A Thesis

Entitled

MODELING INTERMODAL FREIGHT FLOWS USING GIS

By

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The purpose of this research is to demonstrate the use of Geographical Information Systems (GIS) for analyzing Intermodal Freight Networks. A complete GIS network comprising of the seven states of 1) Illinois, 2) Indiana, 3) Iowa, 4) Michigan, 5) Minnesota, 6) Ohio and 7) Wisconsin of the upper Midwest region of Unites States is created using Oak Ridge National Laboratory’s (ORNL) Intermodal Network Database.

The GIS application for Intermodal freight flow analysis developed in this research is capable of displaying Intermodal freight flows on the transportation network, based on, ‘Finding Shortest Path’ concept of minimizing total transportation costs. Specifically, a network capable of analyzing containerized freight movements has been developed. The research begins with an exploration of existing GIS applications and the state of the practice in the intermodal freight industry. A simple mathematical model is formulated taking into account the multiple modes and complex routing rules involved in the intermodal freight transportation. This research concludes demonstrating the ability of GIS to analyze intermodal freight flows over a transportation network.
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# TABLE OF CONTENTS

ABSTRACT ................................................................................................................................. i
ACKNOWLEDGMENTS ............................................................................................................. ii
TABLE OF CONTENTS .............................................................................................................. iii
LIST OF FIGURES .................................................................................................................... vi
LIST OF TABLES ....................................................................................................................... vii

CHAPTER 1
INTRODUCTION
1.1 Introduction.......................................................................................................................... 1
1.2 Intermodal Freight Transportation...................................................................................... 3
1.3 Growth of Intermodal Freight Transportation ................................................................... 7
1.4 Elements of Intermodal Freight Transportation ............................................................... 8
1.5 GIS technology in Transportation (GIS-T) ................................................................. 12
1.6 Objectives......................................................................................................................... 13

CHAPTER 2
PROJECT GOALS AND METHODOLOGY
2.1 Project Goals....................................................................................................................... 14
2.2 Research Methodology ..................................................................................................... 15

CHAPTER 3
LITERATURE REVIEW
3.1 Introduction......................................................................................................................... 18
3.2 Overview of Freight Transportation Modeling .................................................................... 19
3.3 Freight Transportation Network Models ........................................................................... 20
3.4 Intermodal Freight Research using GIS ........................................................................... 23
3.5 Multimodal Freight Network developed by ORNL ......................................................... 25
3.6 ArcView GIS and Network Analyst .................................................................................. 27
3.7 Summary........................................................................................................................... 29
CHAPTER 8
CONCLUSIONS

8.1 Conclusions .................................................................94
8.2 Recommendations .........................................................94

REFERENCES ..................................................................96

APPENDICES

APPENDIX A .................................................................98
APPENDIX B .................................................................100
APPENDIX C .................................................................101
APPENDIX D .................................................................106
APPENDIX E .................................................................114
LIST OF FIGURES

Figure 1.1: Typical Intermodal Journey ..............................................6
Figure 1.2: Relative comparison among modes by Distance and
Transportation cost .................................................................9
Figure 1.3: Transportation costs in an intermodal shipment ..............11
Figure 2.1: Research Methodology ...............................................17
Figure 3.1: Components of Intermodal Network ..............................28
Figure 4.1: Examples of Intermodal Movements ...............................33
Figure 5.1: Upper Midwest Freight Corridor Study Region ..................42
Figure 5.2: Upper Midwest Region ...............................................45
Figure 5.3: Construction of a Multi-layer intermodal shipment routing ....48
Figure 6.1: Population Distribution in the counties ............................65
Figure 6.2: Population Density Distribution in the counties .................66
Figure 6.3: Selected counties-Phase 1 ..........................................67
Figure 6.4: Final Selected counties ..............................................72
Figure 6.5: Intermodal Base Network ..............................................77
Figure 6.6: Final Selected Intermodal Network .................................78
Figure 6.7: Highway Network in Midwest Region .............................79
Figure 6.8: Rail Network in Midwest Region ...................................80
Figure 6.9: Water Network in Midwest Region ..................................81
Figure 7.1: Organization of GIS Application ..................................86
Figure 7.2: Truck Flows .............................................................89
Figure 7.3: Rail Flows ...............................................................90
Figure 7.4: Water Flows .............................................................91
LIST OF TABLES

Table 5.1: Tons and Value of Freight Moving To, From, and Within the Seven States of the Corridor Region………………………………………….....43
Table 5.2: Representation of Network Elements……………………………………..47
Table 6.1: Counties selected-Phase 1…………………………………………………...64
Table 6.2: Final counties selected-Phase 2…………………………………………..69
Table 6.3: Ports selected in the Study Area…………………………………………71
Table 6.4: List of Intermodal Container Terminals……………………………..73-74
Table 7.1: Sample origin and destinations…………………………………………88
Table 7.2: Results from Model Run…………………………………………………..93
CHAPTER 1

INTRODUCTION

1.1 Introduction

Transportation is an important human activity, which supports and makes possible most of the social and economic interactions among communities of the world. Freight Transportation, in particular, is one of today’s most important economic activities, not only as measured by its share of nation’s Gross National Product (GNP), but also by the increasing influence that the transportation and distribution of goods have on the performance of many economic sectors like wholesale & retail trade, manufacturing & production etc. In United States, with the advent of Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and Transportation Equity Act for the 21st Century in 1998 (TEA-21), the transportation planners and policy makers have become extremely concerned about putting in the best use of existing transportation infrastructure. There is also a need for them, to anticipate the future developments of the transportation network by identifying the deficiencies in the present transportation system and projected growth of traffic. For this purpose, transportation experts rely on various techniques of modeling transportation flows to analyze the existing traffic and estimating the future demand of transport for passenger and freight traffic. During the course of implementation of the above legislative actions, the concept of intermodality in passenger and goods movement has gained great importance. Especially, in freight sector, intermodal freight
transportation is being seen as an important solution to energy saving and congestion relieving issues.

Various models have been developed to analyze intermodal freight transportation using operations research techniques (see, for example, Kresge and Roberts, 1971; Freisz, et.al, 1983 and Crainic, 1987). The models are purely analytical, complex to implement and place greater demands with respect to data requirements. While modeling, being the difficult task, transportation planners and other policy makers are finding a hard time to understand, interpret and analyze the results of freight demand models. There is hence a need to look for an alternative in the form of quick- and- easy- to-understandable methods, which could help to analyze the freight flows with available data. The present study is to model intermodal freight flows using Geographic Information Systems (GIS) taking network characteristics of transportation infrastructure into consideration and minimizing the total transportation cost incurred during transportion. Since its inception, GIS has been an excellent tool for transportation planners helping them to analyze the transportation systems due to the spatial nature of transportation data and its excellent displaying properties. Modeling freight flows in GIS would help to visualize the results of freight demand models through maps and so it would be easy for transportation planners and policy makers to identify the bottlenecks in the transportation network and make effective policies on infrastructure improvements. Presently there are many transportation demand modeling software packages, (for example, Tranplan, TransCAD, EMME/2, QRSII) that are capable of modeling freight flows, but these packages are often costly and require special expertise to model. The goal of this study is to develop a cost effective and indigenous tool using widely available ArcView GIS software and its
extension Network Analyst to model the intermodal freight flows, so that, it would be helpful to all users interested in modeling freight flows who do not have access to travel demand modeling software packages. The tool is intended to get a quick idea of freight flow patterns, provided the data on origin and destination of the freight flows is available. The flows are assigned to the network based on minimum transportation costs, which are external inputs that a modeler has to provide. A tool of this stature is needed, considering the large amount of time and money involved in collecting and authenticating freight data and using complex freight demand modeling procedures.

1.2 Intermodal Freight Transportation

Intermodality deals with the movement of goods using various modes of transport. It is a tool of inestimatable value to shippers which has given them greater choice of routings and a technique to lower costs by enabling them to select carrier combination and vehicles which offer most efficient service at least expense. According to Muller [1] the concept of logistically linking a freight movement with two or more transport modes is centuries old, but the recent focus on this particular type of transportation is due to radical developments in technology of freight transportation brought by containerization. A seamless and continuous door-to-door transportation of freight on two or more transportation modes is the goal of intermodalism and it is defined as,

“ Intermodal freight transportation is the concept of transporting freight using more than one mode of travel in such a way that all parts of the transportation process are
effectively connected and coordinated, safe, environmentally sound and offering flexibility”[1]

In general, an intermodal shipment is one that is carried by two or more modes during a single journey. Intermodal transportation has been broadly defined as the sequential use of two or more modes of transport. Often, one entity takes the responsibility for the entire multimodal movement of a freight shipment. Intermodal Freight Transportation (IFT), in the narrowest usage of the term, refers to transport of goods in containers that can be moved on land by rail or truck and on water by ship or barge. Containers save handling costs when freight must be transferred from one mode to another (e.g., from ships to trucks); also, a truck–rail container movement can yield a savings compared with truck alone if the cost of the transfer (the cost of added handling of the container plus the cost of the difference in speed and reliability between truck and Intermodal) is offset by rail’s lower cost per ton mile. In the present study, the narrower usage of the term “Intermodal Freight Transportation” could truly justify the conceptual framework, adopted in this project. It is defined as the movement of goods in containers (unitized cargo) from point of origin to point of destination using two or more different modes of transportation, which are linked end to end.

The definitions of intermodalism usually concentrate on operational aspects and transport infrastructure. However, successful intermodal transport also requires a conducive administrative and legal environment, and interchange of information. Key to intermodalism in a transfer between modes is coordination amongst multiple freight transportation providers. For example, a container shipment from Asia to the US East coast will likely have 8 different responsible shippers; a truck firm in Asia, a port agency
in Asia, a shipping firm for the cross pacific trip, a port agency on the US West coast, a Western US railroad, an Eastern US railroad, and a trucking firm for final delivery. All of these firms must coordinate to insure that connections are made, and the delivery is properly tracked. In addition, each of these transfers incurs additional cost. The entire process is very complicated to manage and is generally done by companies called Intermodal Marketing Companies (IMC’s), which serve as the shipper representative, tracking deliveries and letting contracts for the multiple modes and doing transfers.

Figure 1.1 shows the intermodal movements involved in the above example. The limits of intermodality are imposed by factors of space, time, form, pattern of the network, the number of nodes and linkages, and the type and characteristic of the vehicles and terminals. Intermodality can be conceived as the transition from one mode of transportation to another, and is organized around the followings concepts:

1. The nature and quantity of the transported commodities;
2. The modes of transportation being used;
3. The origins and destinations;
4. Transportation time and costs;
5. The value of the commodities and the frequencies of the shipments.

The present study focuses on spatial dimension of the intermodal system and costs associated with physical transfer of goods, while it is assumed that other factors influencing intermodality of goods (administration, information exchange, etc..) are ideally practiced.
Figure 1.1: Typical Intermodal Journey
1.3 Growth of Intermodal Freight Transportation

Review of literature indicates that intermodalism originated in the field of marine transportation, with the development of the container in the late 1960's. With the deregulation and privatization trends begun in the 1980's, the intermodalism has grown at significant rate and spread inland. Presently, a growing share of the medium and long haul freight flows across the globe is transforming into Intermodal transport.

Deregulation in the United States in the early 1980s liberated firms from government control. Companies were no longer prohibited from owning across modal types, and thus developed a strong impetus towards intermodal competition. Shipping lines in particular, began to offer integrated rail and road service to customers. Thus, a seamless system has created tremendous advantages in terms of time and cost to customers and shippers.

Customers could purchase the service to ship their products from door to door, without having to concern themselves of modal barriers. Techniques for transferring freight from one mode to another have facilitated intermodal transfers. Examples include piggyback (TOFC: Trailers on Flat Cars), where truck trailers are placed on rail cars, and LASH (lighter aboard ship), where river barges are placed directly on board sea-going ships.

The major development undoubtedly has been the container, which permits easy handling between modal systems. Double stacking of containers on railways (COFC: Containers On Flat Cars) has doubled the capacity of trains to haul freight with marginal costs, thereby improving the competitive position of the railways with regards to trucking for long-haul shipments. Containerization is becoming a privileged mode of shipping for rail and maritime transportation. While handling technology has influenced the development
of intermodalism, the most important factors have been the changes in public policy and developments in information technology.

1.4 Elements of Intermodal Transportation

The intermodal freight industry is represented by a broad range of modes, with different cost structures and performance functions which are typically evaluated in terms of cost, time, reliability and potential damage/theft of goods. There are many issues that must be considered when addressing intermodal transportation routing; the most critical factor is transportation costs. Typical transportation costs incurred during transporting are fuel costs, equipment costs, crew costs, overhead costs, general and administrative costs. When different modes are used in transportation, transfer costs and drayage costs are also incurred. Transfer cost is the cost of transferring the cargo from one mode of transportation to another and drayage cost is the cost of transporting the cargo from the point of origin to the terminal, where the goods are transferred. Thus from the economics point of view, Intermodal Freight Transportation is justified fully when the savings from switching modes exceed transfer and drayage costs.

1. Figure 1.2 shows different transportation modes, which have different cost functions depending on the distance of haulage. Road, rail and water transport have respectively a C1, C2 and C3 cost functions. While road has a lower cost function for short distances, its cost function climbs faster than rail and maritime cost functions. At a distance D1, it becomes more profitable to use railway transport than road transport while from a distance D2, maritime transport becomes more advantageous. Point D1 is located between 300 and 450 miles
Figure 1.2: Relative comparison among modes by distance and transportation cost

Source: Approaches for Improving Drayage in Rail- Truck Intermodal Service (14)
of the point of departure while D2 is at approximately 900 to 1000 miles.

Figure 1.3 illustrates a typical cost curve for a Truck-Rail intermodal freight shipment. The shipment starts its travel from origin by road and to an intermodal terminal where it is transferred to rail. As described above, if the sole purpose of travel on truck from origin to a terminal is an intermodal transfer, it is called Drayage, and shown as Cost ‘C1’. If a drayage component is not involved during initial journey, the cost incurred is simply called a line haul cost for the truck. At the terminal 1, a transfer of the shipment occur from road to rail and is known as transfer cost ‘T1’. The shipment travels on rail to another terminal, costing (C3-C2). At the terminal, the shipment is again transferred to road, incurring a transfer cost T2. The final leg of the travel is then completed by traveling on road to destination costing (C5-C4) and is called destination cost or drayage cost.

The scope of the present study is limited to the analysis of transportation costs, transfer costs and drayage costs. These costs are the only determining factors in the Transportation choice during Intermodal Freight Transportation. Intermodality enables economies of scale within a transportation system where modes are used in the most productive manner. Besides, above there are numerous benefits of intermodal freight transportation like,

1. Reduced congestion and burden on over stressed highway infrastructure.
2. Increased economic productivity and efficiency of the transportation network.
3. Reduced energy consumption
4. Reduced environmental pollution and
Source: Approaches for Improving Drayage in Rail-Truck Intermodal Service (14)

Figure 1.3: Transportation costs in an intermodal shipment
5. Lower overall transportation costs.

1.5 GIS technology in Transportation (GIS-T)

Geographic Information Systems for Transportation (GIS-T) refers to the principles and applications of applying geographic information technologies to transportation problems. Geographic Information Systems (GIS) is a product of increased computing power, improved database technology and sophisticated Computer Aided Design (CAD) capabilities. GIS-T applications have benefited from many of the standard GIS functions (Querying, geocoding, buffering, overlaying, etc.) to support data management, analysis, and visualization needs. Like many other fields, transportation has developed its own unique analysis methods and models. Examples include shortest path and routing algorithms (e.g., traveling salesman problem, vehicle routing problem), spatial interaction models (e.g., gravity model), network flow problems (e.g., user optimal equilibrium, system optimal equilibrium, dynamic equilibrium), facility location problems (e.g., p-median problem, set covering problem, maximal covering problem, p-centers problem), travel demand models (e.g., the 4-step trip generation, trip distribution, modal split, and traffic assignment models), and land use-transportation interaction models. Popular products include ARC/INFO, Arc View, Intergraph, TransCAD and MapInfo. As with most software, GIS programs vary greatly, there are trade-offs between functionalities and user-friendliness among the variants of GIS software. For the present study, Arc View 3.2 of Environmental Systems and Research Institute (ESRI) is used because of its large pool of user community and the network analysis capabilities of Network Analyst.
The easy customization of Arc View through Avenue, a powerful object oriented language is also one of the reason for choosing Arc View for this project.

1.6 Objectives of study

The objective of the present study is to develop an algorithm to model the selection of best combination of transportation modes to move a shipment from its origin to destination considering transportation cost and transfer costs and also to demonstrate the feasibility of GIS in the analysis of intermodal freight shipments. The task is accomplished by using the multimodal transportation network developed by Oak Ridge National Laboratory (ORNL) and Arc View GIS.

The study is intended to accomplish the following objectives:

- Develop a mathematical model for taking decision on the best sequence of modes considering the transportation network and shipment characteristics.
- Develop an analysis tool using Network Analyst of Arc View GIS and multimodal transportation network developed by ORNL.
- Provide a platform for future research and analysis of modeling intermodal freight flows.
CHAPTER 2
PROJECT GOALS AND METHODOLOGY

2.1 Project goals

Development of project goals and methodology is a key step in any research effort. This chapter builds upon the state of the art technology presently available to develop an appropriate framework for analysis. The development of a GIS based intermodal analysis tool was driven by three primary goals such as:

1) To demonstrate feasibility of GIS for analysis of intermodal freight shipments,
2) to accurately characterize the intermodal transportation network, and
3) to provide a platform for future research and analysis.

The first goal is the demonstration of GIS feasibility. It is an attempt to build upon work done by the Center for Transportation Analysis at Oak Ridge National Laboratory. This is the most important part of this research. The GIS transportation network should be capable to represent all the important elements of intermodal movement as discussed in Chapter 1. It should be shown that through this application of GIS; one could be able to solve the real world problems of intermodal freight transportation. It should hence, show that the integration of intermodal network models with GIS provides a generic, user friendly functional environment to develop and analyze networks and evaluate the effects of policies and measures aimed to improve the service provided by one mode to the performance of other, competing modes. In this research, a
decision supporting analysis tool using ArcView and its extension Network analyst for analyzing intermodal freight flows will be created. This will fulfill the first goal.

The second goal of creating an accurate transportation network is marred by the limited scope of this research. It is due to, the amount of time and resources required to collect the details of each links in the study area. Impedances are assigned to each link in terms of costs incurred for transporting a container on each mode. The intermodal terminals are assigned with appropriate transfer and drayage costs. However, the availability of impedance values by links are available in the ORNL database of multimodal network. These values were basically arrived by modeling of 1997 CFS freight flows. By using impedances developed by ORNL, it helped to get an idea of real time representation of the intermodal transportation network to some extent.

The output of this research will be a basic GIS application that could be used as a guide tool for more complex assignment procedures. It can also be used in demand modeling of freight shipments in future research efforts.

2.2 Research Methodology

The following describes step-by-step methodological procedures adopted in this research.

1. Identify Issues: The literature review will aid in knowing the current trends of intermodal freight network models and the extent of GIS usage in this field. The spatial cost allocation and realistic network movement across multiple modes is identified as the key issue.
2. Selection of study Area: The study area is derived from the Upper Midwest freight corridor study that is jointly conducted as a cooperative research by University of Wisconsin at Madison, University of Illinois and the University of Toledo. It is comprised of the states of Indiana, Illinois, Iowa, Michigan, Minnesota, Ohio and Wisconsin. Road, rail and water modes are the chief means of freight transportation in this region. The existence of good connectivity between the modes and the large amount of freight activity taking place in this region is a good reason for exploring the opportunities in the field of Intermodal Freight Transportation.

3. Identify Modes and commodities: Truck, Rail and Water modes are selected, as these are most commonly used modes and the only modes presently modeled in the ORNL multi modal network. This research is applicable to all types of commodities, which can be containerized.

4. Formulate mathematical routing problem: A mathematical model is developed, based on the classic shortest path routing algorithm. The aim of this model is to minimize the total transportation cost incurred to transport a container from its origin to destination.

5. Identify Data: Understand clearly the network structure of the ORNL multi modal network. Identify the data that is necessary to make the network logically routable in real time conditions and develop the tool.

6. Analytical Tools and Application development: The analytical tool used in this research is ArcView GIS, because of its ability to calculate shortest paths based on link impedances and also the vast base of users having this software on their desktops. Figure 2.1 shows the flow of the research methodology adopted in this study.
Figure 2.1: Flow of Activities for Research Methodology
CHAPTER 3
LITERATURE REVIEW

3.1 Introduction

Due to the economic significance and the volume of traffic generated by goods movement, estimation of freight flows has become an important issue in freight transportation planning. Despite the growing importance of freight movements in transportation planning processes, efforts for modeling freight have been lagging behind passenger travel demand modeling in the fields of research and data collection. This may be attributed to the complex behavior of freight demand like:

1) The existence of multiple dimensions of freight, which has to be considered when transporting like value, weight, volume and trips.

2) Freight movements result from decisions made in various sectors of the economy concerning production, consumption and sales that have little to do with transportation per se.

3) A diversity of participants in the process - drivers, shippers and carriers are involved in transportation decision-making. These people interact dynamically and take decisions that affect freight demand.

Moreover, the commercial sensitiveness of the freight demand data and a wide range of abstract nature of opportunity costs in freight transportation, adds to difficulty in
Modeling the freight traffic flows. The following section provides a brief review of the previous work done in modeling freight transportation.

3.2 Overview of Freight Transportation Modeling

Models used for freight transportation modeling are classified into two general categories, spatial and network models. Spatial models are used to determine the flows between production and consumption regions using a simplified transportation network. Many regional freight modeling takes place in this category, where the model relies upon aggregate type of data. The significant data used in this analysis is at the level of finding the aggregate share of freight mode at a certain geographic level. Though these models are generally good in taking into consideration the socio economic dynamics and demographic trends of the study area they do not capture the behavior at the level of individual decision maker (i.e., shipper). On the other hand network models takes into account the logistics decisions of shippers and carriers for moving freight based on the commodity type and network characteristics. Network models are hence popular in modeling intermodal freight flows where the shipping decisions are based on the rational choices of decision maker i.e., minimizing the total transportation costs. But successful modeling of freight using network models is always a difficult task because of lack of data at disaggregate level, the shipment data are of a proprietary nature and it exists in the private sector. Since the present research topic is on modeling the intermodal freight flows, which obviously comes under the category of network modeling, the literature search is focused on researching the current and past work done in this field.
3.3 Freight Transportation Network Models

Network models are based on the foundations of graph theory and principles of Operations Research. They are defined on graphs containing nodes or vertices, connected by links. Typically links are directed and are represented by arcs in a network. Some of the vertices represent origins of some transportation demand, while some others represent destinations of this traffic. Links have various characteristics like length, capacity and cost. In network models, the aim is to choose links in a network in order to enable the goods to flow from their origin to destination at the lowest possible system cost.

The simplest version of this model is probably the Shortest Spanning Tree Problem (SSTP) which consist of determining a minimal tree linking all the vertices of an undirected graph $G = (V,E)$, where $V$ is a vertex set and $E$ is an edge set. The SSTP is then formulated as:

If

$c_{ij}$: the length of the edge $(v_i, v_j)$

$x_{ij}$: a variable which is equal to 1 if and only if edge $(v_i, v_j)$ belongs to the SSTP, otherwise it is equal to 0.

The problem is then:

Minimize $\sum c_{ij} x_{ij}$

Subject to $\sum x_{ij} \geq 1$

The SSTP can be solved to optimality by applying one of several shortest path-finding algorithms like Dijkstra’s algorithm, K-Shortest Paths etc.

Harvard Brookings model developed by Roberts (1966) [2] and later extended by Kresge and Roberts in 1971 [3] is the first significant freight network model. The model
is explicitly multimodal—including highway, rail, air and water modes. Also it is explicitly a multi commodity model. The model considers shipper’s modal choices and general routings which are determined from shortest path calculations for the intermodal network. The arc impedances are measured as constant unit for a pair of origin and destination (path) through perceived shipping costs. The model uses simple economic and spatial factors as the basis for assignment, but the micro-level details in the model formulation and its extensive data requirements had inhibited the practical application of this model.

Middendorf [4] developed a multimodal freight forecasting procedure for the state of Florida. The methodology involved two step process; first, the generation and distribution of freight were projected through a Fratar model that applied growth factors to current commodity flows. In the second step, the projected freight flows were distributed among competing modes through modal split models. The Fratar model was successful in producing reasonable projections of freight traffic, to, from, and within Florida in 1985 and 2000. One advantage of this approach was that the Fratar model was based on existing secondary sources of data. Because these sources exist in the same analogous form for other states, a similar modeling approach could be developed and applied elsewhere.

Guelat, et al. [5] developed a network model for freight flows on Brazil’s transportation network. This model considers multiple products by specifying a cost function for the flow of each product on a link through a transfer that corresponds to one mode using a set of origin-destination matrices. The novel aspects of the model are the way in which the network representation is used, the specification of demand, the
mathematical programming solution algorithm, and the adaptation of the shortest path algorithm.

Kim and Hinkle [6] proposed a planning model for statewide freight transport systems planning. The model was modified such that it could be used for analysis of multi commodity freight flows by highway, rail, water, and pipeline, for a region or state. The proposed model was divided into five sub-models:

1. Network analysis models,
2. Freight transport demand analysis model,
3. Vehicle requirement model,
4. Assignment model and
5. Evaluation model.

Issues and problems that could be analyzed by using this process included the identification of anticipated impacts of deregulation, rail mergers, shifts in the economic base of an area, and changes in transportation rate, energy availability, and service. This model could be used for both freight and passenger transportation analyses, since the network would be coded using the Urban Transportation Planning System framework. However, a major drawback of this method is that no application had been performed.

Kornhauser and Bodden [7] developed the first elements of a nationwide analysis of freight and intermodal movement. They used a bi-modal network consisting of the highway and railway networks in Princeton, New Jersey. They classified the highways into four categories of Interstates, toll roads, divided and undivided links. The railway network was a subset of the total rail links with only those that contributed to intermodal traffic being considered. Intermodal ramps across the United States connected these two
networks and these links were capacity coded with the total carload volume of the interchange. Routing was accomplished using a minimum cost, unconstrained path finding algorithm.

The National Cooperative Highway Research Program Report (NCHRP-Project 8-30) [8] is the most comprehensive freight transportation study. It provides many techniques and supporting information for a variety of freight demand analyses. This report outlines the methodologies for specific, model developments using other successful efforts as its basis. However, it does not provide concise information on the adaptation of these models to a broad range of freight transportation issues.

### 3.4 Intermodal Freight Research using GIS

Using GIS in the analysis of freight is a new concept. The popularity of GIS in freight modeling is due to its abilities of displaying data and handling of huge databases. The simplest usage of GIS for freight analysis is data display and manipulation. The GIS is usually interfaced with an external analysis program for showing the results in the form of maps. Integration of intermodal network models within GIS models provides a generic user friendly functional environment to evaluate the effects of policies and measures aimed to improve the cost effectiveness among competing modes.

Boile [9] has presented a framework to analyze and evaluate intermodal networks in a GIS environment for auto and rail commuter networks. The method starts by generating the network specific data files necessary for the analysis in TransCAD. These files included information on network, service and demand characteristics, capacity of
network facilities and cost components associated with the transportation services such as tolls, parking fees and transit fares.

Rowinski, et al. [10] have developed a demand forecasting model for assigning multi-commodity, multi-class truck trips between various origin and destination points. The model takes into account the impacts of congestion on truck route choice and is implemented as a GIS within TransCAD and Microsoft Access. The model is basically formulated as a policy analysis tool and for only highway mode.

Standifer and Walton [11] “Development of a GIS model for intermodal freight” is one of a kind study that the present research effort is closely followed upon, though on different approach on the Intermodal network creation. The authors have put in an exceptional effort in creating the intermodal network for Texas by merging each individual mode into one final intermodal network by using data conflation and several other techniques on the each of the mode networks. These methods included planar separation, turn penalties and dummy links. Large transfer facilities were modeled as single points using a turntable within Arc View to set turn prohibitions and turn penalties as proxies for intermodal transfer costs. The model built by them, was able to demonstrate the feasibility of GIS to model intermodal freight transportation and performed a rich set of analyses as a decision support system for shippers, planning agencies and researchers.

Creating a truly representative and easy to use intermodal freight network in GIS has been always a problem to most researchers until Oakridge National Laboratory (ORNL) developed the nationwide intermodal transportation network integrating the highway, rail and water modes, along with a set of intermodal terminals and a terminal
model to connect them for modeling freight flow data from commodity flow survey of 1997.

3.5 Multimodal Freight Network developed by ORNL

The Commodity Flow Survey (CFS) multimodal network was constructed to simulate the routes taken by freight shipments in the 1997 Commodity Flow Survey by ORNL. Southworth, et. Al. [12], did the earlier work at ORNL to develop the intermodal network. They worked on the practical issues involved in constructing intermodal freight networks in GIS. They proposed the following:

1) Linking together different primary modal networks through an intermodal terminal network database using three sets of “notional” links. These sets include, Traffic generator/traffic attractor links, Intermodal terminals transfer links, and Intra-modal, carrier-based interlining links.

2) Developing carrier, and in some cases, service-specific sub networks necessary for the generation of sensible intermodal routing alternatives

3) Attaching intermodal networks to a set of traffic analysis zones using geographic centroids of analysis zones, or centroids at the population-weighted or activity weighted center of the zones, depending on the sparseness of the network relative to the number and size of the Transportation Analysis Zones (TAZs) used.

They have also specified that the intermodal database should contain appropriate representation of intermodal transfer terminals and intra-modal carrier transfers as well as traffic origin and destination links to each of the modes of interest.

A research paper by Southworth and Peterson [13] published in Transportation Research Part C, has a clear description about the development and application of a
single, integrated digital representation of a multimodal and transcontinental freight transportation network. The network was constructed to support the simulation of some five million origins to destination freight shipments reported as part of the 1997 United States CFS. The paper focuses on the routing of the tens of thousands of intermodal freight movements reported in this survey.

The CFS uses zip code locations to capture both shipment origin and destination locations, while city and country of destination as well as US port of exit are also reported for export shipments. They developed a digital network capable of routing freight between some forty-eight thousand different traffic generators and attractors. Given the voluminous number and variety of possible shipments generated by the survey, a number of reasonably generic computer programs were developed to accommodate an automated set of shipment distance calculations.

The methods used are described below:

- **Intermodal network construction**: placing components of intermodal freight shipments within a network structure, by merging different modal networks into a single, intermodal network.
- **Intermodal network access**: ways to connect shipment origins and destinations to networks, and the need to evaluate multiple origin as well as multiple destination network access and egress options in order to select most likely shipment routes.
- **Modeling intermodal terminal transfers and inter-carrier interlining practices within a network structure**: including the modeling of trans-oceanic and trans-border export shipments and
The use of generalized impedance functions for modeling the trans-global as well as trans-continental routing of domestic and export shipments.

Figure 3.1 shows the components used in creating Multimodal network by ORNL. The multimodal CFS network was created by merging traffic routable single mode networks. This was done by linking them through a series of intermodal truck-rail (TR), truck-water (TW) and water-rail (WR) transfer terminals. The intermodal network used in the present research is an improved version modified to use in commercial GIS packages like Arc View developed by Center of Transportation Analysis (CTA) of ORNL. The CTA considers transportation networks as geographically based link-node networks of major roadways and all active railroads in the U.S., Canada and Mexico. While intended primarily for network analyses (such as routing, traffic assignment, investment, and reliability analyses), the geographic base also supports cartographic applications and the association of auxiliary data that also has a geographic base.

3.6 Arc View GIS and Network Analyst

ArcView GIS is powerful software that provides for visualizing, querying, exploring, and analyzing data geographically. ArcView is a powerful GIS tool that can display information, read spatial and tabular information from a variety of data formats, access external databases, produce thematic maps (use colors and symbols to represent features as well to represent features based on their attributes), perform spatial queries, and connect spatial information to database attributes. Arc View allows for a high degree of customization using Avenue. Avenue is Arc View’s object-oriented programming language used for customizing and developing ArcView applications. Avenue has a
Figure 3.1: Components of Intermodal Network by ORNL
Library of classes that represent the objects found in Arc View. The program executes
tasks by accessing and manipulating these objects. Arc View has many extensions which
Perform a plethora of geographic and spatial analysis. The most popular among them are
Network Analyst, Spatial Analyst and 3D Analyst. For performing transportation analysis
in Arc View, Network Analyst is considered as the main tool. Arc View Network Analyst
solves the problems of network traffic on streets, rivers, railroads, pipes or any
interconnected set of lines. The ArcView Network Analyst (AVNA) extension module
allows the user to solve 3 categories of network analysis problems; Find Best Route, Find
Closest Facility and Find Service Area. Find Best Route problems involve finding the
"least cost impedance" path on the network between two or more stops. Find Closest
Facility pertains to finding the distances from an event to the nearest facilities, or vice
versa, finding the distance from a facility to one or more events. Find Service Area
determines the area that a particular facility can serve within a given time or cost frame.
Network Analyst allows to build sophisticated models of traffic flow that incorporate
speed limits, prohibited turns, closed or one-way streets, underpasses, overpasses
incorporating various impedances into the network. For more complex analyses
customization of Network Analyst using Avenue scripts is always an apparent solution.

3.7 Summary

The literature review has made an attempt to bring the relevant studies in the field
of intermodal freight transportation. It was hard to skim through the research done in
freight transportation, finding literature on real-time routing of intermodal shipments on
the transportation networks because of lack of a single universal modeling techniques for
freight analysis. Analyzing freight demand is a complex task due to a variety of issues; it involves multiple dimensions (i.e., value, weight, volume, etc) and multiple decision makers (e.g., drivers, shippers, carriers). The proprietary nature of freight data and its commercial sensitivity makes it formidable to model freight based on disaggregate commodity flow model. Use of GIS for transportation and incorporating in freight model would provide an invaluable tool to perform routing analysis.
CHAPTER 4
ISSUES IN INTERMODAL FREIGHT TRANSPORTATION

4.1 Issues of Intermodal Freight Transportation

There are many issues that must be considered when addressing intermodal transportation routing. The major factor is the cost of freight transportation. Transportation cost covers the carrier’s fuel costs, equipment costs, crew costs, overhead costs, and general and administrative costs. When different modes of transportation are used, a transfer cost is incurred for transferring cargo from one mode of transportation to another. Transfer costs can be fixed or variable. They may depend upon the transfer point at which they occur, as well as the incoming and outgoing modes at a transfer point. The transfer cost may also depend on the type and the quantity of commodity that is being shipped. The cargo shipped may have effect on the best mode or combination of modes of transportation.

Several components must be examined in modeling intermodal transportation systems. Various factors can affect the reality and the complexity of the model. One factor that must be investigated by the modeler is the combination of single or multiple routes, available for shipment between origin and destination. By considering each additional path, there is a large increase in the complexity of the model, besides there are already a number of modes available at each end in the freight transportation network. Also consideration of linear versus non-linear transportation costs adds another
dimension to complexity. Linear costs are fixed on the basis of weight and distance traveled. Non-Linear transportation costs are more realistic, but much more difficult to model. Multiple objectives may also need to be considered, when modeling. Different objectives may include minimizing total time, minimizing total cost, and / or maximizing service level. The information needed by the carrier in order to determine the various cost/times of transporting goods is often very hard to determine. This imprecise nature of the information can also add to the complexity to intermodal transportation models.

4.2 Types of Intermodal Movements

The transportation infrastructure for freight movement usually consists of a vast network of highways, rail lines, waterways, airline routes and pipelines. These are linked together at various points of modal and intermodal interchange, such as ports, rail terminals, truck terminals and airports. The key modal components of the system generally provide efficient line-haul service. However the interchange points, such as terminals, where freight changes from mode to another are the most important components of the intermodal freight transportation network. To understand the intermodal movements’ three general examples of intermodal movements are shown in the Figure 4.1. The routing of shipments is done by shippers, freight forwarders and by third party logistical companies.

Example 1: International Ship-Rail-Truck Movement - This example shows an international movement of container from a foreign shipper to a domestic receiver. The sequence of steps taken by an arriving shipment includes: The shipment is delivered from the producer (or warehouse) to the port in a foreign country, usually by truck or rail.
Figure 4.1: Examples of Intermodal Movements

Source: Intermodal Freight Transportation, Volume 1, DOT-T-96-04
• A shipload is assembled to meet the arrival of a container ship scheduled to serve the appropriate US port. The loading is usually accomplished in 12 to 24 hours.

• The ship sails for its destination and during the journey information is exchanged between the carriers about the expected arrival time, the type of equipment and the number of railroad cars required at the port to unload the container and proceed to its destination.

• On arrival at the port, the containers are loaded directly onto a train or into an area where they will be loaded onto a chassis and trucked to their destinations. Some containers may be off loaded onto barges and transported to other coastal destinations.

• Double stacked trains, some more than a mile long are made up at the ports which are routed such that the train drops off sections of railcars bound for other destinations at switching yards as it moves across the country.

• When a train carrying the shipment arrives at a destination intermodal terminal, it is unloaded onto a chassis and is usually picked up and trucked to its destination by the receiver.

A domestic container movement also follows the same pattern as described above.

Example 2: Air Cargo Movement - Air Cargo generally includes items that have a large value per pound, are small in size and especially time sensitive. Typically these include electronic equipment, clothing, flowers, medical supplies, small packages and similar goods. Because of their high value these goods are generally small shipments. The steps in air cargo movement usually include:
Arranging for air shipment through a freight forwarder, this includes selecting the airline, airport from which the airline departs and negotiating the cost of the shipment.

Trucking goods from the shipper to a freight forwarder or to the airline’s freight center or to the airport of origin.

The shipment is then packed into suitable containers and the flown to the destination airport, where the shipments are unloaded and trucked to their final destinations.

Example 3: Pipelines - Pipelines are very efficient modes of transportation, moving large volumes of liquid and gas products to long distances without generating traffic on the surface transportation network used for passenger and freight movements.

Typical steps in the shipment of products by pipeline are:

- The origin point is often a well or a large refinery that is connected directly to a pipeline.
- The commodity is pumped to a terminal or a tank farm near its final destination through pipeline, where it is delivered through tank trucks to the consumers.

4.3 Intermodal Service Deficiencies

In the early development of intermodal freight transportation, intermodal service was synonymous with “piggyback” service. Piggyback or trailer on flat car generally involved highway trailers being loaded onto rail flat cars. These are then sent to destinations, several hundred miles away. But the service was hampered by poor service
characterized by high cargo damage, slow transit time, infrequent pick up and deliveries and poor on time performances. With rail and truck deregulation in the 1970s and 1980s, there was rapid increase in numbers of international containers and all set of new delivery requirements of shippers such as “Just-in-Time” have risen, which prompted for focus on improving intermodal transportation. Although very substantial improvements are made, intermodal transportation faces a strong competition from the trucking industry. Some of the deficiencies as perceived by intermodal freight industry are:

1. Less control over goods: Intermodal rail involves trucking to a terminal, rail delivery and draying to the customer- three different moves which means some loss of control. On the other hand, trucking can offer point to point service which means that trucks can pick up a good from a shipper and deliver it to a receiver without intermediate handling.

2. Multiple handling of goods: Containers or trailers are lifted on to and off of rail cars. The extra handling can lead to more damage to fragile goods.

3. Longer time required for short hauls: Containers must be drayed to rail terminals to make “cut off” times which allow for loading and train make-up. At the other end of the journey, time is required to unload the train, pick up and dray the container (or trailer) to the receiver. A truck can go directly from the shipper to the receiver.

4. Less flexible scheduling of intermodal shipments: Trains are scheduled at specific times of day (or day of the week) and containers (and trailers) must be put on certain trains or wait for the next one. Whereas trucks can leave when the load is ready and avoid delays.
5. Costs of intermodal shipping over short and medium haulages: Although the line-haul transportation cost by rail may be lower, costs of draying containers and lifting them onto and off of rail cars must be added. Terminal costs add significantly to the cost of intermodal transportation. Generally intermodal container shipments must be over 500 miles to be competitive with the cost of trucking.

Eliminating or alleviating some of the specific impediments (discussed in next section) to intermodal transportation will help to reduce some of the problems listed above and provide faster, more reliable and more competitively priced intermodal transportation. This will help intermodal transportation to increase its share of the market in the long haul corridors and grab some share of the short–haul freight market (less than 500 miles), which constitutes to about 70 percent of all intercity freight traffic.

4.4 Impediments in Intermodal Freight Transportation

The increasing volume of intermodal freight is placing heavy burdens on transportation infrastructure. This is mainly due to the transportation structure is built keeping into account the single modal travel needs rather than multimodal needs. Some of the current impediments to achieving “seamless” intermodal service are briefly described as:

1. Lack of adequate infrastructure: There is a need for large well-located terminals, which have good landside access and loading and unloading equipment. Bridge improvements should be undertaken for adequate clearances and weight capacities. Dredging is needed to increase water depths at intermodal ports that handle larger container ships.
2. Congestion: Steps must be taken to avoid congestion on access routes to terminals located in urban areas as the delays increases the cost and adversely affect the ability to provide reliable Just-in-Time services.

3. Operational inefficiencies: Lack of Electronic Data Interchange (EDI) facilities for managing and tracking shipments. Delays in scheduling the equipments for loading and unloading of the cargo. Absence of coordination among modes at the terminals is some of the operational inefficiencies that have to be resolved.

4. Regulations: Regulations that delay and/or raise the cost of developing new facilities, such as long lead times for obtaining environmental permits for dredging and other improvements. Inconsistent state regulations such as differing truck size and weight limits that effect the interstate shipments need to be examined and eliminated.

5. Institutional: Factors affecting institutional relationships that impede the efficient interconnection of modal transportation have to be worked upon to build a better public and private sector relationships in terminal planning and operations.

4.4 Data Sources for Intermodal Transportation Planning

Effective intermodal transportation planning requires that pertinent data be available to transportation planners. A variety of data sources and analytical programs that attempt to address these needs are currently in place. There are, however, a significant data and analytical gaps that will need to be filled in order to improve intermodal transportation planning.
Intermodal Surface Transportation Equity Act (ISTEA) requires the states to develop, establish and implement an Intermodal Management System (IMS) for managing transportation facilities. The primary purpose of an IMS is to provide additional information needed to make effective decisions on the use of limited resources to improve the efficiency of, and protect the investment in, the nation’s existing and future transportation infrastructure at all levels of jurisdictional control.

In order to build effective IMS and to evaluate the overall effectiveness and market penetration of intermodal technologies, improvements in data currently are not required. At present all of the data sources are information on either the movements by a single mode or information by type of facility. For example, the Carload Waybill sample, provides data on rail movements of commodities, Waterborne Commerce provides information on inland movements by water, the Truck Activity Survey and the Truck Inventory and Use Survey provide data on highway movements, the Federal Aviation Administration Air Traffic Activity provides information on air movements, and the Port Import/Export Reporting Service and U.S. Waterborne Exports and General Imports provide information on oceanborne water movements. Similarly, other sources provide information on specific types of equipment or facilities. For example, the American Intermodal Equipment Inventory records stocks of intermodal equipment for major U.S. marine carriers and leasing companies. The problems with these various data sources are that they are not designed to be used together and therefore do not provide information on the linkages that are essential of intermodal planning. The Carload Waybill sample provides detailed information on railroad movements including starting and ending points, transfers, tonnage, revenues, names of carriers, and a host of other information.
Unfortunately, it does not indicate where a particular movement entered the rail system, whether that is where the movement actually started or whether it was moved to rail on another mode such as truck. Since almost all of the existing transportation data are mode or facility specific and are not designed to be linked, they lack the “network” capability that is central to measuring and improving intermodalism.

The Commodity Flow Survey (CFS) is the most detailed multimodal data source that compiles information on freight movements from origin to destination. The 1997 CFS has information, which could tell about the amount of freight moved on one transport mode and by using combination of modes. As, discussed earlier in Chapter 3 that, the Center for Transportation Analysis (CTA) at ORNL, has worked in conjunction with the U.S Bureau of census for analyzing the 1997 CFS data. CTA has developed a large and detailed digital transportation network, which was used to simulate some five million origins to destination freight shipments, including tens of thousands of intermodal shipments both within and across the borders of United States. Each of these shipments was reported to U.S Census bureau as part of its 1997 CFS. The CFS is a congressionally mandated survey of approximately 100,000 freight shippers within the U.S, carried out by the Bureau of census with sponsorship from the Bureau of Transportation Statistics (BTS). The purpose of this survey is to ascertain how, and how much, shippers are using the nation’s multimodal transportation system to move freight, both domestically and for export.
CHAPTER 5
MODEL DEVELOPMENT

5.1 Study Area

The selection of a study area is based upon the University of Toledo’s current research project - Upper Midwest Freight Corridor Study, which follows a corridor that stretches from Manitoba, Minnesota, and Iowa in the west to Ontario and Ohio in the east. Figure 5.1 shows that the corridor is generally defined by interstate highways 94, 90, and 80. Although the corridor follows roads, the study is multi-modal, looking not only at major roads, but also the rail network, inland waterways, the Great Lakes, pipelines, intermodal facilities, and major cargo-handling airports. This corridor is crucial in the movement of freight for the region, nation, and continent. Not only does the corridor handle the major east-west movements of freight, it is also becoming important in the north-south movements of freight in the region and continent. Table 5.1 summarizes the amount of freight in terms of tons and dollars that either originated or was destined for the seven states in 1998. The region is responsible for about forty percent of this nation’s international trade in terms of dollars (2). The values in Table 5.1 do not include the freight that is simply moving through the region, neither destined nor originating in the region. The present study is limited to only, the seven states in the Upper Midwest region of United States of America and not including Manitoba and Ontario provinces of
Figure 5.1: Upper Midwest Freight Corridor Study Region

(Source: Improving Freight Transportation in the Upper Midwest and Great Lakes Region (TRB paper-unpublished))
Table 5.1: Tons and Value of Freight Moving To, From, and Within the Seven States of the Corridor Region (Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, and Wisconsin)

<table>
<thead>
<tr>
<th>Tons (Millions)</th>
<th>Value (Billion $)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corridor Region</strong></td>
<td></td>
</tr>
<tr>
<td>By Mode</td>
<td></td>
</tr>
<tr>
<td>Air</td>
<td>&lt;9 (&lt;50)</td>
</tr>
<tr>
<td>Highway</td>
<td>3295 (30.3)</td>
</tr>
<tr>
<td>Other</td>
<td>&lt;9 (&lt;6.6)</td>
</tr>
<tr>
<td>Rail</td>
<td>1065 (37.8)</td>
</tr>
<tr>
<td>Water</td>
<td>543 (37.7)</td>
</tr>
<tr>
<td>By Destination/Market</td>
<td></td>
</tr>
<tr>
<td>Domestic</td>
<td>4577 (33.9)</td>
</tr>
<tr>
<td>International</td>
<td>337 (18.8)</td>
</tr>
<tr>
<td>Total</td>
<td>4914 (32.2)</td>
</tr>
<tr>
<td><strong>U.S.</strong></td>
<td></td>
</tr>
<tr>
<td>By Mode</td>
<td></td>
</tr>
<tr>
<td>Air</td>
<td>18</td>
</tr>
<tr>
<td>Highway</td>
<td>10858</td>
</tr>
<tr>
<td>Other</td>
<td>136</td>
</tr>
<tr>
<td>Rail</td>
<td>2818</td>
</tr>
<tr>
<td>Water</td>
<td>1440</td>
</tr>
<tr>
<td>By Destination/Market</td>
<td></td>
</tr>
<tr>
<td>Domestic</td>
<td>13484</td>
</tr>
<tr>
<td>International</td>
<td>1787</td>
</tr>
<tr>
<td>Total</td>
<td>15271</td>
</tr>
</tbody>
</table>

(Source: Improving Freight Transportation in the Upper Midwest and Great Lakes Region (TRB paper-unpublished))
Canada. It is intended to limit the scope of study area to United States of America alone. The multimodal transportation network of seven states: 1) Indiana, 2) Illinois, 3) Iowa, 4) Michigan, 5) Minnesota, 6) Ohio and 7) Wisconsin, in the upper mid west region are proposed for this research. Figure 5.1 shows the study region of upper mid west freight corridor study.

According to the Upper Midwest Freight Corridor Study Proposal – the Upper Midwest serves as a critical corridor for domestic and international freight moving in all directions. It is projected that these freight movements will increase significantly in the future and the current practices will no longer be sufficient to meet the increased demands on the infrastructure and/or increased costs associated with freight transport. Assessing the Intermodal alternatives for Freight Transportation is looked upon as the best solution for improving the freight flows in the region. It is anticipated that, the tool developed in this research would provide a useful insight in analyzing the intermodal freight flows along the corridors of I-80, I-90 and I-94 in this region. Figure 5.2 shows the current study area adopted in this project. The study area is being discussed in detail in Chapter 6.
Figure 5.2: Midwest Region

Data Source: NTAD 2003
5.2 ORNL Multi-modal Transportation Network

The CFS multi-modal network of ORNL was constructed to simulate routes taken by freight shipments in the 1997 Commodity Flow Survey. Logically, the network is composed of independently constructed single-mode networks for highway, rail, and water, along with a set of intermodal terminals to connect them. The result is a unified routable network, with a single node list, a single link list, and a topology defined by the links, endpoint nodes, a structure common to most network analysis programs. It is easier to imagine that each modal network occupies a horizontal plane, while intermodal terminals connecting two modes lie between the planes and are attached above and below by vertical access links. Traffic generators are typically located at a different level and similarly attached to an arbitrary modal network by vertical access links. Terminals connect mode-specific sub networks. Logically, each terminal is a link in this network with impedance that represents the generalized cost of terminal activities. Each terminal link connects exactly two modes in a single direction. If, at a particular facility, more than two modes are connected, or connected in more than one direction, or if it handles more than one specific type of commodity, the facility is represented by multiple terminal links. These links have endpoints that are logically considered the modal entry and exit points of the terminal facility, like gates in its fence. Mode-specific access links run from the terminal gate to the modal sub-network. Gates are mode-specific (in fact carrier-specific) but not commodity-specific, so multiple terminal links may emanate from the same gate. Access links that are part of a specific mode's sub network then run in the opposite direction from the gate to line-haul facilities. The modes and their identifying numbers and letters as used in network element IDs are shown in the Table 5.2.
Table 5.2: Representation of Network Elements

<table>
<thead>
<tr>
<th>ID #s</th>
<th>ID Letter</th>
<th>Modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>v</td>
<td>Private Truck</td>
</tr>
<tr>
<td>2</td>
<td>t</td>
<td>For-Hire Truck</td>
</tr>
<tr>
<td>3</td>
<td>r</td>
<td>Rail Roads</td>
</tr>
<tr>
<td>4</td>
<td>s</td>
<td>Inland Water</td>
</tr>
<tr>
<td>5</td>
<td>g</td>
<td>Great Lakes</td>
</tr>
<tr>
<td>6</td>
<td>d</td>
<td>Ocean Vessels</td>
</tr>
<tr>
<td>9</td>
<td>Y</td>
<td>Traffic Generators</td>
</tr>
<tr>
<td>10</td>
<td>f</td>
<td>Intermodal Terminals</td>
</tr>
</tbody>
</table>

The For-Hire truck network is an exact duplicate of the private truck network. This allowed CFS routes that were combinations of private and for-hire trucks. For the present study, for hire truck network is removed, because our interest is only to model truck flows in general by not going into the specifics of for hire and private truck logistical decisions.

Figure 5.3 -Illustrates the multimodal network representation for a truck-rail-truck (TRT) shipment. Using a suitable "shortest path" route-finding algorithm, a route is generated by first of all accessing the highway sub-network, linking this via a Truck-Rail TR terminal to the rail sub-network and returning to the highway network via a second intermodal terminal transfer.
Figure 5.3: Construction of a Multi-layer intermodal shipment routing
5.2.1 Network Structure

An analytically useful “routable” Intermodal Network Database is created by three different sets of links:

1. Traffic generator/traffic attractor links;
2. Intermodal terminals transfer links; and
3. Intra-modal carrier based interlining links.

A network database is said to be “routable” if it is possible to use the network to find the shortest, fastest or least costly routes through it, for a set of pre specific traffic origination and destination pairs. To make the network database routable, the above mentioned links are generated by a computer code and are created as a set of add-on links to a network database already populated with a set of “real” highway, rail and water links. Although all links are common entries in a link list with impedance and endpoint nodes, but they are different types of links and have different characteristics.

A. Line Haul links:

These are original physical trafficways which are direct input from the modal networks. There are some circumstances where logically different line haul links are directly overlaid one another and map into the same physical trafficway. These are:

1. Railroad links of different companies when the underlying rail line is shared.
2. Waterways where two or more different vessel types may operate.
3. Every highway link is contained in both "v" (private) and "t" (for-hire truck) layers.

Every logical line-haul link is considered a polyline and includes the entire list of vertices describing its shape.
B. Railroad interlines:

From the intermodal perspective, railroads are a single layer. Yet this sub network has an internal structure similar to the multimodal network. The rail network is a set of stacked layers, one for each railroad company, which overlay the same geographic space. Vertical interline links connect the layers. The difference is that these connectors run directly between nodes in the companies' layers without the intermediate terminals of the CFS network. The interline links are records in the railroad link list presented to the CFS network builder, just like any other rail link. But unlike the links in any other input network, they are not real on-the-ground trafficways, and it is needed to take care that interline links in the composite network are treated differently.

C. Terminal links:

The terminal model used in the CFS network supposes that there is a terminal "facility" where shipments are off-loaded from one mode and loaded onto another. The terminal has a "fence" enclosing it with distinct entry and exit gates for each mode (or each railroad company) that serves it. Connecting the entrance and exit gates for different modes are terminal links, which are always mode-specific and may be commodity-specific. This terminal link is intended to represent all of the processes and costs involved in the transfer of shipments, which will naturally vary widely. Like for instance, loading and unloading by cranes, forklifts, or conveyors; storage; blending; break-bulk; or drayage.

D. Access links:

Because all the networks are in some sense sparse, an arbitrary traffic generator cannot be expected to fall on a network link. Instead, some traverse, whether physical or
logical, is needed to travel from the generator to the network where standard trafficway routing can occur. Access links to the network are added to represent this traverse, making the traffic generator a network node. For highways, access links represent local streets that serve as collectors for the arterials in the national highway network. For rail, access links represent industrial spurs not contained in the rail network. For waterways, access links represent the distance across a broad channel or harbor to a dock. In all cases, access links accommodate the geographic imprecision of both generator and network. Also, traffic generators are often zones, representing a broad distribution of origins, and access links attempt to reproduce the average penalty faced by traffic in reaching their destinations, as well as loading traffic onto the appropriate network facilities.

Figure 5.4 - shows the different types of links present in the multimodal transportation network structure developed at ORNL. Figure 5.4(a) shows the access links, which are connecting the Traffic generators (or centroids) to the nodes A and B of a rail line. The roads are also connected to the centroids in a similar way. Figure 5.4(b) shows all the types of links that are typically present at a freight terminal.
Figure 5.4: Different links present in the Network Structure

Source: Transportation Research Part C 8 (2000) 147-166
5.3 Decision Rules for Intermodal Freight Routing

This section describes the meaning and definition of the term “Intermodal Freight Routing” on a geographical transportation network. As being discussed in earlier chapters, Intermodal Freight, is the freight which is shipped from its origin to destination by using more than one mode of transportation. In this research, only container freight is modeled for Intermodal Freight Movements, because presently, container freight is more favored for intermodal transportation due to the following reasons:

1. Container Freight is easy to handle, when transferring it from one mode to other, and
2. most of the international shipments are shipped through containers.

Given the scope of this research, some assumptions are made for Intermodal Freight Routing of Containers, to make the model simpler. The following are the rules / assumptions adopted for intermodal freight routing in this study:

1. The county centroids and port locations (Traffic Generators) given in the ORNL’s Intermodal Network Database are assumed to be the origin and destination of freight, although these are connected to the transportation network through “dummy” links. This assumption would lead to minor problems, for, not considering the local transportation network consisting of streets within the city connecting to the highway network.
2. All the Intermodal Container Freight movements have drayage costs associated with them. This may however, be not true for all the cases, as the traffic generators may have a direct access to other modes of transportation like rail or water.
3. The traffic generators at ports are treated like intermodal terminals, because of the cargo transfer facilities and the equipment available at the ports chose for analysis in this study.

4. The transportation costs for each mode are taken as constant, not examining the non-linear cost structure adopted by transportation companies, depending on the distance of haulage.

5. Each Intermodal terminal is associated with a fixed drayage cost, which are calculated by taking into consideration the population and the distance of the traffic generators located in its service area.

6. Fixed modal transfer costs are used in the model, which can easily be made terminal specific, if suitable data is available.

7. It is assumed that, the trackage rights of rail do not pose problem for freight companies and all freight carriers can use the existing rail infrastructure without incurring additional costs.

8. The freight flows are assigned on the network using “All or Nothing” assignment based on minimal transportation costs.

9. It is also assumed that at every stage of intermodal transportation, factors like Reliability, Accessibility of Intermodal facilities, Legal and Regulatory issues Safe Intermodal Choices, and Time, have no impact on intermodal freight decision-making.
5.4 Mathematical Modeling of Intermodal Freight Routing Problem

A “good” intermodal freight route is considered as a route that minimizes the total costs of transportation for a container shipment to travel from its origin to destination, by choosing an optimal sequence of modes. Freight transfer from one mode to other takes place, at points called intermodal terminals. In the present research, the mathematical model for modeling intermodal freight flows is accomplished by implementing shortest route problem method for network models under the domain of Operations Research. The shortest route problem determines the shortest route between an origin and destination nodes in a transportation network by taking into account the costs or impedances of the links connecting the nodes in a network. The shortest path problem definition is well suited for the present study and model structure because, present network represents intermodal freight activity as a link with appropriate impedance associated with it. As has been said earlier, the impedance costs of the multimodal transportation network would be transportation costs and intermodal costs. In order to keep this model simple, it is assumed that these are the only two transport decision-making elements for intermodal freight transportation. However, the model can be easily modified by incorporating other intermodal decision factors like inventory carrying costs, administrative costs, safety, congestion and reliability in terms of monetary units. These costs can be summed up with the impedances on the links.

In this model structure another term “generalized cost” is proposed which integrates all the factors relevant for transport decision making in terms of monetary units, thus reducing the whole intermodal decision making process into a simple shortest path finding problem. The generalized costs for this model are the sum of Transportation
costs and Intermodal costs. One of the main concerns is to use realistic price functions for the transportation and the terminal operations. The transportation cost of a link viewed from the customer point of view, is a function of fixed handling costs, load size, traveled distance or other customized requirements specified. However in real life, carriers supply the pricing information of any transportation assignment within their network, depending upon the demand and supply of transportation services. Thus the pricing can be considered as a specific given structure supplied by the carrier. The cost of the operations at a terminal is a function of the load size, the congestion at the terminal, local labor wages and the technology employed at the terminal. This again leads to very complex functions; to decrease the complexity of cost estimation a fixed cost called terminal transfer cost is supplied externally into the model for a typical container transfer at the terminal. A fixed terminal transfer cost for a container is the general practice adopted by the terminal owners for the transportation services provided by them to transfer a container from one mode to another. 

The following are the costs envisioned in this model for a typical container intermodal shipment.

1. Transportation Costs:

   \[ T_m = C_m \times d_m \]

   Where,
   \[ T_m = \text{Transportation cost per unit, for mode, } m. \]
   \[ C_m = \text{Cost Rate for mode } m \ (\$/\text{container-mile}) \]
   \[ d_m = \text{distance traveled in miles on the mode } m. \]
2. Intermodal Costs:

\[ IC = D + T_{m,n} \]

Where,

- IC = Intermodal Cost
- D = Drayage Cost for a container.
- \( T_{m,n} \) = Transfer Costs between modes m,n for a container.

Thus,

\[ \text{Total Generalized Costs} = N(T_m + IC) \]

Where,

- \( N \) = Number of containers in the shipment.

Shortest route problem definition then becomes a simple minimization of total generalized costs. The problem looks simple because of the way the impedances are assigned to each link on the network in the intermodal network structure, constituting the entire intermodal freight operations.

The above minimization problem is solved using “Dijkstra's” shortest path finding Algorithm as used by ESRI’s Network Analyst Extension.

Dijkstra's algorithm computes the shortest paths from a starting vertex to all other vertices in a directed graph. In the following description of Dijkstra's algorithm, \( OUT(v) \) is defined as the set of all vertices, \( u \), such that there is a directed edge from vertex \( v \) to \( u \). Dijkstra's algorithm maintains three sets for keeping track of vertices: the solution set, \( S \), the frontier set, \( F \), and the set of vertices not in \( S \) or \( F \) (i.e. unexplored vertices). The set \( S \) stores vertices for which the shortest distance has been computed. The set \( F \) holds vertices that have an associated currently best distance but do not have a determined
shortest distance. Any vertex in \( F \) is directly connected to some vertex in \( S \). We assume that all vertices in the graph are reachable from the source.

Initially the source vertex, \( s \), is put in \( S \), and the vertices in the \( OUT \) set of \( s \) are put in \( F \).

(*) The algorithm proceeds by selecting the vertex \( v \) that has the minimum distance among those in \( F \) and moves it to \( S \). The shortest distance to \( v \) is now known. Then for each vertex, \( w \), that is in \( OUT(v) \) but not in \( S \), the following steps are taken:

- Distance, \( d \), is calculated by adding together the shortest distance found for \( v \) and the edge length from \( v \) to \( w \).
- If ‘\( w \)’ was already in \( F \), then we update \( w \)'s currently best distance with the minimum of its current value and \( d \).
- Otherwise if ‘\( w \)’ is not in \( F \), then we add ‘\( w \)’ to \( F \) and set its currently best distance as \( d \).

This process continues from (*) until \( F \) is empty; that is, the shortest distance to all reachable vertices has been computed.

### 5.5 Network Analyst and Decision Tool

Computation of shortest paths is a famous and classical area of research in Computer Science, Operations Research and GIS. There are many algorithms to calculate shortest paths depending on the type of network and problem specification. Dijkstra’s algorithm is one of the most popular algorithms used to solve shortest path problems.

Arc View’s Network Analyst uses Dijkstra’s algorithm for shortest path finding routine. The ArcView Network Analyst is an extension product designed for ArcView to use networks more efficiently. It can solve common network problems on any theme.
containing lines that connect. This theme can be a shapefile, an ARC/INFO coverage, or a CAD drawing. ArcView's Network Analyst implements a modified Dijkstra with a d-heap [15] in combination with a custom memory management strategy to deal with very large networks. The network representation of the spatial data is a proprietary data structure that was built for ArcView Network Analyst to facilitate quick access to the topology of the spatial data. Before solving a problem, the extension allows to model networks precisely, including setting up average travel times, one-way streets, prohibited turns, overpasses and underpasses, and closed streets. Some of the functions a Network Analyst helps to do are:

1. Find efficient travel routes: Find the best way to get from one location to another, or the best way to visit several locations.

2. Determine which facility or vehicle is closest: Find the closest facility to any location on a network. The Network Analyst identifies the closest facilities and displays the best way to get to or from them.

3. Generate travel directions: We can generate sophisticated, easy-to-use travel directions for any route found with the Network Analyst, whether it’s a route between two locations, one that visits several locations, or a route to the closest facility.

4. Find a service area around a site: The Network Analyst provides two tools that allow learning, what is near a particular site, service networks and service areas. Service networks identify the accessible streets within a specified travel time or distance via the road network. Service areas identify the region that encompasses the accessible streets.
5. Customize work: All of the problems solved with the user interface can also be solved by writing and running Avenue scripts. Network Analyst, comes with several Avenue classes and requests for solving network problems. These classes and requests can be used to automate tasks, add new capabilities, and build applications.
CHAPTER 6

STUDY AREA AND INTERMODAL NETWORK CREATION

6.1 Study Area Components

As discussed in Chapter 5, the study area comprises of seven states in the upper Midwest region of United States, which are: 1) Indiana, 2) Illinois, 3) Iowa, 4) Michigan, 5) Minnesota, 6) Ohio and 7) Wisconsin. The study region encompasses an area of 379,030 sq-mi and has a total of 623 counties.

The main geographic components considered in the study area are:

1. Traffic Generators
2. Intermodal Container Terminals and
3. Intermodal Transportation Network

6.2 Traffic Generators

The traffic generators are nodes representing the centroidal points of the counties and port locations in the region, which are connected to the existing road, rail and water networks. These represent the origins / destinations for container freight in the study region of the transportation network. In ORNL’s Intermodal Transportation Network database, the Upper Midwest region consists of 636 Traffic generators. In order to, model domestic intermodal container freight flows in the region, few traffic generators are selected due to the following reasons:
1. Intermodal Freight transportation is practically feasible over large distances, typically greater than 600 miles [14]. Since, we are confining the modeling of freight flows only in the study area, thus it is necessary, that the origins and destinations are located far apart. Also the model can be built up for internal-external and external-external freight flows. This could be achieved by selecting OD points outside the study area and connect them with a hypothetical network. For example, trips originating / destined out of country.

2. Container freight is mostly export oriented and all generators are not capable enough to generate or attract container freight. This depends usually on their economic and manufacturing base.

3. Drayage distances should not be greater than 50-75 miles [14] from its origin/destination to the terminal location. Because, of limited number of Intermodal container terminals present in the region, the traffic generators are chosen according to their proximity to the intermodal container terminals.

6.2.1 Selection of Traffic Generators

As described in the previous section, there is a need for limiting the number of traffic generators in the study region, to satisfactorily model intermodal container freight flows. Given, the scope of this research, it is assumed that the population of a county is considered as an indicative factor, for the region’s economic and manufacturing abilities to attract container freight.

The selection of traffic generators is done in two steps:

Step1: Selection of Counties based on population and population density.
Step 2: Final selection of Counties/Generators based on the proximity to Intermodal Terminals.

Step 1: Selection of Counties based on population and population density

The study is limited to forty most populated counties, according to US census 2000, are selected in the upper mid west region. Anticipating a higher population density is an indicative of higher economic activity. Thus the list of counties is appended with the forty counties of high population density. The resulting combined list of counties, which are highly populated and or having high densities consisted of forty eight counties. Five more counties (Brown (WI), Clay (MN), Koochiching (MN), Pennington (MN) and Pottawattamie (IO)) are added to the list as special counties because intermodal container terminals are located in these counties. Brown County has a port on the Great Lakes, Koochiching and Pennington are bordering with Canada. Clay and Pottawattamie counties are located alongside the eastern edge of the study region. Finally a total of 53 counties are selected during the first phase. A minimum of 100,000 county population was considered in the selection of counties except, for the specially chosen counties. Table 6.1 shows the counties selected in the first phase along with their Federal Information Processing System (FIPS) number.

Figures 6.1–6.3 shows the sequence of GIS operations in the selection of counties for Phase1.
Table 6.1: Selected Counties – Phase 1

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*FIPS – Federal Information Process System
Figure 6.1: Population Distribution in the Counties

Data Source: NTAD 2003
Figure 6.2: County Population Density per Square Mile

Data Source: NTAD 2003
Figure 6.3: Selected Counties Phase 1

Data Source: NTAD 2003
Step 2: Final selection of Counties based on the proximity to Intermodal Terminals

As per earlier discussion, intermodal freight movement is not economical when the distance between origin/destination to the transfer terminals is greater than 50 miles. The component of drayage costs of the transportation increases substantially making the total transportation cost unattractive or uneconomical. Thus, all fifty-three counties selected in phase 1 are checked for the drayage distance or their proximity to the intermodal terminals. The proximity analysis is done by using the ArcView-Network Analyst (AVNA) extension. The proximity analysis eliminates the counties that are more than 50 miles of away from the intermodal terminals.

The following methodology is used for the final selection of counties:

1. All the intermodal terminals that handle container freight in the Upper Midwest region are selected from the National Transportation Atlas Data (NTAD) 2003 and a service area of 50 miles is generated for each of the terminal using Arc View Network Analyst on NTAD’s National Highway Planning Network (NHPN). The procedure for finding service area in GIS using AVNA is described in Appendix-A.

2. All the selected counties from phase 1, which fall under these service areas, are then selected as the final set of counties. This analysis yields a total of 45 counties for the study.

Table 6.2 shows the final selected counties.

Each selected county has a centroidal point in the intermodal network database. The centroids of all the counties are linked by dummy links are linked to the network to represent the final traffic generators in the study area. Also nine ports that are traffic
Table 6.2: Final selected counties -Phase 2

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<td>182740</td>
</tr>
<tr>
<td>Vanderburgh</td>
<td>Indiana</td>
<td>18163</td>
<td>171922</td>
</tr>
<tr>
<td>Kenosha</td>
<td>Wisconsin</td>
<td>55059</td>
<td>149577</td>
</tr>
<tr>
<td>Ashtabula</td>
<td>Ohio</td>
<td>39007</td>
<td>102728</td>
</tr>
<tr>
<td>Pottawattamie</td>
<td>Iowa</td>
<td>19155</td>
<td>87704</td>
</tr>
<tr>
<td>Clay</td>
<td>Minnesota</td>
<td>27027</td>
<td>51229</td>
</tr>
<tr>
<td>Koochiching</td>
<td>Minnesota</td>
<td>27071</td>
<td>14355</td>
</tr>
<tr>
<td>Pennington</td>
<td>Minnesota</td>
<td>27113</td>
<td>13584</td>
</tr>
</tbody>
</table>
generators are located in these selected counties are added to the final list of traffic
generators in the region. Finally, a total of 54 traffic generators are considered for further
analysis. Table 6.3 shows the nine ports selected for analysis. Figure 6.4 shows the final
selected counties. Each county has either intermodal terminal or port within 50-mile
distance.

6.3 Intermodal Container Terminals

According to National Transportation Atlas Data 2003, the upper Midwest region has
Seventy One Intermodal Container terminals. These terminals cater to the needs of
different freight movements like:

1. Freight flows having origin and destination within the region
2. Freight originating in the region and destined to other regions
3. Freight destination in the region, but originating in other regions and
4. Freight flows just moving through the region using its transportation network

Similar procedure is used in the selection of intermodal terminals. The terminals that are
within a distance of 50-mile from the final selected counties are selected for freight flow
analysis in the model. A total of Fifty-Nine intermodal terminals are finally selected.
Table 6.4 shows the list of selected intermodal container terminals. It shows the terminal
ID # as given in NTAD 2003.
Table 6.3: Ports selected in the Study Area

<table>
<thead>
<tr>
<th>PORT CITY</th>
<th>COUNTY</th>
<th>STATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicago</td>
<td>Cook</td>
<td>Illinois</td>
</tr>
<tr>
<td>Detroit</td>
<td>Wayne</td>
<td>Michigan</td>
</tr>
<tr>
<td>Cleveland</td>
<td>Cuyahoga</td>
<td>Ohio</td>
</tr>
<tr>
<td>Toledo</td>
<td>Lucas</td>
<td>Ohio</td>
</tr>
<tr>
<td>Ashtabula</td>
<td>Ashtabula</td>
<td>Ohio</td>
</tr>
<tr>
<td>Conneaut</td>
<td>Ashtabula</td>
<td>Ohio</td>
</tr>
<tr>
<td>Fairport</td>
<td>Lake</td>
<td>Ohio</td>
</tr>
<tr>
<td>Milwaukee</td>
<td>Milwaukee</td>
<td>Wisconsin</td>
</tr>
<tr>
<td>Green Bay</td>
<td>Brown</td>
<td>Wisconsin</td>
</tr>
<tr>
<td>S.No</td>
<td>Terminal ID</td>
<td>Terminal Name</td>
</tr>
<tr>
<td>-----</td>
<td>--------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>17031001</td>
<td>CSXI Bedford Park TOFC/COFC</td>
</tr>
<tr>
<td>2</td>
<td>17031002</td>
<td>IAIS Blue Island Burr Oak TOFC/COFC</td>
</tr>
<tr>
<td>3</td>
<td>17031003</td>
<td>CP Bensenville TOFC/COFC</td>
</tr>
<tr>
<td>4</td>
<td>17031004</td>
<td>BNSF Chicago Corwith Yd TOFC/COFC</td>
</tr>
<tr>
<td>5</td>
<td>17031005</td>
<td>CN Harvey Gateway Intermodal Term'l</td>
</tr>
<tr>
<td>6</td>
<td>17031006</td>
<td>CR Chicago 47th St TOFC/COFC</td>
</tr>
<tr>
<td>7</td>
<td>17031007</td>
<td>CR Chicago 63rd St TOFC/COFC</td>
</tr>
<tr>
<td>8</td>
<td>17031009</td>
<td>UP Chicago Global One COFC</td>
</tr>
<tr>
<td>9</td>
<td>17031010</td>
<td>Ceres: Chicago Iroquois Landing</td>
</tr>
<tr>
<td>10</td>
<td>17031011</td>
<td>SP Chicago IMX Yd TOFC/COFC</td>
</tr>
<tr>
<td>11</td>
<td>17031015</td>
<td>NS Chicago Landers Yd TOFC/COFC</td>
</tr>
<tr>
<td>12</td>
<td>17031018</td>
<td>CSXI/SP Forest Hill TOFC/COFC</td>
</tr>
<tr>
<td>13</td>
<td>17031019</td>
<td>NS Chicago TCS RoadRaider</td>
</tr>
<tr>
<td>14</td>
<td>17031020</td>
<td>UP Chicago Canal St TOFC/COFC</td>
</tr>
<tr>
<td>15</td>
<td>17031021</td>
<td>BNSF Cicero TOFC/COFC</td>
</tr>
<tr>
<td>16</td>
<td>17031023</td>
<td>UP Dolton Yard Center TOFC/COFC</td>
</tr>
<tr>
<td>17</td>
<td>17031024</td>
<td>Moyers Intermodal Terminal: Harvey</td>
</tr>
<tr>
<td>18</td>
<td>17031025</td>
<td>UP Proviso Yd Global Two TOFC/COFC</td>
</tr>
<tr>
<td>19</td>
<td>17031026</td>
<td>CP Schiller Park East COFC</td>
</tr>
<tr>
<td>20</td>
<td>17031027</td>
<td>CP Schiller Park West COFC</td>
</tr>
<tr>
<td>21</td>
<td>17031028</td>
<td>BNSF Willow Springs TOFC/COFC</td>
</tr>
<tr>
<td>22</td>
<td>17031032</td>
<td>CP Schiller Park Glenway TOFC/COFC</td>
</tr>
<tr>
<td>23</td>
<td>17031077</td>
<td>Federal Marine Terminals: Chicago</td>
</tr>
<tr>
<td>24</td>
<td>17119001</td>
<td>GWWR/IC Venice TOFC/COFC</td>
</tr>
<tr>
<td>25</td>
<td>17163001</td>
<td>UP Dupo TOFC/COFC</td>
</tr>
<tr>
<td>26</td>
<td>17163002</td>
<td>CR E St Louis Rose Lake TOFC/COFC</td>
</tr>
<tr>
<td>27</td>
<td>17163003</td>
<td>SP E St Louis TOFC/COFC</td>
</tr>
<tr>
<td>28</td>
<td>18003001</td>
<td>NS Ft Wayne Piqua Yd TCS RoadRaider</td>
</tr>
<tr>
<td>29</td>
<td>18063001</td>
<td>CR Indianapolis Avon Yd TOFC/COFC</td>
</tr>
</tbody>
</table>
### Table 6.4: List of Intermodal Container Terminals (Contd...)

<table>
<thead>
<tr>
<th>S.No</th>
<th>Terminal ID</th>
<th>Terminal Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>18163001</td>
<td>CSXI Evansville TOFC/COFC</td>
</tr>
<tr>
<td>31</td>
<td>18181001</td>
<td>TPW Remington Hoosier Lift</td>
</tr>
<tr>
<td>32</td>
<td>19099001</td>
<td>IAIS/UP Newton TOFC/COFC</td>
</tr>
<tr>
<td>33</td>
<td>19155001</td>
<td>CC Council Bluffs TOFC/COFC</td>
</tr>
<tr>
<td>34</td>
<td>26125001</td>
<td>CN Ferndale MOTERM TOFC/COFC</td>
</tr>
<tr>
<td>35</td>
<td>26163001</td>
<td>CP Detroit Container Terminal</td>
</tr>
<tr>
<td>36</td>
<td>26163002</td>
<td>CR Detroit Livernois Yd TOFC/COFC</td>
</tr>
<tr>
<td>37</td>
<td>26163003</td>
<td>NS Detroit Oakwood Yd TOFC/COFC</td>
</tr>
<tr>
<td>38</td>
<td>26163004</td>
<td>NS Detroit Delray Container Term'l</td>
</tr>
<tr>
<td>39</td>
<td>26163017</td>
<td>APL Stacktrain Woodhaven Terminal</td>
</tr>
<tr>
<td>40</td>
<td>26163018</td>
<td>NS Melvindale TCS RoadRail</td>
</tr>
<tr>
<td>41</td>
<td>26163030</td>
<td>Detroit Marine Terminals-Scotten St</td>
</tr>
<tr>
<td>42</td>
<td>27027001</td>
<td>BNSF Dilworth TOFC/COFC</td>
</tr>
<tr>
<td>43</td>
<td>27053001</td>
<td>CP Minneapolis Shoreham TOFC/COFC</td>
</tr>
<tr>
<td>44</td>
<td>27071001</td>
<td>MDW International Falls TOFC/COFC</td>
</tr>
<tr>
<td>45</td>
<td>27113001</td>
<td>CP Thief River Falls COFC</td>
</tr>
<tr>
<td>46</td>
<td>27123001</td>
<td>BNSF St. Paul Midway TOFC/COFC</td>
</tr>
<tr>
<td>47</td>
<td>39033001</td>
<td>CR Crestline TCS RoadRaider</td>
</tr>
<tr>
<td>48</td>
<td>39035001</td>
<td>CR Cleveland Collinwood TOFC/COFC</td>
</tr>
<tr>
<td>49</td>
<td>39035002</td>
<td>NS Cleveland Container Terminal</td>
</tr>
<tr>
<td>50</td>
<td>39049001</td>
<td>CR Columbus Buckeye Yd TOFC/COFC</td>
</tr>
<tr>
<td>51</td>
<td>39049002</td>
<td>NS Columbus Watkins Rd Yd TOFC/COFC</td>
</tr>
<tr>
<td>52</td>
<td>39061001</td>
<td>CSXI Cincinnati TOFC/COFC</td>
</tr>
<tr>
<td>53</td>
<td>39061002</td>
<td>NS Cincinnati Gest St Yd TOFC/COFC</td>
</tr>
<tr>
<td>54</td>
<td>39095001</td>
<td>CR Toledo TOFC/COFC</td>
</tr>
<tr>
<td>55</td>
<td>39151001</td>
<td>WE Stark County Neomodal Terminal</td>
</tr>
<tr>
<td>56</td>
<td>55009001</td>
<td>WC Green Bay TOFC/COFC</td>
</tr>
<tr>
<td>57</td>
<td>55079001</td>
<td>CP Milwaukee TOFC/COFC</td>
</tr>
<tr>
<td>58</td>
<td>55079002</td>
<td>Meehan Seaway Services: Milwaukee</td>
</tr>
<tr>
<td>59</td>
<td>55139001</td>
<td>WC Neenah TOFC/COFC</td>
</tr>
</tbody>
</table>
6.4 Selection of Intermodal Transportation Network

The ORNL intermodal transportation network consists of network data for the entire USA. From this network, the intermodal network for only the Upper Midwest Region is selected. The following are the reasons for the selection of network:

1. The focus of the present research is only the Upper Midwest Region.
2. Reduction in the input network data improves the computer process ability to model the network flows.
3. Also, it is necessary to further clean up the network, so as to reflect in entirety the selected traffic generators and intermodal terminals.

As described in Chapter 5, Section 5.2.1, the intermodal network structure has various attribute data, which can be used to isolate the desired network from the original network by using standard database queries. The database queries used in this process are given in Appendix B. The following paragraphs describe the methodology for the extraction of desired network for the current model use.

The network data is extracted from the original ORNL intermodal network data in two stages as described below.

Stage 1: Selection of the Base Network.

The network for the model is selected from the original ORNL intermodal network using the clip function of Geo Processing extension present in ArcView with the Upper Midwest Region Polygon. The water network of Great Lakes is then, appended to the network by querying for great lake links in the intermodal network. As a result a base network for the model with about 89,000 links is selected from the original ORNL
Intermodal network comprising of 360,620 links. Figure 6.5 shows the base network selected for the model.

**Stage 2: Cleaning Up of the Base Network**

The base network is further cleaned based on the following criteria.

1. The Base Network consists of two identical sets of road network. One, for each of the two modes: Private Network and For Hire Truck Network. The present model does not distinguish between Private and For Hire truck flows, both of them are considered into one modal network called truck/road network. Thus, it is decided to remove for hire truck network from the base network. As a result the selected network has been reduced to 50,976 links.

2. In the next step, the generator links and terminal links that do not belong to the final selected generators and intermodal terminals are removed. This is done to further reduce the number of unnecessary links. The resultant network comprised of 37045 links.

Figure 6.6 shows the final intermodal network used in the model. Figures 6.7-6.9 shows the individual modal networks.

**6.5 Link Impedances in Intermodal Transportation Network.**

To make the intermodal transportation network suitable for modeling the freight flows; the network database has to be populated with modal impedances. As discussed earlier in Chapter 5, Section 5.4, this research models the flows based on Modal costs, drayage costs and Intermodal Transfer Costs. These costs are to be assigned to the links, so that the GIS application uses these impedances in order to find the least cost
Figure 6.7: Highway Network in Midwest Region

Data Source: ORNL
transportation path for moving freight. The cost fields have been created in the final selected Intermodal network using the GIS Application developed in this research.

6.5.1 Modal Costs

The modal impedances adopted in this model are taken from the research project conducted by Mack Blackwell Transportation Center- University of Arkansas [16]. The modal costs are based on 1996 Rates. The following are the modal impedances used in this model.

Truck = $0.9 per Container-Mile
Rail = $0.35 per Container-Mile
Water = $0.12 per Container-Mile

Intermodal Transfer Costs:

Truck-Rail = $100 per Container
Truck/Rail-Water = $200 per Container

These costs can however be interactively changed by the user through the GIS application.

6.5.2 Drayage Costs

Drayage refers to the regional movement of containers by trucks between origin/destination to the nearby intermodal terminal. Although drayage represents a small fraction of total distance of an intermodal shipment, it accounts for a substantial share of shipping costs. Forty percent of a 900 mile movement cost is incurred in the drayage portions, typically less than 50 miles [14]. The costs are exacerbated by the lack of coordination among parties, including shippers, consignees, railroads, trucking
companies, and intermodal marketing companies. The current research however does not make an effort to deal the discrepancies involved in drayage operations. It is assumed that all the drayage operations are performed perfectly well, under ideal conditions and an analytical gravity model calculates the cost of drayage. In reality, the drayage costs are a characteristic of an intermodal terminal serving an area and is usually has a fixed amount that depends on various factors like proximity to the traffic generator and presence of other intermodal terminals. The drayage model adopted in this research, allow for calculating the average drayage cost of a intermodal terminal by taking into account the relative measure of attractiveness of all the generators present in its service area with regards to their population and arrive at appropriate drayage cost. Appendix C, describes the drayage model and the custom Avenue code used for calculating distances to a terminal from all the generators. The drayage costs are assigned as impedances to the terminal access links in the intermodal network database.

6.6 Routable Intermodal Transportation Network Database

With all the costs assigned to the links, the intermodal network database has now, became a logically routable network structure suitable for use by the Arc View Network Analyst. The ORNL Intermodal Network database also has an impedance measure as one of the attribute to each link. This impedance function is based on the physical characteristics of and the context of the link. The impedance values are normalized so that one-mile of travel on the best facilities of each mode would require approximately one impedance unit. In case of highways typical impedances vary between 0.9/mile for rural interstates to 5/mile for 2 lane urban streets or unpaved rural roads. Rail impedances
also vary between 1/mile for A-Mainlines to 4/mile for the lowest traffic B-Branch lines. Waterway links are all identical at 1/mile. It is hence possible in the model to take into consideration of the impedance values to make it into a more sensible routable network for the region. The GIS model developed in this research facilitates the use of modal cost impedances. The modal cost impedances weighted with the impedance measure based on the existing physical conditions of the transportation infrastructure.
CHAPTER 7
GIS APPLICATION DEVELOPMENT

7.1 GIS Application

The Intermodal Freight Flow Analysis Model (IFAM) is developed using Avenue programming language in Arc View 3.2. The application allows analyzing the intermodal freight flows between a set of origin and destination pairs in the Upper Midwest Region. The freight flows are assigned to transportation network, on the basis of minimizing the total transportation cost with the help of the classical Dijkstra’s shortest path algorithm. IFAM is developed by customizing the Arc View Network Analyst ‘s Shortest Path Finding function using Avenue language script. The avenue code for the GIS application is given in Appendix D. Figure 7.1 describes the organization of the GIS application developed in this research. IFAM is designed as a tool that could be run in a project document in Arc View 3.2. The following section describes the application of this model to a sample data.

7.2 Model Run for Study Area

Given the scope of this research, it was not possible to evaluate the performance of this model with real time data. To represent the actual transportation network for the entire upper Midwest region require large amount of data and time presently this data is
Figure 7.1: Organization of GIS Application
not readily available. It was also difficult to get data of origin and destination and container freight volumes. It is however, anticipated that the data collected by the research team, working on the Upper Midwest Freight Corridor Study at the University of Toledo, University of Illinois and the University of Wisconsin would be able to put together a realistic scenario for the model. Presently, the application is run by using a hypothetical pair of origins and destinations. Also, the intermodal transportation network used in this study may not truly represent the actual conditions. Although, it is possible to make flow analysis on the network, by using the impedances of links supplied by ORNL in their intermodal network database. In the ORNL network database, each mode has an impedance based on the characteristic and context of the link. The impedance values are normalized so that one-mile of travel on the best facilities of each mode will require one impedance unit. In the case of highways, typical impedances vary between 0.9/\text{mi} for rural interstates to 5/\text{mi} for 2-lane urban streets or unpaved rural roads. Rail impedances also vary between 1/\text{mi} for A-mainlines to 4/\text{mi} for the lowest traffic B-branch lines. Waterway links are all identical at 1/\text{mi}. The application allows the user to choose either the modal costs as the cost factor or the weighted units (link impedances multiplied by modal costs) while minimizing the total transportation costs. However, the model run is performed using modal costs as the only impedance factors. Table 7.1 shows the sample origin and destination of container shipments along with hypothetical freight volumes. The modal impedances used for this model run are: Truck-$0.9 per Container-mile, Rail-$0.35 per Container-mile, Water-$0.12 per Container-mile, Truck-Rail Intermodal transfer-$100 per container, Truck -Water Intermodal Transfer-$200 per container and Rail-Water Intermodal Transfer-$200 per container. Figures 7.2-7.5 shows
Table 7.1: Sample Origin and Destinations

<table>
<thead>
<tr>
<th>ORIGIN</th>
<th>DESTINATION</th>
<th>HYPOTHETICAL QUANTITY (CONTAINERS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicago Port</td>
<td>Franklin</td>
<td>23</td>
</tr>
<tr>
<td>Detroit Port</td>
<td>Ramsey</td>
<td>45</td>
</tr>
<tr>
<td>Cleveland Port</td>
<td>Hennepin</td>
<td>11</td>
</tr>
<tr>
<td>Milwaukee Port</td>
<td>Cuyahoga</td>
<td>67</td>
</tr>
<tr>
<td>Green Bay Port</td>
<td>Cleveland Port</td>
<td>45</td>
</tr>
<tr>
<td>Cook</td>
<td>Franklin</td>
<td>76</td>
</tr>
<tr>
<td>Summit</td>
<td>Polk</td>
<td>12</td>
</tr>
<tr>
<td>Polk</td>
<td>Detroit Port</td>
<td>34</td>
</tr>
<tr>
<td>Madison</td>
<td>Summit</td>
<td>57</td>
</tr>
<tr>
<td>St.Clair</td>
<td>Lucas</td>
<td>81</td>
</tr>
<tr>
<td>Allen</td>
<td>Cleveland Port</td>
<td>9</td>
</tr>
<tr>
<td>Hamilton(OH)</td>
<td>St.Clair</td>
<td>34</td>
</tr>
<tr>
<td>Pottawattamie</td>
<td>Genesee</td>
<td>67</td>
</tr>
<tr>
<td>Vanderburgh</td>
<td>Green Bay Port</td>
<td>50</td>
</tr>
<tr>
<td>Polk</td>
<td>Marion</td>
<td>35</td>
</tr>
<tr>
<td>Wayne</td>
<td>Ashtabula</td>
<td>66</td>
</tr>
<tr>
<td>Clay</td>
<td>Wayne</td>
<td>72</td>
</tr>
<tr>
<td>Hennepin</td>
<td>Allen</td>
<td>45</td>
</tr>
<tr>
<td>Pennington</td>
<td>Madison</td>
<td>36</td>
</tr>
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<td>Ramsey</td>
<td>Lucas</td>
<td>71</td>
</tr>
<tr>
<td>Ashtabula</td>
<td>Koochiching</td>
<td>82</td>
</tr>
<tr>
<td>Cuyahoga</td>
<td>Madison</td>
<td>56</td>
</tr>
<tr>
<td>Franklin</td>
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<tr>
<td>Hamilton(OH)</td>
<td>Cook</td>
<td>65</td>
</tr>
<tr>
<td>Lucas</td>
<td>Ramsey</td>
<td>89</td>
</tr>
<tr>
<td>Montgomery</td>
<td>Cleveland Port</td>
<td>20</td>
</tr>
<tr>
<td>Hamilton(IN)</td>
<td>Ramsey</td>
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</tr>
<tr>
<td>Milwaukee</td>
<td>Cleveland Port</td>
<td>15</td>
</tr>
</tbody>
</table>
the freight flows between the selected origin and destinations using modal costs as the only cost factor.

7.2 Results and Discussion

For the sample set of origins and destination, the results indicated that of the total distance traveled by all modes on the transportation network is 19,917 miles, of which road mileage is 12,483 miles, while rail mileage is 1,668 miles. The distance traveled in water is 5,766 miles. Table 7.2 shows the results obtained by running the application. The average distance of shipment is 712 miles. There are 11 shipments, which are shipped by intermodal transportation and 17 shipments, which travel by single mode. This indicates that for the given network characteristics and modal impedances, the highway is the most-traveled mode aggregating to about 62.68%. Although, the results may vary, depending upon the prevailing modal costs and availability of intermodal services.

This model can provide promising results, and can be used as an efficient tool for shippers to estimate the cost of shipping. The planners and policy makers can easily identify the bottlenecks in the network and undertake necessary measures.
Table 7.2: Result Table from the model run

<table>
<thead>
<tr>
<th>ID</th>
<th>FROM</th>
<th>TO</th>
<th>DISTANCE</th>
<th>ROAD_DIST</th>
<th>RAIL_DIST</th>
<th>WATER_DIST</th>
<th>TOTAL_COST</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Chicago Port</td>
<td>Franklin</td>
<td>381.23</td>
<td>380.97</td>
<td>0.00</td>
<td>0.26</td>
<td>542.00</td>
<td>Intermodal</td>
</tr>
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<td>1</td>
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<td>Ramsey</td>
<td>990.97</td>
<td>369.29</td>
<td>0.00</td>
<td>621.68</td>
<td>603.62</td>
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<td>2</td>
<td>Cleveland Port</td>
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<td>1134.37</td>
<td>384.44</td>
<td>0.00</td>
<td>749.93</td>
<td>632.64</td>
<td>Intermodal</td>
</tr>
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CHAPTER 8
CONCLUSIONS

8.1 Conclusions

Results from this research effort demonstrate the feasibility of Arc View 3.2 to model intermodal freight transportation. A comprehensive network is developed for the Upper Midwest Region, which can be used to perform basic modal split analysis of freight transportation based on modal costs, drayage costs and intermodal transfer costs. Modeling Container freight flows is done by implementing appropriate terminal costs at the intermodal transfer terminals.

8.2 Recommendations

The following are the recommendations that are inferred from this research experience.

1. The analysis performed by using this model is done at the most basic level, not depending on any external data sources except ORNL’s Intermodal Network Database. The modeling can yield more reliable results by using real time data from carriers, shippers, and intermodal terminal operators.

2. The intermodal network used in this research consists of entire highway network, rail network and water network in Upper Midwest Region. By using only the freight
designated road, rail or water network in the analysis, it is possible to get more realistic flows on the transportation network.

3. The freight flows are assigned to network, by using All or Nothing Assignment technique. Although freight flow modeling does not require complex assignment procedures, it is recommended to use other assignment techniques to ensure that network irregularities like congestion and level of service are taken into account.

4. Analysis capabilities should be examined before selecting a software package. Specifically, project goals must be compared against GIS capabilities. GIS software can be somewhat limited in “off-the-shelf” capabilities. In the context of this research effort, the selection of ArcView was a trade-off limiting analysis to routing problems in exchange for ease of use. Future efforts might choose to use a software package with more complete GIS-T analysis capabilities.

5. When Freight Demand Modeling is done using the Classical Four Step modeling technique, it is recommended to use the modal share values derived from this model, so that the modal split is done taking into consideration of the transportation network characteristics.

6. It is recommended that the intermodal freight flow analysis is to be done over larger area like on entire transportation network of United States, to realize the benefits of intermodal freight transportation.

7. It is also recommended that, when the factors like reliability and non-linear cost structure of transportation are implemented, the model would yield realistic solutions.
REFERENCES


APPENDIX –A

Finding Service Area using Arc View Network Analyst

**Service areas:** Service areas are themes created with the Network Analyst to help you evaluate the accessibility of a site. Service areas identify the region within a certain traveling time or distance from a site. For example, the regions within a ten minute drive of a shopping center. Service areas are represented by polygon themes. You can use these themes to identify how many people, how much land, or how much of anything else is within the neighborhood.

**Method to find a service area and service network around a site**

1. Open a view with a line theme.
2. Click on the line theme in the Table of Contents to make it active.
3. From the Network menu choose Find Service Area. This displays the problem definition dialog and adds two themes to the view’s Table of Contents, Snet1 and Sarea1.
4. Click the Properties button in the problem definition dialog. In the Properties dialog, choose the cost field in your line theme’s feature table. The Network Analyst will use the cost field to determine the extent of the service area and service network.
5. Specify the working units. These are the units in which you’ll specify the travel time or distance under the Costs column in the problem definition dialog.
6. Specify the site or sites on the line theme for which you would like to find the service area by using the Load Sites button to load a point theme.
7. Double-click the costs field and type in the travel time or distance. Make sure it’s in the same units as the working units you specified in step 5. The costs define the extent of the service area and network around the site. If you want to specify more than one travel time or distance for a site, separate them by a blank space or a comma.

8. Click the Compact area checkbox if you would like a compact service area. Leaving this box unchecked will create a general service area.

9. Click Travel from site or Travel to site to indicate the direction of travel.

10. Press the Solve button to find the service area and service network. This displays the themes in your view and reports the total land area covered by the service area and the total street distance covered by the service network at the top of the problem definition dialog.

Source: Arc View 3.2 Help File
APPENDIX –B

Standard Queries used on Intermodal Network Attribute Data in Arc View

1. Selecting Great Lake Links
   
   **Query**: ([Block] = "?5")

2. Selecting For Hire Truck Links
   
   **Query**: ([Block] = "?2")

3. Selecting Original Line Haul Links
   
   **Query**: ([Block] = "11") or ([Block] = "33") or ([Block] = "44") or ([Block] = "55") or ([Block] = "66")

4. Selecting Terminal Access links:
   
   **Query**: ([Modes] = "F?") or ([Modes] = "?F")

   Note: Port access links are queried by ([Lid] = "F?q*")

5. Selecting Terminal Transfer links
   
   **Query**: ([Block] = "13") or ([Block] = "14") or ([Block] = "15") or ([Block] = "31") or ([Block] = "41") or ([Block] = "51") or ([Block] = "34") or ([Block] = "35") or ([Block] = "43") or ([Block] = "53") or ([Block] = "45") or ([Block] = "54")

6. Selecting Traffic Generator links
   
   **Query**: [Modes] = "Y?"
APPENDIX –C

Calculating Drayage Cost of an Intermodal Terminal

Drayage Costs of an Intermodal shipment represent a major chunk of total transportation cost. The estimation of drayage cost depends on various factors like

1. Labor wages,
2. Availability of equipment
3. Time of travel between rail yards, shippers, consignees and equipment yards and
4. Demand for intermodal terminal service

Collecting real time information of the drayage costs at each of the terminal is a tedious task and is not within the scope of this work, so an analytical model is developed to estimate the drayage costs at each terminal. The following is the procedure adopted for calculating drayage costs.

1. Distances from intermodal terminals to all the generators within the 50 mile service area are calculated using a custom developed avenue program in ArcView.
2. Drayage cost for each generator and terminal pair is calculated by the following formula:

   \[
   \text{Drayage Cost} = \text{Labor wages} + \text{Congestion Cost} + \text{Travel Cost} + \text{Overhead Cost}
   \]

   Where

   Labor Wages = Hourly wage rate of truck drivers*3.5 hrs of drayage time
   Congestion Cost= (Initial 30 minutes of trip starting from generator)*$1.25
   Travel Cost = (Time of Travel from Terminal to Generator)*$1
Overhead Cost = Labor Wages * 1.5

3. Due to the presence of more than one generator within the service area of an intermodal terminal it is necessary to calculate average drayage cost for each terminal. A weighted drayage cost is calculated for each of the terminal based on the following formula:

If a terminal is having 3 generators say, G1, G2, G3 in its service area with Populations $P_1$, $P_2$, $P_3$ and the distances to each generator from the terminal are $R_1$, $R_2$ and $R_3$ respectively. The drayage costs calculated in step 2 to each of the generator for the terminal being $X$, $Y$ and $Z$ then

$$\text{Average Drayage Cost} = \frac{(W_1 \times X + W_2 \times Y + W_3 \times Z)}{(W_1 + W_2 + W_3)}$$

Where

$$W_i = \frac{P_i}{R_i^2} \quad i = 1, 2, 3$$

The average drayage costs are then assigned to each of the intermodal terminal access link in the intermodal network database as impedances.
Avenue Code to find the distance of all generators within a 50 mile service area of a terminal:

'This Script is used to find the distance between multiple points within a specified maximum distance Developed by Praveen Kumar Chanda

aView = av.GetActiveDoc

if (not (aView.Is(View))) then
    msgBox.Error("Active document is not a view.","")
    exit
end
' get the FTab of the first network theme
aNetFTab = nil
for each t in aView.GetThemes
    ft = t.GetFTab
    if (NetDef.CanMakeFromFTab(ft)) then
        aNetFTab = ft
        break
    end
end

' did we find a networkable FTab?
if (aNetFTab = nil) then
    msgBox.Error("Network theme not found.","")
    exit
end

' make the NetDef and check it for error
aNetDef = NetDef.Make(aNetFTab)
if (aNetDef.HasError) then
    msgBox.Error("NetDef has error.","")
    exit
end

' make the Network object
aNetwork = Network.Make(aNetDef)

' make a list of point themes for the user to choose from
aPointThemeList = {}
for each t in aView.GetThemes
    if (t.GetFTab.GetSrcName.GetSubName = "Point") then
        aPointThemeList.Add(t)
    end
end

' did we find any point themes?
if (aPointThemeList.Count = 0) then
    msgBox.Error("No point themes found.","")
    exit
end

' prompt for the origin theme
origTheme = msgBox.Choice(aPointThemeList,
    "Select the origin point theme:",
    "Origin selection")

' prompt for the destination theme
destTheme = msgBox.Choice(aPointThemeList,
    "Select the destination (facility) point theme:",
    "Destination selection")
"Destination (facility) selection")

    origFTab = origTheme.GetFTab
    destFTab = destTheme.GetFTab
    origShapeField = origFTab.FindField("Shape")
    destShapeField = destFTab.FindField("Shape")
    origLabelField = origFTab.FindField("Name")
    destLabelField = destFTab.FindField("Label_")

    myFile=FileDialog.Put("rambabu.dbf".AsFileName, "+", "+", "+")
    theVtab= VTAb.MakeNew(myFile,dbase)
    myTable=Table.Make(theVtab)
    f1=Field.Make("Evt_id",#FIELD_DOUBLE,10,0)
    f2=Field.Make("Fac_id",#FIELD_DOUBLE,10,0)
    f3=Field.Make("Evt_Label",#FIELD_CHAR,10,0)
    f4=Field.Make("Fac_Label",#FIELD_CHAR,10,0)
    f5=Field.Make("Cost",#FIELD_DOUBLE,10,4)
    theVtab.AddFields({f1,f2,f3,f4,f5})

    ' Make point lists from the origin and destination point themes,
    ' validate points, and set the names of the points

    destPointList = {}
    for each rec in destFTab
        p = destFTab.ReturnValue(destShapeField, rec)
        if (aNetwork.IsPointOnNetwork(p)) then
            if (origLabelField <> nil) then
                p.SetName(destFTab.ReturnValueString(destLabelField, rec))
            else
                p.SetName("Destination" + (destPointList.Count + 1).AsString)
            end
        destPointList.Add(p)
    end

    for each rec in origFTab
        origPointList = {}
        p = origFTab.ReturnValue(origShapeField, rec)
        if (aNetwork.IsPointOnNetwork(p)) then
            if (origLabelField <> nil) then
                p.SetName(origFTab.ReturnValueString(origLabelField, rec))
            else
                p.SetName("Origin" + (origPointList.Count + 1).AsString)
            end
        origPointList.Add(p)
    end

    ' set the parameters for FindClosestFac

    numToFind = destPointList.count         ' find all destinations
    cuttOff   = 0.72452                         ' no cut off distance
    toFrom    = False                        ' travel to destination

    ' Note: No cost field is selected here, so <line length> will be
    ' used by default.

    ' solve the problem
    numFoundList = aNetwork.FindClosestFac(origPointList, destPointList, numToFind, cuttOff, toFrom)
if (not (aNetwork.HasClosestFacResult) or (numFoundList.count=0)) then
  MsgBox.Error("Solution not found.","")
  MsgBox.info("solution found","hi")
  'exit
  break
else
  aNetwork.WriteClosestFac("hi.shp".asFileName)
  theResultTheme=Theme.Make(SrcName.Make("hi.shp"))
  theResultThemeFTab=theResultTheme.GetFTab
  theResultThemeFTab.BeginTransaction
    if (theVtab.StartEditingWithRecovery) then
      theVtab.BeginTransaction
        for each theRec in theResultThemeFTab
          theRecord=theVtab.AddRecord
          theVtab.SetValue(f1,theRecord,theResultThemeFTab.ReturnValueNumber(theResultThemeFTab.FindField("Evt_id"),theRec))
          theVtab.SetValue(f2,theRecord,theResultThemeFTab.ReturnValueNumber(theResultThemeFTab.FindField("Fac_id"),theRec))
          theVtab.SetValue(f3,theRecord,theResultThemeFTab.ReturnValueString(theResultThemeFTab.FindField("Evt_label"),theRec))
          theVtab.SetValue(f4,theRecord,theResultThemeFTab.ReturnValueString(theResultThemeFTab.FindField("Fac_label"),theRec))
          theVtab.SetValue(f5,theRecord,theResultThemeFTab.ReturnValueNumber(theResultThemeFTab.FindField("Cost"),theRec))
        end
        theVtab.EndTransaction
    end
    theResultThemeFTab.EndTransaction
end
end

' Make sure FindClosestFac succeeded
' The user will be prompted to choose one of the origin and destination pairs ("assignments"). A graphic for this path will then be added to the view.

' Build a string list with the results.
' Note: Writing out the complete "od matrix" would be very similar.
APPENDIX –D

GIS Application –Avenue Code

Master Script:

'Author: Praveen Kumar Chanda
If (MsgBox.YesNo("Welcome to the Intermodal Freight Flow Analysis "+NL+NL+TAB+"Do you want to Proceed with the Analysis ?", "Welcome", true)) then
'
if you want to CHANGE these DEFAULT values, you HAVE TO CHANGE values in 'the populating
cost fields script also where you have checked values to update FIELD ‘costs individually.
theView = av.GetProject.FindDoc("Intermodal Freight Flow Analysis")
theNetTheme = theView.FindTheme("Intermodal Network")
theNetTab = theNetTheme.GetFTab
theNetTab.FindField("Truck_Cost").SetAlias("Truck_Costs")
theNetTab.FindField("Water_Cost").SetAlias("Water_Costs")
theNetTab.FindField("TR_TF_Cost").SetAlias("TR_TF_Costs")
theNetTab.FindField("LW_TF_Cost").SetAlias("LW_TF_Costs")
Truck_Cost = 0.9
Rail_Cost = 0.35
Water_Cost = 0.12
Truck_Rail_Tf_Cost = 100
Land_Water_Tf_Cost = 200
If (MsgBox.YesNo("Do you want to Update these Costs ?"+NL+NL+"Truck=$ " +Truck_Cost.AsString +"/Container-Mile" +TAB+TAB+
+"Rail=$ " +Rail_Cost.AsString +"/Container-Mile" +NL+
+"Water=$ " +Water_Cost.AsString +"/Container-Mile" +TAB+TAB+
+"Truck-Rail =$ " +Truck_Rail_Tf_Cost.AsString +"/Transfer" +NL+
+"Land-Water =$" +Land_Water_Tf_Cost.AsString +"/Transfer" +TAB+TAB,
"Modal Impedances Used Currently", False)) then
labels = { "Truck($/Container Mile)", "Rail($/Container Mile)", "Water($/Container Mile)", "Truck-Rail
Transfer($/Container)", "Land-Water Transfer($/Container)" }
defaults = { "0.9", "0.35", "0.12", "100", "200" }
ModalCostList = MsgBox.MultiInput("Update Your Transportation Costs here !!!" +NL+NL,"Modal Costs", labels, defaults)
Truck_Cost = ModalCostList.Get(0)
Rail_Cost = ModalCostList.Get(1)
Water_Cost = ModalCostList.Get(2)
Truck_Rail_Tf_Cost = ModalCostList.Get(3)
Land_Water_Tf_Cost = ModalCostList.Get(4)
ResultPopulating = av.Run( "My Populating Cost Fields";{ Truck_Cost, Rail_Cost,
Water_Cost, Truck_Rail_Tf_Cost, Land_Water_Tf_Cost }) MsgBox.Info(ResultPopulating,"")
end
ResultSP = av.Run("My SP_Calculator","{}")
MsgBox.Info(ResultSP,""")
' Removing the Documents not needed in the project
theRemODTable = av.GetProject.FindDoc("ODTable")
theRemLinkTable = av.GetProject.FindDoc("Table1")
av.GetProject.RemoveDoc(theRemODTable)
av.GetProject.RemoveDoc(theRemLinkTable)
else
    MsgBox.Info("Bye !!!!", "Bye")
exit
end
Populating Cost Fields Script:

'Author Praveen Kumar Chanda
'This script is executed from the master script
'Populating Cost Fields
Truck_Cost=SELF.Get(0)
Rail_Cost=SELF.Get(1)
Water_Cost=SELF.Get(2)
Truck_Rail_Tf_Cost=SELF.Get(3)
Land_Water_Tf_Cost=SELF.Get(4)
MsgBox.Info (NL+"Truck=$ "+Truck_Cost.AsString+" /Container-Mile"+TAB+TAB
   +"Rail=$ "+Rail_Cost.AsString+" /Container-Mile"+NL
   +"Water=$ "+Water_Cost.AsString+" /Container-Mile"+TAB+TAB
   +"Truck-Rail =$ "+Truck_Rail_Tf_Cost.AsString+" /Transfer"+NL
   +"Land-Water =$ "+Land_Water_Tf_Cost.AsString+" /Transfer"+TAB+TAB,
   "These are your New Transportation Costs")
theView=av.GetProject.FindDoc("Intermodal Freight Flow Analysis")
theNetTheme=theView.FindTheme("Intermodal Network")
theNetFTab=theNetTheme.GetFTab
theNetFTab.FindField("Truck_Cost").SetAlias ("Truck_Costs")
theNetFTab.FindField("Water_Cost").SetAlias ("Water_Costs")
theNetFTab.FindField("TR_TF_Cost").SetAlias ("TR_TF_Costs")
theNetFTab.FindField("LW_TF_Cost").SetAlias ("LW_TF_Costs")
theNetFTab.SetEditable(True)
'Checks for the cost fields and if they are not there, creates them
if(theNetFTab.FindField("Port_Costs")=nil) then
   thePortCostFld=Field.Make("Port_Costs",#FIELD_DECIMAL,15,2)
   theNetFTab.AddFields({thePortCostFld})
end
if(theNetFTab.FindField("Truck_Costs")=nil) then
   theTruckCostFld=Field.Make("Truck_Costs",#FIELD_DECIMAL,15,2)
   theNetFTab.AddFields({theTruckCostFld})
end
if(theNetFTab.FindField("Rail_Costs")=nil) then
   theRailCostFld=Field.Make("Rail_Costs",#FIELD_DECIMAL,15,2)
   theNetFTab.AddFields({theRailCostFld})
end
if(theNetFTab.FindField("Water_Costs")=nil) then
   theWaterCostFld=Field.Make("Water_Costs",#FIELD_DECIMAL,15,2)
   theNetFTab.AddFields({theWaterCostFld})
end
if(theNetFTab.FindField("TR_TF_Costs")=nil) then
   theTRCostFld=Field.Make("TR_TF_Costs",#FIELD_DECIMAL,15,2)
   theNetFTab.AddFields({theTRCostFld})
end
if(theNetFTab.FindField("LW_TF_Costs")=nil) then
   theLWCostFld=Field.Make("LW_TF_Costs",#FIELD_DECIMAL,15,2)
   theNetFTab.AddFields({theLWCostFld})
end
if(theNetFTab.FindField("Cost")=nil) then
   theTotalCostFld=Field.Make("Cost",#FIELD_DECIMAL,15,2)
   theNetFTab.AddFields({theTotalCostFld})
end
if(theNetFTab.FindField("Units")=nil) then
   theUnitsFld=Field.Make("Units",#FIELD_DECIMAL,15,2)
theNetFTab.AddFields({theUnitsFld})
end
theNetFTab.Calculate(0.asString,theNetFTab.FindField("Port_Costs"))
theNetFTab.Calculate(0.asString,theNetFTab.FindField("Truck_Costs"))
theNetFTab.Calculate(0.asString,theNetFTab.FindField("Rail_Costs"))
theNetFTab.Calculate(0.asString,theNetFTab.FindField("Water_Costs"))
theNetFTab.Calculate(0.asString,theNetFTab.FindField("TR_TF_Costs"))
theNetFTab.Calculate(0.asString,theNetFTab.FindField("LW_TF_Costs"))
theNetFTab.Calculate(0.asString,theNetFTab.FindField("Cost"))
theNetFTab.Calculate(0.asString,theNetFTab.FindField("Units"))
theNetBitmap=theNetFTab.getSelection
'Populating Costs to Port Generator Links
'The generator links which connect to Water have zero cost and
'the generator links which connect to road and rail have values equal to
'Land-water transfer costs
if(not(Land_Water_Tf_Cost=200)) then
theQryPortStr1="(( [Lid] = "YGcq*" ) or ([Lid] = "YScq*"))"
theNetFTab.Query(theQryPortStr1,theNetBitmap,#VTAB_SELTYPE_NEW)
theNetFTab.Calculate("0",theNetFTab.FindField("Port_Costs"))
theNetFTab.Calculate([Port_Costs].asNumber,theNetFTab.FindField("Port_Costs"))
theNetBitmap.ClearAll
theQryPortStr2="(( [Lid] = "YZcq*" ) or ([Lid] = "YRcq*"))"
theNetFTab.Query(theQryPortStr2,theNetBitmap,#VTAB_SELTYPE_NEW)
theNetFTab.Calculate(Land_Water_Tf_Cost.asString,theNetFTab.FindField("Port_Costs"))
theNetFTab.Calculate([Port_Costs].asNumber,theNetFTab.FindField("Port_Costs"))
theNetBitmap.ClearAll
end
'Populating Costs to Original Road Haul Links
if(not(Truck_Cost=0.9)) then
theQryTruckStr="( [Lid] = "v*" )"
theNetFTab.Query(theQryTruckStr,theNetBitmap,#VTAB_SELTYPE_NEW)
'theNetFTab.Calculate(Truck_Cost.asString+"*"+[Dist],theNetFTab.FindField("Truck_Costs"))
theNetFTab.Calculate(Truck_Cost.asString+"*"+[Dist1],theNetFTab.FindField("Truck_Costs"))
theNetFTab.Calculate([Truck_Costs].asNumber,theNetFTab.FindField("Truck_Costs"))
theNetBitmap.ClearAll
end
'Populating Costs to Traffic Generator Links
if(not(Truck_Cost=0.9)) then
theQryGenStr="( [Lid] = "YVK+*" )"
theNetFTab.Query(theQryGenStr,theNetBitmap,#VTAB_SELTYPE_NEW)
'theNetFTab.Calculate(Truck_Cost.asString+"*"+[Dist],theNetFTab.FindField("Truck_Costs"))
theNetFTab.Calculate(Truck_Cost.asString+"*"+[Dist1],theNetFTab.FindField("Truck_Costs"))
theNetFTab.Calculate([Truck_Costs].asNumber,theNetFTab.FindField("Truck_Costs"))
theNetBitmap.ClearAll
end
if(not(Water_Cost=0.12)) then
theQryGenStr="(( [Lid] = "YGcq*" ) or ( [Lid] = "YScq*" ))"
theNetFTab.Query(theQryGenStr,theNetBitmap,#VTAB_SELTYPE_NEW)
'theNetFTab.Calculate(Water_Cost.asString+"*"+[Dist],theNetFTab.FindField("Water_Costs"))
theNetFTab.Calculate(Water_Cost.asString+"*"+[Dist1],theNetFTab.FindField("Water_Costs"))
theNetFTab.Calculate([Water_Costs].asNumber,theNetFTab.FindField("Water_Costs"))
theNetBitmap.ClearAll
end
'Populating Costs to Original Rail Haul Links and Rail road Interlines

if(not(Rail_Cost=0.35)) then
    theQryRailStr="(( [Lid] = "r*" ) or ( [Modes] = "FR" ) or ( [Modes] = "RF" ))"
    theNetFTab.Query(theQryRailStr,theNetBitmap,#VTAB_SELTYPE_NEW)
    'theNetFTab.Calculate(Rail_Cost.asString+"*"+[Dist],theNetFtab.FindField("Rail_Costs"))
    theNetFTab.Calculate(Rail_Cost.asString+"*"+[Dist1],theNetFtab.FindField("Rail_Costs"))
    theNetFTab.Calculate("[Rail_Costs].asNumber",theNetFtab.FindField("Rail_Costs"))
    theNetBitmap.ClearAll
end

'Populating Costs to Original Water Haul Links

if(not(Water_Cost=0.12)) then
    theQryWaterStr="(( [Lid] = "s*" ) or ([Lid] = "g*"") or ( [Modes] = "FS" ) or ( [Modes] = "SF"")
    "or ([ Modes] = "FG"") or ([ Modes] = "GF")"
    theNetFTab.Query(theQryWaterStr,theNetBitmap,#VTAB_SELTYPE_NEW)
    'theNetFTab.Calculate(Water_Cost.asString+"*"+[Dist],theNetFtab.FindField("Water_Costs"))
    theNetFTab.Calculate(Water_Cost.asString+"*"+[Dist1],theNetFtab.FindField("Water_Costs"))
    theNetFTab.Calculate("[Water_Costs].asNumber",theNetFtab.FindField("Water_Costs"))
    theNetBitmap.ClearAll
end

'Populating Costs to Truck Rail Terminal Transfer Links (this is not necessary)

'theQryTruckRailStr1="(( [Lid] = "vr*" ) or ([Lid] = "rv*"))"
'theNetFTab.Query(theQryTruckRailStr1,theNetBitmap,#VTAB_SELTYPE_NEW)
'theNetFTab.Calculate("9999",theNetFtab.FindField("TR_TF_Costs"))
'theNetFTab.Calculate("[TR_TF_Costs].asNumber",theNetFtab.FindField("TR_TF_Costs"))
'theNetBitmap.ClearAll

'Populating Costs to Truck Rail Container Terminal Transfer Links

if(not(Truck_Rail_Tf_Cost=100)) then
    theQryTruckRailStr2="(( [Lid] = "vr*" ) and ([Cargo] = "C") or ( [Lid] = "rv*") and ([Cargo] = "C"))"
    theNetFTab.Query(theQryTruckRailStr2,theNetBitmap,#VTAB_SELTYPE_NEW)
    theNetFTab.Calculate(Truck_Rail_Tf_Cost.asString, theNetFtab.FindField("TR_TF_Costs"))
    theNetFTab.Calculate("[TR_TF_Costs].asNumber", theNetFtab.FindField("TR_TF_Costs"))
    theNetBitmap.ClearAll
end

'Populating Costs to Land Water Terminal Transfer Links

if(not(Land_Water_Tf_Cost=200)) then
    theQryLandWaterStr1="(( [Lid] = "vg*") or ([Lid] = "gv*") or ( [Lid] = "vs*") or ( [Lid] = "sv*") or ( [Lid] = "rg*") or ([Lid] = "gr*") or ([Lid] = "rs*") or ([Lid] = "sr*")"
    theNetFTab.Query(theQryLandWaterStr1,theNetBitmap,#VTAB_SELTYPE_NEW)
    theNetFTab.Calculate("9999", theNetFtab.FindField("LW_TF_Costs"))
    theNetFTab.Calculate("[LW_TF_Costs].asNumber", theNetFtab.FindField("LW_TF_Costs"))
end

'Populating Costs to Land Water Container Terminal Transfer Links

if(not(Land_Water_Tf_Cost=200)) then
    theQryLandWaterStr1="(( [Lid] = "vg*") or ([Lid] = "gv*") or ( [Lid] = "vs*") or ( [Lid] = "sv*") or ( [Lid] = "rg*") or ([Lid] = "gr*") or ([Lid] = "rs*") or ([Lid] = "sr*")"
    theNetFTab.Query(theQryLandWaterStr1,theNetBitmap,#VTAB_SELTYPE_NEW)
    theNetFTab.Calculate("9999", theNetFtab.FindField("LW_TF_Costs"))
    theNetFTab.Calculate("[LW_TF_Costs].asNumber", theNetFtab.FindField("LW_TF_Costs"))
end

'Populating Costs to Land Water Container Terminal Transfer Links
theQryLandWaterStr2="(( [Lid] = "vg*" ) and ([Cargo] = "C")) or (([Lid] = "gv*" ) and ([Cargo] = "C")) or (([Lid] = "vs*" ) and ([Cargo] = "C")) or (([Lid] = "sv*" ) and ([Cargo] = "C")) or (([Lid] = "rg*" ) and ([Cargo] = "C")) or (([Lid] = "gr*" ) and ([Cargo] = "C")) or (([Lid] = "rs*" ) and ([Cargo] = "C")) or (([Lid] = "sr*" ) and ([Cargo] = "C"))"
theNetFTab.Query(theQryLandWaterStr2,theNetBitmap,#VTAB_SELTYPE_NEW)
theNetFTab.Calculate(Land_Water_Tf_Cost.asString,theNetFtab.FindField("LW_TF_Costs"))
theNetFTab.Calculate("[LW_TF_Costs].asNumber",theNetFtab.FindField("LW_TF_Costs"))
theNetBitmap.ClearAll
end

'Populating Cost field as a sum of total costs
theNetFTab.Calculate("[Fac_dray_c] + [Port_Costs] + [Truck_Costs] + [Rail_Costs] + [Water_Costs] + [TR_TF_Costs] + [LW_TF_Costs]",theNetFtab.FindField("Cost"))
theNetFTab.Calculate("[Cost]*[Emp]",theNetFtab.FindField("Units"))
theNetFTab.SetEditable(False)
return "Your Network Cost Fields are Successfully Updated"

Flow Display Script:
theView = av.GetProject.FindDoc("Intermodal Freight Flow Analysis")
theDisplayView = av.GetProject.FindDoc("Traffic Flow Display")
aNetTheme=theView.FindTheme("Intermodal Network")
aNetTheme.ClearSelection
theNetFTab=aNetTheme.GetFTab
theNetRecFld=theNetFTab.FindField("Record _")
theNetBM=theNetFTab.GetSelection

theSumTableFName=(av.GetProject.GetWorkDir.asString+"\Results\sum_link.dbf").asFileName
theSumTableVTab=VTab.Make(theSumTableFName,false,false)
theSumTable=Table.Make(theSumTableVTab)
theSumTable.Setname(" Link Summary")
theSumRecFld=theSumTableVTab.FindField("Rec_num")

'Creating the Display Result Theme
theDisplayResultFName=(av.GetProject.GetWorkDir.asString+"\Results\FlowDisplay.shp").AsFileName
theDisplayResultFTab=FTab.MakeNew(theDisplayResultFName,Polyline)

theNetFTab.UnJoinAll
theNetFTab.Join(theNetRecFld,theSumTableVTab,theSumRecFld)
theNetTab.query("([sum_QTY] >0)",theNetBM,#VTAB_SELTYPE_NEW)
theNetFTab.UpdateSelection

'Displaying only necessary fields from Intermodal Network attribute table
'into the Display Result Theme
theNetFTab.FindField("Fnode ").SetVisible(False)
theNetFTab.FindField("Tnode ").SetVisible(False)
theNetFTab.FindField("Lpoly ").SetVisible(False)
theNetFTab.FindField("Rpoly ").SetVisible(False)
theNetFTab.FindField("Length").SetVisible(False)
theNetFTab.FindField("Length1").SetVisible(False)
theNetFTab.FindField("Ckg02lvd_").SetVisible(False)
theNetFTab.FindField("Ckg02lvd_i").SetVisible(False)
theNetFTab.FindField("Block").SetVisible(False)
theNetFTab.FindField("Lid_1").SetVisible(False)
theNetFTab.FindField("Lid_2").SetVisible(False)
theNetFTab.FindField("Ja").SetVisible(False)
theNetFTab.FindField("Jb").SetVisible(False)
theNetFTab.FindField("Dist").SetVisible(False)
theNetFTab.FindField("Emp").SetVisible(False)
theNetFTab.FindField("Acc").SetVisible(False)
theNetFTab.FindField("Dms").SetVisible(False)
theNetFTab.FindField("Oneway").SetVisible(False)
theNetFTab.FindField("Kp_or_del").SetVisible(False)
theNetFTab.FindField("Fac_dray_c").SetVisible(False)
theNetFTab.FindField("Port_costs").SetVisible(False)
theNetFTab.FindField("Truck_cost").SetVisible(False)
theNetFTab.FindField("Rail_costs").SetVisible(False)
theNetFTab.FindField("Water_cost").SetVisible(False)
theNetFTab.FindField("Rail_costs").SetVisible(False)
theNetFTab.FindField("Tr_tf_cost").SetVisible(False)
theNetFTab.FindField("Lw_tf_cost").SetVisible(False)
theNetFTab.FindField("Count").SetVisible(False)

theNetFTab.Export(theDisplayResultFName,Shape,True)
theNetFTab.UnJoinAll
aNetTheme.ClearSelection

theDisplayResultTheme=Theme.Make(SrcName.Make(theDisplayResultFName.AsString))
theDisplayView.AddTheme(theDisplayResultTheme)
theDisplayResultTheme.SetVisible (True)
theDisplayResultTheme.ClearSelection
theDisplayResultTheme.SetName("Traffic Flows")
theDisplayResultFTab=theDisplayResultTheme.GetFtab
theDisplayResultBM=theDisplayResultFTab.GetSelection

'Loading DisplayResult Legend
theDisplayResultLegend=theDisplayResultTheme.GetLegend
theDisplayResultLegend.SetLegendType(#LEGEND_TYPE_SYMBOL)
theDisplayResultLegend.Natural(theDisplayResultTheme,"Sum_qty",5)
theDisplayResultLegendFile=(av.GetProject.GetWorkDir.asString+"\Legends\sy_trafficflows.avl").AsFileName
theDisplayResultLegend.Load(theDisplayResultLegendFile,#LEGEND_LOADTYPE_SYMBOLS)
theDisplayResultLegend.SetScaleSymbols(True)
theDisplayResultTheme.UpdateLegend

'Creating Modal Display Flows
'Creating the Modal Flow themes
theDisplayRoadResultFName=(av.GetProject.GetWorkDir.asString+"\Results\RoadFlowDisplay.shp").AsFileName
theDisplayRoadResultFTab=FTab.MakeNew(theDisplayRoadResultFName,Polyline)

theDisplayRailResultFName=(av.GetProject.GetWorkDir.asString+"\Results\RailFlowDisplay.shp").AsFileName
theDisplayRailResultFTab=FTab.MakeNew(theDisplayRailResultFName,Polyline)
theDisplayWaterResultFName=(av.GetProject.GetWorkDir.asString+"\Results\WaterFlowDisplay.shp").AsString
theDisplayWaterResultFTab=FTab.MakeNew(theDisplayWaterResultFName,Polyline)

'Creating Road Display Flows

theDisplayRoadResultQry="(([Modes]="v") or ([Modes]="FV") or ([Modes]="VF") or ([Modes]="YV") or ([Modes]="v?"))"

theDisplayResultFTab.query(theDisplayRoadResultQry,theDisplayResultBM,#VTAB_SELTYPE_NEW)
theDisplayRoadResultFName=theDisplayResultFTab.Export(theDisplayRoadResultFName,Shape,True)
theDisplayRoadResultTheme=Theme.Make(SrcName.Make(theDisplayRoadResultFName.AsString))
theDisplayView.AddTheme(theDisplayRoadResultTheme)
theDisplayRoadResultTheme.SetVisible (False)
theDisplayResultTheme.ClearSelection
theDisplayRoadResultTheme.SetName("Road Traffic Flows")

'Loading Road Flow Legend

theDisplayRoadResultLegend=theDisplayRoadResultTheme.GetLegend
theDisplayRoadResultLegendFile=(av.GetProject.GetWorkDir.asString+"\Legends\sy_roadflows.avl").AsString
theDisplayRoadResultLegend.Load(theDisplayRoadResultLegendFile,#LEGEND_LOADTYPE_ALL)
theDisplayRoadResultTheme.InvalidateLegend

'Creating Rail Display Flows

theDisplayRailResultQry="(([Modes]="r") or ([Modes]="YR") or ([Modes]="FR") or ([Modes]="RF") or ([Modes]="r?"))"

theDisplayResultFTab.query(theDisplayRailResultQry,theDisplayResultBM,#VTAB_SELTYPE_NEW)
theDisplayRailResultFName=theDisplayResultFTab.Export(theDisplayRailResultFName,Shape,True)
theDisplayRailResultTheme=Theme.Make(SrcName.Make(theDisplayRailResultFName.AsString))
theDisplayView.AddTheme(theDisplayRailResultTheme)
theDisplayRailResultTheme.SetVisible (False)
theDisplayResultTheme.ClearSelection
theDisplayRailResultTheme.SetName("Rail Traffic Flows")

'Loading Rail Flow Legend

theDisplayRailResultLegend=theDisplayRailResultTheme.GetLegend
theDisplayRailResultLegendFile=(av.GetProject.GetWorkDir.asString+"\Legends\sy_railflows.avl").AsString
theDisplayRailResultLegend.Load(theDisplayRailResultLegendFile,#LEGEND_LOADTYPE_ALL)
theDisplayRailResultTheme.InvalidateLegend

'Creating Water Display Flows

theDisplayWaterResultQry="(([Modes]="g") or ([Modes]="FG") or ([Modes]="GF") or ([Modes]="s")")+
"or ([Modes]="g?") or ([Modes]="SF") or ([Modes]="FS")")+
"or ([Modes]="YG") or ([Modes]="s?"))"

theDisplayResultFTab.query(theDisplayWaterResultQry,theDisplayResultBM,#VTAB_SELTYPE_NEW)
theDisplayWaterResultFName=theDisplayResultFTab.Export(theDisplayWaterResultFName,Shape,True)
theDisplayWaterResultTheme=Theme.Make(SrcName.Make(theDisplayWaterResultFName.AsString))
theDisplayView.AddTheme(theDisplayWaterResultTheme)
theDisplayWaterResultTheme.SetVisible(False)
theDisplayResultTheme.ClearSelection
theDisplayWaterResultThemesetName("Water Traffic Flows")
'Loading Water Flow Legend
theDisplayWaterResultLegend=theDisplayWaterResultTheme.GetLegend
theDisplayWaterResultLegendFile=(av.GetProject.GetWorkDir.asString+"\Legends\sy_waterlows.avl").AsFileName
theDisplayWaterResultLegend.Load(theDisplayWaterResultLegendFile,#LEGEND_LOADTYPE_ALL)
theDisplayWaterResultTheme.InvalidateLegend

theDisplayResultTheme.ClearSelection

theNetFTab.FindField("Fnode_").SetVisible(True)
theNetFTab.FindField("Tnode_").SetVisible(True)
'theNetFTab.FindField("Lpoly_").SetVisible(True)
'theNetFTab.FindField("Rpoly_").SetVisible(True)
'theNetFTab.FindField("Length").SetVisible(True)
theNetFTab.FindField("Length1").SetVisible(True)
'theNetFTab.FindField("Ckg02ld_").SetVisible(True)
'theNetFTab.FindField("Ckg02ld_i").SetVisible(True)
theNetFTab.FindField("Block").SetVisible(True)
'theNetFTab.FindField("Lid_1").SetVisible(True)
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theNetFTab.FindField("Ja").SetVisible(True)
theNetFTab.FindField("Jb").SetVisible(True)
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theNetFTab.FindField("Oneway").SetVisible(True)
'theNetFTab.FindField("Kp_or_del") SetVisible(True)
theNetFTab.FindField("Fac_dray_c").SetVisible(True)
theNetFTab.FindField("Port_costs").SetVisible(True)
theNetFTab.FindField("Truck_cost").SetVisible(True)
theNetFTab.FindField("Rail_costs").SetVisible(True)
theNetFTab.FindField("Water_cost").SetVisible(True)
theNetFTab.FindField("Rail_costs").SetVisible(True)
theNetFTab.FindField("Tr_tf_cost").SetVisible(True)
theNetFTab.FindField("Lw_tf_cost").SetVisible(True)

return"The Modal Flows are added to Traffic Flow Display View"
APPENDIX E

SCREEN SHOTS FROM THE GIS APPLICATION
<table>
<thead>
<tr>
<th>#</th>
<th>From</th>
<th>To</th>
<th>Evidence</th>
<th>Mode</th>
<th>Dist</th>
<th>Flat</th>
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