30 - X39 = 0
53) X20 - X27 - X27T + X33 - X34 - X40 = 0
54) X35 + X35T + X36 + X41 + X41T + X42 - X47 - X47T - X49 + X50 <= 300
55) X37 + X47 - X48 + X49 - X50 + X51 - X52 <= 100
56) X38 + X38T + X39 + X43 + X43T + X44 + X47 - X48 - X48T + X49 - X50 + X53 - X54 <= 100
57) X41 + X41T + X42 + X51 <= 400
58) X45 + X48 + X48T + X50 + X52 <= 285
59) X39 + X44 - X50 >= 0
60) X37 + X51 <= 100
61) X22 + X36 - X45 >= 0
62) X39 + X44 - X46 >= 0
63) X40 - X47 + X53 >= 0
64) X40 + X48 + X53 - X54 >= 0
65) X40 - X47 - X47T + X48 + X53 >= 0
66) X37 + X47 - X48 + X51 >= 0
67) X43 + X43T + X44 + X53 <= 316
68) X46 + X47 + X47T + X49 + X54 <= 316
69) X47 + X47T + X48 + X48T + X49 + X50 <= 75
71) X35 + X41 - X47 >= 0
72) X36 + X42 - X49 >= 0
73) X38 + X43 - X48 >= 0
74) X35 + X41 - X47 - X55 = 0
75) X36 + X42 - X45 - X49 - X56 = 0
76) X37 - X48 + X51 - X52 - X57 = 0
77) X38 + X43 - X48 - X58 = 0
78) X39 + X44 - X46 - X50 - X59 = 0
79) X40 - X47 - X47T + X53 - X54 - X60 = 0
80) - X5 + X16 >= 0
81) - X25 + X36 >= 0
82) - X45 + X56 >= 0
84) X61 = 16650
85) X1T - X7T >= 0
86) X3T - X8T >= 0
87) - X7T + X13 >= 0
88) X1T - X7T - X15T = 0
89) X3T - X8T - X18T = 0
90) X15T + X21T - X27T >= 0
91) X18T + X23T - X28T >= 0

92) X20 + X23 - X27T >= 0
93) X15T + X21T - X27T - X35T = 0
94) X18T + X23T - X28T - X38T = 0
95) X35T + X41T - X47T >= 0
96) X38T + X43T - X48T >= 0
97) X40 + X43 - X47T >= 0
98) X35T + X41T - X47T - X55T = 0
99) X38T + X43T - X48T - X58T = 0
100) X15 + X15T + X16 <= 300
101) X35 + X35T + X36 <= 300
102) X55 + X55T + X56 <= 300
103) X18 + X18T + X19 + X20 <= 100
104) X38 + X38T + X39 + X40 <= 100
105) X58 + X58T + X59 + X60 <= 100

END

APPENDIX K

CASE A - To find the level of activities needed for break even.

MAX 6 X1 + 6 X1T + 6 X2 + 6 X3 + 6 X3T + 6 X4 + 6 X5 + 6 X6 + 19 X7
+ 19 X7T + 19 X8 + 19 X8T + 10 X9 + 10 X10 + 6 X11 + 3 X12 + 3 X13
+ 3 X14 + 6 X15 + 6 X15T + 6 X16 + 6 X17 + 6 X18 + 6 X18T + 6 X19
+ 6 X20 + 6 X21 + 6 X21T + 6 X22 + 6 X23 + 6 X23T + 6 X24 + 6 X25
+ 6 X26 + 19 X27 + 19 X27T + 19 X28 + 19 X28T + 10 X29 + 10 X30
+ 6 X31 + 3 X32 + 3 X33 + 3 X34 + 6 X35 + 6 X35T + 6 X36 + 6 X37
+ 6 X38 + 6 X38T + 6 X39 + 6 X40 + 6 X41 + 6 X41T + 6 X42 + 6 X43
+ 6 X43T + 6 X44 + 6 X45 + 6 X46 + 19 X47 + 19 X47T + 19 X48
+ 19 X48T + 10 X49 + 10 X50 + 6 X51 + 3 X52 + 3 X53 + 3 X54 + 6 X55
+ 6 X55T + 6 X56 + 6 X57 + 6 X58 + 6 X58T + 6 X59 + 6 X60 - X61

SUBJECT TO

2) X1 + X1T + X2 - X7 - X7T - X9 + X10 <= 300
3) X7 - X8 + X9 - X10 + X11 - X12 <= 100
4) X3 + X3T + X4 + X7 - X8 - X8T + X9 - X10 + X13 - X14 <= 100
5) X1 + X1T + X2 + X11 <= 400
6) X5 + X8 + X8T + X10 + X12 <= 285
7) X3 + X3T + X4 + X13 <= 316
8) X6 + X7 + X7T + X9 + X14 <= 316
9) X7 + X7T + X8 + X8T + X9 + X10 <= 75
11) X1 - X7 >= 0
12) X2 - X9 >= 0
13) X3 - X8 >= 0
14) X11 <= 100
15) X4 - X10 >= 0
16) X2 - X5 >= 0
17) X4 - X6 >= 0
18) - X7 + X13 >= 0
19) X8 + X13 - X14 >= 0
20) - X7 - X7T + X8 + X13 >= 0
21) X7 - X8 + X11 >= 0
22) X15 + X15T + X16 + X21 + X21T + X22 - X27 - X27T - X29 + X30
<= 300
23) X17 + X27 - X28 + X29 - X30 + X31 - X32 <= 100
24) X18 + X18T + X19 + X23 + X23T + X24 + X27 - X28 - X28T + X29
- X30 + X33 - X34 <= 100
25) X21 + X21T + X22 + X31 <= 400
26) X25 + X28 + X28T + X30 + X32 <= 285
27) X19 + X24 - X30 >= 0
28) X17 + X31 <= 100
29) X16 + X22 - X25 >= 0
30) X19 + X24 - X26 >= 0
31) X20 - X27 + X33 >= 0
32) X20 + X28 + X33 - X34 >= 0
33) X20 - X27 - X27T + X28 + X33 >= 0
34) X17 + X27 - X28 + X31 >= 0
35) X23 + X23T + X24 + X33 <= 316
36) X26 + X27 + X27T + X29 + X34 <= 316
37) X27 + X27T + X28 + X28T + X29 + X30 <= 75
39) X15 + X21 - X27 >= 0
40) X16 + X22 - X29 >= 0
41) X18 + X23 - X28 >= 0
42) X1 - X7 - X15 = 0

43) X2 - X5 - X9 - X16 = 0
44) - X8 + X11 - X12 - X17 = 0
45) X3 - X8 - X18 = 0
46) X4 - X6 - X10 - X19 = 0
47) - X7 - X7T + X13 - X14 - X20 = 0
48) X15 + X21 - X27 - X35 = 0
49) X16 + X22 - X25 - X29 - X36 = 0
50) X17 - X28 + X31 - X32 - X37 = 0
51) X18 + X23 - X28 - X38 = 0
52) X19 + X24 - X26 - X30 - X39 = 0
53) X20 - X27 - X27T + X33 - X34 - X40 = 0
54) X35 + X35T + X36 + X41 + X41T + X42 - X47 - X47T - X49 + X50 <= 300
55) X37 + X47 - X48 + X49 - X50 + X51 - X52 <= 100
56) X38 + X38T + X39 + X43 + X43T + X44 + X47 - X48 - X48T + X49 - X50 + X53 - X54 <= 100
57) X41 + X41T + X42 + X51 <= 400
58) X45 + X48 + X48T + X50 + X52 <= 285
59) X39 + X44 - X50 >= 0
60) X37 + X51 <= 100
61) X22 + X36 - X45 >= 0
62) X39 + X44 - X46 >= 0
63) X40 - X47 + X53 >= 0
64) X40 + X48 + X53 - X54 >= 0
65) X40 - X47 - X47T + X48 + X53 >= 0
66) X37 + X47 - X48 + X51 >= 0
67) X43 + X43T + X44 + X53 <= 316
68) X46 + X47 + X47T + X49 + X54 <= 316
69) X47 + X47T + X48 + X48T + X49 + X50 <= 75
71) X35 + X41 - X47 >= 0
72) X36 + X42 - X49 >= 0
73) X38 + X43 - X48 >= 0
74) X35 + X41 - X47 - X55 = 0
75) X36 + X42 - X45 - X49 - X56 = 0
76) X37 - X48 + X51 - X52 - X57 = 0
77) X38 + X43 - X48 - X58 = 0
78) X39 + X44 - X46 - X50 - X59 = 0
79) X40 - X47 - X47T + X53 - X54 - X60 = 0
80) - X5 + X16 >= 0
81) - X25 + X36 >= 0
82) - X45 + X56 >= 0
83) 6 X1 + 6 X1T + 6 X2 + 6 X3 + 6 X3T + 6 X4 + 6 X5 + 6 X6 + 19 X7 + 19 X7T + 19 X8 + 19 X8T + 10 X9 + 10 X10 + 6 X11 + 3 X12 + 3 X13 + 3 X14 + 6 X15 + 6 X15T + 6 X16 + 6 X17 + 6 X18 + 6 X18T + 6 X19 + 6 X20 + 6 X21 + 6 X21T + 6 X22 + 6 X23 + 6 X23T + 6 X24 + 6 X25 + 6 X26 + 19 X27 + 19 X27T + 19 X28 + 19 X28T + 10 X29 + 10 X30 + 6 X31 + 3 X32 + 3 X33 + 3 X34 + 6 X35 + 6 X35T + 6 X36 + 6 X37 + 6 X38 + 6 X38T + 6 X39 + 6 X40 + 6 X41 + 6 X41T + 6 X42 + 6 X43 + 6 X43T + 6 X44 + 6 X45 + 6 X46 + 19 X47 + 19 X47T + 19 X48 + 19 X48T + 10 X49 + 10 X50 + 6 X51 + 3 X52 + 3 X53 + 3 X54 + 6 X55 + 6 X55T + 6 X56 + 6 X57 + 6 X58 + 6 X58T + 6 X59 + 6 X60 = 16650
84) X61 = 16650
85) X1T - X7T >= 0
86) X3T - X8T >= 0

87) - X7T + X13 >= 0
88) X1T - X7T - X15T = 0
89) X3T - X8T - X18T = 0
90) X15T + X21T - X27T >= 0
91) X18T + X23T - X28T >= 0
92) X20 + X23 - X27T >= 0
93) X15T + X21T - X27T - X35T = 0
94) X18T + X23T - X28T - X38T = 0
95) X35T + X41T - X47T >= 0
96) X38T + X43T - X48T >= 0
97) X40 + X43 - X47T >= 0
98) X35T + X41T - X47T - X55T = 0
99) X38T + X43T - X48T - X58T = 0
END

LP OPTIMUM FOUND AT STEP 37

OBJECTIVE FUNCTION VALUE

1) .0000000

VARIABLE	VALUE	REDUCED COST
X1	.000000	.000000
X1T	.000000	.000000
X2	.000000	.000000
X3	100.000000	.000000
X3T	75.000000	.000000
X4	.000000	.000000
X5	.000000	.000000
X6	.000000	.000000
X7	.000000	.000000
X7T	.000000	.000000
X8	.000000	.000000
X8T	75.000000	.000000
X9	.000000	.000000
X10	.000000	.000000
X11	100.000000	.000000
X12	.000000	.000000
X13	.000000	.000000
X14	.000000	.000000
X15	.000000	.000000
X15T	.000000	.000000
X16	.000000	.000000
X17	100.000000	.000000
X18	100.000000	.000000
X18T	.000000	.000000
X19	.000000	.000000
X20	.000000	.000000
X21	.000000	.000000
X21T	.000000	.000000
X22	300.000000	.000000
X23	.000000	.000000
X23T	75.000000	.000000
X24	.000000	.000000
X25	.000000	.000000

X26	.000000	.000000
X27	.000000	.000000
X27T	.000000	.000000
X28	.000000	.000000
X28T	75.000000	.000000
X29	.000000	.000000
X30	.000000	.000000
X31	.000000	.000000
X32	.000000	.000000
X33	.000000	.000000
X34	.000000	.000000
X35	.000000	.000000
X35T	.000000	.000000
X36	300.000000	.000000
X37	100.000000	.000000
X38	100.000000	.000000
X38T	.000000	.000000
X39	.000000	.000000
X40	.000000	.000000
X41	.000000	.000000
X41T	25.000000	.000000
X42	.000000	.000000
X43	25.000000	.000000
X43T	.000000	.000000
X44	.000000	.000000
X45	.000000	.000000
X46	.000000	.000000
X47	.000000	.000000
X47T	25.000000	.000000
X48	50.000000	.000000
X48T	.000000	.000000
X49	.000000	.000000
X50	.000000	.000000
X51	.000000	.000000
X52	.000000	.000000
X53	250.000000	.000000
X54	225.000000	.000000
X55	.000000	.000000
X55T	.000000	.000000
X56	300.000000	.000000
X57	50.000000	.000000
X58	75.000000	.000000
X58T	.000000	.000000
X59	.000000	.000000
X60	.000000	.000000
X61	16650.000000	.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	300.000000	.000000
3)	.000000	.000000
4)	.000000	.000000
5)	300.000000	.000000
6)	210.000000	.000000
7)	141.000000	.000000

8)	316.000000	.000000
9)	.000000	.000000
11)	.000000	.000000
12)	.000000	.000000
13)	100.000000	.000000
14)	.000000	.000000
15)	.000000	.000000
16)	.000000	.000000
17)	.000000	.000000
18)	.000000	.000000
19)	.000000	.000000
20)	.000000	.000000
21)	100.000000	.000000
22)	.000000	.000000
23)	.000000	.000000
24)	.000000	.000000
25)	100.000000	.000000
26)	210.000000	.000000
27)	.000000	.000000
28)	.000000	.000000
29)	300.000000	.000000
30)	.000000	.000000
31)	.000000	.000000
32)	.000000	.000000
33)	.000000	.000000
34)	100.000000	.000000
35)	241.000000	.000000
36)	316.000000	.000000
37)	.000000	.000000
39)	.000000	.000000
40)	300.000000	.000000
41)	100.000000	.000000
42)	.000000	.000000
43)	.000000	.000000
44)	.000000	.000000
45)	.000000	.000000
46)	.000000	.000000
47)	.000000	.000000
48)	.000000	.000000
49)	.000000	.000000
50)	.000000	.000000
51)	.000000	.000000
52)	.000000	.000000
53)	.000000	.000000
54)	.000000	.000000
55)	50.000000	.000000
56)	.000000	.000000
57)	375.000000	.000000
58)	235.000000	.000000
59)	.000000	.000000
60)	.000000	.000000
61)	600.000000	.000000
62)	.000000	.000000
63)	250.000000	.000000
64)	75.000000	.000000

65)	275.000000	.000000
66)	50.000000	.000000
67)	41.000000	.000000
68)	66.000000	.000000
69)	.000000	.000000
71)	.000000	.000000
72)	300.000000	.000000
73)	75.000000	.000000
74)	.000000	.000000
75)	.000000	.000000
76)	.000000	.000000
77)	.000000	.000000
78)	.000000	.000000
79)	.000000	.000000
80)	.000000	.000000
81)	300.000000	.000000
82)	300.000000	.000000
83)	.000000	1.000000
84)	.000000	-1.000000
85)	.000000	.000000
86)	.000000	.000000
87)	.000000	.000000
88)	.000000	.000000
89)	.000000	.000000
90)	.000000	.000000
91)	.000000	.000000
92)	.000000	.000000
93)	.000000	.000000
94)	.000000	.000000
95)	.000000	.000000
96)	.000000	.000000
97)	.000000	.000000
98)	.000000	.000000
99)	.000000	.000000

NO. ITERATIONS= 37

RANGES IN WHICH THE BASIS IS UNCHANGED:

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X1	6.000000	.000000	INFINITY
X1T	6.000000	.000000	INFINITY
X2	6.000000	.000000	INFINITY
X3	6.000000	.000000	.000000
X3T	6.000000	.000000	.000000
X4	6.000000	.000000	INFINITY
X5	6.000000	.000000	INFINITY
X6	6.000000	.000000	INFINITY
X7	19.000000	.000000	.000000
X7T	19.000000	.000000	INFINITY
X8	19.000000	.000000	INFINITY
X8T	19.000000	.000000	.000000
X9	10.000000	.000000	INFINITY

X10	10.000000	.000000	INFINITY
X11	6.000000	.000000	.000000
X12	3.000000	.000000	INFINITY
X13	3.000000	.000000	.000000
X14	3.000000	.000000	INFINITY
X15	6.000000	.000000	.000000
X15T	6.000000	.000000	INFINITY
X16	6.000000	.000000	.000000
X17	6.000000	.000000	.000000
X18	6.000000	.000000	.000000
X18T	6.000000	.000000	INFINITY
X19	6.000000	.000000	INFINITY
X20	6.000000	.000000	.000000
X21	6.000000	.000000	INFINITY
X21T	6.000000	.000000	INFINITY
X22	6.000000	.000000	.000000
X23	6.000000	.000000	INFINITY
X23T	6.000000	.000000	.000000
X24	6.000000	.000000	INFINITY
X25	6.000000	.000000	INFINITY
X26	6.000000	.000000	INFINITY
X27	19.000000	.000000	INFINITY
X27T	19.000000	.000000	.000000
X28	19.000000	.000000	INFINITY
X28T	19.000000	.000000	.000000
X29	10.000000	.000000	INFINITY
X30	10.000000	.000000	INFINITY
X31	6.000000	.000000	INFINITY
X32	3.000000	.000000	INFINITY
X33	3.000000	.000000	INFINITY
X34	3.000000	.000000	.000000
X35	6.000000	.000000	.000000
X35T	6.000000	.000000	INFINITY
X36	6.000000	.000000	.000000
X37	6.000000	INFINITY	.000000
X38	6.000000	.000000	.000000
X38T	6.000000	.000000	INFINITY
X39	6.000000	.000000	INFINITY
X40	6.000000	.000000	INFINITY
X41	6.000000	.000000	INFINITY
X41T	6.000000	.000000	.000000
X42	6.000000	.000000	INFINITY
X43	6.000000	.000000	.000000
X43T	6.000000	.000000	INFINITY
X44	6.000000	.000000	INFINITY
X45	6.000000	.000000	INFINITY
X46	6.000000	.000000	INFINITY
X47	19.000000	.000000	INFINITY
X47T	19.000000	.000000	.000000
X48	19.000000	.000000	.000000
X48T	19.000000	.000000	INFINITY
X49	10.000000	.000000	INFINITY
X50	10.000000	.000000	INFINITY
X51	6.000000	.000000	INFINITY
X52	3.000000	.000000	INFINITY

X53	3.000000	.000000	.000000
X54	3.000000	.000000	.000000
X55	6.000000	.000000	INFINITY
X55T	6.000000	.000000	INFINITY
X56	6.000000	.000000	.000000
X57	6.000000	.000000	.000000
X58	6.000000	.000000	.000000
X58T	6.000000	.000000	.000000
X59	6.000000	.000000	INFINITY
X60	6.000000	.000000	INFINITY
X61	-1.000000	INFINITY	INFINITY

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	300.000000	INFINITY	300.000000
3	100.000000	INFINITY	.000000
4	100.000000	108.000000	.000000
5	400.000000	INFINITY	300.000000
6	285.000000	INFINITY	210.000000
7	316.000000	INFINITY	141.000000
8	316.000000	INFINITY	316.000000
9	75.000000	54.000000	9.840000
11	.000000	.000000	INFINITY
12	.000000	.000000	INFINITY
13	.000000	100.000000	INFINITY
14	100.000000	INFINITY	.000000
15	.000000	.000000	INFINITY
16	.000000	.000000	INFINITY
17	.000000	.000000	INFINITY
18	.000000	.000000	INFINITY
19	.000000	.000000	INFINITY
20	.000000	.000000	INFINITY
21	.000000	100.000000	INFINITY
22	300.000000	.000000	13.666670
23	100.000000	INFINITY	.000000
24	100.000000	.000000	98.400000
25	400.000000	INFINITY	100.000000
26	285.000000	INFINITY	210.000000
27	.000000	.000000	INFINITY
28	100.000000	INFINITY	.000000
29	.000000	300.000000	INFINITY
30	.000000	.000000	INFINITY
31	.000000	.000000	INFINITY
32	.000000	.000000	INFINITY
33	.000000	.000000	INFINITY
34	.000000	100.000000	INFINITY
35	316.000000	INFINITY	241.000000
36	316.000000	INFINITY	316.000000
37	75.000000	54.000000	9.840000
39	.000000	.000000	INFINITY
40	.000000	300.000000	INFINITY
41	.000000	100.000000	INFINITY
42	.000000	.000000	.000000
43	.000000	.000000	300.000000

44	.000000	.000000	41.000000
45	.000000	.000000	150.000000
46	.000000	.000000	.000000
47	.000000	.000000	.000000
48	.000000	.000000	.000000
49	.000000	20.500000	.000000
50	.000000	.000000	20.500000
51	.000000	49.200000	75.000000
52	.000000	.000000	.000000
53	.000000	.000000	.000000
54	300.000000	INFINITY	.000000
55	100.000000	INFINITY	50.000000
56	100.000000	122.727300	35.142860
57	400.000000	INFINITY	375.000000
58	285.000000	INFINITY	235.000000
59	.000000	.000000	INFINITY
60	100.000000	.000000	10.250000
61	.000000	600.000000	INFINITY
62	.000000	.000000	INFINITY
63	.000000	250.000000	INFINITY
64	.000000	75.000000	INFINITY
65	.000000	275.000000	INFINITY
66	.000000	50.000000	INFINITY
67	316.000000	INFINITY	41.000000
68	316.000000	INFINITY	66.000000
69	75.000000	75.000000	17.571430
71	.000000	.000000	INFINITY
72	.000000	300.000000	INFINITY
73	.000000	75.000000	INFINITY
74	.000000	.000000	.000000
75	.000000	41.000000	225.000000
76	.000000	41.000000	225.000000
77	.000000	41.000000	225.000000
78	.000000	.000000	.000000
79	.000000	24.600000	75.000000
80	.000000	.000000	INFINITY
81	.000000	300.000000	INFINITY
82	.000000	300.000000	INFINITY
83	16650.000000	246.000000	1350.000000
84	16650.000000	INFINITY	16650.000000
85	.000000	.000000	INFINITY
86	.000000	.000000	INFINITY
87	.000000	.000000	INFINITY
88	.000000	.000000	.000000
89	.000000	.000000	.000000
90	.000000	.000000	INFINITY
91	.000000	.000000	INFINITY
92	.000000	.000000	INFINITY
93	.000000	.000000	.000000
94	.000000	200.000000	.000000
95	.000000	.000000	INFINITY
96	.000000	.000000	INFINITY
97	.000000	75.000000	37.500000
98	.000000	.000000	.000000
99	.000000	.000000	225.000000

APPENDIX L Balancing of the results of the decision variables

For Full Containers coming in and leaving the facility by Truck

Day of operation	O Carry over from previous day	A Full Cont coming In by Truck	B Full Cont transferred to Rail	D Full Cont carried over to next day	Balancing D=O+A-B
For CASE A					
1	-	0	0	0	0=0-0
2	0	0	0	0	0=0-0
3	0	75	0	75	75=75-0

For Empty Containers coming in and leaving the facility by Truck

Day of operation	O Carry over from previous day	A Empty Cont coming In by Truck	B Empty Cont going Out by Truck	C Empty Cont transferred to Rail	D Empty Cont carried over to next day	Balancing D=O+A-B-C
For CASE A						
1	-	200	100	0	100	100=200-100
2	100	100	100	0	100	100=100+100 -100
3	100	0	50	0	50	50=100-50

For Full Containers coming in and leaving the facility by Rail

Day of operation	O Carry over from previous day	A Full Cont coming In by Rail	B Full Cont transferred toTruck	D Full Cont carried over to next day	Balancing D=O+A-B
For CASE A					
1	-	75	75	0	0=75-75
2	0	75	75	0	0=75-75
3	0	125	75	50	50=125-75

For Empty Containers coming in and leaving the facility by Rail

Day of operation	O Carry over from previous day	A Empty Cont coming In by Rail	B Empty Cont going Out by Rail	C Empty Cont transferred to Truck	D Empty Cont carried over to next day	Balancing D=O+A-B-C
For CASE A						
1	-	100	100	0	0	0=100-100
2	0	100	100	0	0	0=100-100
3	0	0	0	0	0	0

For Empty Frames coming in and leaving the facility by Truck

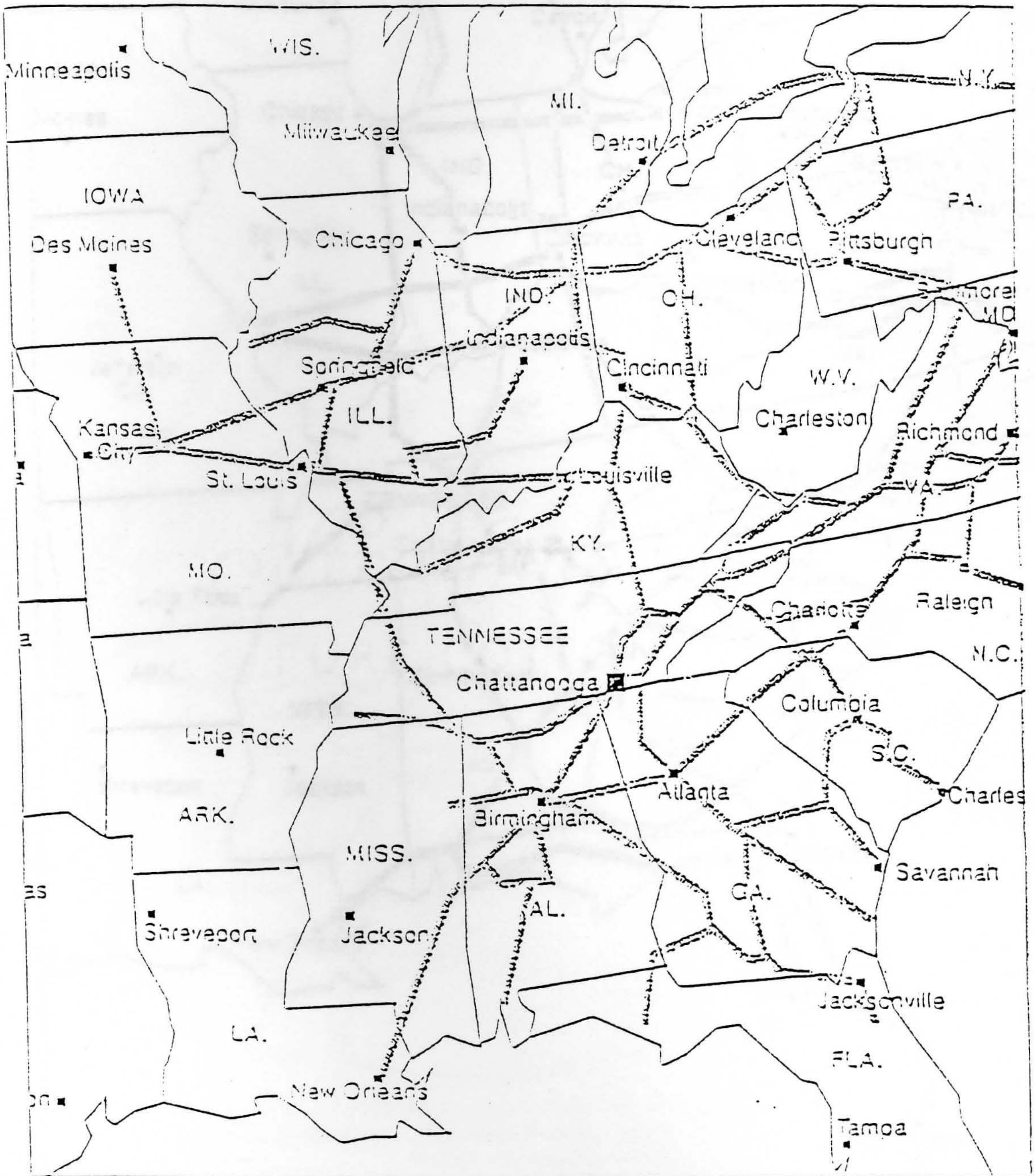
Day	O Carry OVER	A Empty Frame coming In by Truck	B Empty Frame going Out by Truck	C Empty Frame leaves with Cont	D Empty Frame carried over to next day	Balancing D=O+A-B-C
For CASE A						
1		100	25	75+0	0	0=100-25-75
2	0	75	0	75+0	0	0=75-75
3	0	100	0	75+0	25	25=100-75

For Empty Railcars coming in and leaving the facility by Rail

Day of operation	O Carry over from previous day	A Empty Railca coming In by Rail	B Empty Railca going Out by Rail	C Empty Railca leaves with Cont	D Empty Railca carried over to next day	Balancing D=O+A-B-C
For CASE A						
1		0	0	0+0	0	0
2	0	0	0	0+0	0	0
3	0	75	75	0+0	0	0=75-75

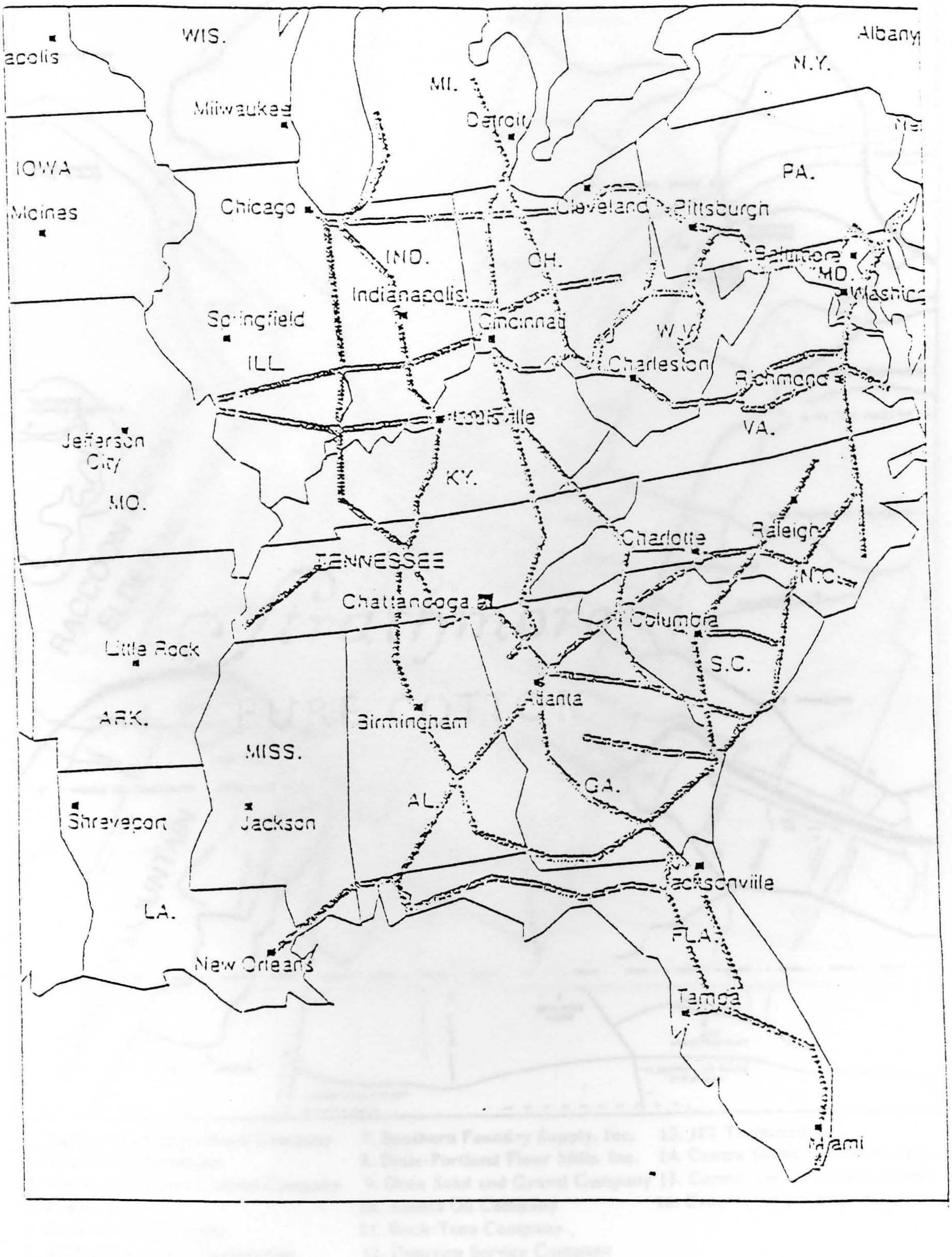
APPENDIX M

Figure 1.1 Norfolk Southern rail network map

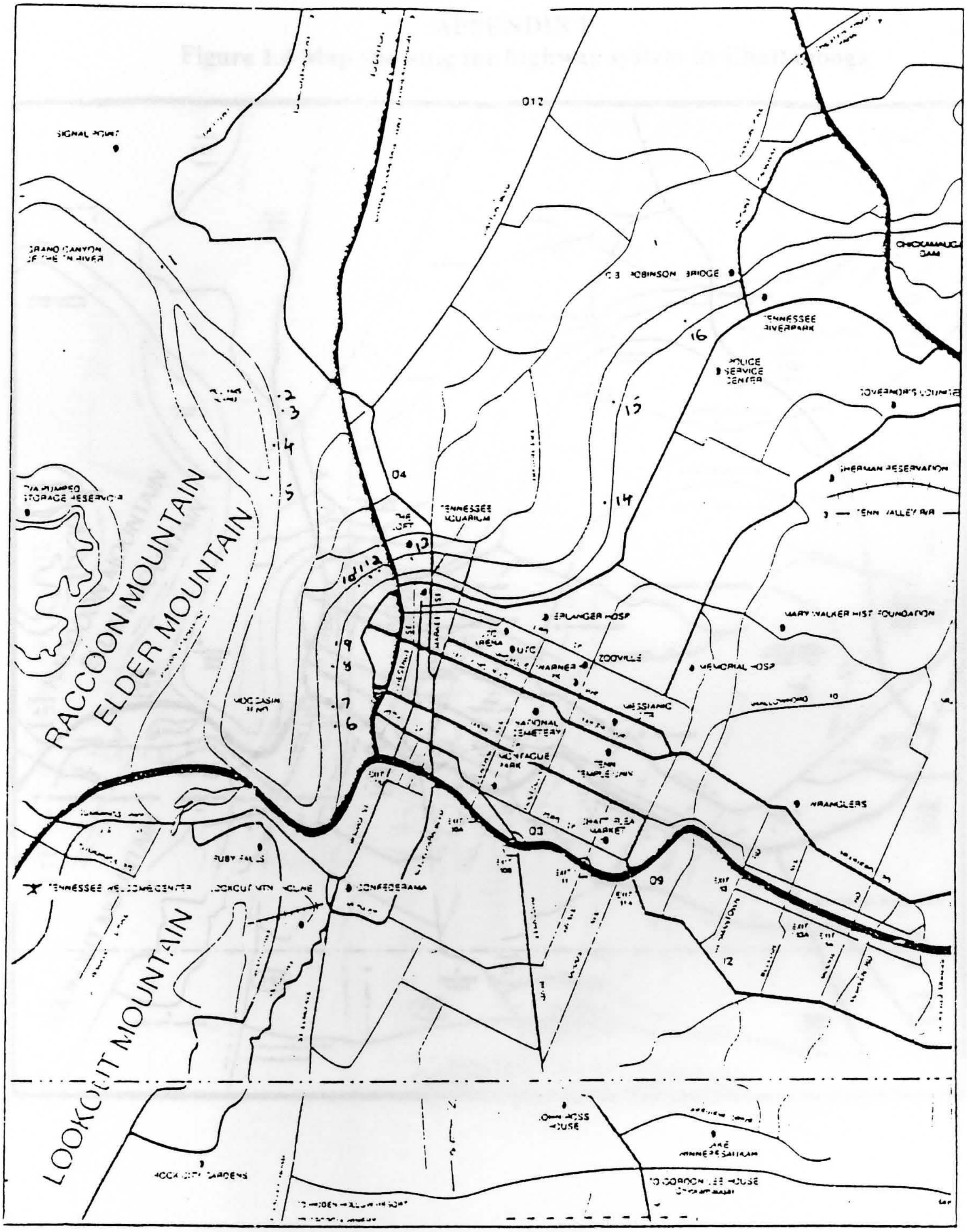


APPENDIX N

Figure 1.2 CSX rail network map



APPENDIX O

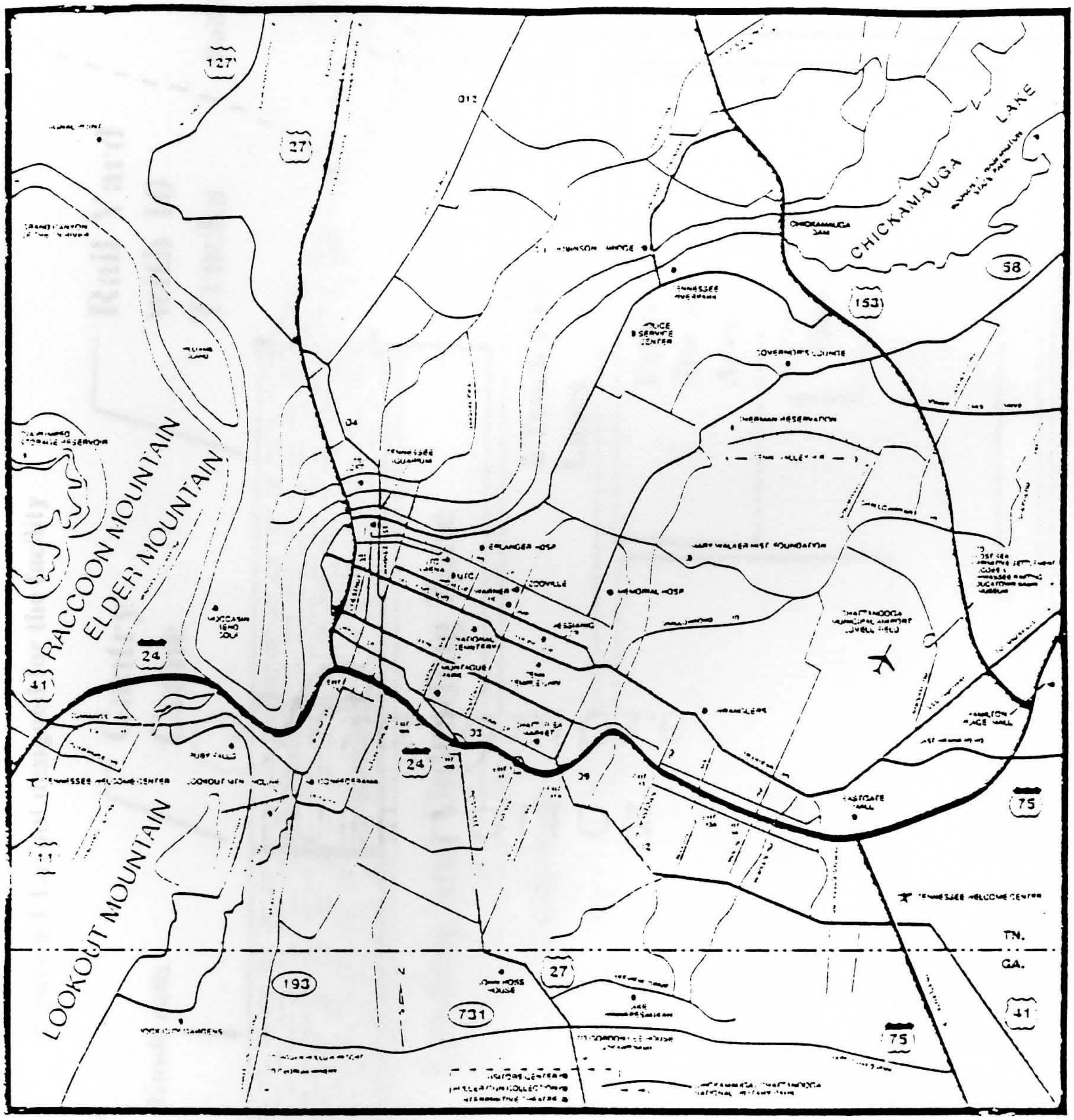


1. Signal Mountain Cement Company
2. Mid-South Terminals
3. Missouri-Porland Cement Company
4. Ergon, Inc.
5. General Oil Company
6. ABB-Combustion Engineering
7. Southern Foundry Supply, Inc.
8. Dixie-Portland Flour Mills, Inc.
9. Dixie Sand and Gravel Company
10. Amoco Oil Company
11. Rock-Tenn Company
12. Concrete Service Company
13. JIT Terminals, Inc.
14. Centre South Industrial Park
15. Cargill, Inc.-Seaboard Cargill
16. Central Soya Company

Figure 1.3 Map showing barge terminals along Tennessee river

APPENDIX P

Figure 1.4 Map showing the highway system in Chattanooga



APPENDIX Q

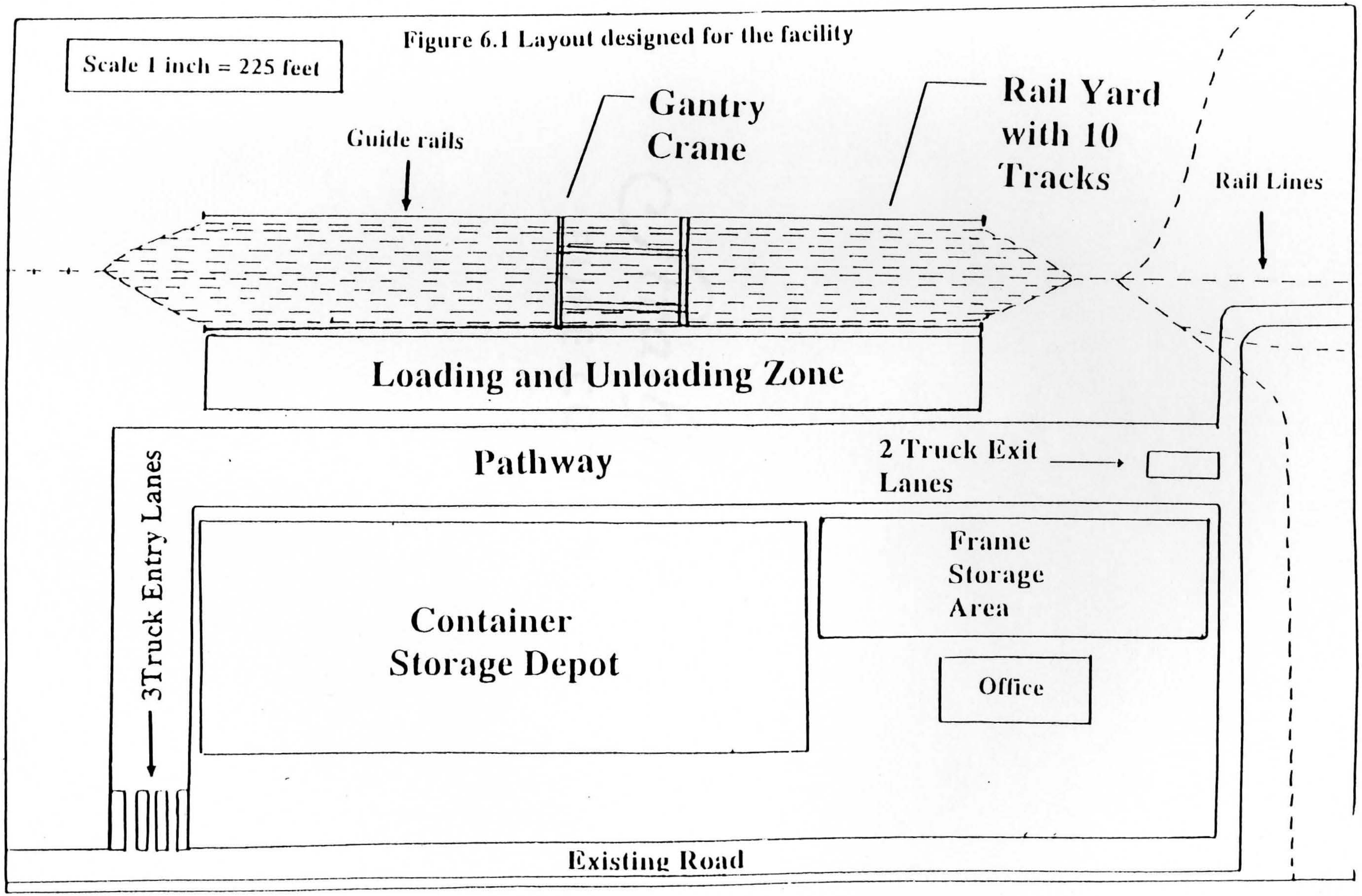


Figure 6.1 Layout designed for the facility