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A GIS-based multi-commodity freight model: typology, model refinement and field validation

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For the Graduate College

To my loving wife Karen, forever and always

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LIST OF ACRONYMS

AAR	American Association of Railroads
AASHTO	American Association of State Highway and Transportation Officials
ADTT	Average Daily Truck Traffic
AFNA	Arizona Freight Network Analysis
AFTA	Asian Free Trade Area
BCUN	Build Cost User Network
BEA	Bureau of Economic Analysis
BTS	Bureau of Transportation Statistics
CAZ	Commodity Analysis Zones
CFS	Commodity Flow Survey
CGM	Calibrate Gravity Model
CIN	Commercial and Industrial Network
CMT	Carload Miles Traveled
COFC	Container on Flatcar
DBA	Doing Business As
DOT	Department of Transportation
DWD	Department of Workforce Development
EDI	Electronic Data Interchange
ESAL	Equivalent Single Axle Loads
EU	European Union
FAK	Freight, All Kinds
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMCSR	Federal Motor Carrier Safety Regulations
FMM	Freight Model Manager
FRA	Federal Railroad Administration
GDP	Gross Domestic Product

GIS	Geographic Information System
GM	Gravity Model
GUI	Graphical User Interface
HMR	Hazardous Material Regulations
HPMS	Highway Performance Monitoring System
HSS	Highway Selected Summation
I/O	Input / Output
ICC	Interstate Commerce Commission
ICC MC	Interstate Commerce Commission, Motor Carrier
ISTEA	Intermodal Surface Transportation Efficiency Act
ITS	Intelligent Transportation System
ITS/CVO	Intelligent Transportation System for Commercial Vehicle Operations
JIT	Just-in-time
LTL	Less-than-truckload
MCMIS	Motor Carrier Management Information System
MPO	Metropolitan Planning Organization
NAFTA	North American Free Trade Agreement
NETS	National Energy Transportation Study
NN	National Network
NTAD	National Transportation Atlas Database
NTAR	National Transportation Analysis Regions
O/D	Origin / Destination
RMSE	Root Mean Square Error
SCM	Supply Chain Management
SCTG	Standard Commodity Transportation Group
SIC	Standard Industrial Classification
STB	Surface Transportation Board
STCC	Standard Transportation Commodity Classification
TAZ	Transportation Analysis Zones

TEA21	Transportation Equity Act for the 21st Century
TIUS	Truck Inventory and Use Survey
TL	Truckload
TNM	Transportation Network Model
TOFC	Trailer on Flatcar
TS&W	Truck Size and Weight
TTS	Transportation Technical Services
U.S.	United States
USDOT	United States Department of Transportation
VIUS	Vehicle Inventory and Use Survey
VMT	Vehicle Miles Traveled

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ABSTRACT

Historically, public sector transportation planning activities, especially in urban areas, have focused primarily on the movement of passengers. Recent emphasis, however, has been placed on statewide planning, and the movement of freight has received increased attention. This research developed a layered, statewide freight model of Iowa. In the layered approach, each model layer represents a commodity grouping or economic sector.

The primary commodity data used in the model was Reebie Associates' TRANSEARCH database. Fifteen commodity groups were selected to be included in the layered model, at the 3-digit STCC level. The TRANSEARCH data, as available for the model, was at a level too coarse to support intrastate modeling purposes. Consequently, these data were disaggregated to the county level proportional to selected indicator variables chosen after careful inspection of input-output accounts. For each commodity model, the disaggregated TRANSEARCH O/D data were synthesized into a production/attraction table. The production and attractions data were distributed with a gravity model and assigned to the network using an all-or-nothing assignment algorithm. The assigned flows were then converted to truck or carloads, as appropriate, using commodity specific factors.

Current practice is to validate statewide freight models with volume counts. The layered models, however, do not include all freight demand, limiting the effectiveness of this validation method. The innovation of this research was to create a validation data set of volumes for each commodity group at locations in Iowa based on observations of trucks and railcars in the field. To support the validation method developed in this research, an extensive data collection effort was undertaken. Some 11,400 trucks and 4,400 railcars were observed

at 20 locations around the state. Data on observed cargo, truck configuration, trailer type, and carrier information were collected for trucks. Similar data were collected for rail. All of the observed data were compiled into a single database. For trucks, the observed carrier name and number were matched to carrier information in the Motor Carrier Management Information System (MCMIS) database, which was used to estimate the commodity being carried.

For highway flows, commodity estimates were made for each observed truck, based on the type of trailer observed. Commodities were estimated for approximately 50 percent of the trucks observed. This technique compared well with an independent source, the 1991 Iowa Truck Survey, which stopped trucks to determine their commodities. For rail, commodity flows were estimated based upon the observed car type and commodity.

The commodity flow data were then used to validate the model. The data contains volumes of commodity groups in numbers of vehicles (trucks, railcars) which were compared to the model output. Results of the validation varied, depending on the commodity group. For highways, the technique was most effective for validating flows where specialized equipment was required (automobiles, chemicals, farm machinery, etc.). Average model errors for these commodity groups ranged from 8% to 70%. Other commodities transported in more general equipment had a larger variation in model error. For rail, model errors ranged from 20% to 90% for commodities that could be validated.

The sensitivity of the model to changes in model parameters was also examined. Finally, to demonstrate the model's applicability, a simple case study was developed that forecasted distribution patterns of the selected commodity groups ten years in the future.

CHAPTER 1 - INTRODUCTION

The transportation of freight is an important component of the United States (U.S.) economy. In 1997, the nation's expenditures on all modes of freight transportation was $503.5 billion, roughly 6% of the gross national product (*1*). The latest national survey of freight transportation, the 1997 Commodity Flow Survey, indicates that from 1993 to 1997 the value of freight transported in the U.S. grew 9.2%, the total tons shipped grew 14.5%, and total ton-miles grew 9.9%. Forecasts indicate that the demand for freight transportation will continue to grow. A second source, Standard & Poor's DRI, forecasts that the total tons of freight being transported in the United States will grow from 10.9 billion tons in 1996 to 13.2 billion tons by 2006 (*2*). These figures demonstrate the importance of freight transportation to the nation's economy.

The primary goal of transportation systems is to provide for economical, safe, and, most importantly, productive mobility of passengers and goods. Historically, public sector transportation planning activities, especially in urban areas, have focused primarily on the movement of passengers. Recent emphasis, however, has been placed on statewide planning, and the movement of freight has received increased attention. The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) and the 1998 Transportation Equity Act of the 21st Century (TEA21) mandated freight planning in statewide planning activities. Planning activities for freight are now taking place at the national, state and metropolitan levels.

The movement of freight uses infrastructure that is both privately and publicly owned. Considerable planning is required to ensure the expansion and operation is consistent with overall objectives of productive mobility. An understanding of the mechanisms and patterns of freight transportation is a primary input into the planning process. For several decades, and for a variety of purposes, mathematical models have been developed to better understand and predict measures of freight transport. Models can help to identify and prioritize proposed improvements to the transportation infrastructure and quantify the economic, environmental, equity, and safety impacts of policy decisions. While many freight models have been developed since the mid-sixties, most have met with limited success, especially when applied at the state or regional level.

1.1 Problem Statement

Freight transport involves a complex interaction among carriers, shippers, consumers, and government agencies to transport many commodities using different modes. The heterogeneous nature of freight transportation is a primary reason why the modeling of freight transportation demand is generally considered much more difficult than modeling passenger traffic (*3*). Early models of the freight system were developed for national-level analysis in response to competition and energy use concerns (*4*). Most of these models were abandoned as unworkable due to significant data requirements and computational difficulties (*5*). Disaggregate models of freight transportation demand were also developed using the individual shipper or carrier as the basis for analysis (*3, 6*). The data requirements of these models were so significant that their application was limited (*6*).

The heterogeneous nature of freight, however, can also be viewed as a modeling opportunity. Souleyrette et al. and Maze et al. have proposed a layered approach to freight modeling, with each layer representing a commodity grouping or economic sector (*7, 8*). For most state or regional economies, a small number of economic or commodity sectors are likely to be the primary sources of freight demand. The layered approach creates a model for each important commodity or industry sector; the layers can then be combined to produce a composite picture of freight transportation. Given that these commodities have similar transportation requirements and characteristics in the aggregate, modeling approaches of this type are less data intensive then models of the entire freight system.

Recent freight transportation models at the state-level have been developed for freight planning in Indiana, Iowa, Michigan, Wisconsin using versions of a layered methodology. The current statewide models have two general problems: 1) data for validation and 2) mode-split analysis capabilities. One focus of this research was to address the validation issue with a new approach.

Analysts have developed extensive procedures for the calibration and validation of urban travel models *(9, 10)*. During the early development of urban models, large origin-destination (O/D) surveys were conducted in many urban areas that served as the basis for the modeling effort. The models were calibrated to replicate the O/D patterns of the survey (*9*). These models were validated by comparing the assigned traffic volumes to ground counts. These O/D surveys were very expensive, however, and the availability of large scale O/D surveys to modelers soon declined. Without these surveys, trip generation and distribution models were developed to forecast the trip-making behavior of travelers.

In freight demand models, commodity flow data are substituted for passenger O/D surveys. For recent statewide freight models, O/D data were either: 1) purchased from a private vendor; or 2) developed from national level surveys of freight transportation. The use of either data requires an appropriate modeling methodology, as both have limitations. The output from these models have been validated in one of three ways:

1) collect independent O/D data;

2) verify modeled flows by expert opinion;

3) compare modeled flows to vehicle counts or historical data.

The first method, to collect independent data, is an ambitious effort. If this type of data collection is undertaken, it is almost always used as the primary O/D database limiting its usefulness as the primary validation data set. For example, the State of Washington conducted an extensive O/D survey of truck movements in their state in 1993 that involved 25 locations and surveyed 30,000 trucks in a one-year period (*11*).

The second method, to verify the modeled freight flows by expert opinion, requires consensus of industry experts that the model is accurately replicating freight flows. This type of validation is usually not sufficient by itself to statistically validate the model. For this reason, this technique is often used to supplement other validation methods. In addition, validation by these means is not repeatable should the model be updated in the future.

The third method, comparing modeled flows to vehicle counts, is attractive because data on vehicle flows is more readily obtained than commodity flows. In order to validate the model in this way, modelers have converted the commodity flows to vehicle units (i.e. trucks) and compare them to ground counts. In the layered approach, not all commodity groups are modeled, making direct comparison to ground counts less useful. Models developed with the layered approach would benefit from an improved validation method using independent commodity flow data to supplement the ground counts.

1.2 Contributions of the Research

The innovation of this research was to create a validation data set of volumes for each commodity group in the layered model at locations in Iowa based on observations of trucks and railcars in the field. Data were collected at 20 locations throughout Iowa on interstate, U.S., and state highways as well as main and branch line railroads. Some 11,427 trucks and 4,375 railcars were observed during the months of March, June and July in 2000. For each truck observed, data were collected on the type of trailer, the carrier markings, and the commodity transported. This information was used to identify the carrier in the Motor Carrier Management Information System (MCMIS) database. This database, maintained by the Federal Motor Carrier Safety Administration (FMCSA), contains data on the general commodity groups transported, as indicated by the motor carrier. Nearly 78 percent of the trucks observed were either matched to a carrier in the MCMIS or the commodity being transported was observed.

For highway flows, commodity estimates were made for each observed truck, based on the type of trailer observed. Commodities were estimated for approximately 50 percent of the trucks observed. This technique compared well with an independent source, the 1991 Iowa Truck Survey, which stopped trucks to determine their commodities. The new technique was able to predict 13 of the top 15 commodity groups identified in the Iowa Truck Survey. For rail, no supplemental database available such as the MCMIS and the technique only was able to create commodity flows for those commodity groups that were observed. For rail, commodity flows were estimated based upon the observed car type and commodity.

The commodity flow data created were then used to validate the model. The data contains volumes of commodity groups in numbers of vehicles (trucks, railcars) which were compared to the model output. Results of the validation varied, depending on the commodity group. For highways, the technique was most effective for validating flows where specialized equipment was required (automobiles, chemicals, farm machinery, etc.). Average model errors for these commodity groups ranged from 8% to 70%. Other commodities in more general equipment had a larger variation in model error. For rail, the commodities that could be validated, model errors ranged from 20% to 90%.

In addition to the validation efforts, numerous tools and techniques were developed. Commodity specific link costs were developed for both truck and rail. A method and the supporting data were developed to convert commodity flows to an equivalent number of vehicles. A interface between the geographic information system (GIS), the travel demand software, and other data sources was created. This program, the "Freight Model Manager (FMM)", was written in Visual Basic program language. This program was the control box for all model routines and was a significant improvement in the usability of the model framework. The FMM provided a simple graphical-user-interface (GUI) that provided easy management of the data and output files needed by the model. The code for the FMM is in Appendix A.

1.3 Overview and Organization of Research

This research developed a statewide freight transportation model for Iowa using a sequential network model based on the four-step approach. The objectives in the development of the state-level, multimodal, multicommodity freight transportation planning model were the following:

1) review relevant freight models and principles;
2) investigate data requirements;
3) develop a representation of the freight transportation network in iowa;
4) develop calibrated distribution models for each commodity group in the layered approach;
5) convert commodity flows in tons to vehicle units;
6) validate the assignment of freight flows to the multimodal network; and
7) demonstrate the model's capabilities by using it to evaluate policy in a case study.

The document is divided into two general sections. The first group of chapters, 2-4, set the stage by presenting supporting material. In Chapter 2, legislative issues and market forces in freight transportation are discussed. Chapter 3 reviews existing freight transportation planning models in a typology. In Chapter 4, a summary of the freight data sources used in the model is presented. The key elements of each data set, including its limitations and its use in the current model, are presented.

The second group of chapters, 5-13, document the development of the freight model. The model methodology and the related chapters are shown in Figure 1. In Chapter 5, the

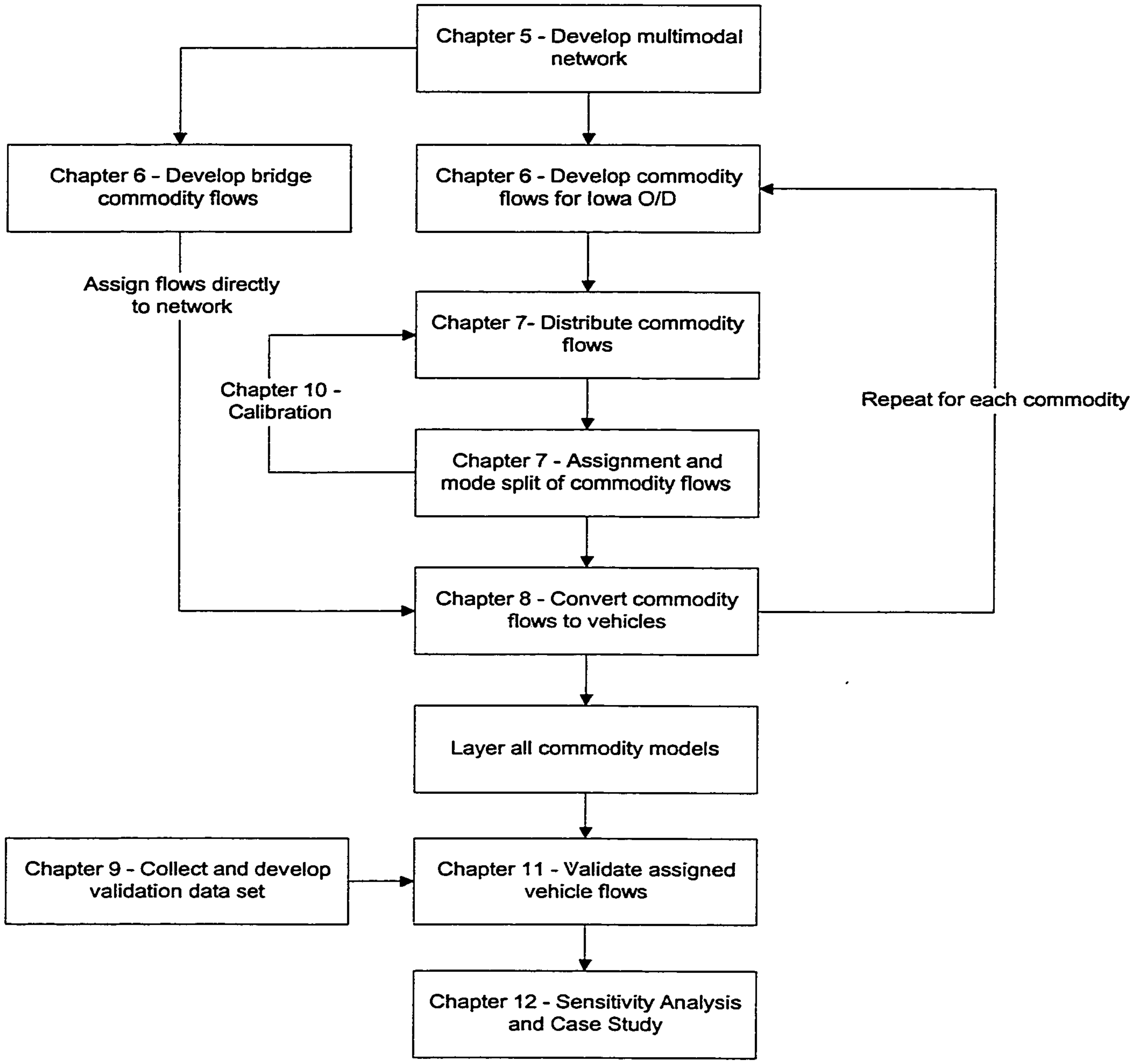


Figure 1 Model Development Overview

multimodal network, including all of the network links and analysis zones, is documented. The network was constructed in a geographic information system (GIS) (MapInfo®), then exported to the travel demand software package used in the model (TRANPLAN). In Chapter 6, the commodity groups in the layered model were selected. The primary commodity data used in the model, Reebie Associates' TRANSEARCH database, was disaggregated to correspond to the analysis zones created for the multimodal network. A separate set of commodity flows were also developed from the 1997 Commodity Flow Survey to model flows through Iowa.

Chapter 7 describes the method used to distribute the commodity flows, the method used to model mode split, and traffic assignment. In Chapter 8, the method used to convert the model output in tons to vehicle units is described. The data collected to develop the validation data set is described in Chapter 9. The chapter describes the data collection method, a summary of the information collected, the data collection locations, and the results.

Model calibration is described in Chapter 10. Two components had to be calibrated – the parameters for the distribution models and the link costs that were used to model the modal split. In Chapter 11, the layered model was validated using the data collected in Chapter 9 and the ground counts of freight vehicles. A detailed section is presented describing how the data were used to estimate the commodity flows of the observed vehicles. Finally in Chapter 12, the sensitivity of certain model assumptions were investigated. A simple case study is included in this chapter to demonstrate the model's use in a policy study. The final chapter, 13, is the summary, conclusions and recommendations.

CHAPTER 2 - BACKGROUND

The purpose of this chapter is to summarize the current planning climate for freight transportation and identify future trends. The first section summarizes the recent federal legislation relating to freight transportation planning. The second section of the chapter provides a synopsis of the long-range multimodal plan developed by the Iowa Department of Transportation (Iowa DOT). The third section of this chapter discusses market forces and trends in freight transportation. In part to set the stage for the case study developed in the model, a summary of logistics trends, market patterns, and shipment size, and vehicle size and weight trends is presented. Finally, the fourth section presents implications for the use of the model.

2.1 Federal Legislation

The first federal legislation that mandated transportation planning was the Federal-Aid Highway Act of 1962 (*12*). During the construction era of the interstate system, planning efforts concentrated heavily on passenger travel. As the interstate neared completion, transportation agencies turned efforts to the efficient operation and maintenance of the system. In 1991, Intermodal Surface Transportation Efficiency Act (ISTEA) promulgated a requirement that states adopt a continuous statewide transportation planning process. States were required to develop a comprehensive long-range plan for all modes of transportation (*13*). The act identified twenty-three factors to be addressed in each state's planning process, including freight. Specfically, ISTEA states that statewide planning should address "international border crossings and access to ports, airports, intermodal transportation facilities, major freight distribution routes, national parks, recreation and scenic areas, monuments and historic sites, and military installations." and include "methods to enhance the efficient movement of commercial motor vehicles" (*13*).

In 1998, ISTEA was reauthorized when Congress passed Transportation Equity Act for the 21st Century (TEA 21)(*14*). TEA 21 mentions freight in its policy statement and continued many of the principles of ISTEA. The twenty-three factors for planning activities originally specified in ISTEA were consolidated to the following factors:

1) support the economic vitality of the United States, the States, and metropolitan areas, especially by enabling global competitiveness, productivity, and efficiency;
2) increase the safety and security of the transportation system for motorized and nonmotorized users;
3) increase the accessibility and mobility options available to people and for freight;
4) protect and enhance the environment, promote energy conservation, and improve quality of life;
5) enhance the integration and connectivity of the transportation system, across and between modes throughout the State, for people and freight;
6) promote efficient system management and operation; and
7) emphasize the preservation of the existing transportation system

2.2 Multimodal Statewide Planning in Iowa

The state of the practice in multimodal planning has progressed quickly since the passage of ISTEA (*15*). Like many states, the Iowa DOT prepared a comprehensive, multimodal long-range transportation plan for the state titled "*Iowa in Motion*" (*16*). The objective of the plan is "to provide and preserve adequate, safe, efficient transportation services based on their benefits to the public"(*17*). The plan is presented in modal sections: highways; transit; rail; water; air; non-motorized; and intermodal. Each section of the plan describes the historical perspective of planning (in that mode) and the Iowa DOT's then current plan.

To facilitate long-range statewide plan for the highway mode, the Iowa DOT performs functional classification and system stratification. This stratification guides funding and improvement plans. The highway network is divided into five functional classification levels:

1) interstate;
2) Commercial and Industrial Network (CIN);
3) area development;
4) access routes; and
5) local service.

The CIN is a designation for roads which "enhance opportunities for the development and diversification of the state's economy by improving the flow of commerce; making travel more convenient, safe and efficient; and better connecting Iowa with regional, national, and international markets" (*16*, p. 33). The freight distribution system is primarily supported by the CIN and interstate systems.

For railways, the Iowa DOT's goal in the long-range statewide plan is "to provide assistance for the development and maintenance of a safe, efficient, and economical railway transportation system" (*16*, p. 48). Unlike highways, the DOT is not actively involved in the construction, operation, or maintenance of railway facilities. Rather, capital assistance is provided for improving branch rail lines to maintain service levels. The Iowa DOT stratifies rail lines based on:

1) traffic levels;
2) national defense priorities; and
3) future economic development potential.

The Iowa DOT is also concerned with maintaining efficient freight movements on main lines and "encouraging the development of an integrated transportation system utilizing inherent advantages of each mode" (*16*, p. 48).

No state money is used in the construction, operation, or maintenance of water-based transportation. Only two navigable waterways are accessible from Iowa, the Missouri and Mississippi rivers. The Mississippi river has an extensive lock system that is maintained by the U.S. Army Corps of Engineers. The policy of the Iowa DOT for river transportation is "to promote efficient use of river transportation" (*16*, p. 54).

Lastly, the *Iowa in Motion* plan identifies intermodal as a separate planning area. The transportation plan of Iowa calls for the development of a "total transportation system plan ... which considers all transportation modes as interacting elements" (*16*, p. 62). The statewide plan stresses that most planning is done modally but the overall integration of modes is a goal.

2.3 Trends in Freight Transportation

The motivation to develop a freight model is to allow planners to forecast system-wide impacts of trends and public policy decisions. The ability to assess the impact of these trends and develop appropriate strategies is hoped to make freight planning more effective. This section identifies freight transportation trends, which has changed dramatically in the past decades. Clearly, most of the trends are national and international in scope and the State of Iowa had little control over them. A clear understanding of these trends and the potential impacts to the Iowa freight distribution system, however, are a requirement for successful freight planning efforts. The majority of these trends and the potential impacts are discussed below.

Supply chain management: Supply chain management (SCM) is an "integrated approach to managing material and information flow among suppliers, carriers, manufacturers, distributors, and end-users with a focus on coordination to eliminate duplication and improve customer service" (*18*, p. 7). SCM integrates transportation with all components of production and distribution systems by considering the supply chain as a system. Firms can gain significant competitive advantages by employing SCM. For example, a computer manufacturer saved millions of dollars on inventory costs by switching to air freight from ocean cargo, even though the air freight costs much more than ocean freight (*18*). Some of the trends discussed in the following sections are not independent trends; they are part of the increasing use of SCM.

Just-in-time delivery: The just-in-time (JIT) delivery concept minimizes inventory levels by coordinating delivery of inputs and production schedules. JIT strategies often involve a reduction of the number of suppliers and a more frequent delivery schedule with smaller shipment sizes (also discussed in next section). This is often accomplished with a third-party logistics firm who arranges transportation services for the shipper. Suppliers often move closer to the demanding firm, resulting in shorter haul lengths. The trend is towards larger firms capable of controlling transportation services in the hundred million or even the billion dollar range" (*19*, p. 63). Shippers may reduce the number of transportation companies they deal with and enter into agreements with carriers to provide logistical support. As more firms move to JIT, system reliability will be come more important. Transportation managers often state that consistent, reliable travel times are more important than shortened travel times. As urban areas experience more congestion, this may become an important factor in the locational decisions of firms.

JIT concepts apply mainly to the shipment of high value goods by truck. Shorter, more frequent trips imply that there will be more trucks on the highway. With increased emphasis on system reliability, it becomes critical to identify and mitigate bottlenecks in the system – since economic development in the state could be directly related to the reliability of the transportation network. For example, Barilla built its only North American pasta production facility in Ames, Iowa with direct access to the Union Pacific and I-35 in the Midwest. Transportation issues were an important factor in the decision to locate the plant in Ames (*20*).

Shipment size: As part of logistical innovations and reduced inventory levels, shipments will likely be of smaller sizes and of greater frequency. The increased availability of information may affect the "size of shipment" versus "cost" tradeoffs made by logistical managers. Typically, the larger each individual shipment, the lower the overall transportation costs to the firm. However, in some situations, it may be economical to make more frequent shipments of higher value goods. Some of the increased traffic as a result of smaller shipments may be mitigated as inventory systems move from "push" to "pull" (*19*, p. 63). Traditional push inventory systems are driven by estimates of consumer demand where sufficient inventory is carried to satisfy estimated consumption, including a reserve stock called "safety stock." Pull systems are based on actual measurements of consumer demand.

Again, the trends for smaller shipments apply mostly to truck shipments of higher value goods. Lighter, more frequent shipments have implications for pavement performance and capacity issues. It is possible that smaller loads could lead to decreased wear on pavement and structures but could be offset by the increase in frequency of trips. Lower value commodities, which are usually heavier, would not be affected by either JIT or smaller shipments trends.

Information technology: The trend towards shorter inventory cycles and pull inventory systems is made possible by the increasing flow of information in electronic form. Real-time inventory levels and locations of freight vehicles are possible through electronic exchange of information. The level of congestion, incidents, and other traffic parameters can be obtained in real-time as the deployment of Intelligent Transportation Systems (ITS) become more commonplace. In addition, electronic data interchange (EDI) protocols have allowed carriers and shippers to become more integrated and to "function in a virtually paperless environment" (*19*, p. 66).

Economic changes / market patterns: Globally, shifts in the production centers can affect the flow of freight in the United States. Production centers now located in the Pacific Rim near Japan and Korea are shifting to the south and west. This Pacific Rim freight usually arrives in the United States in west coast ports, but now has the option of using the Suez Canal and arriving in the United States in east coast ports. This shift in flow affects overland container traffic, since most maritime freight arrives in containers. International trade agreements such as the North American Free Trade Agreement (NAFTA), which lowered trading costs by reducing or eliminating tariffs in the North American market, can also influence the location of production/consumption sites and the flow of freight. Other free trade blocks such as the European Union (EU) and the Asian Free Trade Area (AFTA) have the potential to influence freight patterns in the United States.

Nationally, shifts in production centers can also influence freight flows. Moreover, changes in economic prosperity of certain regional economies can have short-term effects on the distribution of freight. For example, recent changes in Asian economies have meant decreased demand for agricultural exports from Iowa.

Conveyance size and weight: Economies of scale dictate that larger vehicles carrying more freight have lower shipment cost per ton. The size and weights of conveyance vehicles are limited by regulations, infrastructure constraints, or both. For the trucks, current federal truck size and weight laws establish the following limits (21):

- 20,000 pounds maximum for single axles on the Interstate;
- 34,000 pounds for tandem axles on the Interstate;
- application of the bridge formula B for other axle groups, up to a maximum of 80,000 pounds for gross vehicle weight;
- 102 inches vehicle width on the National Network (NN);
- 48 foot minimum length for semitrailers in a semitrailer combination on the NN (not all states);
- 28 foot minimum length for trailers in a twin-trailer combination of the NN.

Federal weight laws apply to the Interstate system and vehicle size laws apply to the NN. It should be noted that many states have limits that are more permissive. For example, all states except for Alaska, Rhode Island and the District of Columbia allow semitrailers to have a maximum length of 53 feet. ISTEA froze the current truck size and weight regulations for longer combination vehicles at the current limits.

Freight shipments in trucks may encounter the size and weight policy in two ways. Low-density shipments may exceed volume capacity before they exceed the maximum weight limitation. Higher density shipments may exceed the weight limits before the volume capacity of the trailer is exceeded. Changes to truck size and weight (TS&W) regulations have potential implications on the pavement performance and number of trucks on the highway.

For railroads, load weights of railcars are increasing from 263,000 pounds to 286,000 pounds. Many of these larger cars are being used by the major carriers, but smaller railroad tracks are not equipped to handle these heavier cars. In a recent survey of short line rail executives, the move to the heavier cars has caused concerns on how they will upgrade track and bridges to handle the cars (*22*). The lack of ability to utilize the heavier cars can also affect the availability of car supply.

2.4 Implications for Model Application

Transportation infrastructure represents a significant public investment. Research indicates a direct relationship between investment in highway infrastructure and productivity gains (*23*). Strategic, long-range planning, can maximize the public's substantial investment in the transportation infrastructure. The freight model developed in this research is one tool that can be used to analyze trends and regulatory changes in freight transportation.

The freight model would be useful for analyzing several of the trends described in the chapter. While significant changes to the commercial industrial network, interstate, and rail transportation improvement plans described in *Iowa in Motion* are unlikely; a freight model could assist in the future updates and analysis of the plan. The model could be coupled with a statewide passenger model and capacity analysis could identify potential bottlenecks in the transportation system.

The layered nature of the model allows it to be used to address commodity specific trends that are the basis for many of the trends discussed in this chapter. The trends would be very difficult to capture in an aggregate model. Changes in production or consumption centers for individual commodity groups can easily be modeled by changing production inputs into the model. Likewise, changes in average shipment loads, average cost per ton-mile, and average shipment distance can be addressed by changing model parameters to reflect the new values. Since each commodity is modeled independently, changes to one will not affect the other model. Similarly, the multimodal design supports the analysis of modal shifts resulting from changes in freight cost, regulatory, or infrastructure.

The following chapter documents the development of freight models. Some of the models were developed to address specific policy issues, such as the ones described in this chapter.

CHAPTER 3 - TYPOLOGY OF FREIGHT NETWORK MODELS

The depth and complexity of the freight transportation has resulted in numerous modeling approaches. Models have been developed to assist logistical decisions, routing plans, and freight infrastructure planning. There are two general approaches to freight demand modeling: 1) econometric (price equilibrium) models; and 2) network models. Econometric models forecast the supply and demand for freight transportation. Network models are used to forecast freight flows on the transportation network.

The purpose of this chapter is to characterize existing freight planning models in a systematic fashion. This chapter is organized into four sections:

1) a discussion of the two general approaches to freight modeling;
2) a characterization of freight models found in the literature; and
3) a summary of this typology.

3.1 General Classes of Models

As stated, many sub-classes exist for both modeling approaches and will be described in the following sections. Given the planning emphasis of the research, the econometric models will receive less attention than the network models.

3.1.1 Econometric Models

In general, econometric models use historical data to forecast economic scenarios. Econometric models do not require a detailed transportation network. Econometric models can be sub-classified into supply and demand models. Harker states that supply models "focus on the issue of describing the production of transportation services (*24*, pg 10)."

Harker further states that the "major impetus of the development of these models was not to make predictions about the freight transportation system, but rather to understand the production/cost characteristics of the industry (*24*, pg 10)." Supply side models were used extensively in the analysis of regulatory reform of the freight industry. Supply models can answer questions about economies of scale and economies of route density.

Demand models aim to explain the demand for freight transportation services as a function of the level of service and the rates charged. Winston further classified demand models as aggregate and disaggregate (*6*). Aggregate models have as their basic unit of observation "an aggregate share of a particular freight mode at a regional or national level" (*6*, p. 419) Disaggregate models have as their basic unit of observation "an individual decision maker's distinct choice of a particular freight mode for a given shipment" (*6*, p. 419). Clearly, data requirements are very high for disaggregate models. Demand models are useful in mode split analysis, intermodal competition, regulatory analysis, and forecasting freight flows.

3.1.2 Network Models

In general, freight network models can be classified as either commodity-based or trip-based (25). Commodity-based models use data on commodities as their base unit for distributing flows. The units are weight or value. Trip-based models are based on vehicle trips, similar to the passenger model paradigm. Trip-based models have been used in urban modeling of freight transportation, but their use in statewide freight models has been limited. Both categories of models can be further categorized as either simultaneous or sequential.

The sequential have explicit steps. The results of each of these steps are fed into the next as the starting point. The four-step approach, used in this research, is a sequential approach. Simultaneous models develop solutions for each sub-model at the same time.

3.2 Review of Freight Models

This section reviews the literature freight models. This typology is by no means exhaustive; it merely strives to present a comprehensive typology of the most significant freight network models developed in the last 20 years. Because the model is a network-based model, only network models are included in the typology. When comparing and contrasting these models, it is useful to have a set of common questions that, when answered, will sufficiently characterize the model. To that end, this typology uses a series of questions to characterize each model. A portion of the work in this section builds directly on a typology presented by Friesz, Tobin and Harker in their 1983 paper (*3*). Friesz originally characterized models using 16 criteria. This typology uses 10 of his criteria which are noted with an * in the question list (some of his criteria are combined in one question). Additional questions were developed to help further classify the model. The following set of questions are answered for each model presented in this typology:

1) What is the general class/sub-class of model?
2) What is the geographic detail or network detail?
3) * Is the model multimodal?
4) * Are there multiple commodities in the model?
5) What are the sources of data used?

6) What is the level of data aggregation?

7) What mechanisms are used for trip generation, trip distribution, mode split, and traffic assignment?

8) * How are the commodities loaded onto the network?

9) * Are congestion effects explicitly modeled?

10) * Does the demand for transportation change based on modeled conditions?

11) * How or is a macroeconomic sub-model incorporated into the model?

12) How is calibration/validation accomplished?

The next sections briefly summarize early models developed in the period from 1969-1980 and then review 11 freight network models from the past decade according to the above criteria.

3.2.1 <u>The Early Models (1969-1980)</u>

The Harvard-Brookings model, which Friesz calls the "first significant multimodal predictive freight network model" (*3*, p. 410) was developed in 1966 by Roberts (*26*) for a developing country, Colombia. The model was multicommodity and multimodal. The structure of the network represented transport routes rather than the exact physical network. The generation of O/D trips was done using a separate macroeconomic model, while distribution of the trips was done with a gravity model. Modal choice and assignment of the traffic was done with a shortest path algorithm that accounted for the shipper's perceived cost. Data on transportation cost were obtained in Colombia's regulated transportation environment.

Some of the early models described by Friesz were developed to model the freight rail network exclusively, such as the work by Peterson and Fullerton (1975), Lansdowne (1981) and Kornhauser et al. (1979) (*27,28,29*). The Peterson and Fullerton model used a systems optimization approach to develop a predictive rail model that was neither multi-carrier nor multicommodity. The Lansdowne model was a rail traffic assignment model designed to predict the total movement of freight including interchange between railroads. The model assumed carriers would maximize profit by keeping freight in their system for the longest time possible. Kornhauser's model, also known as the Princeton Rail Network model, was a refinement of a network model originally developed for the USDOT.

Other models were developed with a planning or policy emphasis. Early work in network models was preformed by Sharp (*30*) in 1979. Sharp's work was a multicommodity network flow model for planning a multi-state transportation system that extended from Jacksonville, Florida to Kansas City, Kansas. Another such model was the Transportation Network Model (TNM) presented by Bronzini in 1980 (*4*). The model was a multimodal freight transportation network model, which was subject to many refinements. The model was initially developed for studying the effects of user charges on the inland waterway system. The model consisted of nodes and links with parameters of mode, capacity, transit time and cost. The model also included access links to connect the network to origin sites as well as transfer links that allow transfers between modes. The first development only included the rail and highway modes. The routing assumptions were: 1) freight was routed by shipper's decisions to minimize cost as assigned to paths and; 2) cost was a linear combination of dollar cost and time (*3*, p. 410). The traffic assignment was done using an all-or-nothing assignment algorithm. Validation was done by comparing the modal split results (how much freight on rail and how much on waterway) to known splits from aggregate data.

The second refinement, in 1977, was done for the Transportation Systems Center of the USDOT. Three major improvements were made to the model's structure and logic. First, the model logic was redesigned to include energy costs. Second, the model allowed the cost and energy functions to be commodity specific. Lastly, the previous model was updated to include highway and pipeline networks and commodities. Again, the mode split results were compared to mode split data on commodities. The last refinement to the model was made for the National Energy Transportation Study (NETS). The major improvement to the model was the replacement of the all-or-nothing assignment algorithm with an equilibrium assignment algorithm. Bronzini recommended using this assignment method to predict freight flows in networks.

3.2.2 Freight Network Equilibrium Model (1986)

An innovative approach to modeling freight transportation was presented by Friesz, Gottfried, and Morlok in 1986 (*31*). The network model presented by Friesz et al. was a commodity-based sequential network model, but not in the four-step approach. The objective was to describe the shipper-carrier interaction using a sequential approach that consists of three sub-models: shipper, decomposition algorithm and carrier. The model was applied to three levels of network detail. The first network was a highly detailed rail and water network of the northeastern United States with a single commodity and 5 carriers. The analysis was conducted for 105 USDOT zones in the northeastern U.S. The disaggregated O/D data were supplied by forecasts from Data Resources, Inc. The second network used a more aggregate rail network of the U.S. with 15 commodities and one carrier. The analysis was conducted at the Bureau of Economic Analysis (BEA) level and the Federal Railroad Administration's Waybill sample was used as a data source. The third network used a combined rail-water network of the U.S. with 15 commodities and 17 railroads. The analysis was conducted at the BEA level and the data were supplied by Reebie Associate's TRANSEARCH database.

The research hypothesized that by modeling separately the decision-making ability of the shipper and carrier, more accurate results could be obtained. The shipper sub-model assumed that shippers would assign freight flows to minimize total distribution costs. The shippers' freight was assigned to a more aggregate, less detailed network than that present in the carrier sub-model. An O/D matrix of shipper demands were translated to modal and O/D specific paths for use in the carrier sub-model by the decomposition algorithm. The In the carrier sub-model, flows were assigned to minimize total operating cost while satisfying the demand of the shipper. The predicted carrier flows were assigned to the complete network.

Trip distribution was accomplished in the shipper's sub-model using a doubly constrained gravity model. The gravity model was calibrated using mean trip length in the first network, a sophisticated procedure by Erlander et.al (*32*) in the second network, and was not specified in the third network. Assignment was done with an equilibrium algorithm solved by a Frank-Wolfe algorithm. Congestion effects were included in the model by varying the cost functions on the transportation links.

Comparing historical flows to the model's predicted flows for three network data sets validated the model. Statistical comparison of the predictive capability was done using goodness-of-fit measures recommended by Smith and Hutchinson (*33*). The measures used were the coefficient of determination (R^2), normalized phi, and normalized mean absolute error (M). Performance of the model varied greatly by commodity.

3.2.3 Arizona Freight Network Analysis (1987)

Rahman and Radwan presented the Arizona Freight Network Analysis (AFNA) model in a 1990 paper (*34*). The model was developed to aid the Arizona DOT in highway freight planning activities. The AFNA is a trip-based, discrete, stochastic simulation model. The model was developed for the truck mode only, and the network was the primary and secondary highway system. Entrance points to Arizona were represented in the network by a node. Using the State of Arizona's weight-distance tax database, a survey of motor carriers was distributed which received a 25% response rate. The survey requested data on trip origin, trip destination, commodity type, and gross weight of trucks. The survey was used to generate O/D flows for 10 commodities in Arizona.

The inputs to the simulation model included: network configuration, network parameters, route-specific origin-destination data on commodity flows, and routing criteria. Using the O/D data, truck traffic was assigned to the network using a conditional branching distribution (probabilistic approach). For example, at points where the network splits, the traffic could be assigned to either link with an assigned probability. Given the discrete simulation nature, commodities must be loaded on the network sequentially; hence, congestion was not addressed. No cost information was included in the model, and the demand for freight was constant. To function as a predictive model, the base O/D table was modified using a growth factor procedure based on personal income data and the national input-output model from the United States Department of Commerce. Validation was not possible from the survey data, but the authors recommended validation by comparing to ground counts (which was not done). The model was tested in two future economic growth scenarios and seemed to provide the necessary planning output.

3.2.4 Strategic Transportation Analysis Network (1990)

One of the most detailed network flow models for the use in strategic freight planning was presented by Guelat, Florian, and Crainic in 1990 (*35*). The model developed was a multimodal, multiproduct network model. The network represented the physical freight distribution network with each link in the network defined by an origin node, a destination node, and a mode of transport. For multiple modes between nodes, a parallel link was included for the alternative mode. The network representation of intermodal transfer points was accomplished by expanding the nodes at transfer points. Cost functions were assigned for each link depending upon the mode or other attributes. The objective function was to minimize total generalized transportation costs across all links and modes, which was solved with a Gauss-Seidel solution algorithm.

Three applications were performed to test its feasibility. The first application was a national level freight model of the Brazilian transportation network. The model consisted of 211 origin and destination nodes, 2,143 nodes, 4,957 links, 5,718 transfer nodes, and six products. The six products (cement and steel, iron ore, fertilizer, soya oil, soya grain, coal, and all others) were chosen because they were the major commodities of interest for Brazil. The Ministry of Transport for Brazil developed the O/D table. Several scenarios of various transportation improvements were modeled. The second application was to model the Sao Francisco corridor in Brazil. The third application involved the coal distribution system of a Scandinavian country.

The network model created by Guelat, Florian, and Crainic was named Strategic Transportation Analysis Network (STAN). The model was found flexible and practical even for large networks. A more detailed analysis of a transportation corridor in Brazil was presented by Crainic, Florian and Leal (*36*) that also presented methods to convert ton flows to carloads, link delay cost functions, and model calibration phases.

3.2.4.1 *Application of STAN*

Recently (1999), Mendoza, Gil, and Trejo (*37*) used the model developed by Guelat et al. in an analysis of the modal share of Mexican-United States freight transportation. The United States was divided into 56 analysis zones and Mexico was divided in 32 zones. Additionally, 16 zones were included for land border crossings between the U.S. and Mexico. The O/D matrix was developed with data from the Mexican Commercial Information System of the Mexican Secretariat of Commerce and Industrial Development (SECOFI). Tonnage and value for each O/D pair was provided. Predicted flows of tons and value were converted to a number an equivalent number of vehicles by using average payload values developed from an earlier survey.

The land transport network in the model included the U.S. and Mexican railroads and highways. The assignment of the O/D flows to the network was performed using the STAN model. Cost data for the links were based on the mode of transport and vehicle type. Three modes were used in the analysis: rail, truck, and customs port (because the operation of the customs port was significantly different, a separate "mode" was needed to address the cost incurred at border ports due to customs processing). An optimal solution of the modal split for the distribution of freight was determined. The analysis concluded that if the modal split of freight transport would reach the predicted optimal split, approximately $52 million dollars per year could be saved.

3.2.5 Kansas Statewide Agricultural Model (1992)

The Kansas model was originally developed in 1992 (*38*) and later updates were described in the Quick Response Freight Manual (*39*). The model was a network based, truck only, agricultural commodity model. Five commodities were used in the model: corn, wheat, sorghum, soybeans, and boxed beef. The original model was developed to forecast equivalent single axle loads (ESAL) loads on the Kansas highway system. The network consisted of state, U.S., and interstate highways which included 202 traffic analysis zones (TAZ) and 2,200 links. The TAZs represented all 105 Kansas counties and 68 external stations. Three networks were developed, varying only in their impedance to flow: a speed network; a terrain network; and a toll facility network. All networks ended at the Kansas border with external stations. Because the model was truck only and five commodity types, the Kansas collected their own data at border points and inside the state. Additional data were collected with mail surveys, telephone reports, and interviews.

Trip distribution was done for internal-to-internal, internal-to-external, and external-to-external trips. The internal-to-internal trip table was developed from the data and the external-to-external trip table was developed from O-D studies conducted at locations around the state. The internal-to-internal trips were distributed with a gravity model. Prior to assignment, commodity flows were converted to vehicle units using average payload capacities. Trucks were assumed to carry 44,000 pounds of boxed beef and 850 bushels of grain. Traffic assignment was performed using an all-or-nothing assignment methodology on the three networks. The resulting assignments were weighted, and then averaged to obtain truck volumes on the network. Capacity effects of the network were not included in the model. Calibration or validation was not done because of lack of accurate link volume estimates.

3.2.6 Alberta Commodity Flow Model (1993)

A model for predicting commodity flows in Alberta, Canada was described in a 1993 paper by Ashtakala and Murthy (*40*). The objective of the study was "to determine the demand for commodity transportation using the conventional, sequential modeling approach." Obviously, the developed model was a commodity-based, sequential network model. The transportation network of the province was not explicitly included, rather, nodes representing population centers were connected by links. The population centers were determined to be producers or consumers. The model was multimodal, including both rail and truck flows, and included multiple commodities. An extensive commodity flow survey conducted by Alberta Transportation was used in the development of this model. The survey collected "origin-destination of the commodity movement, type of commodity, type of firm, annual tonnage, average shipment size, type of load (full load or less then full load), type of hire (private or for-hire), and market share". The O/D flows in the commodity flow survey were at the population center level of detail.

Trip generation was essentially done by the commodity flow survey. An optimized gravity model, described in another paper by Ashtakala and Murthy, was used for the trip distribution (*41*). An optimized production-constrained gravity model was developed for each of the 17 commodity classes analyzed in the model. The optimization technique optimized one of the parameters in the gravity model against a statistical measure of the predictive accuracy. Mode split was done using a logit model described in another paper by Murthy and Ashtakala (*42*). Traffic assignment was not done for the model, since no explicit network was included. Flows were only represented between population centers. The model was sequential and contains no explicit network, hence, the effects of congestion were not included in the model. In addition, changes in demand for freight transportation was not addressed. Calibration was done by comparing commodity haul diagrams, which represents the distribution of length of haul for each commodity, to the results of the survey data.

3.2.7 Iowa Statewide Truck Forecasting Model (1994)

A statewide truck transportation planning methodology was developed by Smadi in his 1994 Ph.D. dissertation (*43*) and published in a 1996 paper with Maze (*8*). The objective of the research was "to develop a procedure for statewide planning of truck commodity flows and apply it to the State of Iowa." The model was a commodity-based, sequential network model at the state level. The approach was to model individual commodities independently, thereby reducing data and modeling requirements. The only mode included in the model was truck. The network was composed of the major routes in Iowa and major nodes (cities) outside of Iowa. The network included a node in all counties and sub-nodes at major producers or attractions of freight. The research identified the most important manufacturing sectors in Iowa for analysis. Eight sectors accounted for 77.1 percent of employment in the state economy.

Freight generation was done using input-output accounts and data from the 1977 Commodity Transportation Survey (the most recent publicly available data at the time). The traffic was generated at the county level and distributed with a gravity model using travel time as the measure of impedance. Prior to assignment, commodity flows were converted to vehicle equivalents using average weights for each commodity group. Trucks were assigned to the network using a shortest path algorithm. It was assumed that capacity in intercity freight transportation was not an issue, so congestion effects were ignored. No forecasts of future demand were made. Calibration and validation were attempted by comparing model results to the Iowa Truck Weight Survey. The survey had a small sample size, so the validation efforts were not completely realized.

3.2.8 Michigan Statewide Truck Model (1996)

The Michigan truck model was developed as part of the Statewide Travel Demand Model (*44*). The objective of the statewide travel model was to "represent all motorized ground travel on an integrated highway, intercity bus and passenger rail network." The truck model was developed independently, and then integrated into the travel model. The truck model was a commodity-based, sequential model written in the computer language C++. The truck model uses the same network as the passenger model, which includes the state's primary trunk lines and county roads. Approximately 7,625 nodes and 11,000 links were included. For the truck model, commodity analysis zones (CAZ) consisted of all counties in Michigan and all states outside Michigan. The model includes 11 commodity groups at the 2-digit Standard Transportation Commodity Classification (STCC) level and import-export flows. The commodity groups and the import-export flow models were developed separately.

For the commodity model, trip generation rates were initially developed from the 1983 Commodity Transportation Survey and were "applied to estimates of Standard Industrial Classification (SIC) data obtained from the County Business Patterns and U.S. Department of Commerce sources." The trip generation rates were to be updated with the 1993 Commodity Flow Survey. A two-stage destination choice model was used with region-to-region flows from the 1983 Benchmark Input-Output Accounts. Flows, in tons, were converted to vehicle units using average load weights obtained from a survey. For the import-export model, data from the Transborder Transportation Data and Stats Canada were used to develop an equation relating the number of trucks to the value of trade. The relationship was found to have a high correlation.

The commodity and import-export trip tables were combined and disaggregated from the CAZ level to the TAZ level of the passenger model. The trips were then assigned to the network using an all-or-nothing algorithm with a generalized cost function that included time, distance, and toll charges. Calibration and validation took place as part of the statewide travel model. Cordon and screen lines were used for comparison to ground counts.

3.2.9 Wisconsin Statewide Model (1996)

In 1996, Wilbur Smith Associates developed a statewide multimodal freight forecasting model for the Wisconsin DOT (WisDOT) (*45*). The forecasting model was used in Wisconsin's long-range multimodal transportation plan, *Translink 21* (*46*). The model included an econometric forecast for future freight flows and a commodity-based, sequential assignment model. The geographic level of analysis for the Wisconsin model was the county level. Each of the 72 Wisconsin counties was represented, as well as 34 counties of adjacent states and 34 multiple Bureau of Economic Analysis (BEA) regions that represent other states. The model was multimodal (air, rail, truck and water), although only truck volumes were assigned to an actual network. The model includes 39 of Wisconsin's most important commodities and was analyzed at the county-level. Total flows for each commodity group were developed from the proprietary database from Reebie Associates, with some supplementary data . The TRANSEARCH flows were disaggregated to the county level by a four-step process described in *A Guidebook on Statewide Travel Forecasting* (*47*) and quoted here:

> First, the total flows are determined from the TRANSEARCH database for each commodity group. Second, freight origins are identified and are assigned to the county level TAZs based on county employment data. Third, based on a national input-output table it is determined which proportion of each commodity group's flow is destined for industrial consumption and which is destined for household consumption. Finally, county-level destinations are allocated based on employment

(for industrial consumption) and population (for household consumption). (p. 111)

An econometric model was used to forecast future freight flows that used employment forecasts and productivity forecasts. A procedure was developed for an expert panel to have input on the modal shares of freight traffic in the future forecasts. The commodity flows were converted to vehicle units using estimates of the weight per vehicle for each of the major commodities. Using the vehicle flow matrix, the freight was assigned to the network using a stochastic multipath assignment procedure (*39*).

Congestion effects were not included in the model. Demand for transportation was included in the econometric models. No calibration or validation assignment procedure was discussed.

3.2.10 Indiana Commodity Flow Model (1997)

The Indiana Commodity Flow model was developed by Black in 1997 for the Indiana Department of Transportation (*48*). The model was a network commodity-based, sequential model. The objective was to "create a database of commodity flows into and out of the counties of Indiana and to allocate this commodity traffic to the transportation network of the state." The model was ambitious in scope and detail. Included in the model were 21 commodity groupings at the 2-digit STCC level that account for over 93% of all freight traffic in Indiana. The network was developed in a GIS platform and included the principal highways in Indiana, most major highways in neighboring states, and interstates in more spatially distant states. The rail network was also included. The model includes the rail and truck modes. Other modes were considered but were not included.

The model used many data sources in the development stages. The 1977 Commodity Transportation Survey, the 1993 Commodity Flow Survey (CFS), the County Business Patterns, the Census of Population, the Federal Highway Administration (FHWA) digital highway network, and the Federal Railroad Administration (FRA) digital rail network were used. The 92 analysis zones in the model were at the county level and 53 zones outside of Indiana were of greater geographic area.

The methodology used in the Indiana Commodity model was presented in the classical urban transportation modeling form. The four steps of the approach were explicitly included here, although modified for freight transportation. Trip generation equations for each commodity were developed using multiple linear regression on the 1993 CFS data for most commodity groupings. Employment and population were included as some of the explanatory variables. The equations were developed for attractions and productions. Trip distribution was done with a constrained gravity model, also called an entropy model. Modal split was done by investigating historical splits and distributing flows based on those splits. The assignment algorithm was an all-or-nothing assignment with an adjustment for speed on the link. An all-or-nothing assignment without a speed adjustment produced erroneous results with almost all of the traffic being routed on the interstate. Two other assignment algorithms were investigated: stochastic user equilibrium and capacity restraint. These assignment algorithms did not produce satisfactory results in this model. Congestion effects were not considered in the model.

Future flows of freight were forecasted by using the trip production and attraction variables. The future values of the independent variables in the regression equation were forecasted which were used to determine future freight flows. The new production and attractions were distributed on the network using the calibrated gravity model developed for the base model. Two future years were analyzed, 2005 and 2015. Validation of the base model was done by comparing the predicted flows to actual ground counts where data were available. A statistical analysis was performed to compare predicted and actual flows.

3.2.11 Massachusetts Truck Model (1998)

A state-level, network based truck assignment model was described by Krishan and Hancock for the State of Massachusetts in a 1998 paper (*49*). The objective of the research was to "develop a GIS-based approach for distributing and assigning freight flows in Massachusetts." The network in the model was developed from the National Transportation Atlas Database (NTAD) and included all state, U.S., and Interstate highways in the Massachusetts. The model included only the truck mode. The modelers created an O/D table from the 1993 Commodity Flow Survey (CFS). The state level CFS data were disaggregated to combinations of 5-digit zip code regions using a total employment indicator from the 1990 Census. Initially, individual 5-digit zip code areas were considered as analysis regions but the data requirements were too great. In addition, 3-digit zip code regions were too large for analysis purposes. All commodities shipped by truck in the CFS were combined for one large O/D matrix.

Development of the O/D matrix essentially completed the distribution step. Traffic assignment was done in the model by the user equilibrium algorithm. All-or-nothing and capacity restraint assignment algorithms were also tried, but did work in the model. Prior to the assignment phase, the O/D matrix was converted to vehicle units. Because the CFS derived matrix was in tons of freight, a method was used to convert the tons to vehicle units. The tons of freight were converted using five variables:

1) average density of freight;
2) average percentage of truck type;
3) average volume of truck type;
4) average weight of non-empty trucks; and,
5) average percentage of non-empty trucks.

The flows were converted to annual volumes using an average number of working days, 260 days. Because of the aggregate O/D matrix, all commodities were assigned simultaneously.

The model was not designed as a predictive model, so the demand factors for transportation of freight were not included, nor was a macroeconomic sub-model. The assignment results were compared to ground counts from the Highway Performance Monitoring System (HPMS), and within 15 % of actual ground counts for 81% of the estimated links.

3.2.12 Iowa Statewide Freight Forecasting Model (1998)

One of the more recent freight models was developed by Souleyrette and Preissig for the Iowa Department of Transportation in 1998 (*50*). The model class was a commodity-based, sequential network type developed for application at the state level. The primary network includes all of the interstate system, U.S., and state highways in Iowa. Beyond the borders of Iowa, the network in the model was reduced to include principal highways and interstates. The railroad network included all rail lines in Iowa and the major routes of the large Class I railroads outside of Iowa. The model includes two modes, truck and rail, and was designed to be a multicommodity model.

The commodity flow data for the model, TRANSEARCH, was purchased by the Iowa DOT from a private company, Reebie Associates. It consists of commodity flows by Standard Transportaion Commodity Classification (STCC) codes from Bureau of Economic Analysis zones (BEA) to BEA zones. It was determined that for the statewide model, the BEA level of detail was not sufficient. The TRANSEARCH data were disaggregated to a county level of detail for origin data by proportioning the total flow by the ratio of county level employment to BEA level employment. Destination data were disaggregated by proportioning the total flow by the ratio of county level measure of consumption to BEA level measure of consumption.

The model methodology took a layered approach (similar to Smadi) where freight flows for each commodity type were analyzed individually then the resulting network flows were layered to provide statewide flows of freight. The general model methodology can be summarized as follows (*51*, p. 19):

1) Identify commodity tonnage produced and attracted to each zone.
2) Construct multi-modal network representing all feasible routes for freight movements to, from, and within the state.
3) Assign freight flows to the network with the objective of minimizing total

logistics cost for each movement.

4) Calibrate and validate the resulting traffic assignment with other data sources.

Trip distribution was preformed using a gravity model. Costs were assigned to all links in the network including intermodal transfer points. It was assumed that shipments would move on the least cost path and would therefore perform modal choice based upon cost. In essence, the mode split and traffic assignment steps were combined into one step.

The demand for freight transportation was not explicitly modeled. There was a cost associated with transportation along links, but it was not dynamic. There was no macroeconomic sub-model associated with the model, the O/D data were accepted as given by the TRANSEARCH data.

Model validation was conducted by comparing the network flow to the original commodity O/D data. Validation was also done by comparing model output with the Iowa Truck Survey conducted by the Iowa DOT in 1989. The validation part of this model was a recommended improvement area for future research.

3.3 Summary

The characterization of the freight network models in this typology has revealed common and diametrical methodological approaches. This is a summary of the insights gained from the models developed in the last 20 years. Nine models presented approach freight modeling in the classic sequential form while two approached with an operations research type methodology. One model, AFNA, used a discrete stochastic simulation method. Many of the models that were developed in the early 1980s were for an application at the national level, while most of the models developed in the past decade were at the state level. A majority of the state level models aggregated commodities at the county (or equivalent) level. The typology indicates that the county level is the appropriate level for a statewide model.

Six of the models were developed explicitly for the rail and truck modes. The remaining five models were developed for the truck mode only. Interestingly, many of the models developed in the 1969-80 period were developed for the rail mode. All of the models in the typology were developed as multicommodity models. The models presented used a variety of data sources. Often, a model was required to fuse data from many different sources. Freight data were purchased from private suppliers, generated from survey results, or gathered from state or federal sources.

Trip generation in most the models was done almost exclusively using the O/D data (either collected or purchased). Two exceptions were the Indiana and Michigan models that developed their O/D table using trip generation rates derived from the 1993 CFS. Traffic distribution was done by some version of a gravity model in seven of the models. If a gravity model was not used, assignment was done directly from the O/D matrix or a detailed network was not used (i.e. flows could only travel between O/D on one route). If traffic assignment was done, it was done with either an all-or-nothing or an equilibrium assignment algorithm.

CHAPTER 4 - SELECTED FREIGHT DATA SOURCES

Historically, the primary impediment to the development of models for the freight transportation system has been access to robust, accurate data. Freight modelers have encountered this lack of data in almost every model developed, except in those countries where government controls the transportation system. The model developed in this research is also burdened by data issues. The proprietary nature of freight transportation inherently makes the collection of data on the movement of freight difficult. The sheer volume of freight being transported compounds this problem.

There are, however, a variety of data sources with varying degrees of coverage, accuracy, and completeness that can be used to characterize the transportation of freight. The development of the statewide model in this research required a number of databases related to freight transportation. The purpose of this chapter is to provide a succinct summary of each data source used in model and a brief description of how the data were used in the model. The list is not conclusive - there are many other sources of information that were not used in the model. The types of data sources used in the model include:

1) commodity flow data;
2) employment and economic data;
3) field surveys of freight transportation; and
4) vehicle fleet surveys.

At the conclusion of this chapter, Table 1 summarizes the sources of freight data described in this chapter.

4.1 Freight Data Sources

For the purposes of this chapter, freight data sources can be divided into two categories: 1) commodity flow; and 2) supplementary sources. The commodity flow category of sources provides detail on the inter-regional flow of commodities. The aggregation level of the data and the commodities covered varies widely. These sources typically include data on the type of commodity, the origin, the destination, the weight, and the value of the shipments. Generally, commodity flow data have problems with spatial aggregation because of confidentiality concerns. Most data have been aggregated to state, Bureau of Economic Analysis (BEA) zones, or National Transportation Analysis Regions (NTAR) (which are slightly larger than BEAs). Since BEA zones are discussed often in the research, the BEA zones for the United States are illustrated in Figure 2. The BEAs are centered around centers of economic activity. The spatial aggregation is intended to provide confidentiality constraints and limit the release of sensitive data for an individual shipper or carrier. In addition, some of the commodity flow data were designed for other uses that degrade their applicability and make them difficult to use.

In addition to data describing commodity flows, many other data sources can be used in freight modeling. These "supplementary" data sources include employment data, vehicle inventories, indicators of economic activity, traffic data, and industry directories. These data sources are readily available but suffer from many of the same spatial aggregation limitations. The following subsections describe each of the data sources used in the model. Each section contains a brief description of the data source and how it was used in the model.

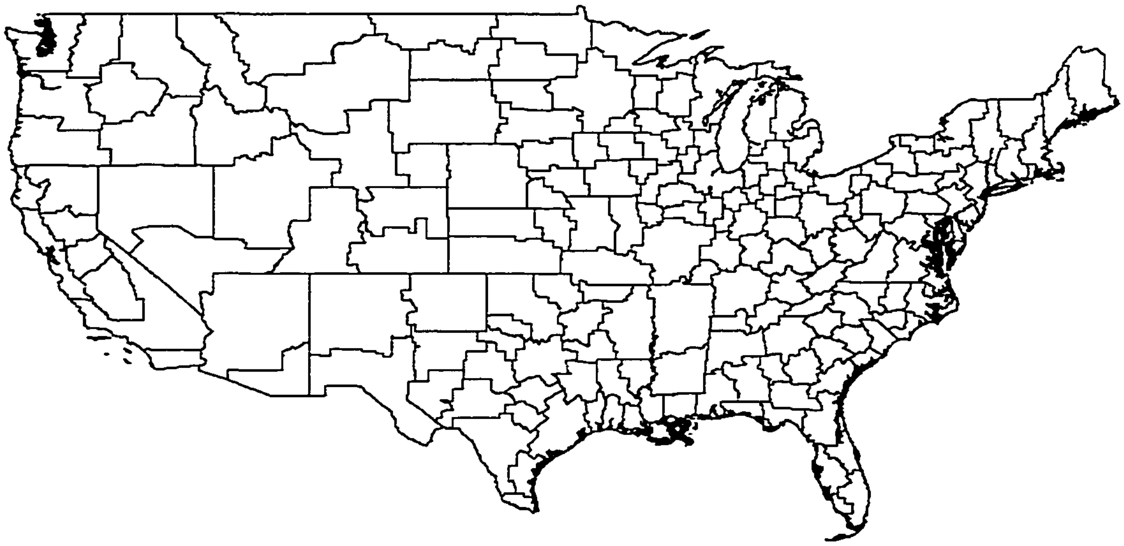


Figure 2 Bureau of Economic Analysis Zones

4.1.1 Reebie Associates TRANSEARCH Database (1992 & 1997 Forecast)

The TRANSEARCH database was developed and maintained by a private company, Reebie Associates. The TRANSEARCH database collects data from a variety of sources, synthesizes the data, and then analyzes the data to produce a comprehensive database of commodity movements in the United States. The database is for sale to trucking firms, rail companies, ship companies, and state agencies. The data used for the commodity flow were collected and synthesized from many data sources including the Census of Transportation, Department of Agriculture, Census of Manufacturing, Rail Carload Waybill sample, the U.S. Army Corps of Engineer's Waterborne Commerce data, and other sources. Reebie has produced the database annually since 1978 except for 1980.

The TRANSEARCH data set contains freight movements by rail, water, air, truck movements from manufacturing plants, truck movements of coal, and inland truck movements of imports. The data do not include shipments by pipeline, mail or small package shipments (except by rail), and secondary truck shipments involving warehouses. These data mainly are of manufactured goods, but does include movements of fresh produce. Other non-manufactured movements of agricultural products are not included.

For the previous statewide modeling effort, the Iowa DOT purchased data for the 1989 and 1992 years and forecasted data for 1997 and 2002. The 1992 TRANSEARCH includes data on the value of commodities shipped, all other years do not (the 1997 forecast was used in this model for commodity flows). The purchased TRANSEARCH data contains commodity flow information for all flows with an Iowa origin or destination and is aggregated to the BEA level (combinations of BEAs at further from Iowa). The data contains O/D state and BEA, 3-digit STCC code, value of freight, total tons, tons by mode.

The TRANSEARCH data set was the most important data source used in the model. The data set was the primary source of the commodity flow information. The TRANSEARCH data, however, were aggregated at the BEA level and were of insufficient detail for a state level planning model. With the use of the supplementary data sets, the TRANSEARCH data were disaggregated to the spatial level of the model.

4.1.2 Commodity Flow Survey

The Commodity Flow Survey (CFS) was conducted in 1993 and 1997 (*52*). The CFS was preceded by the Commodity Transportation Survey that was conducted every five years between 1963 and 1977. The CFS is conducted by the Census Bureau as part of the Census of Transportation and covers mining, manufacturing, wholesale trade and selected retail establishments. The commodity data are presented at the state-to-state level and are aggregated at the 2-digit Standard Commodity Transportation Group (SCTG) level. The SCTG was developed by the U.S. and Canadian governments and is based on the Harmonized System (HS)(*52*). The SCTG replaces the STCC coding used in the 1993 CFS.

The CFS contains data on shipments by domestic establishments in manufacturing, wholesale, mining, and selected other industries. The 1993 and 1997 CFS covered establishments in mining, manufacturing and wholesale trade, and selected retail and service industries. The survey also covered selected auxiliary establishments (e.g., warehouses) and retail companies. The survey coverage excluded establishments classified as farms, forestry, fisheries, oil and gas extraction, governments, construction, transportation, households, foreign establishments, and most establishments in retail and services.

The primary use of the CFS in this model was in the development of a bridge traffic sub-model for validation purposes. Bridge flow is freight that originates and terminates outside of Iowa but is transported on Iowa's transportation system (i.e. flows from Illinois to Nebraska on I-80). Since the TRANSEARCH data only contains flows with an Iowa origin or destination, the data did not contain any bridge flow. This bridge flow, however, is needed to validate the model. Therefore, the CFS was used to develop bridge commodity flows that were assigned to the network. Developing these bridge flows are discussed in detail in Chapter 7 on developing commodity flows.

4.1.3 Rail Waybill Data

The annual Rail Waybill sample contains shipment data from a stratified sample of rail waybills submitted by freight railroads to the Surface Transportation Board (STB), previously the Interstate Commerce Commission (ICC). The database has national coverage and is collected by the American Associations of Railroads (AAR) annually. The Rail Waybill sample contains public-use, non-confidential information (*53*).

The data contains origins and destination points, types of commodity, number of cars, tons, revenue, length of haul, participating railroads, and interchange locations. Movements are reported at the Bureau Economic Analysis (BEA)-to-BEA level (or multi-county BEA areas) and the 5-digit STCC level. The public-use version of the sample contains non-confidential data. For a particular commodity, the origin or destination BEA is not included unless there are at least three freight stations in the BEA and there are at least two more freight stations than railroads in the BEA. Each year contains greater than 350,000 records that are 249 characters long.

The Waybill data were used to develop the parameters for the conversion of tons of freight flow assigned to the network to a number of railcars. It was also used to determine which are the most common types of railcars used to transport commodities. These methods are discussed in detail in Chapter 9.

4.1.4 Iowa Truck Survey

The Iowa Truck Survey was conducted in 1991 by the Iowa DOT to supplement classification data for the state highway system (*54*). The survey was conducted at various locations around the state over a period of four months. The locations are shown in Figure 3. Locations were classified as either interstate and primary for both urban and rural. Motor carriers were stopped, surveyed, and weighed. Data on the configuration of the vehicle, axle weights, axle spacing, type of fuel used, STCC of the primary commodity carried, and the origin of the vehicle and the destination was collected. Approximately 15,000 vehicles were surveyed. The Iowa DOT has not performed an update of this survey.

The Iowa Truck Survey was a unique data source because it was an field survey of trucks in Iowa. The data were used in the process of selecting the most important commodity groups for the model. The survey was also used to generate the parameters that were used to convert tons assigned to the highway network to a number of trucks. Similar to the Waybill data, it was also used to determine the most common trailer type for each commodity group that was included in the model.

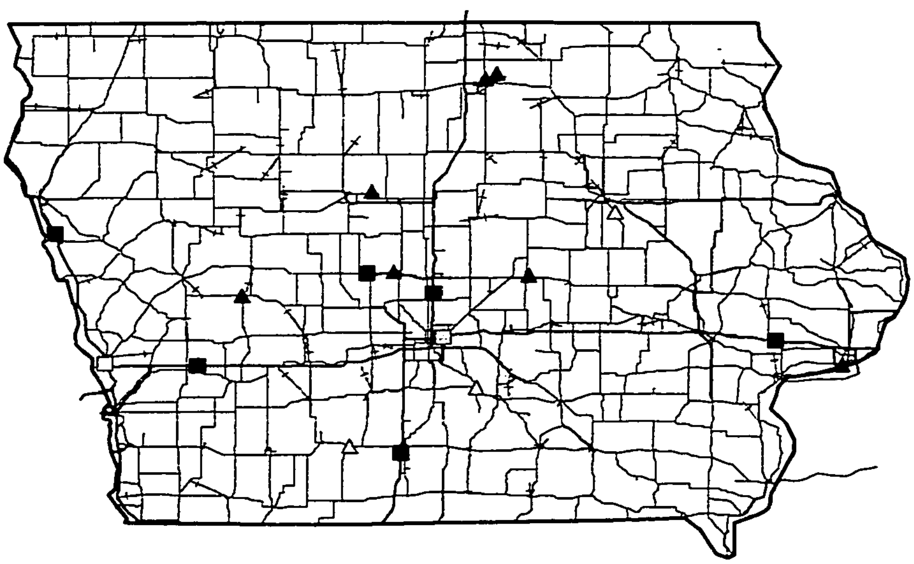


Figure 3 Locations of Iowa Truck Survey Locations

4.1.5 Motor Carrier Management Information System (MCMIS) Census File

The Motor Carrier Management Information System (MCMIS) is an inventory file of the safety performance of motor carriers and hazardous material shippers subject to Federal Motor Carrier Safety Regulations (FMCSR) or Hazardous Materials Regulations (HMR). The data file is maintained by the Federal Motor Carrier Safety Administration (FMCSA) and is continuously updated. Approximately 470,000 active motor carriers are in the database. Each record in the database contains data on the name, address, doing-business-as name, operation classification, ICC motor carrier number, USDOT motor carrier number, and type of business. The file also includes data on the type of cargo carried (including hazardous materials). Supplemental data on the number of trucks owned or leased, number of drivers, date of last safety inspection or review, accident rate, and safety rating of the carrier is also included.

The current version of the Census flat file was obtained from the Federal Motor Carrier Safety Administration (FMCSA) in late May 2000 (*55*). The flat Census file contains all active and inactive motor carriers subject to the federal regulations. The complete Census file contains well over 763,000 records in space-delimited text file format with a file size of 1,000,000 kilobytes (1 gigabyte). As part of the data collection effort the name and/or motor carrier number of the observed trucks was recorded. The MCMIS Census File was used to relate the names of observed carriers to a record of the actual carrier. In Chapter 9, data on each carrier were used to estimate the general types of cargo carried.

4.1.6 Vehicle Inventory Use and Survey (VIUS)

The purpose of the Vehicle Inventory Use and Survey (VIUS), formerly the Truck Inventory and Use Survey (TIUS), was to measure the physical and operational characteristics of the nation's trucking fleet (*56*). The TIUS was first conducted in 1963 and has been conducted every 5 years since, for years ending in "2" and "7." The VIUS covers trucks, vans, and truck-tractors that are registered with motor vehicle departments in the 50 states and the District of Columbia. Government fleet and off-road vehicles are excluded. There are some 60 million private and commercial trucks registered in the U.S. The VIUS contains information on physical characteristics includes date of purchase, empty weight, average and maximum loaded weight, number of axles, overall length, type of engine, and body type. Operational data including the predominant type of use, lease characteristics, operator classification, base of operation, gas mileage, annual and lifetime miles driven, weeks operated, commodities hauled by type is also included.

The VIUS microdata are available from the Census for further analysis. The VIUS data were used to supplement the Iowa Truck Survey in determining the average cargo weight for various truck configurations.

4.1.7 Benchmark Input-Output Accounts of the U.S.

The Benchmark Input-Output (I/O) Accounts are based primarily on data collected from the economic censuses conducted every 5 years by the Bureau of the Census (*57*). The I/O accounts are used to understand how different sectors of the economy interrelate. The Input/Output accounts provide data on the level of production of goods and services by industry sector, the use of commodities by each industry, the commodity composition of gross domestic product (GDP), and the industry distribution of value added. These accounts also provide information on the consumption of specified commodities.

The I/O accounts were used to estimate which sectors were consumers of the commodity groups that were included in the model. Disaggregation measures for the TRANSEARCH data were developed with this information.

4.1.8 Iowa Department of Workforce Development Employment Data

The Iowa Department of Workforce Development (Iowa DWD) maintains employment records for the State of Iowa. The data, obtained under confidentially agreements for another Iowa State University research project, identified (for each employer) the address, SIC code and number of employees. Accurate data were available for all SIC codes for all counties in the state. These employment data were to select the modeled commodities and to develop the disaggregation measures for the TRANSEARCH data.

4.1.9 Transportation Technical Services Bluebook

The Transportation Technical Services (TTS) Bluebook is a private publication that contains operational and financial characteristics of a sample of motor carriers in the United States (*58*). The majority of data in the Bluebook is extracted from annual reports that motor carriers file with the USDOT. The data supplied in the TTS Bluebook includes data on the motor carrier name, USDOT motor carrier number, the address of the carrier, the general type of carrier, detailed financial data (gross revenue, taxes, salary, wages), type of cargo carried, revenue per ton-mile, average loads, average shipments length, number of tractors, number of trailers and other data. The TTS data were used to determine the link costs for highway trucks based on revenue per ton-mile in each general category of cargo.

4.2 Summary

The data sources included in this chapter were used in the model. For the most part, the data sources were compatible with slight modifications or assumptions. In some cases, a cross-reference table had to be developed to use the data sources. The following chapter discusses the development of the multimodal network, using many of the data sources described in this chapter.

Table 1 Freight Data Sources

Database	Sponsor	Coverage of Data	Level of Aggregation	Spatial Aggregation	Years Available	Use in Model
Transearch Database	Reebie Associates	*Multimodal.* Origins and destination state and BEA, volume of freight by mode. Only commodities with origins or destinations in Iowa as used in the model.	3-digit STCC	BEA-to-BEA. Other aggregations available.	Annually: 1989 and 1992 data available for model	Selecting commodity groups for model, Development of commodity flows, calibration of mode split
Commodity Flow Survey	USDOT, U.S. Census	*Multimodal.* Mining, manufacturing, wholesale trade and selected retail establishments. Excludes farms, forestry, fisheries, oil and gas extraction, governments, construction, transportation, households, foreign establishments	2-digit STCC (1993) 2-digit SCTG (1997)	State-to-state.	1993, 1997, and every 5 years. Future updates in discussion.	Development of bridge traffic flows
Rail Waybill Data	FRA, STB, AAR	*Rail.* Origins and destination points, types of commodity, number of cars, tons, revenue, length of haul, participating railroads, and interchange locations	5-digit STCC	BEA-to-BEA	Annually, but sample size changes	Conversion of tons to railcars, selecting compatible car types for each STCC
Vehicle Inventory and Use Survey	U.S. Census	*Truck.* Vehicle characteristics such as loaded weight, number of axles, overall length, type of engine, and body type. Operational data such as the type of use and the commodities hauled by type.	Truck type	State	TIUS - 1963, 1967, and every 5 yrs. VIUS - 1997	Conversion of tons to trucks – estimating empty weights
Benchmark Input-Output Accounts of the U.S.	U.S. Census	*N/A.* Contains the make, use, direct requirements coefficients; industry-by-commodity total requirements, and commodity-by-commodity total requirements tables; estimates of commodity transportation costs and wholesale and retail trade margins	2-digit SIC 6-digit SIC	National	1982, 1992 updated in 1996	Selecting appropriate indicators for disaggregation purposes

Table 1 Freight Data Sources (Continued)

Database	Sponsor	Coverage of Data	Level of Aggregation	Spatial Aggregation	Years Available	Use in Model
TTS Trucking Data	TTS Trucking Services	*Truck.* Motor carrier name, USDOT motor carrier number, address of the carrier, general type of carrier, detailed financial data (gross revenue, taxes, salary, wages), type of cargo carried, revenue per ton-mile, average loads, average shipments length, number of tractors, number of trailers	Selected motor carriers in the U.S.	National	Annually, private data source	Estimating trucking costs on ton-mile basis. Verification of typical truck loads.
Iowa Truck Survey	Iowa DOT	*Truck.* Configuration of the vehicle, axle weights, axle spacing, type of fuel used, STCC of the primary commodity carried, and the origin of the vehicle and the destination	10 survey location in Iowa	Iowa (Statewide)	Last updated in 1991, no further updates planned	Selecting top commodity groups for model. Conversion of tons to vehicles, Selecting most common truck type for each STCC.
MCMIS Motor Carrier Database	FMCSA	*Truck.* Name, address, doing-business-as name, operation classification, ICC motor carrier number, USDOT motor carrier number, and type of business, type of cargo carried, hazardous materials.	All registered motor carriers in the U.S.. Broad classifications of products carried.	Actual address	Continuous updates. Used April 2000 data.	Estimating commodity of carriers observed in field survey
Employment Database	Iowa DWD	*Employment.* Employer site address, SIC code, ownership, tax ID number, Iowa employment social security number. Data restricted by confidentiality agreement.	SIC	Iowa - Individual employer address	Continuous updates. Used 1991 data.	Selecting commodity groups for model, Indicator variables for disaggregation

CHAPTER 5 - MULTIMODAL NETWORK DEVELOPMENT

The mulitimodal network created for this model was developed in a Geographic Information System (GIS), then exported in a format for a standard travel demand package. The network is a link-node type that represented highways, railways, interconnections between railroads, and intermodal transfer facilities between rail and truck. Within the borders of the State of Iowa, the network contained all interstate and primary highways as well as all branch and main rail lines. Outside Iowa, the highway network was less detailed and included mostly interstate highways. The rail network was also modified to include only major rail lines. The complete network is shown in Figure 7 at the end of this chapter. In addition, a modified network was created for a separate model of external-to-external flows.

The use of GIS-based network has many advantages, particularly in the modification and analysis of the network and the model results. The GIS allows for a variety of such as the type of facility, number of lanes or tracks, average travel speed, existing traffic flow, and segment length to be stored in a spatial environment.

Much of the development of the network, which was complete, was done by earlier researchers (*7*). In this version, changes were made to the network to reflect the new model methodology, including the development of specific link costs by commodity group and facility type. This chapter documents the modifications made to the developed network to accommodate new model methodology, the development of link costs for each commodity group and link type, and the method for checking the network for errors.

5.1 Commodity Analysis Zones

The spatial detail of the network was dictated by the travel demand modeling package. As in any conventional transportation planning model, the first step was to define the spatial analysis zones for the model. These transportation analysis zones (TAZ) are the smallest spatial areas that have similar transportation, employment, production, and consumption characteristics. For convention, in this statewide freight model the TAZ were called commodity analysis zones (CAZ).

In addition to the constraints of the travel demand software, the CAZs had to be selected for a spatial size where commodity data were available. For this model, the Reebie TRANSEARCH data were used as the primary source of commodity data. The geographical structure of the TRANSEARCH data corresponded to the BEA structure developed by the U.S. Census Bureau. The CAZ directly correspond to TRANSEARCH. At the furthest distances from Iowa, the CAZ are aggregations of multiple BEAs. Closer to the state, individual BEAs were assigned individual CAZ. Within Iowa, the state was divided into six BEAs resulting in insufficient detail to model freight flows on a statewide level. Instead, counties in Iowa were used as CAZs (there are 99 counties in Iowa). Counties were ideal choices for CAZ because they would allow for sufficient modeling detail and much of the supplementary freight data that were available were aggregated to the county level. In Chapter 6, the process of disaggregating the TRANSEARCH from the six BEAs to the 99 CAZ are described.

The final CAZ structure is 144 analysis zones; which are the 99 counties in Iowa and aggregations of BEA regions outside of Iowa. The CAZ are shown in Figure 4. Centroid nodes, which are required elements of the travel demand software, are included in each analysis zone. The centroid nodes are placed near the economic center of activity of each of the zones. For most of the CAZs in Iowa, the node was placed at the geographical center. Larger BEAs required some analysis for the placement of the centroid nodes. Centroid connectors connect the centroids to the rail and highway networks. Centroid nodes are shown by the orange diamonds in Figure 7.

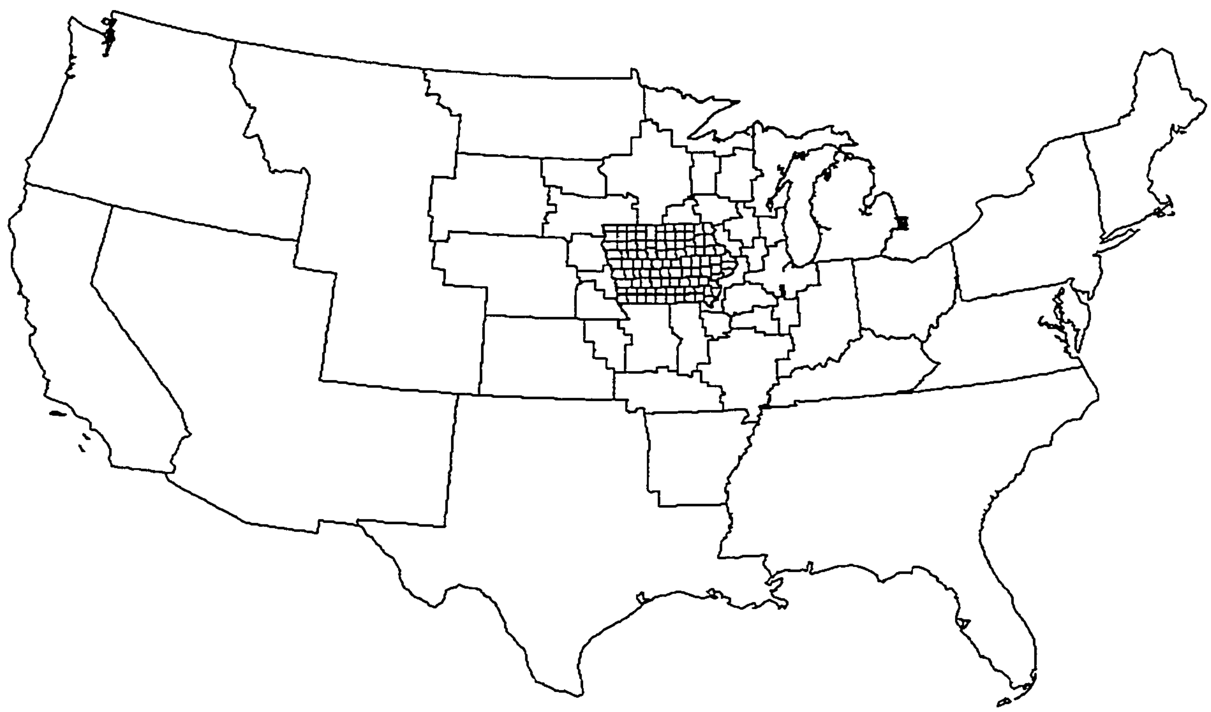


Figure 4 Commodity Analysis Zones

5.2 Rail Network

The rail network was composed of every operating rail line inside Iowa. Outside of Iowa, the network was reduced to the main lines of major Class I carriers. The rail network is privately owned – meaning that the Iowa DOT has less control of infrastructure and service improvements that could result from changes in policy. The Iowa DOT does, however, administer grant and loan programs for the purposes of upgrading rail infrastructure, primarily on the branch line system. The prioritization of these programs is made by the Iowa DOT. These programs are described in Chapter 2.

The rail network was developed from the USDOT North American Transportation Atlas Database (NTAD) GIS coverage and verified by the Iowa DOT's rail service map. The network consisted of 65,600 total rail miles. (4,000 miles were inside Iowa). For purposes of the transportation planning model, rail links were coded to five types:

1) main-line rail (link group 3);
2) regional or short line (link group 4);
3) rail centroid connectors in and near Iowa (link group 5);
4) rail centroid connectors at greater distance from Iowa (link group 6); and
5) interline transfers between railroads (link group 7).

The network was coded with main and regional/short lines because of the different operating characteristics of the two types. Rail lines are shown by the blue hatched lines in Figure 7. The final link type was the interconnection between railroads. This link was used to add additional impedance for interlining freight between railroads. Interline connections are shown by the blue circles in Figure 7.

Unlike highways, the rail network does not have unlimited access to every destination in each CAZ. For this reason, the rail centroid connector represented access to the rail network for each CAZ. The cost assigned to the rail centroid links was essentially an impedance penalty to reflect the additional costs associated with transporting the rail shipment from the terminal to the final destination. Each CAZ was examined to determine the opportunity for access to the rail network. If no rail access existed in the CAZ, no connection was made to the rail network with a centroid connector. Furthermore, during calibration (described in Chapter 10), the need to distinguish between types of rail centroid connectors by geographical area was discovered. This resulted in two types of centroids, those in Iowa and adjacent states CAZ (link group 5) and the rest of the CAZ (link group 6). Rail centroids connectors are shown by the green hatched lines in Figure 7 (costs for these link groups are developed in Chapter 10 on calibration).

In the previous model, both the interline and centroid connector impedance was accomplished by using a turn penalty methodology in the travel demand model. This required a separate file with from-through-to node coding. The use of the links as impedance reduced the coding effort.

The link costs for the model network were developed for the main and interline link types. The summary of rail costs by link type is shown in Table 2. All railroads are required to publish a public rate tariff for various commodities. To estimate the ton-mile costs for the commodities selected in the model, public carload rate tariffs were obtained by STCC for city

Table 2 Rail Link Costs by Commodity

STCC	Commodity Description	Rail - Main Link Group 3 ($/ton-mile)	Rail - Other Link Group 4 ($/ton-mile)	Interline Link Group 7 ($/ton-mile)
11	Field Crops	0.02	0.03	3
112	Bituminous coal or lignite	0.01	0.01	3
201	Meat or poultry, fresh or chill	0.05	0.04	3
202	Dairy products	0.03	0.04	3
204	Grain mill products	0.03	0.07	3
209	Misc food preparations	0.03	0.03	3
262	Paper	0.03	0.03	3
281	Industrial chemicals	0.02	0.04	3
287	Agricultural chemicals	0.02	0.04	3
291	Products of petroleum refining	0.02	0.04	3
324	Cement, hydraulic	0.03	0.03	3
331	Steel mill products	0.02	0.02	3
352	Farm and garden machinery	0.07	0.09	3
371	Motor vehicles and equipment	0.10	0.11	3
	Average cost	0.03	0.04	3

Source: Published 2000 Public Rate Tariffs of the Union Pacific, Burlington Northern Santa Fe, I&M Rail Link, Cedar Rapids and Iowa City Railroad

pairs that were more that 1,000 miles apart with one terminal in Iowa. Using the carload published tariff, the estimated average weight per railcar (developed in Chapter 9), and the distance between city pairs in the published tariff, an average cost per ton-mile was developed for each commodity group. When the rate tariffs were available, a sample of 2-3 city pairs for each commodity group was obtained from the Burlington Northern Santa Fe, the Union Pacific, I&M Rail Link, Cedar Rapids and Iowa City Railroad. If no rate tariff was available for the commodity groups, then an estimate was made based on the cost of a commodity group with similar transportation requirements. The public rate tariffs do not reflect rates that could be obtained through shipper contracts. These contracts are common between shippers and railroads, but are not public knowledge. While the contract rates would be lower than the published rates, the use of the public tariff rates in a state-level planning model was appropriate.

The costs for rail centroid connectors were developed in the calibration of the model. Each centroid is the connection from the CAZ centroid node to the rail network. The model distance for every connector was one mile, so the cost was adjusted until the modeled mode spilt was close to the actual mode split in the TRANSEARCH. This was accomplished by adjusting the ton-mile cost on the rail centroids.

Interline links were included to model the transfer of carload freight from one carrier to the next. The inclusion of an interline link reflects that railroads prefer to keep traffic on their own line, thereby increasing revenue. If two equal routes were available, but one requires a transfer to another carrier, the inclusion of the interline costs ensures that the least cost path will be on the same carrier. The cost to transfer cars between railroads was developed from the published interline rates from the I&M Rail Link, Cedar Rapids and Iowa City Railroad, and Iowa Interstate Railroad. The rates were published for the carload transfer. Assuming an average carload weight of 72 tons and a $300 per car charge, the average cost for transferring cars between carriers was estimated at $4 per ton-mile. This cost may be high for more efficient transfer points but is representative for most of the interline points in Iowa.

5.3 Highway Network

The highway network is a combination of the State of Iowa primary system and a simplified national highway network. The network consisted of approximately 40,000 miles outside of Iowa and 10,000 miles inside Iowa. The state owned facilities are of primary interest in the planning model, since state level policy decisions are made that affect these facilities. In addition, these higher standard facilities carry the majority of truck traffic in the state. The Commercial and Industrial Network (CIN), designated by the Iowa DOT as the facilities that are of primary importance were included in the network and discussed in Chapter 2.

As distance increases from the state, a detailed network becomes less important for an accurate analysis of truck flows inside Iowa. In adjacent states, major facilities such as interstates and principal state routes were sufficient. At the Iowa border, connections from the Iowa network to the adjacent national network only loosely followed the actual alignment of the roads, however, were sufficient for modeling purposes. At greater distances from the state border, the network is reduced to interstate facilities since it was assumed that long distance truck trips would be completed on these high-speed, access controlled facilities.

For purposes of the transportation planning model, the highway network links were classified into two types:

1) two-lane highways (link group 1); and
2) four-lane highways (link group 2).

Highway centroid connectors, since they have no different properties in a modeling function than the two-lane highway were not assigned their own link-type. Trucks have unlimited access to any destination in each CAZ which precluded the need to develop an impedance link similar to the rail network to represent the end handling of shipments. The highway network is shown in Figure 7. The double line indicates 4-lane facilities and the single line represents 2-lane facilities.

Link costs for both 2-lane and 4-lane facilities were developed. The principal source for estimating the link costs for each commodity group was the Transportation Technical Service (TTS) Bluebook data. The TTS database contains information on revenue earned per ton mile for 21 types of specialized commodities carried by trucks (only 15 categories were applicable to this model). Nearly 15,000 records were used to estimate the average revenue per ton-mile for each of the specialized categories. To estimate the appropriate ton-mile cost for each of the commodity groups that were in the model, judgment was used to select the TTS groups that best represented the transportation requirements of the commodity group. This cost was assigned to the cost per ton-mile on the four-lane facility.

An adjustment to the ton-mile costs was made to account for the speed differential between two-lane and four-lane facilities. The average speed on the facilities was assumed to be 45 mph for 2-lane and 65 mph for 4-lane facilities. This increase in ton-mile costs was essentially a speed penalty (or impedance) to reflect the preference of longer distance trips to the use of four lane facilities.

The ton-mile costs shown in Table 3 reflect both the special requirements of some commodities and lower loads. For example, the farm and garden machinery has a lower cargo-load weight because the trailer reaches its carrying capacity before it reaches its weight capacity. The majority of costs are still incurred for the transportation, which results in the ton-mile cost being higher for the transportation of farm and garden machinery.

5.4 Intermodal Connections

Intermodal connections are locations where transfers can be made between modes and occur at specific interchanges designed to efficiently transfer freight between the modes. In this model, only truck - rail transfer locations are considered. Physical locations of intermodal connections were gathered from the Bureau of Transportation Statistics' National Transportation Atlas Data and added to the network by previous researchers. The researchers selected all intermodal transfer points in Iowa and one transfer facility per CAZ for each of the major rail operators in Iowa. The locations of the intermodal transfer facilities are shown by the red squares in Figure 7.

Like the interline and centroid connectors, the intermodal links are impedance links that reflect the additional cost of transferring the shipment between modes. These costs were determined by analyzing the published carload tariffs of the Class I carriers that operate in Iowa. Only Class I tariffs were examined, since most of the large intermodal terminals and transfer locations are operated by them. The carload rates and length of haul were plotted and are shown in Figure 5. The figure shows all carload costs for all commodity groups. A best-fit line was fitted to the data and is shown on the figure. The zero distance cost, $2,594, can be interpreted as the fixed cost for a rail shipment (loading, unloading, transferring). By dividing the average load per railcar (72 tons), the cost on a ton-mile basis was determined at $36 (all

Table 3 Highway Link Costs by Commodity Group

STCC	Commodity Description	4-lane (Link Group 1) ($/ton-mile)	2-lane (Link Group 2) ($/ton-mile)
11	Field Crops	0.07	0.09
112	Bituminous coal or lignite	0.10	0.13
201	Meat or poultry, fresh or chill	0.12	0.16
202	Dairy products	0.08	0.11
204	Grain mill products	0.12	0.16
209	Misc food preparations	0.12	0.16
262	Paper	0.20	0.27
281	Industrial chemicals	0.12	0.16
287	Agricultural chemicals	0.12	0.16
291	Products of petroleum refining	0.12	0.16
324	Cement, hydraulic	0.10	0.13
331	Steel mill products	0.20	0.27
352	Farm and garden machinery	0.20	0.27
371	Motor vehicles and equipment	0.55	0.73
	Average	0.15	0.20

Source: TTS Bluebook Data - Revenue per ton-mile

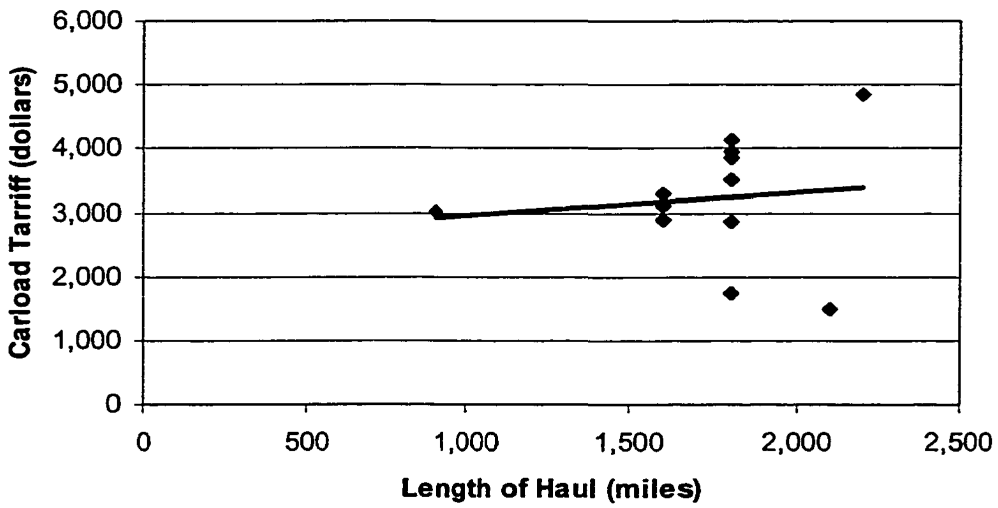


Figure 5 Carload Tariff Rates by Commodity

intermodal connections were one mile in length in the model). For the model, a cost of $40 per ton-mile was assigned as the transfer penalty to move from one mode to the other.

5.5 Error Checking

In link-node networks, problems often occur with network continuity because of coding errors. Multiple techniques were used to check network for connectivity and coding errors. First, the network was verified using existing maps – a few highway and rail links were missing from the original network and added. For the most part, the existing network developed by the previous researchers was accurate. Next, the network was exported from the GIS software and viewed in the travel demand software's network viewer. This step verified that the network in the GIS was exported correctly to the travel demand network format. Finally, the network was checked for connectivity. Random origins and destinations were input and the least cost path in the network was traced. In addition, loaded networks were analyzed in the GIS environment to detect any unusual loaded links. Again, several errors were discovered and corrected.

5.6 Network and Commodity Analysis Zones for Bridge Traffic Model

TRANSEARCH data (as purchased by the Iowa DOT) only include commodity flows with either an Iowa origin or destination. Flows with out origins or destination in Iowa that travel thought Iowa are clearly important. To address this issue, a separate model was created for external-to-external flows (bridge traffic model). The first step in this bridge traffic model was to modify the network in the base model for the bridge traffic model.

Bridge traffic was modeled using the 1997 CFS which contains state-to-state flows. The process of extracting the data for the model from the 1997 CFS is described in Chapter 6. The existing CAZ structure was modified to be states. On the two coasts, states were grouped together to form CAZ. The modified CAZ structure is shown in Figure 6.

The existing network was also modified for the bridge traffic model to match the modified CAZ structure. The network was modified such that each CAZ had only one centroid. All other centroid connectors were removed from the network and centroids were renumbered. The bridge traffic model had 23 CAZ. The centroids for the bridge traffic model were placed near the population center of each new CAZ.

The average cost per ton-mile for the selected commodity groups in the base model was used for the rail and highway link costs. Mode split was not required for the bridge traffic, so centroid and link costs were set according to the mode being assigned to the

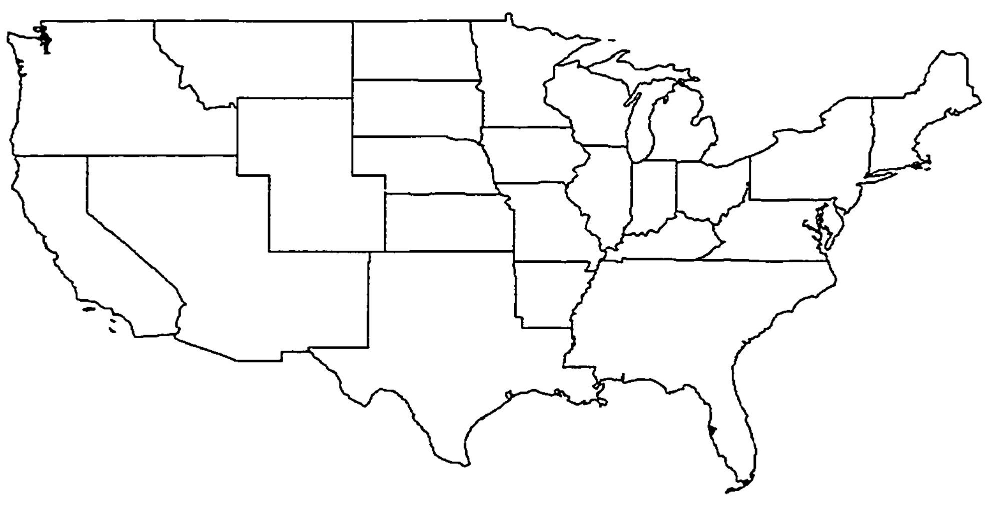


Figure 6 CAZ for CFS Bridge Traffic Analysis

network. For example, when assigning the truck flows to the network, all rail links were assigned a prohibitively high cost per ton-mile. This forced all of the flows on the highway network when assigning by the shortest path. The development of the commodity flows that are assigned to the bridge model network is described in Chapter 6 and the actual assignment is documented in Chapter 7.

5.7 Summary

This chapter summarized the development of the multimodal network. While much of the network was already developed by previous research, some important modifications were made to the network. The use of "turn penalties" to add impedance for the rail centroid, interline and intermodal transfer locations was eliminated and separate categories of link types were used instead. Costs were developed for each commodity group on highway and rail links. Common costs were developed for interline links and intermodal transfer locations. Costs for rail centroid connectors, links that represent the end cost of rail shipments, were developed in the calibration chapter of this model. The next chapter describes the development of the commodity flows that were assigned to the network developed in this chapter.

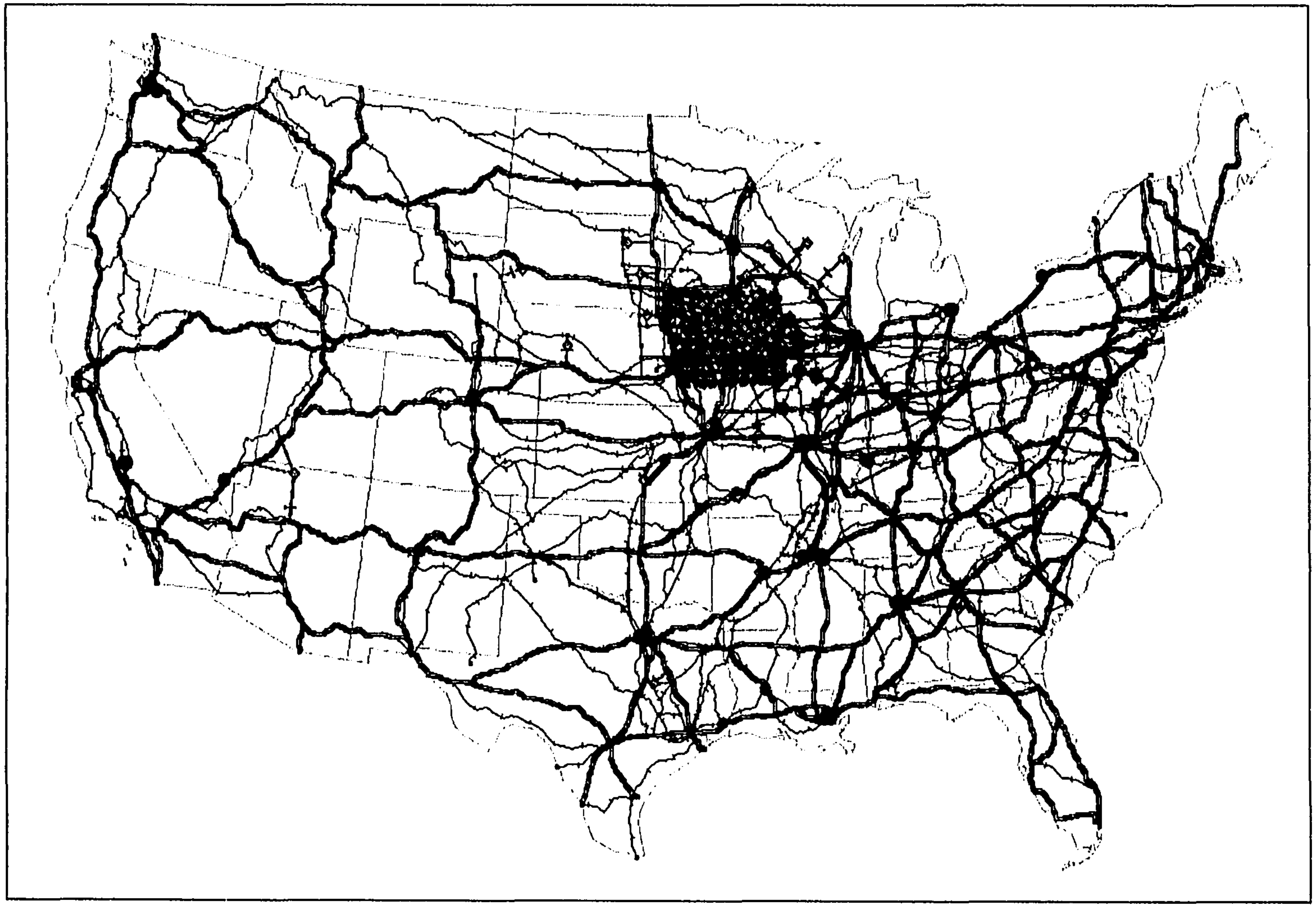


Figure 7 Multimodal Network

CHAPTER 6 - DEVELOPMENT OF COMMODITY FLOWS

Three methods have been used in previous research to develop commodity flow patterns as the primary input for freight generation in freight models:

1) conduct an extensive O/D survey which is extrapolated to a larger O/D destination matrix;
2) use available commodity flow data directly or with some modification; and
3) develop productions and attraction rates based on indicator variables of employment, population, or other related data in the classical trip generation step in the four-step approach.

The method chosen for this research used existing data, the Reebie TRANSEARCH database, as the primary source of commodity flows. The method was chosen because the TRANSEARCH was readily available (purchased by the Iowa DOT) and the existing model structure was developed with this approach. The model used the 1997 forecasted data to develop the commodity flows.

This chapter is a summary of the methods used to develop the commodity flows used as input to the model. The chapter describes the commodity flow data used in the model, the selection of the major commodity groups, the method used to disaggregate the selected commodity data, and the method used to develop the external-to-external flows (bridge traffic).

6.1 Commodity Flow Data

The Reebie TRANSEARCH data, as purchased by the Iowa DOT, was not sufficient to be applied directly in the state-level model. To be used in the model, the BEA-to-BEA flows had to be disaggregated to the county-to-county level in Iowa and the county-to-BEA level for flows with external origins or destinations. In addition, since the TRANSEARCH only includes flows with an Iowa component, an overlay of bridge flows (flows that pass through Iowa) was generated from the 1997 CFS as part of the validation process.

6.2 Selection of Commodity Groups

As a layered model, an important step in the modeling procedure was to determine which commodity groups would be included in the model. In theory, the model could include all commodities in the Reebie TRANSEARCH database but the amount of work to develop, disaggregate, and calibrate a great number of commodity groups precluded the inclusion of more than twenty commodity groups. In considering which commodities to include in the model four factors were considered:

1) the total tons of the commodity group;
2) the total value of the commodity group;
3) the total employment in the commodity group sector; and
4) the ability of Iowa-level policy to affect the transportation requirements of commodity group.

Three primary data sources were used to evaluate the commodity groups using the above criteria:

1) the 1992 Reebie TRANSEARCH Database;

2) the 1995 Iowa Department of Workforce Development (DWD) employment data;

3) the 1991 Iowa Truck Weight Survey.

The method used to select the commodity groups was a heuristic procedure. Three separate selections of the commodity groups were made by:

1) the 20 highest commodity groups by average rank of weight and value;

2) the commodity groups that had a rank in the top 10 of weight, value, or employment in their production sector; and

3) the 20 most frequent observations in the 1991 Iowa Truck Survey.

The commodity groups identified by these three methods were compared and analyzed, after which a selection of 15 commodity groups was made. Figure 8 shows a schematic of the process.

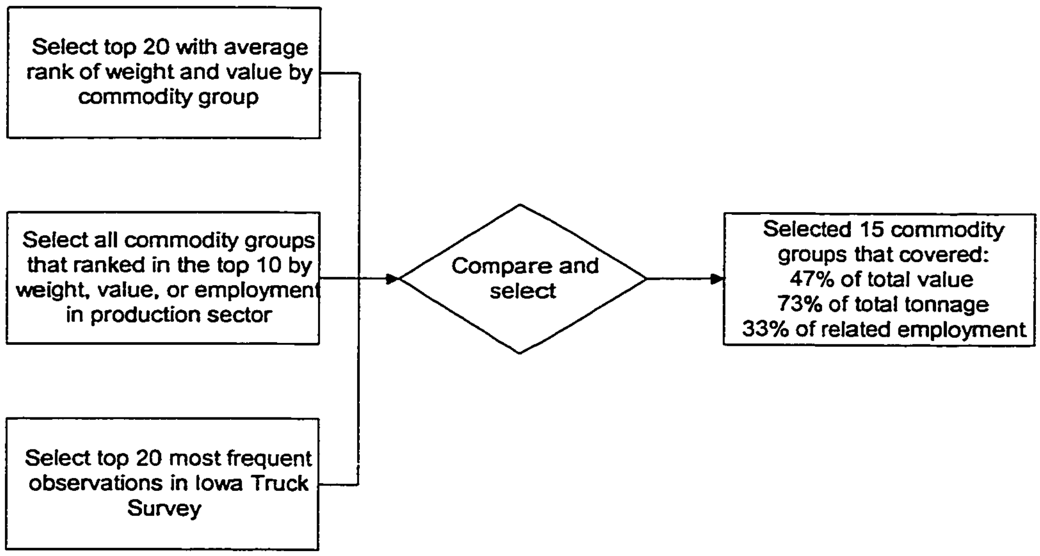


Figure 8 Selection Process for Commodities

6.2.1 Average Rank of Weight and Value

When the Iowa DOT purchased the TRANSEARCH, the 1992 set was the only set that contained data on the value of the commodity. For this reason, the 1992 data were used in the selection of commodity groups even though the 1997 data were used in the model. TRANSEARCH were analyzed to determine the rank of each 3-digit STCC commodity group in terms of total value and tons (1 is the highest rank). All reported O/D pairs of the STCC were used. After the rank of each commodity group was determined, the top 20 commodity groups with the highest average rank were selected. The results of this procedure are shown in Table 4.

6.2.2 Commodity Groups in the Top 10 of Weight, Value, or Employment

Any commodity group that ranked in the top 10 by weight, value, or employment in the production sector was selected. The rank by STCC commodity group was determined in the previous selection. The employment rank was developed by ranking the employment data provided by the Iowa DWD. A cross-reference was developed to relate SIC sector to 3-digit STCC commodity group. Only SIC sectors that related to an STCC in the TRANSEARCH were included in the ranking. The total employment in Iowa, around 1.8 million, includes service, health, education and many other non-manufacturing related sectors that do not have a corresponding STCC sector that was in the TRANSEARCH. (i.e. one of the largest employment sectors in the state, elementary and secondary schools, was not included in the ranking because there is no corresponding STCC in the TRANSEARCH). Coincidentally, this list contained 19 commodity groups. The results of this procedure are shown in Table 5.

Table 4 Commodity Groups with Highest Average Rank of Value and Weight

Sorted in ascending order by average rank

		Rank by			Total	
					Value	Weight
STCC	Commodity Description	Average	Value	Weight	(million $)	(1,000 tons)
204	Grain mill products	2.0	2	2	6,189	19,248
11	Field Crops	3.0	5	1	2,988	28,399
201	Meat or poultry, fresh or chill	3.5	1	6	10,801	6,303
209	Misc. food preparations	6.5	8	5	2,418	13,091
281	Industrial chemicals	10.5	14	7	1,630	4,840
371	Motor vehicles and equipment	10.5	3	18	3,988	929
202	Dairy products	11.0	11	11	1,968	2,082
307	Miscellaneous plastics products	13.0	6	20	2,799	906
461	FAK shipments	15.5	4	27	3,704	606
287	Agricultural chemicals	16.0	24	8	887	3,937
262	Paper	17.5	21	14	1,002	1,049
327	Concrete, gypsum, and plaster	18.5	33	4	668	15,635
363	Household appliances	20.5	13	28	1,632	583
208	Beverages or flavor extracts	20.5	28	13	744	1,294
352	Farm and garden machinery	21.5	10	33	2,328	503
203	Canned or preserved food	22.0	22	22	911	835
112	Bituminous coal or lignite	23.0	43	3	435	16,744
335	Nonferrous metal basic shapes	23.5	16	31	1,435	549
265	Paperboard containers and boxes	23.5	26	21	803	904
282	Plastics and synthetics fibres	23.5	23	24	890	693
	Commodity Group Subtotal:				48,220	120,130
	All Commodity Groups Total:				81,737	142,976
	Percent of Total:				59%	83%

Table 5 Commodity Group with Rank in Top 10 of Value, Weight, or Employment

Sorted in ascending order by STCC

		Rank			Total		
STCC	Commodity Description	Value	Weight	Employ-ment	Value (million $)	Weight (1,000 tons)	Employees
11	Field Crops	5	1	77	2,988	28,399	610
112	Bituminous coal or lignite	43	3	127	435	16,745	1
201	Meat or poultry, fresh or chill	1	6	1	10,801	6,303	44,929
204	Grain mill products	2	2	5	6,189	19,248	16,532
209	Misc. food preparations	8	5	49	2,418	13,091	1,837
243	Millwork or prefab wood products	40	51	9	467	221	10,856
271	Newspapers	52	56	8	375	132	11,500
281	Industrial chemicals	14	7	89	1,630	4,840	274
287	Agricultural chemicals	24	8	31	887	3,937	2,933
291	Products of petroleum refining	41	10	119	453	2,549	6
307	Miscellaneous plastics products	6	20	-	2,799	906	-
324	Cement, hydraulic	70	9	65	183	3,056	1,002
327	Concrete, gypsum, & plaster products	33	4	13	668	15,635	5,949
352	Farm and garden machinery	10	33	3	2,328	503	26,185
353	Construction & related machinery	9	41	7	2,362	344	11,831
363	Household appliances	13	28	10	1,632	583	9,848
371	Motor vehicles and equipment	3	18	4	3,988	929	19,687
431	Mail or express traffic	7	91	-	2,511	23	-
461	FAK shipments	4	27	-	3,704	607	-
	Commodity Group Subtotal:				46,818	119,051	74,502
	All Commodity Groups Total:				81,737	142,976	373,190
	Percent of Total:				58%	83%	22%

6.2.3 Most Frequent Observations in the Iowa Truck Survey

The Iowa Truck Survey was an actual field survey of the truck traffic on Iowa highways. The first two selection methods used the same data set, therefore the use of the Iowa Truck Survey served as an independent verification of the selected commodity groups. The survey was analyzed to determine the 20 most common commodity groups, which are presented in Table 6.

6.2.4 Final Selection of Commodity Groups

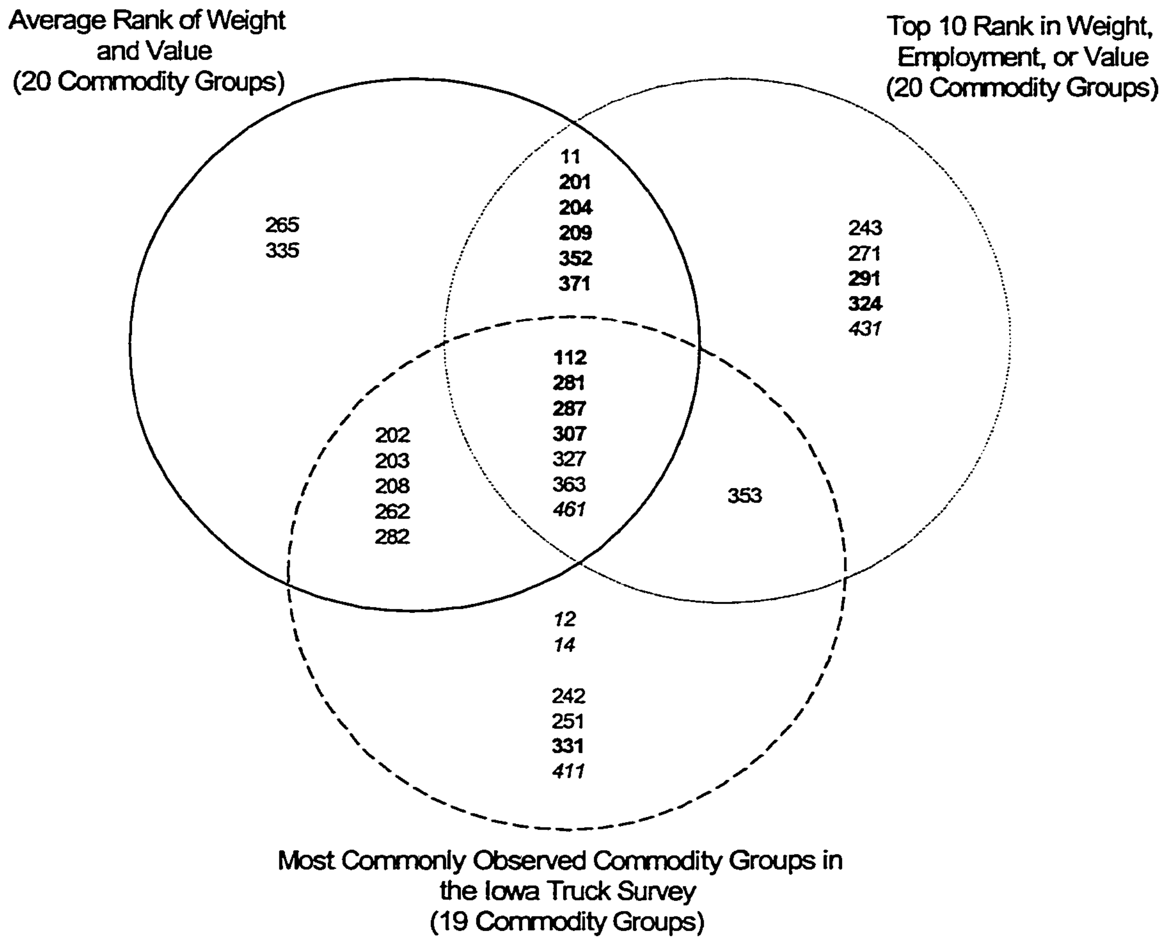
The process used to select the final commodity groups was based on the data, and a significant component of judgment to select the 15 commodity groups. Figure 9 visually shows the STCC of commodity groups selected by each criteria in a union graph. The commodity groups selected for the model are shown in bold and those excluded from the model are shown in italics. The three analysis procedures identified a total of 33 commodity groups, 7 of which were identified by all three selections, 12 by two methods, and 14 by one method only.

A primary consideration was that the commodities selected represent a significant percentage of the all the commodity groups transported in Iowa. A survey of the commodity groups selected using the TRANSEARCH in Table 4 and Table 5 indicate that the 20 commodity groups on each table accounted for 58% of the total value of freight and 83% of the total weight in tons of freight with origins or destinations in Iowa. The commodity groups in both tables account for 22% of employment for the STCC groups included in the

Table 6 Most Common Observed Commodity Groups in the Iowa Truck Survey

Sorted in descending order by number of observations

STCC	Commodity Description	Number of Field Observations	Percent of Total Observations
411	Misc. freight shipments	1781	11.72%
201	Meat or poultry, fresh or chill	974	6.41%
331	Steel mill products	506	3.33%
204	Grain mill products	443	2.92%
14	Livestock or livestock products	431	2.84%
262	Paper	400	2.63%
371	Motor vehicles and equipment	374	2.46%
203	Canned or preserved food	322	2.12%
200	Food or kindred products	316	2.08%
202	Dairy products	315	2.07%
353	Construction and related machinery	261	1.72%
242	Sawmills and planing mills products	258	1.70%
11	Field Crops	251	1.65%
12	Fresh fruits or tree nuts	250	1.65%
208	Beverages or flavor extracts	244	1.61%
461	FAK shipments	239	1.57%
251	Household or office furniture	234	1.54%
209	Misc. food preparations	189	1.24%
352	Farm and garden machinery	167	1.10%
282	Plastics materials and synthetics fibres	163	1.07%
	Subtotal Observations	8,118	53.42%
	Total Observations	15, 196	



Notes:
1) Commodity groups in the final model shown in **bold.**
2) Commodity groups in the excluded for final model shown in *italics*.

Figure 9 Union Graph of Commodity Groups by STCC Selected by Each Method

TRANSEARCH. The employment represented by the commodity groups is so low for two reasons: 1) much of the freight is produced outside of the state for consumption inside Iowa; 2) the total employment includes all employment in Iowa – many of which generate little or no freight.

6.2.4.1 *Commodity Groups Excluded from Consideration*

It was decided that the model would not include any mail, small package, or mixed freight shipments. These commodity groups would be difficult to model, are highly aggregate, and would not fit in a layered model approach. This eliminated STCC 461 (*FAK shipments*), STCC 411 (*Miscellaneous freight shipments*), and STCC 431 (*Mail or express traffic*) from further consideration. Two commodities identified by the Iowa Truck Survey were not included in TRANSEARCH because the data excludes non-manufactured agricultural items and were eliminated from consideration: STCC 14 (*Livestock*) and STCC 12 (*Fresh fruit or tree nuts*).

6.2.4.2 *Selected Commodity Groups*

The six commodity groups identified by all three methods were a priority for inclusion in the model. These commodity groups are clearly important to Iowa in terms of total tons, value and employment. The selection of the final nine commodity groups involved a great deal of judgment. Of the commodity groups that were identified by two of the methods STCC 11 (*Field Crops*), STCC 112 (*Coal*), 202 (*Dairy Products*), 262 (*Paper*), 281 (*Industrial chemicals*), 287 (*Agricultural chemicals*), and 307 (*Misc. plastic products*) were selected based on their high rank in of one of the selection criteria. STCC 11 (*Field Crops*) was selected to be included as rail only (since the TRANSEARCH data does not include truck shipment of agricultural products). STCC 112 (*Coal*) is obviously an important commodity by weight and was selected. Coal is transported mostly by rail, which is why it was not identified as part of the Iowa Truck Survey. STCC 202 (*Dairy Products*) ranked 11th by weight and value. STCC 262 (*Paper*) was selected primarily because it was the fifth most frequent observation in the Iowa Truck Survey. It was also 14th by weight and 21st by value. STCC 281 (*Industrial chemicals*) was selected because it was 7th by weight (14th by value). STCC 287 (*Agricultural chemicals*) was also selected because it ranked eighth by weight (24th by value). STCC 307 (*Misc. plastic products*) was selected because it ranked sixth by value. Of the commodity groups identified by one method STCC 291 (*Petroleum*), 324 (*Cement*), 331(*Steel mill products*) were selected. STCC 291 (Petroleum Products) was selected because it ranked 10th by weight. STCC 324 (*Cement*) was also selected because of the total flows in tons – it ranked 9th by weight STCC 331 (*Steel Mill Products*) was selected because it was the third most observed commodity group in the Iowa Truck Survey. STCC 331 was ranked 15 and 16 by weight and value, respectively.

6.2.4.3 Commodity Groups Not Selected

A short discussion of the commodity groups **NOT** selected is also warranted. The average rank selection method was arbitrary, but it easily identified the top commodity groups. However, commodities with a low rank in one category but a high rank made the selection list but should not necessarily be included in the model. For example, STCC 203 (*Canned food*) was ranked 22nd by weight and value (average=22) was ahead of STCC 112

(*Coal*) which was ranked 3rd by weight and 43rd by value (average=23). STCC groups 203 (*Canned food*), 208 (*Beverage*), 282 (*Plastic materials*), 327 (*Concrete*), 363 (*Household appliances*), 265 (*Paperboard*) and 335 (*Nonferrous metal*) were commodity groups with low rankings in either weight, value or both. They were not included in the model.

The top 10 method identified some commodity groups with a top 10 rank in weight, value, or employment but very low ranks for other category. Three commodity groups were excluded because of low weight rankings: STCC 243 (*Millwork*), STCC 353 (*Construction machinery*), and STCC 271 (*Newspaper*). The Iowa Truck Survey identified two commodity groups STCC 242 (*Sawmill products*), and 251 (*Household furniture*) that were not identified by the other methods. These commodity groups were judged not important enough in the overall picture of Iowa's freight transportation to be included.

6.2.4.4 *Summary*

The final selected 15 commodity groups are shown in Table 7. They account for 47% of the total value reported in the TRANSEARCH, 73% of the total tons reported in the TRANSEARCH, and 33% of the employment in the production sectors relating to STCC in the TRANSEARCH. The inclusion of additional commodity groups would improve the model, but only incrementally.

Table 7 Final Commodity Groups Selected for Model

Sorted in ascending order of STCC

STCC	Commodity Description	Rank: Value	Rank: Weight	Rank: Employ -ment	Total: Value (million $)	Total: Weight (1,000 tons)	Total: Number of Employees
11	Field Crops	5	1	77	2,988	28,399	610
112	Bituminous coal or lignite	43	3	127	435	16,745	1
201	Meat or poultry, fresh or chill	1	6	1	10,801	6,303	44,929
202	Dairy products	11	11	12	1,968	2,083	6,322
204	Grain mill products	2	2	5	6,189	19,248	16,532
209	Misc. food preparations	8	5	49	2,418	13,091	1,837
262	Paper	21	14	111	1,002	1,050	31
281	Industrial chemicals	14	7	89	1,630	4,840	274
287	Agricultural chemicals	24	8	31	887	3,937	2,933
291	Products of petroleum refining	41	10	119	453	2,549	6
307	Miscellaneous plastics products	6	20	-	2,799	906	-
324	Cement, hydraulic	70	9	65	183	3,056	1,002
331	Steel mill products	35	15	63	596	1,042	1,021
352	Farm and garden machinery	10	33	3	2,328	503	26,185
371	Motor vehicles and equipment	3	18	4	3,988	929	19,687
	Commodity Group Subtotal:				38,665	105,681	121,370
	All Commodity Groups Total:				81,737	142,976	373,190
	Percent of Total:				47%	73%	33%

6.3 Disaggregation Method

When the Iowa DOT purchased the commodity flow data from Reebie, they elected to purchase flows to and from Iowa developed at the BEA level in Iowa and adjacent states. Flows were aggregated at a higher spatial level at further distances from Iowa. The BEAs inside the state border of Iowa was not sufficient for a statewide freight model. It would not be possible to accurately assign freight flows to the highway and rail network with an accuracy. In order for the model to be useful, the data had to be spatially disaggregated to match the commodity analysis zones (CAZ) developed for the statewide freight model in Iowa. As described in the network chapter, the model has 144 CAZs. The CAZ match the TRANSEARCH except for the BEA's contained in Iowa. Four BEAs are entirely contained in Iowa and five BEAs are partially contained inside Iowa's border. Flows to or from the BEAs that were contained within the Iowa borders had to be disaggregated to the 99 CAZs.

The method to disaggregate the flows to the CAZ from the BEA level for those flows with an Iowa origin/destination pair was developed in the previous model. This method is also similar to the method Reebie uses to disaggregate the original data.

The disaggregation method assumes that flows to or from a larger spatial area (BEA) can be separated into smaller spatial areas (CAZ) by proportioning the total flows by indicator values that are measures of the production or consumption of a particular commodity group. These indicator values are measures of production or consumption that were determined for both the BEA and the CAZ. The following formulas indicate the method used to disaggregate origin flows:

$$O_{CAZ} = O_{BEA}\left(\frac{p_{CAZ}}{p_{BEA}}\right)$$, where:

O_{CAZ} is the tons of flow at the originating CAZ;

O_{BEA} is the tons of flow at the originating BEA;

p_{cnty} is the measure of production of commodity group at the CAZ; and

p_{BEA} is the measure of production of commodity group at the BEA.

Similarly, the disaggregation of the destination flows was done as specified:

$$D_{CAZ} = D_{BEA}\left(\frac{C_{CAZ}}{C_{BEA}}\right)$$, where:

D_{CAZ} is the tons of flow with destinations at the CAZ;

D_{BEA} is the tons of flow with destinations at the BEA;

C_{cnty} is the measure of consumption of commodity at the CAZ; and

C_{BEA} is the measure of consumption of commodity at the BEA.

The disaggregation ratios were developed for each commodity group. In many previous freight models, employment and population measures have been shown to be relatively good indicators of the level of freight activity in spatial areas (*49*). Combinations of employment measures, population, and others indicators were used in this model. Two sets of disaggregating measures were developed – one for origins (production) and one for destinations (attractions).

For all but two commodity groups, the employment in each related SIC was used as the measure for productions. As discussed in Chapter 5, the employment data used in this model were from the Iowa DWD and provided more than enough detail to calculate the employment in each county and each BEA. In some cases, however, large groups of employees were reported as working at the physical address of a particular establishment. For example, the Hy-Vee grocery store chain reports all employees as based in Des Moines, the address and county of their corporate headquarters. Hy-Vee has many grocery stores throughout Iowa, not just in Des Moines. It not clear how much this affected the disaggregation process.

To develop the disaggregation measures for the destination (attraction) flows, the 1996 Benchmark Input/Output Accounts were used. As discussed in Chapter 5, the I/O accounts provide general information on the inter-relationship of different sectors of the economy. The economic sectors represented in the I/O data do not directly correspond with either the employment (SIC) data or the commodity (STCC) data, but a relationship could be developed. The commodity group codes in the I/O accounts were translated to a SIC code since employment would be used to develop most of the disaggregation measures.

The I/O accounts are presented in matrix form with producing and consuming sectors included in the table. By examining the column totals for each producing sectors, it can be determined which sectors of the economy are the top consumers of the producing sector. The I/O accounts also track the consumption of the particular sector group by government, export, and personal consumption so measures other than employment can be used for disaggregation. The I/O tables were analyzed to determine the five largest consuming sectors for each commodity group in terms of value that was selected for inclusion in the statewide model. When the largest consuming sector of a commodity was personal consumption, population was used as the disaggregating measure. This was the case for commodity groups such as food. In some cases, multiple employment measures were combined to develop the disaggregation measure when the employment data in the sector was not sufficient or the sector represented in the I/O tables covered more than one SIC sector. For example, the employment data to disaggregate STCC 262 (*Paper*) was combined for SIC groups 270-273 which all use paper as a primary input in the production of newspapers, magazines, and books. Table 8 shows the measures that were used to develop the ratios for disaggregation.

The actual mechanics of disaggregating the 15,000 records of the TRANSEARCH was accomplished with a two-step process using a combination of queries in a Microsoft Access database. After extracting all records of the selected commodity group by STCC from TRANSEARCH, the origin records were disaggregated by the calculated ratios, then the destination flows were disaggregated by their ratios. A simple example is shown in Figure 10. In the example, 100 tons flows from BEA C to D. Both BEAs contain four CAZ, so the flow must be disaggregated from a 1x1 to a 4x4 flow matrix. First, the originating flows from C are disaggregated into the four sub-CAZ of BEA C (4x1 flow matrix) using the production indicator. The ratios listed in the first column are the ratio of the indicator variable in the CAZ to the total BEA value of the indicator variable (CAZ C-1 had 60% of the total production of BEA C so 60 tons originate from C-1). Next, the disaggregated originating flows from each CAZ of C are disaggregated to the four destination CAZs of BEA D in the same manner as the first step. The final matrix conserves the total flow from BEA C to BEA D at 100 tons, but has been spatially disaggregated to more detail.

6.4 Development of Data for Bridge Traffic Model

Recall that a separate model for the bridge traffic was required to supplement the base model. The commodity data for the bridge traffic model were developed from the 1997 Commodity Flow Survey (CFS). The CFS contains data on total flow in tons from state-to-

Table 8 Summary of Disaggregation Measures

STCC	Commodity Description	Productions	Attractions
11	Field Crops	Acres of Farm Land	Farm product raw materials (SIC515)
112	Bituminous coal or lignite	Population	Employment in electric services and gas production and distribution (SIC 491, 493)
201	Meat or poultry, fresh or chill	Employment in SIC 201	Population
202	Dairy products	Employment in SIC 202	Population
204	Grain mill products	Employment in SIC 204	Population
209	Misc. food preparations	Employment in SIC 209	Population
262	Paper	Employment in SIC 260-265	Employment in newspapers, periodicals, books (SIC 270-279)
281	Industrial chemicals	Employment in SIC 516	Employment in industrial and agricultural chemicals (SIC 281, 286, 289, 282)
287	Agricultural chemicals	Employment in SIC 287	Acres of farm land
291	Products of petroleum refining	Employment in SIC 517	Population
307	Miscellaneous plastics products	Employment in SIC 307-308	Employment in knitting mills, textiles, carpets, rugs (SIC 221-229)
324	Cement, hydraulic	Employment in SIC 324	Employment in residential, highway, masonry construction (SIC 151, 152,161, 162, 174, 177, 138,148)
331	Steel mill products	Employment in SIC 331	Employment in Iron and steel foundries, fabricated metal products (SIC 332, 339, 343, 344)
352	Farm and garden machinery	Employment in SIC 352	Acres of Farm Land
371	Motor vehicles and equipment	Employment in SIC 371	Population

Step 1:		
Ratio of Indicator Variables	From BEA C- CAZ (tons)	To BEA D (tons)
0.6	C-1	60
0.0	C-2	0
0.2	C-3	20
0.2	C-4	20
Total		100

Step 2:	Ratio of Indicator Variables				
	0.25	*0.40*	*0.10*	*0.25*	
From /To	D-1	D-2	D-3	D-4	*Total*
C-1	15	24	6	15	60
C-2	0	0	0	0	0
C-3	5	8	2	5	20
C-4	5	8	2	5	20
Total	25	40	10	25	100

Figure 10 Example of Disaggregation Procedure

state in matrix form. Unfortunately, the state-to-state flow matrix in CFS documentation was a total flow matrix in tons (all commodity groups and modes combined). State-to-state flows by mode or commodity group were not reported.

The CFS data have to be transformed from the state-to-state matrix of total flows to a state-to-state matrix of the selected commodity groups in the base model for both rail and highway modes. The general process for developing the bridge traffic flows, described in the following subsections was to:

1) obtain the state-to-state flows by total tons for the United States;
2) estimate the percentage of tons originating in each state for the selected commodity groups;
3) determine the modal share in each state (all commodity groups in aggregate);
4) convert the state-to-state matrix to an origin/destination survey format (one each for truck and rail); and
5) format the matrices for use in TRANPLAN.

The method used to generate the state-to-state matrix of the select commodity groups by mode requires the assumption that all flows for individual commodity groups from a state are proportional to the total flows. Likewise, the assumption is made that the flows from the state by mode are proportional to the total. These are significant assumptions that impact the reliability of using this method for anything other than generating the bridge traffic flows across the State of Iowa. The levels of aggregation – and the specific application – make the CFS suitable for estimating bridge traffic flows in Iowa.

The state-to-state commodity flow matrix was a primary product of the CFS. The matrix contains flows from state to state, including Hawaii and Alaska. Some state-to-state flows are not reported because of sampling variability or are suppressed. These states are reported as “S” in the matrix. The totals for each state, however, are reported. The total amount of flow that was unreported (no destination for state of origin) was 312,524 thousand tons out of 11,089,733 thousand tons (an omission error of 2.8%). Three states (Alaska, Hawaii, and Iowa) and the District of Columbia were removed from the state-to-state matrix since the flows to and from these states were not included in the Iowa bridge traffic model. Iowa flows were, obviously, excluded from the bridge traffic model because they are already in the base model. This modified matrix had a 2.4% omission error.

An examination of the CFS reveals that the majority of flows are to adjacent states (excluding internal flows). To estimate the impact of omission errors on the bridge traffic model, states adjacent to Iowa were analyzed to determine what percentage of the flows from the adjacent states were unreported. If the omission error was high, the bridge traffic model would significantly underestimate bridge flows across Iowa. Table 9 reports the total flows and the unassigned flows for Minnesota, Wisconsin, Illinois, Missouri, Nebraska, and South Dakota. As shown in the table, South Dakota has high percentage of unreported flows (22%) but is one of the smallest in terms of total flow. Overall, the unreported flows for the adjacent states had a 4% omission error. Not all of the unreported flows, however, would contribute to error in the Iowa bridge traffic model (since not all of the flows originating in the adjacent state would pass through Iowa). By examining the modified matrix and making assumptions on the path of flows from one state to another, only 13 of the 53 instances where destinations were not reported had possible paths through Iowa. For example, flows from Missouri to New Mexico that were not reported would not contribute to the error in Iowa bridge traffic since the path of the freight would not travel through Iowa. Since the total flows that were not reported for the adjacent states resulted in a 4% error (and only 20% of those errors could be attributed to paths that might pass through Iowa) – a reasonable estimate of error of the bridge traffic model would be between 2-3%, or equivalent to the error in the modified state-to-state matrix.

The next step was to estimate the percentage of the total origins in each state that correspond to the commodity groups in the base model. The CFS reports commodities at the 2-digit STCG level while the TRANSEARCH is reported at the 3-digit STCC level. (recall that the STCG is a new designation developed for use in the CFS and future surveys). The STCG can be related to the STCC but the detail of the CFS data makes it impossible to extract the same commodity groups from the CFS. Nonetheless, the commodity groups

Table 9 Summary of 1997 CFS for Adjacent States

State of Origin	Total Tons (000s)	Reported Tons (000s)	Unreported Tons (000s)	Omission Error
Illinois	670,949	660,411	10,538	1.57%
Minnesota	279,607	253,499	26,108	9.34%
Missouri	187,537	184,552	2,985	1.59%
Nebraska	120,354	111,636	8,718	7.24%
South Dakota	36,853	28,755	8,098	21.97%
Wisconsin	238,700	233,801	4,899	2.05%
Total	1,534,000	1,472,654	61,346	4.00%

shown in Table 10 (which most closely match the commodity groups used in the model) were used to estimate the percentage of the total originating tons in each state that are represented by the selected commodity groups in the base model.

Two state-to-state flow matrices were created (truck and rail modes) using the modified state-to-state matrix using the following formula applied to each cell:

$M_{i,j}^{m} = T_{i,j}(P_t)(P_m)$ for all *i* (origin state) and *j* (destination state) and for each mode *m* (truck and rail); where:

$M_{i,j}^{m}$ is the tons of flow for cell *i*, *j*; for mode (*m*);

$T_{i,j}$ is the total tons of flow for cell *i*, *j* from modified state-to-state matrix;

P_t is the percentage of the total origin flow represented by selected commodity groups (for each state);

P_m is the percentage of the total flow by each mode (for each state);

The total flows originating in each state for the STCG in Table 10 were determined from data reported in Table 5 "*Shipment Characteristics by Two-Digit Commodity for State* *of Origin*" of the 1997 CFS (in each state report). The percentage of originating tons that were represented by the selected commodity groups was then calculated for each state (P_t). On the average, the selected commodity groups represented 37% of the total reported flows in the CFS for each state. The total tons by mode for each originating state were estimated from Table 1 "*Shipment Characteristics by Mode of Transportation for State of Origin*" of the CFS (in each state report). These data were used to estimate the modal share of the originating flows in each state by rail and truck (P_m). On the average, 72% of the total flows were by truck and 16% were by rail.

Table 10 STCG Selected for Use in the Bridge Traffic Model

SCTG	Commodity Description	Percent of Total Tons in 1997 CFS
02	Cereal Grains	3.9%
03	Other agricultural products	1.5%
04	Animal feed and products of animal origin, n.e.c.	1.7%
05	Meat, fish, seafood, and their preparations	0.7%
06	Milled grain products and preparations, and bakery products	0.8%
15	Coal	10.8%
17	Gasoline and aviation turbine fuel	8.3%
19	Coal and petroleum products, n.e.c.	4.0%
20	BaSIC chemicals	2.6%
28	Paper or paperboard articles	0.7%
32	Base metal in primary forms and in finished baSIC shapes	2.8%
33	Articles of base metal	0.9%
34	Machinery	0.4%
36	Motorized and other vehicles (including parts)	0.9%
	Total	40.0%

6.5 Summary

In this chapter, the modeled commodity groups were selected. Three ranking methods were used to select 15 commodity groups that accounted for 47% of demand by value, 73% of demand by tons, and 33% of the total employment in related STCC groups. Using the method developed in the previous research, the TRANSEARCH data were disaggregated from the BEA level to the CAZ level using indicators of production and consumption. These indicators were selected based on input-output tables and employment by sector. Finally, the development of commodity flows for use in the bridge traffic model was described. The next chapter describes how the model was run.

CHAPTER 7 - MODEL METHODOLOGY

This chapter discusses the mechanics of using a travel demand software package for the two steps of the freight model: distribution, and mode split/assignment. The process of trip distribution is described in the first section. The second section describes how mode split and assignment were combined in one step for the model. Finally, the chapter concludes with a summary of the method.

7.1 Trip Distribution

The model in this research assumes the availability of a base set of origin-destination flows. Therefore, distribution of trips is in one sense known. However, existence of a base year set of flows does not provide:

1) the ability to forecast future flows, or

2) the ability to be sensitive to policy options that impact freight demand.

Therefore a trip distribution model is calibrated based on a known O/D table. A gravity model is typically used to perform the trip distribution in a conventional four-step model. The gravity model provides the ability to forecast future O/D pairs and is sensitive to changes in freight demand (productions and attractions). Previous research indicated that statewide application of the gravity model was appropriate for the commodity groups analyzed (*7*). The framework developed in the current research uses the gravity model for trip distribution. In a gravity model, "the number of trips between two zones is directly proportional to the number of trip attractions generated by the zone of destination and inversely proportional to a function of travel time between the two zones" (*59*, p. 405). If travel times are considered to be insensitive to freight demand, a "trip" can be considered as equivalent to a unit of freight being modeled (e.g. tons or vehicles). The general formulation of the gravity model is:

$$T_{ij} = \frac{P_i A_j f(t_{ij})}{\sum_j A_j f(t_{ij})}, \text{ where:}$$

T_{ij}	is the number of trips (tons) for zone i to j;
P_i	is the production (tons) in zone i;
A_j	is the attraction (tons) in zone i;
t_{ij}	is the impedance (cost) from zone i to j; and
$f(t_{ij})$	is the friction factor from zone i to j.

The gravity model used in this research was the $GRAVITY MODEL ($GM) routine of the TRANPLAN travel demand software. A sample of the TRANPLAN control file for the $GM routine can be found in Appendix B. The $GM routine requires three inputs that were developed for each commodity group:

1) a table of the productions and attractions in each CAZ;
2) a set of skim trees describing the least cost path between zones; and
3) a set of friction factors.

These inputs are described in the following subsections.

7.1.1 Production / Attraction Table

In order to create the production/attraction table for the $GM routine, the TRANSEARCH O/D data were synthesized into production/attraction format (the data were first disaggregated from BEA to CAZ level in Chapter 6). The total origins (productions) and destinations (attractions) for each CAZ were summed for each of the selected commodity groups. The results were output to a text file that was formatted for TRANPLAN by the Freight Model Manager.

As a result of the calibration efforts, it was discovered that the TRANPLAN $CALIBRATE GRAVITY MODEL (CGM) was generating friction factor curves with increasing values for all commodity groups with production/attractions coded as one trip types (in urban modeling, a trip purpose is a trip of a specific type such as home-based work trips). In his development of a statewide truck travel forecasting model, Park coded trips to different trip types based on the origin and destination of each pair (*60*). The TRANSEARCH data were further analyzed by inspection of the origin and destination patterns in thematic GIS maps. It was concluded that in order to facilitate calibration, the commodity flow data should be stratified into three trip types:

1) Iowa-to-Iowa (I-I);
2) Iowa-to-external (I-E); and
3) External-to-Iowa (E-I).

Recall that TRANSEARCH does not include any flows that have both origins and destinations outside of Iowa - so the obvious fourth trip purpose, external-to-external (E-E) was not required as part of the gravity model. However, as these trips are clearly important to determining truck traffic on Iowa roads, external flows are addressed by a separate model which assigns the flows based on data from the Commodity Flow Survey (see Chapter 6, Section 4).

7.1.2 Skim Trees

Skim trees (sets of least-cost paths between each CAZ) were developed in Chapter 5. The skim trees were built by the $HIGHWAY SELECTED SUMMATION ($HSS) routine of the TRANPLAN software. The $HSS requires an input file from the $BUILD COST USER NETWORK ($BCUN) routine which creates a network file encoded with cost information. Ton-mile cost data for all ten links groups were developed in Chapter 5 were input as parameters in the $BCUN routine. Available paths included all possible rail or highway path combinations, including intermodal connections.

7.1.3 Friction Factors

Friction factors for each commodity group used in the $GM routine were developed during the model calibration (see Chapter 10). (Friction factors are measures of the attractiveness of each zone based on the impedance value between the zones). In the calibration process, the friction factors were adjusted until the distribution of the gravity model compared to the original O/D table within the tolerance level.

7.1.4 Gravity Model Parameter Settings

Several options and parameter settings are required for the $GM routine in the TRANPLAN software. The setting used in the $GM routine are described in the following list:

1) Hold productions constant. This setting insures that no CAZ would have more

tons produced then were specified in the production/attraction table because of balancing the gravity model.

2) Iterate until adjusted attractions are within 5.0 percent of the attraction totals.
3) Impedance value was set to the cost. (In TRANPLAN, users may also define impedance to be equal to time, distance or some combination).
4) Number of iterations that the gravity model will iterate up to before it stops (even if convergence hasn't been reached) was set to three.
5) Maximum time for which friction factors were included in the friction factor file was 100. Any impedance (cost) value larger than 100 would be truncated to the maximum. None of the models had impedance costs that were close to the maximum value.

7.2 Mode Split and Assignment

After distribution, commodity flows were assigned to the multimodal network. In the model, mode split and assignment are combined in one step. The primary motivation for combining mode split and traffic assignment was the ability to replicate shipper modal decisions based on ton-mile costs The following subsections document the assignment and mode split methods used in the model.

7.2.1 Assignment Algorithms

Many assignment algorithms are available for assigning trips to a network in a travel demand model. Horowitz discusses four:

1) capacity restraint;
2) stochastic;
3) equilibrium; and
4) all or nothing (*47*).

The capacity restraint algorithm assigns traffic to a network based on link congestion levels. In statewide freight models, however, congestion is usually not an issue, negating the benefits of using the capacity restraint algorithm. This is not to say that local or regional impacts of automobile congestion do not affect freight, but for most long distance, intercity trips, congestion is not an issue. This model does not attempt to predict shifts in freight patterns as a result of congestion. It is possible in the modeling framework to add known congestion to links by increasing the impedance (cost) which would divert freight to lower cost routes.

The stochastic algorithm probabilistically assigns traffic to several reasonable paths. Horowitz suggests that "stochastic multipath shows promise, but there is comparatively little experience with the technique for statewide freight forecasting" (*47*, p. 59). Equilibrium assignment assigns traffic to the network such that no assigned trip would be better off changing paths in the network. The Massachusetts model discussed in the typology used the equilibrium assignment algorithm. All-or-nothing assignment algorithm assigns all flows between an O/D pair on the shortest path.

The all-or-nothing assignment has been used in many previous freight models. The assumption of the shortest path is generally accepted as valid for routing trucks (*48*). Trucks tend to travel on shortest path for most trips, especially for long distance trips where they are attracted to high speed, access controlled facilities (lowest cost path in the model). Congestion effects can be included as link costs in this assignment. Railroads, however, tend to route freight that keeps it on their system the longest in order to maximize revenue, which may not necessarily be the shortest path (*48*). The purpose of the interline penalty discussed in the network chapter was to keep traffic on the originating railroad's line by adding additional costs to this transfer.

7.2.2 Mode Split Techniques

A modal-split component is important for policy analysis. There are four general methods for mode split analysis:

1) mode split tables;
2) diversion models/elasticities;
3) expert opinion; and
4) mode split models (*47*).

Mode split tables are readily developed from aggregate data such as the CFS or TRANSEARCH. These tables provide the share of each commodity by mode and can be applied to the modeling process. Models of modal split by diversion or elasticity have also been developed. These models predict the cross elasticity of commodity groups which can be used to estimate mode split. Cross elasticity measures the change in one mode as a result of changes in another. For example, raising truck costs 1% may cause a 0.2% shift to rail for that commodity. The use of expert opinion for mode split requires opinions of industry experts on the model's representation of mode split.

Finally, there are mode split models are mathematical formulations that have calibrated inputs that predict mode split. The use of these models in statewide planning models has been limited. Most of the models reviewed in the typology used an expert panel or developed mode split tables. Many models that were developed were for one mode only, excluding the issue of mode split altogether.

7.2.3 Combined Approach

The primary motivation for combining mode split and traffic assignment was the ability to replicate shipper modal decisions based on ton-mile costs. Table 11 shows a summary of the decision variables that are common in mode shipping choices. Cost on a ton-mile basis can be assumed to address the factors of weight of shipment, rate, and distance. Factors that would influence shipping decisions that can not be addressed with ton-mile cost only include: completeness of service, transit time, reliability, frequency of service, and packaging cost. In the calibration of the model, however, rail centroid connector costs were adjusted to reflect other trade-off costs (including additional shipping costs from rail terminal to final destination). Centroid connector costs were then calibrated so that the modal share between truck and rail was closely matched to the modal share documented by TRANSEARCH.

Traffic assignment and mode split were combined into one step in this model. The all-or-nothing assignment algorithm was chosen as the assignment algorithm and link costs were used to calculate the shortest path between two zones. The available paths included all possible rail or highway path combinations, including any intermodal connections. Freight

Table 11 Variables in Mode Split Models

Commodity type	Frequency of service
Completeness of service	Size of firm
Transit time	Packaging costs
Weight / density of shipment	Seasonally or peaking characteristics
Rate Distance	Fragility
Reliability of service	Perishability

Source: *Freight Data Requirements for Statewide Transportation Systems Planning* (*61*)

was assigned to the shortest path (rail, highway, or intermodal); this simultaneously accomplished mode split and traffic assignment. Traffic was assigned to the network with the TRANPLAN routine $LOAD HIGHWAY NETWORK using cost skim trees and output from the gravity model.

7.2.4 Assigning Bridge Traffic Flows

The commodity flow matrices that were developed from the 1997 CFS for the bridge traffic model were modified to resemble an O/D survey, then formatted by the Freight Model Manager for the TRANPLAN routine $BUILD TRIP TABLE. The trip tables were then directly assigned to the network using the all or nothing and the cost skim trees developed for each mode. A sample of the TRANPLAN code is in Appendix B.

7.3 Summary

The mechanics of trip distribution, traffic assignment, and mode split were discussed in this chapter. The commodity flows developed in the model were distributed with a gravity model. In addition, the method for combining the traffic assignment and mode split in the model were described by assigning all freight to the mulitmodal network by least cost path. In the following chapter, the method used to convert the traffic assigned to the rail and highway network into vehicle units is described.

CHAPTER 8 - CONVERSION OF FREIGHT TONS TO VEHICLES

While commodity flows in tons are useful for a general overview of freight patterns, converting the assigned flows on the network to equivalent vehicle units (trucks, railcars) enables more robust planning analysis, as well as a means for validation. The conversion from tons to vehicle units is complicated by the presence of empty or unloaded vehicles. Both issues are addressed in this chapter. The following sections discuss the method used for conversion, the average load (cargo weight) for truck and rail, the treatment of empties, and the use of the Freight Model Manager (FMM) to convert the commodity flows in tons to vehicle units.

8.1 Method

Other researchers have converted tons of commodity flows into vehicle units to calibrate and validate their models. The Indiana model converted flows to vehicle units using load factors obtained from the Rail Waybill data (*48*). The researchers assumed that trucks would carry approximately 40% of the load carried by railcars. For example, if the average load of a railcar carrying coal was 100 tons, it was assumed that trucks would carry 40 tons. The conversion factors were specific to each commodity group but did not address different types of vehicles. The Massachusetts model converted commodity weight into a number of annual trucks by using average density of freight and average load per truck (*49*). Empty loads were added to the network in a separate step. The conversion was not commodity specific (all commodities were analyzed together) and conversion to types of vehicle was based on the current distribution of vehicle types on the highway.

The method used in the present model is similar to the method used in Massachusetts, with one important difference – the method used is commodity and vehicle specific. Individual variables are identified for each commodity group, allowing conversion from tons to the most common vehicle used to transport the commodity group. An overview of the methodology for converting tons to vehicle units is shown in

Figure 11 and described below:

1) From available data sources, an estimate was made of the two vehicle units (truck trailer type or railcar) most commonly used to transport each commodity group;
2) An estimate of the average load of selected commodities in each freight vehicle unit was developed from the same data sources;
3) Freight flow in tons was converted to vehicle units on a link-by-link basis; and
4) An expansion factor, estimated by commodity, for treatment of empty freight vehicles was applied.

The final output of the process is a loaded network of vehicle types. The following subsections describe in detail the process and data used in each step.

8.2 Average Loads for Trucks

The Iowa Truck Survey was used to determine the two most common trailer types for each commodity group, as well as the average total weight of the vehicle and load carried by truck. The Iowa Truck Survey contained a sample of approximately 15,000 trucks which included the commodity carried at the 3-digit STCC level, the type of vehicle configuration, the type of trailer, and the gross weight of the vehicle and trailer combination. The survey

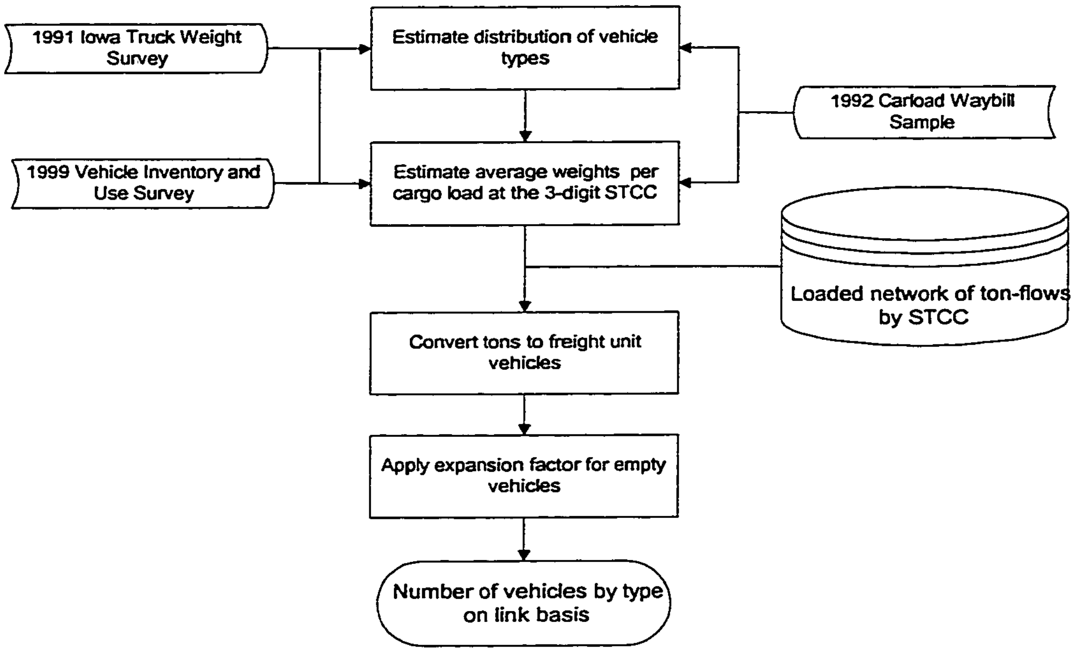


Figure 11 Flowchart for Conversion of Tons to Vehicle Units

was analyzed to determine the two most common vehicle configuration and trailer types carrying each of the selected commodity groups. For all of the commodity groups, the most common truck configuration was the standard tractor-semi-trailer (3-S2). For most commodity groups, the most common type of trailer was obvious from the aggregated survey results. For example, of the 957 observations made of vehicles transporting STCC 201 (*Meat or Poultry*), 839 were of a refrigerated van. Ten of the commodity groups were transported by only one trailer type in nearly 100% of the observations. The remaining five were commonly transported by two trailer types. The probability of a commodity group being transported in each trailer type was estimated from the frequency of observations in the survey. This was input into the model for estimating the type of each trailer type on the network. For example, STCC 204 (*Grain mill products*) were transported 76% of the time in a hopper trailer and 24% in a dry van trailer.

The individual records in the Iowa Truck Survey were averaged to obtain the representative vehicle gross weight for each commodity group. Empty vehicles were not included, since they were not coded to an STCC in the survey. Since the Iowa Truck Survey did not contain information on the empty weight of the vehicle and trailer, a supplementary source was required. The average empty weight of the tractor and trailer combination was obtained from the Vehicle Inventory and Use Survey (VIUS). The VIUS contains data by tractor-trailer type on the empty weight of the vehicle. A simple cross-reference was developed between the trailer types in the Iowa Truck Survey and the VIUS. By subtracting the average empty weight from the average gross weight, the average cargo weight per commodity group was determined.

Table 12 shows the result of the average truckload analysis. It is clear from the table that the average gross weight of the survey was between 10 and 20 thousand below the maximum gross vehicle weight of 80,000 pounds except for the trucks transporting STCC 112 (*Coal*) which were actually over the maximum gross weight. As would be expected, the lower value, higher density commodities (coal, grain, cement) had higher average loaded weights and the higher value, lower density commodities (food preparations, motor vehicles, farm machinery) had lower average weights per cargo.

Table 12 Average Cargo Weights for Trucks

STCC	Commodity Description	Tractor-Trailer Type	Total Weight of Tractor & Trailer (pounds)	Empty Weight of Vehicle (pounds)	Weight of Cargo (tons)	Percent of Vehicles by Type
11	Field Crops	Hopper	72,665	27,297	22.7	100%
112	Bituminous coal or lignite	Open top box	83,756	30,819	26.5	75%
		Hopper	82,300	27,297	27.5	25%
201	Meat or poultry, fresh or chill	Refrigerated Van	72,419	29,937	21.2	100%
202	Dairy products	Refrigerated Van	67,746	29,937	18.9	100%
204	Grain mill products	Van	66,377	25,409	20.5	76%
		Hopper	74,622	27,297	23.7	24%
208	Beverages or flavor extracts	Van	72,186	25,409	23.4	100%
209	Misc food preparations	Refrigerated Van	63,127	29,937	16.6	55%
		Van	61,140	25,409	17.9	45%
262	Paper	Van	65,248	25,409	19.9	100%
281	Industrial chemicals	Tank	71,804	29,255	21.3	44%
		Van	59,550	25,409	17.1	34%
		Refrigerated Van	70,971	29,937	20.5	22%
287	Agricultural chemicals	Van	62,018	25,409	18.3	100%
291	Products of petroleum refining	Petroleum Tank	75,944	29,255	23.3	65%
324	Cement, hydraulic	Hopper	74,726	27,297	23.7	100%
327	Concrete, gypsum, and plaster products	Flatbed	72,660	28,472	22.1	100%
331	Steel mill products	Flatbed	67,764	28,472	19.6	100%
352	Farm and garden machinery	Low-boy trailer	62,870	30,802	16.0	52%
		Flatbed	51,798	28,472	11.7	48%
371	Motor vehicles and equipment	Van	52,783	25,409	13.7	68%
		Automobile Transporter	67,119	36,163	15.5	32%

Source: Iowa Truck Survey (1991) and Vehicle Inventory and Use Survey (1997)

8.3 Average Carload Weights for Rail

The 1992 Carload Waybill Sample was ideally suited to determine the most common railcar used to transport each of the commodity groups and the average weight of the cargo. Unlike the truck data, the waybill reports the billed weight – the weight of the commodity- so there is no need to determine empty carload weights. The waybill sample contains over 350,000 records and included many carloads that do not originate or end in Iowa. Rather than separate out Iowa-only flows, the entire waybill sample was analyzed. Relevant fields were extracted from the waybill sample, including: the 5-digit STCC code (reduced to 3-digit), the number of carloads, the car type, the billed weight, and the actual weight of the commodity. The car type field designates the American Association of Railroads (AAR) mechanical car code. A simple cross-reference was developed to relate the car codes to the car types used in the model.

Table 13 reports the result of the average rail load analysis. Most of the commodity groups were reported as transported exclusively (100%) by one railcar type or similar car type. This was not unexpected since many commodities are transported by rail in special cars (i.e. coal hopper). Like the commodity flow data for trucks, the lower value, high-density commodities had high cargo weight while the higher value, lower density (or bulky) commodities had lower per carload weights.

8.4 Empty vehicle expansion factors

At any given time, a percentage of the trucks and railcars on the network are carrying reduced or empty payloads. Using average weights for conversion from tons to number of vehicles

Table 13 Average Car Loads for Rail

STCC	Commodity Description	Car Type	Weight of Cargo (pounds)	Weight of Cargo (tons)	Percent of Carloads by Type
11	Field Crops	Hopper, covered	185,450	92.73	100%
112	Bituminous coal or lignite	Hopper, special modified	186,586	93.29	100%
201	Meat or poultry, fresh or chill	Tank car	164,388	82.19	77%
		Refrigerated box car	99,179	49.59	23%
202	Dairy products	Refrigerated box car	125,529	62.76	100%
204	Grain mill products	Hopper, covered	148,932	74.47	75%
		Tank car	189,531	94.77	25%
209	Misc food preparations	Hopper, covered	152,931	76.47	65%
		Tank car	156,221	78.11	35%
262	Paper	Box car	135,460	67.73	77%
281	Industrial chemicals	Tank car	168,626	84.31	66%
		Hopper, covered	192,916	96.46	34%
287	Agricultural chemicals	Tank car	197,492	98.75	59%
		Hopper, covered	193,136	96.57	41%
291	Products of petroleum refining	Tank car	140,398	70.20	100%
324	Cement, hydraulic	Hopper, covered	178,081	89.04	100%
327	Concrete, gypsum, and plaster products	Hopper, covered	179,351	89.68	100%
331	Steel mill products	Gondola, w/ roof	172,845	86.42	65%
		Gondola	161,972	80.99	35%
352	Farm and garden machinery	Flat car, specially equipped	42,667	21.33	100%
371	Motor vehicles and equipment	Auto rack	46,148	23.07	100%

Source: Carload Waybill Sample (1991)

addressed the partially loaded vehicles, but does not address empty vehicles. Empty vehicles present a unique problem for validation, since observations of vehicles in field usually cannot indicate if the vehicle is empty or full. The typical validation data, ground counts, includes counts of empty vehicles. Vehicles may be empty for reasons that are difficult to mathematically model. As an example, a shipping manager may decide that it is better to send an empty vehicle to another location for logistical reasons. Clearly, this phenomenon is not captured by the all-or-nothing cost based assignment technique or the conversion method.

The number of vehicles on each link is inflated to account for the number of empties – a factor that is commodity and mode specific. These factors were estimated based upon the commodity characteristics. The factor captures the likelihood that a particular commodity is backhauled. For some commodities transported in specialized trailers or railcars this is relatively easy – coal in specialized coal hoppers that are eastbound from Wyoming to Iowa must return empty – there is no commodity that could be suitably backhauled. Assuming the cars return to Wyoming via the same path in the network – the total number of cars on the rail line would be twice the number estimated. A factor of 2.0 indicates that no backhaul is present – that all vehicles must return empty. A factor of 1.0 indicates the presence of backhaul - the returning vehicle can be used to haul another commodity. A factor of 1.5 was used to account for vehicles that may have an opportunity for a backhaul in some instances, but not in others. The sensitivity of the model output to these assumptions was analyzed in Chapter 12. Table 14 summarizes the expansion factors used in the model.

Table 14 Expansion Factors for the Treatment of Empties

STCC	Commodity Description	Truck Expansion Factor	Rail Expansion Factor
11	Field Crops	2	1.5
112	Bituminous coal or lignite	2	2
201	Meat or poultry, fresh or chill	1.5	2
202	Dairy products	2	2
204	Grain mill products	1.5	1.5
209	Misc food preparations	1.5	1.5
262	Paper	1.5	1.5
281	Industrial chemicals	2	2
287	Agricultural chemicals	2	2
291	Products of petroleum refining	2	2
324	Cement, hydraulic	2	2
327	Concrete, gypsum, and plaster products	1.5	1.5
331	Steel mill products	1.5	1.5
352	Farm and garden machinery	1.5	1.5
371	Motor vehicles and equipment	2	2

8.5 Converting Tons to Vehicle Units

The conversion to number of vehicles by type was accomplished in a programming routine in the Freight Model Manager (FMM) on a link-by-link basis using:

1) the average load weight of each vehicle type;
2) the percentages of each vehicle type; and
3) the expansion factor for the treatment of empties.

For each link in the network, a conversion is made depending on the type of link. If the link is a highway link, the tons are converted to two most common truck trailer types for the commodity group (note that only two trailer types were considered). The same is true for rail links. The conversion was made to conserve the trailer and railcar split observed for each commodity group. The following "weighted" formula (which takes into account the load of each vehicle type) was used:

$$N_i = \frac{Wp^i_{ne}}{\alpha_i} x_i$$, where:

N_i	is the annual total number of all vehicles of type i;
W	is the annual weight of commodity assigned to link (tons);
p^i_{ne}	is the effective percentage of vehicle type i of mode n;
α_i	is the average weight per vehicle type i (tons/unit); and
x_i	is the vehicle expansion factor for empties of type i;

$$p^i_{ne} = \frac{p^i_n}{\left(\frac{\alpha_i}{\alpha_j}\right)\left(p^i_n\right)+\left(p^j_n\right)}$$, where:

p^i_{ne}	is the effective percentage of vehicle type i of mode n;
p^i_n, p^j_n	is the actual percentage of vehicle type i and j of mode n; and
α_i, α_j	is the average weight per vehicle type i and j (tons/unit);

To convert the annual number of vehicles to an average daily truck traffic (ADTT), the annual number of vehicles was divided by 260 (assuming 260 working days per year). This was recommended in previous research (*49*).

As an example of the conversion process, assume that 1,000 tons of STCC 287 (*Agricultural Chemicals*) were assigned to a rail link. The two most common railcars to transport STCC 287 are the tank car with an average cargo weight of 98.75 tons and the covered hopper with an average cargo weight of 96.75 tons. The tank car was used 59% of the time and the covered hopper was used 41% of the time. Using the formula, the effective percentage for the tank car is 47% and 33% for the covered hopper. The 1,000 assigned tons would become 4.78 tank cars and 3.39 covered hoppers. This closely maintains the observed split of 59% and 41% of the car types.

8.6 Summary

The conversion from the assigned tons on each link in the network to a number and type of vehicles was necessary to validate the model. The process is relatively straightforward and was complemented by access to quality data that allowed the development of all the necessary parameters. The average loads for trucks were compared to other sources such as the TTS Bluebook (average difference 5 tons for very general categories) and the data used reported in the Wisconsin model (average difference 1.5 tons as compared to 2-digit STCC) with very favorable results. Using the network counts developed in this Chapter and the observed data in Chapter 9, the model is validated Chapter 11.

CHAPTER 9 - DATA COLLECTION

The primary objective of the data collection was to collect the data required to estimate the commodities being transported in Iowa for model validation purposes. To accomplish this, a method was developed to collect data on freight vehicle movements at locations around the State of Iowa. The data collection effort was unique in that freight vehicles were not stopped; information was obtained by visually observing the vehicles in motion. For highway vehicles, commodity information could be inferred by either directly observing the commodity being carried (such as on a flatbed semi-trailer) or by identifying the motor carrier and then cross referencing commodity information in a motor carrier database. A database useful for this purpose, the Motor Carrier Management Information System (MCMIS) is maintained by the USDOT and contains data on the principal location, safety ratings, and commodities hauled for most carriers. For railcars a significant portion of commodity information could be inferred by directly observing the railcars in the consist. No readily available supplemental database was available for rail traffic to identify commodities.

Data were collected at 20 locations throughout the on interstate, U.S., and state highways, as well as main and branch line railroads. Some 11,427 trucks and 4,375 railcars were observed during the months of March, June, and July in 2000. This chapter documents the data collection conducted by describing the methods used, the limitations, and the results in a summary format. The data presented in this chapter is used in the validation, documented in Chapter 11.

9.1 Overview

As discussed in the opening chapter, independent data on the flow of commodities is required to validate the freight model. In previous models, independent commodity flow data were most often obtained through roadside surveys of motor carriers. While these roadside surveys can be effective, there are drawbacks. First, extensive surveys are expensive. A survey conducted for the Washington DOT at 25 sites required 15 persons per site to conduct the survey for a 24-hour period. The survey also found that data collection was more successful when a uniformed officer was present, which increased the cost (*11*). Second, surveys require that the carrier be delayed and the surveys must take place at locations with sufficient roadside geometry. Similar surveys of rail traffic are not feasible, given the proprietary nature of data that would be obtained. As an alternative to surveys, many models have compared modeled flows to ground counts as a validation measure. While ground count data contain volumes and classification information, they do not reveal commodity information. In a layered approach, simply comparing modeled flows to ground count data would not be sufficient for validation (as shown in Chapter 11), since an estimate of the unmodeled freight is required.

In order to supplement the ground data so that it could be used for model validation, estimates of the commodity data were made by visually observing freight vehicles in Iowa. The approach used was simple and described below:

1) Highway and rail freight vehicles were observed at locations around the state and information about the vehicle such as vehicle type, markings (including placards),

classification, trailer/railcar type, and visible cargo were recorded. These data are used to estimate (or determine) the commodities being transported;

2) The data were compiled into a relational database;
3) The field observations of highway vehicles were matched to carriers in the MCMIS database to estimate the commodity being transported; and
4) Direct field observations of commodities on vehicles were categorized.

A flowchart for the process is shown in Figure 12The total cost for the data collection effort was estimated between $3,000 and $4,000 dollars including labor, travel costs at the field data location, and the labor cost to compile the data from the field forms into a relational database. The cost to match the observed carriers to carriers in the MCMIS database was estimated at $1,000.

9.2 Highway Data

The objective of the highway data collection was to determine the commodities being transported by trucks. This was accomplished by either: 1) determining the commodity being transported by direct observation; or 2) collecting sufficient information about the vehicle that would allow the carrier to be identified in the MCMIS database (which would allow for the commodity to be estimated). Highway vehicles were observed by one or two person teams (sometimes assisted by binoculars).

After some preliminary trials, it was found that one-person was adequate for highways with average daily truck traffic (ADTT) less than 2,500. Two persons were required for volumes greater than 2,500 ADTT. The upper limit of the ADTT for data collection with two

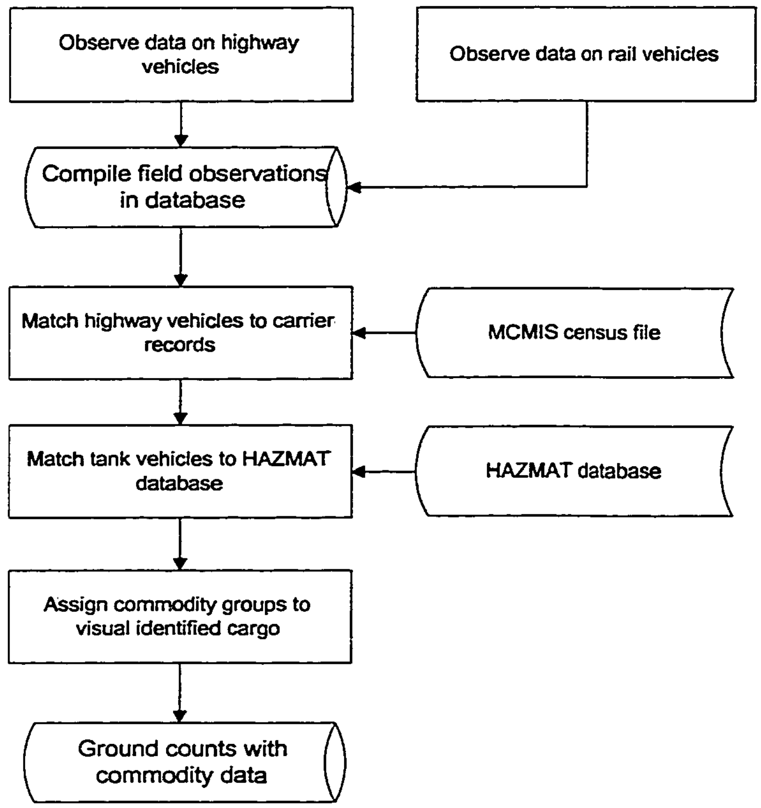


Figure 12 Developing the Commodity Database

persons was not explored as the highest volume road in the data collection was easily covered by a two-person team. In addition, it was found that it was not possible to accurately read some of the information while the vehicles were in motion. Where possible, data collection took place at locations where traffic was stopped or slowed by traffic control devices. Unlike some other states, Iowa's primary highways are stop controlled at major intersections.

The collection of the data by video recording was also considered. In a field trial, samples of video surveillance for highway data collection with available equipment were not satisfactory. The quality was not sufficient to read the motor carrier's identification number and other markings could be read sufficiently with the visual observation method.

The following information was collected for each vehicle that passed the observation location. Not all information could be collected about each vehicle for a variety of reasons. For example, if a platoon of trucks arrived at the same time it was difficult for the field observer to record all details of each vehicle. In other cases, certain data – particularly the motor carrier identification number- was not visible because of dirt, small or missing numbers, or poor contrasting colors between the numbers and the truck cab. The information was recorded on a field data form.

- **Time of observation:** Data were collected in 15-minute time increments.
- **Travel and turning direction:** The initial direction of the observed vehicle was recorded. Most data were collected at intersections since it was advantageous to have the truck slow or stop to collect the data. If the vehicle turned, the final direction was noted.
- **Classification of truck:** The configuration of the straight truck or the tractor-trailer combination was recorded using the American Association of State Highway and Transportation Officials (AASHTO) classification system. Figure 13 illustrates the different classifications.

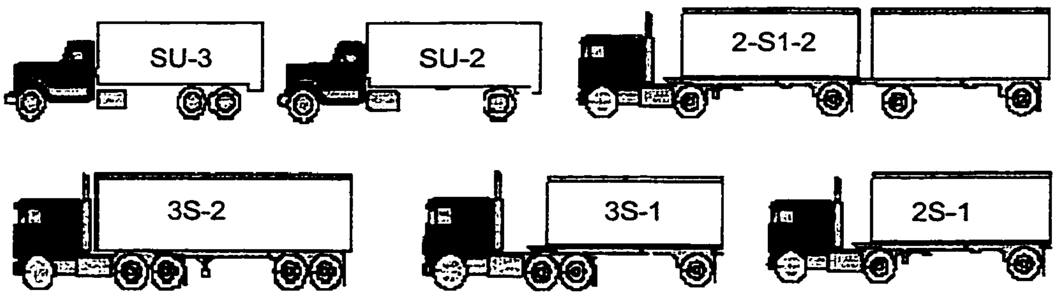


Figure 13 Truck Configurations

- **Motor carrier identification number and markings:** Obtaining the motor carrier identification number, legal name, or city and state of the carrier increases the probability that an identification of the carrier in the MCMIS database can be made. All motor carriers involved in interstate commerce are subject to federal motor carrier safety regulations (almost all trucks) must display by law:

    1) the legal name of the carrier operating the vehicle;
    2) the name of the city and state of the commercial vehicle's principal place of business; and
    3) the motor carrier identification number.

  The information must be displayed on the commercial vehicle and:

    1) appear on both sides;
    2) be in contrasting color;
    3) be legible from 50 feet while the vehicle is stationary; and
    4) be kept clean and legible (*62*).

- The motor carrier identification number can be either an Interstate Commerce Commission motor carrier (ICC MC) number or a U.S. Department of Transportation (USDOT) number. The ICC no longer exists (it was replaced by the Surface Transportation Board in 1996) but motor carriers are still permitted to display their ICC number. Most motor carriers have either an ICC MC or a USDOT number but many have both. The legal name for many motor carriers is displayed on the tractor (and sometimes on the trailer). The city and state are most commonly displayed on the tractor, in less prominent text then the carrier name. A close up photo of a truck tractor in Figure 14 indicates the placement of the identifying information.

- **Trailer type**: For some trailers, the type of trailer can help identify the commodity being hauled. The following types of trailers were identified: dry van; refrigerated van; flatbed; tank; container on trailer; 28-foot doubles, livestock; automobile carrier; grain trailer (hopper); dump trailer; aggregate; dry bulk; and other. Examples of the trailer types are shown in Figure 15.
- **Visual cargo identification:** If the cargo was visible (cars, farm equipment, livestock, steel beams, steel pipes, concrete pipes, lumber, etc). it was recorded on the data collection forms. If the vehicle or trailer was empty, it was also recorded on the form. For tank-type trailers, if the material being transported was hazardous, a DOT placard must be posted on the trailer. This number was recorded for comparison to the hazardous materials table in the federal register (*63*).

9.2.1 Locations

Locations for truck data collection were chosen based on three criteria. First, the general location and facility type was chosen based upon the geographical need for data for model validation. For validation purposes, a "screen line" configuration of the locations was desirable. Second, only highways with truck ADTT greater than 700 were chosen. Lower volume roads are typically not useful for validation purposes and volumes on these roads are not likely to change (most traffic is local). In order to maximize data collection efforts, primary consideration was given to locations where two higher volume roadways intersected.

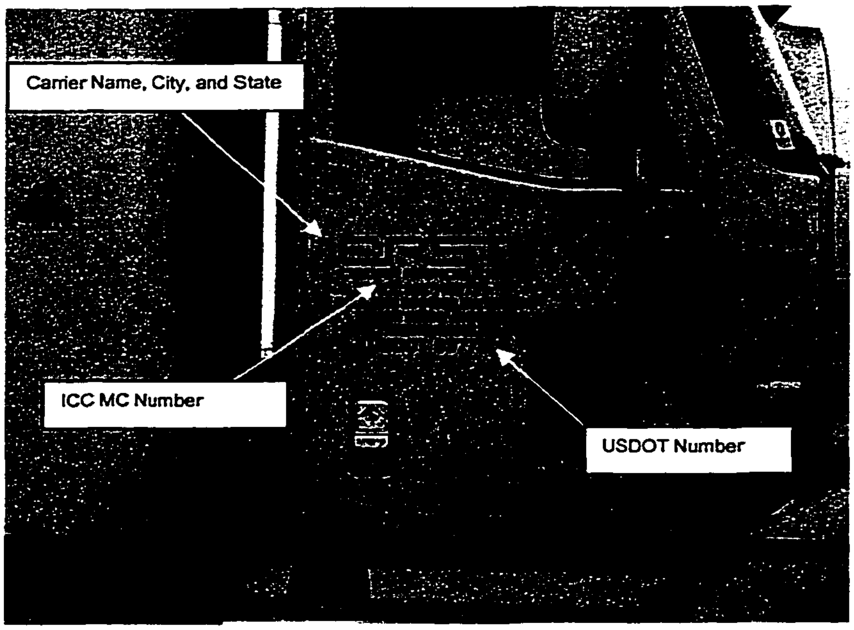
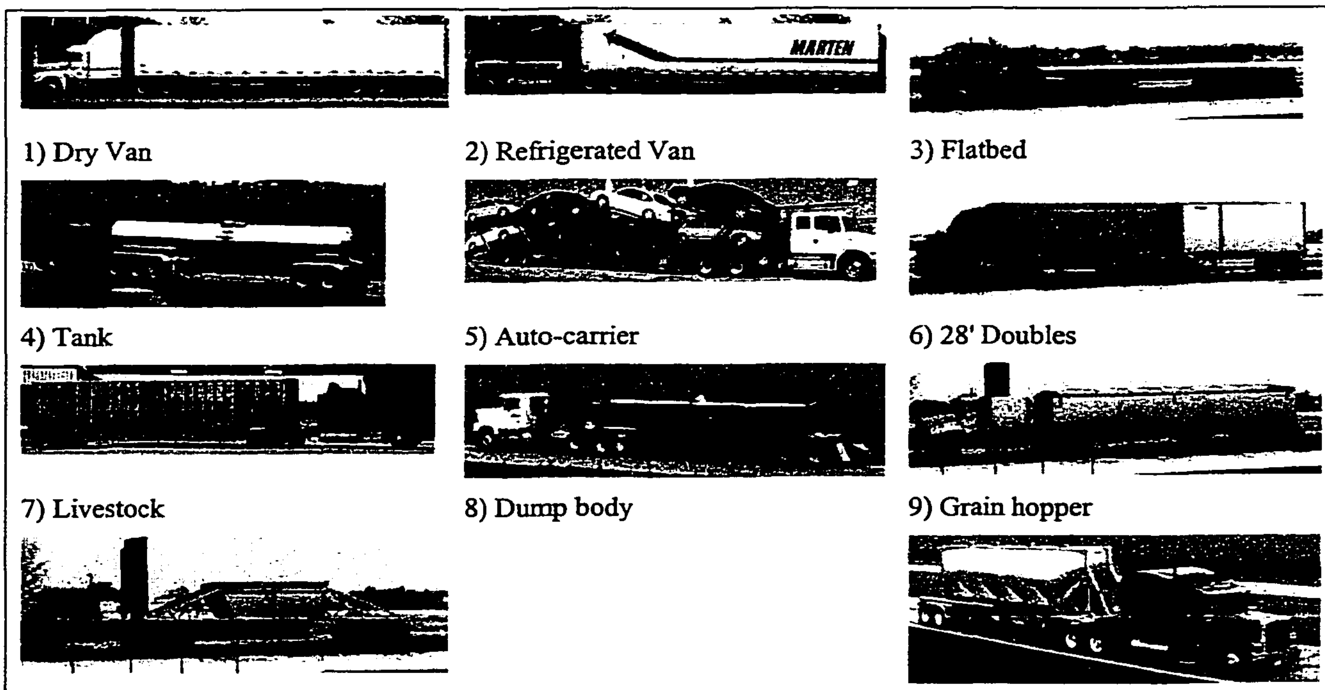


Figure 14 Vehicle Identification Numbers on Motor Carrier



1) Dry Van | 2) Refrigerated Van | 3) Flatbed
4) Tank | 5) Auto-carrier | 6) 28' Doubles
7) Livestock | 8) Dump body | 9) Grain hopper
10) Aggregate | Note: All pictures by author | 11) Bulk tank

Figure 15 Trailer Types

Data were collected for both highway segments, including turning movements, which provided observations on two highways from one location. Third, given that the data were easier to collect at lower vehicle speeds, priority was given to locations that had stop-controlled intersections. These intersections were identified using an inventory of stop signs on primary highways provided by Iowa DOT traffic engineering office.

In a typical setup, the person collecting the data wore a safety vest and located close enough to the highway to be able to read the required information on the traveling vehicles. At some four-way stop controlled intersections, it was possible to setup in the median, which allowed for easier identification of the required information. Otherwise, the setup was in a location that had a clear view of all approaches. For facilities with no stop control, the observer setup close to the highway but at least 30 feet from the edge of the traveled way because of safety issues. In a two-person setup, each observer recorded data for one direction of travel. It was found that it was advantageous to have both observers sitting on the same side of the highway to assist each other in high volume situations.

The selected data collection sites are indicated in Figure 16 by triangles. The number corresponds to the description in Table 15. Facilities were classified by function: 1) interstate; 2) 4-lane divided; and 3) rural highway. Data were collected at five locations in the state on interstate highways. Two locations on I-80, three on I-35 and one on I-29 were chosen. Vehicles at these locations were in motion so it was not possible to read carrier identification numbers, collecting the carrier name and city/state proved to be more feasible. Two 4-lane facilities, U.S. 30 and U.S. 20, were also chosen for data collection. At these locations, the vehicles were also in motion. The remaining seven locations were on rural highways and had some type of stop control, either two-way or four-way, making obtaining the carrier identification number much easier for the stopped vehicles.

9.3 Railway Data

Similar to highway data collection, the objective of the rail data collection was to determine the commodities being transported by rail in Iowa. This was accomplished by direct observation of the commodities in transport. It was possible to determine commodity type for a significant portion of rail traffic by observing cars (coal, automobiles, grain, lumber). In addition, many railcars are commodity-specific allowing for reasonable estimates of the commodity in transport. The data for rail vehicles were collected by a one-person team

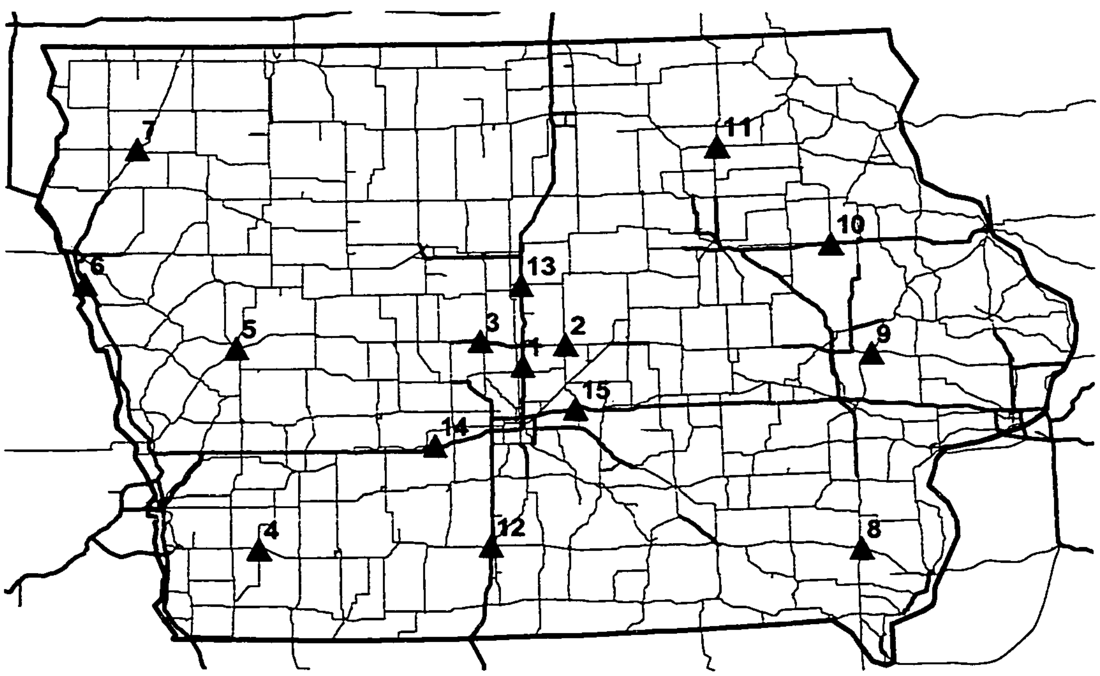


Figure 16 Highway Data Locations

Table 15 Highway Data Collection Locations

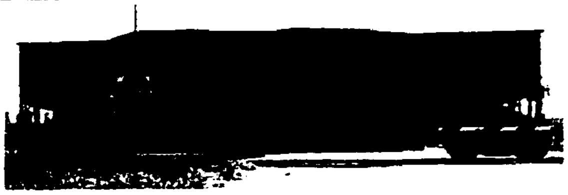
ID#	Date	Nearest Iowa City	Location		Setup	Type of Observation	Facility Type
1	2/2/00	Ames	I 35	near IA 210	1 person	In-motion	Interstate
2	2/2/00	Colo	US 30	at U.S. 65	1 person	In-motion	4-lane divided
3	4/5/00	Boone	US 30	at R 27	1 person	4-Way stop	4-lane divided
4	6/5/00	Red Oak	US 34	at IA 48	1 person	4-Way stop	Rural highway
5	6/6/00	Denison	US 30	at U.S. 59	1 person	2-Way stop (T)	Rural highway
6	6/7/00	Salik	I 29	near IA 141	1 person	In-motion	Rural highway
7	6/8/00	Alton	IA 60	at IA 10	1 person	2-Way stop (T)	Rural highway
8	6/13/00	Mt. Pleasant	IA 34	at U.S. 218	1 person	4-Way stop	Rural highway
9	6/14/00	Mt. Vernon	US 30	at IA 1	1 person	4-Way stop	Rural highway
10	6/15/00	Lamont	US 20	near IA 187	1 person	In-motion	4-lane divided
11	6/16/00	Fredricksburg	US 63	at U.S. 18	1 person	4-Way stop	Rural highway
13	6/27/00	Ames	I 35	near E 18	2 person	In-motion	Interstate
12	6/27/00	Osceloa	I 35	near U.S. 34	2 person	In-motion	Interstate
14	6/29/00	Earlham	I 80	near P 57	2 person	In-motion	Interstate
15	6/29/00	Newton	I 80	near IA 117	2 person	In-motion	Interstate

(T) = T-intersection

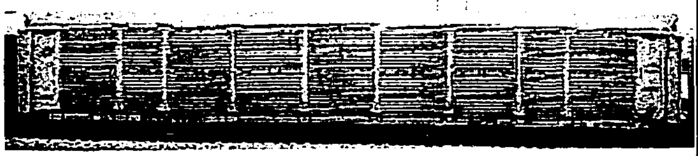
with a video camera. The video method was appropriate for rail because it would not be possible to record all of the information as the train was passing the observation point. The entire train was taped and the data were analyzed in the office.

The following information was collected for each train consist that passed the data collection location:

- **Time of observation:** Time of travel for the train was recorded.
- **Travel direction:** The direction of travel on the railway was recorded.
- **Number of power units:** The number of locomotives was recorded.
- **Car type:** Like truck trailers, the type of railcar may indicate the commodity being carried since many railcars are commodity specific. The following car types were recorded: coal hopper; two cover coil steel; grain hopper; autorack; refrigerated boxcar; open gondola; ore hopper; boxcar; aggregate hopper; flatcar; centerbeam flatcar; Trailer of Flatcar (TOFC); tank car; and Container on Flatcar (COFC). Figure 17 illustrates the various railcar types.
- **Visual cargo identification:** If the cargo was visible (cars, lumber, coal) the information was recorded. Empty cars of any type were also recorded. As with tank trailers, the hazardous materials placard number was recorded if it was visible. The number could be compared with 49 CFR 172.101(b)(1) to determine the commodity. However, most numbers on tank cars were not visible on the tape recording. Rail cars often have the type of commodity carried in the car painted on car (e.g., corn oil, potash, chlorine) and this was used to help estimate commodity carried.



100) Coal Hopper*

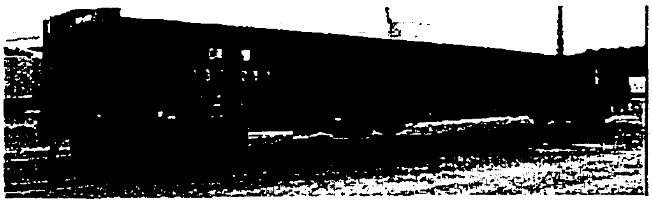


101) Autorack*

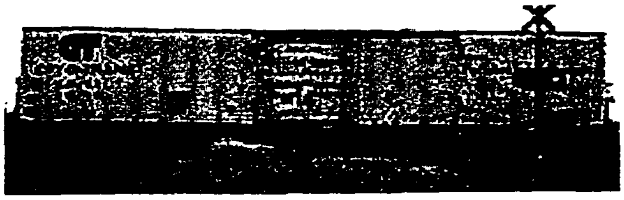
102) Two Cover Coil Steel*

103) Centerbeam Flatcar*

104) Grain Hopper*

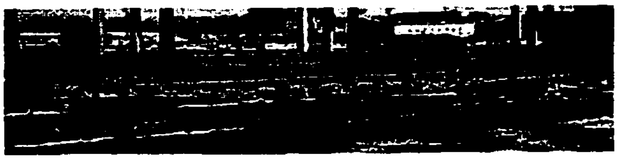


105) Open Gondola+



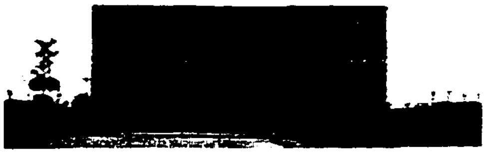
106) Refrigerated Boxcar*

107) Boxcar*



108) Flatcar+

109) Tank Car



110) COFC 20' and 40'*

111) TOFC 28' and 54'

Figure 17 Rail Car Types

*Pictures by author +Pictures from Union Pacific public railcar descriptions catalog.

9.3.1 Locations

Five locations for rail data collection were chosen based on geographical location and freight traffic densities. Two main freight lines run east and west through Iowa, the Burlington Northern Santa Fe (BNSF) in southern Iowa and the Union Pacific (UP) in central Iowa. In 1995, there were 4,268 miles of track in Iowa of which 3,011 miles were operated by Class I railroads (AAR data file). The two east-west main lines account for only approximately 570 miles of track. Given the low volumes on branch line spurs (on some lines one or two trains a week) train data collection was not as comprehensive as highway data collection. It was outside the time constraints for data to be collected on many of these low volume branch lines.

In a typical setup, the observer would setup the video camera near the rail tracks. After some preliminary tests, it was found that setting up the video camera 150-200 feet from the tracks provided for optimal data reduction. The observer would turn on the camera, announce the direction and time, and record an entire train consist. If there were any notes about the cars or cargo, the observer would record them on the tape (by speaking into the microphone). Locations for rail data collection are indicated in Figure 18. The numbers in the figures correspond to the descriptions of the sites in Table 16. Two of the sites were on the main line, and the remaining three were on branch lines.

9.4 Compiling the Collected Data

Significant data collection resources were dedicated to database entry. The data were entered into two tables in a database (highway and rail). In the highway data table each

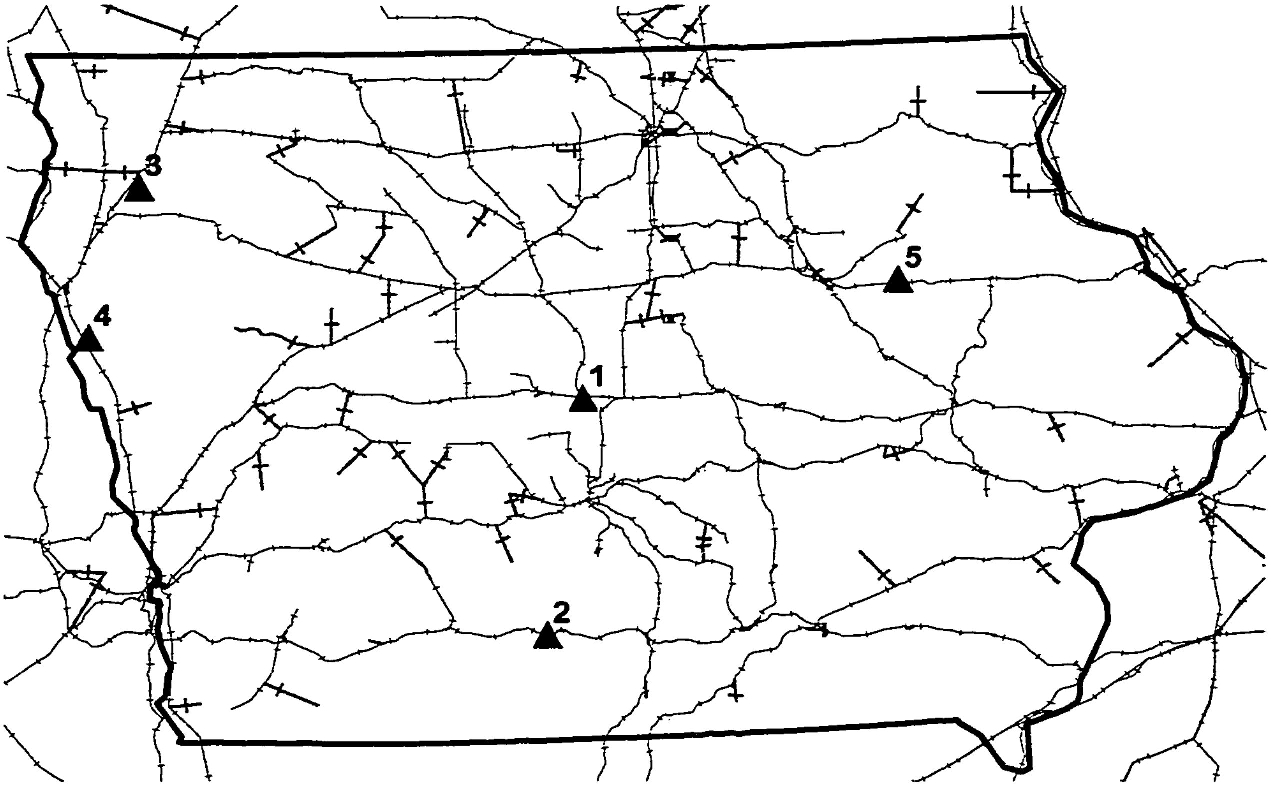


Figure 18 Rail Data Locations

Table 16 Rail Data Collection Locations

ID#	Date	Nearest City (IA)	Owner	Setup	Type
1	3/26/00 & 7/12/00	Ames	Union Pacific	1 person	Main line
2	6/27/00	Osceloa	Burlington Northern Santa Fe	1 person	Main line
3	6/8/00	Alton	Union Pacific	1 person	Branch line
4	6/7/00	Sloan	Union Pacific	1 person	Branch line
5	6/15/00	Lamont	Canadian National (was Illinois Central)	1 person	Branch line

vehicle observed was a record. The table contained the fields in Table 17..

In the truck database, key matching fields included carrier name, ICC MC number, or USDOT number. To reduce the likelihood of errors, the database entry form was equipped with a drop down list that included the names of all carriers that had been previously entered. If the ICC MC number or USDOT number was known for that carrier, it would also be automatically entered. A total of 11,427 records (trucks) were entered.

In the rail data table, each train represents a record. After viewing the data on tape, the information about each train was recorded in the rail data table. The rail data table contained the fields indicated in Table 18, which were previously described in the rail data section 9.3.

9.5 Matching the Highway Data

For the highway data, each truck was matched to the records in the MCMIS database, (recall this database contains information on the commodities carried by each carrier, as described in the following section).

9.5.1 Motor Carrier Management Information System (MCMIS) Census File

The Motor Carrier Management Information System (MCMIS) is an inventory of the safety performance of motor carriers and hazardous material shippers subject to Federal Motor Carrier Safety Regulations (FMCSR) or Hazardous Materials Regulations (HMR). Each record in the database contains identifying data elements such as name and address, business/ operation data, and the type of cargo carried.

The current version of the Census flat file was obtained from the Federal Motor

Table 17 Fields in Highway Data Table

Field Name	Description
ID	Record identifying number
Location	Location of the data collection
Date	Date of record
Time	Time block of record, 15 minute increments
Travel Direction	Travel direction of the freight vehicle
Turning Direction	Travel direction if the vehicle made a turn
Classification	Truck configuration
Observed MC Number	ICC MC Number
Observed DOT Number	USDOT Number
Trailer Type	Trailer type
Markings	Carrier name, city and state
Visual Cargo	Notes of any cargo that was observed
Notes	Field notes

Table 18 Fields in Rail Data Table

Field Name	Description
ID	Record identifying number
Location	Location of the data collection
Date	Date of record
Time	Time block of record, 15 minute increments
Travel Direction	Travel direction of the freight vehicle
Power Units	Number of locomotives
Car Types (*Separate field for empty cars not shown for clarity*)	
Coal Hopper	Two Cover Coil Steel
Grain Hopper	Autorack
Refrigerated Boxcar	Open Gondola
Ore Hopper	Boxcar
Aggregate Hopper	Flatcar
Tank Car	TOFC 28' and 54'
Other	COFC 20' and 40'

Carrier Safety Administration (FMCSA) in late May 2000 (*55*). The flat Census file contains all active and inactive motor carriers subject to federal regulation. The complete Census file contains well over 763,000 records in space-delimited text file format with a file size of 1,000,000 kilobytes (1 gigabyte). The flat file was imported into a Microsoft Access database using a space-definition file that was developed from supporting documentation contained in the Census files. After importing the data into Access, the size was reduced to 604,752 kilobytes (a 40 percent reduction).

In order to further reduce the size of the database, any records that were inactive (out of business) were eliminated from the working data set (inactive carriers are indicated by a code). In addition, any records of motor carriers that were registered only to transport passengers were removed from the database (passenger transportation mode was not included in the model). In addition, many of the fields in the database were related to the safety performance of the motor carrier and were not directly applicable to the freight model and were removed from the working database. For example, fields on safety ratings, federal tax identification, and mailing codes were some of the fields removed from the remaining records of the database. The number of active, non-passenger records remaining was 593,000 with a final file size of 162,000 kilobytes (a 84 percent reduction in size form the original file). Clearly, a smaller size database allows for faster querying and easier file maintenance. The data in MCMIS database that were used in the research are shown in Table 19.

9.5.2 Matching Procedure

Three fields were added to the highway data table to aid in the matching procedure. One field was named "matched" which was a yes/no field that indicated that the observed data had been matched to a carrier in the MCMIS database. If no match could be made, the "unidentified" field, which was also yes/no, would set to "yes." The last field "cargo match" indicated whether the cargo had been visually identified by field observation or by trailer

Table 19 Selected Fields for Use in the Working MCMIS Census File

Field Name	Description
Entity Type	Refers to the type of operation in which the entity is engaged. It identifies the entity as a carrier, hazardous materials shipper, both a carrier and a shipper, or a registrant
USDOT Number	The number assigned by MCMIS to a census record.
Legal Name	Legal name of the entity.
'Doing Business As' (DBA) Name	Trade name under which the entity does business. Any name identifying the entity other than the legal name.
Name Alphabetizer	Index for searching for an entity by DBA name
ICC Docket Number	Federally assigned Interstate Commerce Commission entity's identification number.
Street, City, County, State, Zip	Identifies the address where the entity's principal office is phySIC ally located
Telephone & Fax	The entity's telephone and fax number at the principal place of business
Classification	Identifies the type of entity. MCMIS recognizes the following classifications for entity type: authorized-for-hire. exempt-for-hire. private (property). U.S. mail. federal govt. state govt. local govt. Indian tribe.
Carrier/Shipper Operation	Identifies the carrier as being engaged in interstate, intrastate hazardous material or intrastate non-hazardous material transport activities. In cases of shippers, it identifies the shipper as being engaged in interstate or intrastate hazardous material shipping activities.
Cargo Classifications	See Table 29

type. The matching procedure was a heuristic approach described in following steps:

Step 1: The highway data table and the MCMIS database were joined by USDOT number. A query was run with criteria:

- Observed USDOT Number = "Is Not Null"
- Matched = "No"

The resulting query contained the records from the highway data table with *observed* USDOT number, carrier name, city and state fields and the *actual* carrier name, city state for the USDOT number. If carrier information such as name or city and state were observed, the record would be inspected to see if the fields from the observed and actual carrier matched. If they did, the matched field in the highway data table would be changed to "yes." If no other information besides the USDOT number were observed, the carrier information would be verified. Unlikely matches (such as a carrier from Hawaii with a grain trailer) were marked as unidentified. Most likely, these were a result of errors in field observation or input.

Step 2: The highway data table and the MCMIS database were then linked by ICC MC number. A query was run with parameters:

- Observed ICC MC Number = "Is Not Null"
- Matched = "No"

The resulting query contained the records with *observed* ICC MC number, carrier name, city and state fields and the *actual* carrier name, city, and state for the ICC MC number. The matching procedures described in Step 1 were repeated.

Step 3: The remaining unmatched records were ones with either no identification number or did not correspond with the information in the MCMIS database. A query of the highway data table was prepared so that all the sorted records were in alphabetical order by carrier name. By manually browsing the data, it was possible to see if any currently unmatched record in the database matched one that had been previously matched. If a record contained a carrier that was matched in Step 1 or 2, the USDOT number was recorded in the observed record. This procedure was very helpful since in the data collection process the carrier name may have been observed on one vehicle, and the carrier name and USDOT or MC number observed an another vehicle. The matched field was marked "yes" for any new matches. At the end of Step 3, 5,280 of the 11,427 (46 percent) records were matched.

Step 4: The remaining records with carrier markings that had not been matched were queried out of the highway data table with the following parameters:

- Markings = "Is Not Null"
- Matched = "No"

The resulting query was of all records that had text in the carrier markings field but had not been matched yet. This subset of 4,174 records was the most difficult to match since each of the records had to be matched by manually searching the MCMIS database to find the carrier. A search form was developed in the MCMIS database that allowed the database to be searched quickly. To the extent possible, the search procedure was automated. In the MCMIS database, four search fields: the Census number, the alphabetized locator, the ICC MC number, and the city field were indexed. Indexing is a database procedure that allows for faster querying, especially in fields where there are few duplicates. An example of the search form is shown in Figure 19.

The search query allowed for truncated searches by carrier name. For example, to search for the carrier with the name "DeBoer" it would be possible to search using "DeBo*"

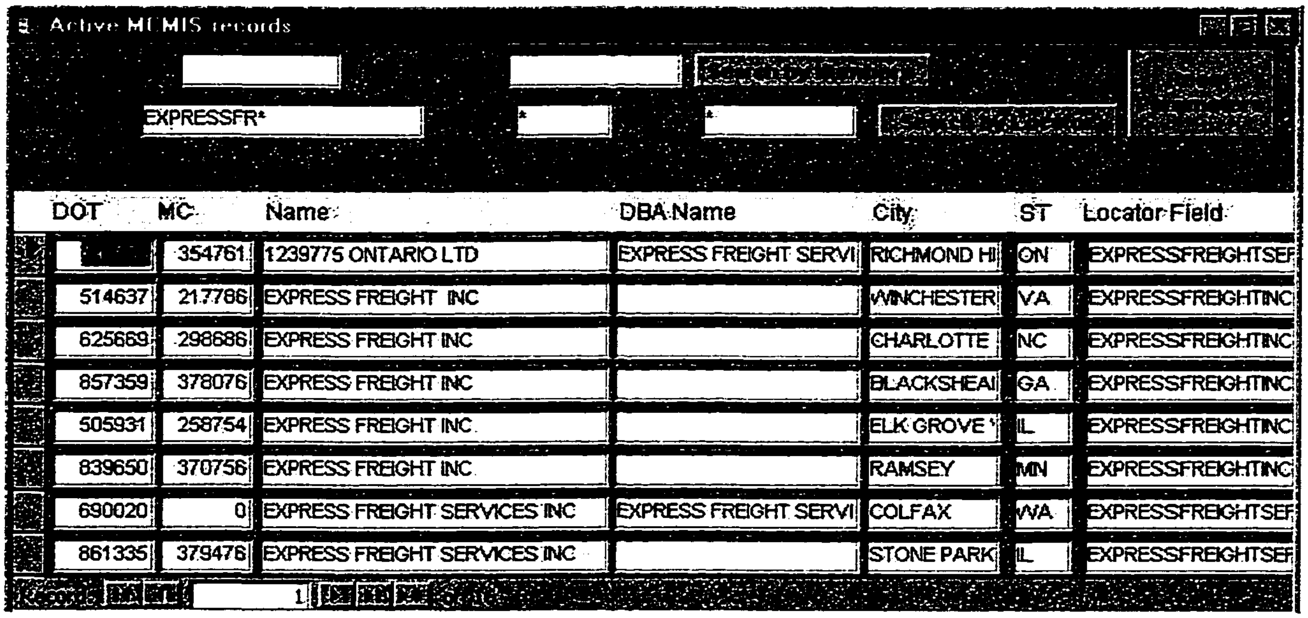


Figure 19 MCMIS Search Dialog

where the "*" is a wildcard character. All records in the MCMIS that had DEBO as their first four characters in the locator field would be retrieved. This search capability allowed searches to overcome misspellings or errors in recording the carrier name either in the field or in the highway database. In addition, searches could be narrowed by including "State" and / or "City" fields. In this manner, it was possible to search for combinations of observed data rather quickly. Whenever the city and/or state were known with the carrier name, the carrier could usually be identified. When only the carrier name was present, unique identification was less common - especially if the name was common such as "Express Freight" which was shown in Figure 19. This sample search yielded 16 matches and without knowing a state or city, an exact match would be impossible. At the end of this Step 4, 1,879 of the 4,174 (45 percent) records were matched bringing the total matched records to 7,159 of 11,427 (63 percent). A total of 4,268 records remained unmatched.

Step 5: The overall goal of the data collection process was to identify the type of cargo being transported. In addition to the DOT or MC number or carrier name, other data that were collected was used to "match" the carrier to the cargo being carried. Trucks with trailers of livestock, grain hoppers, or auto carriers were considered "cargo-matched" because the commodities carried are implied by the trailer. In addition, any commodities that were actually observed in the field were also marked as "cargo-matched" since the commodity being transported was known. All records in the highway data table were searched to determine if they had any of the trailers that would allow a "cargo-match." If they did, the cargo-match field was changed to yes. In addition, any of the records that had the actual cargo observed were marked "cargo-matched." At the end of this Step 5, an additional 2,436 records were matched bringing the total matched records to 8,913 of 11,427 (78 percent).

9.6 Highway Vehicle Results

A total of 3,375 different carriers were observed during the data collection effort. A vast majority (3,236) of carriers were observed less then 10 times for the entire data collection. A few carriers were observed many times throughout the data collection and are shown in Table 20, which lists the top 16 most common carriers. Included in the table is the type of carrier (truckload (TL), less-that-truckload (LTL), or private) and the city and state of the principal place of business. Most of the commonly observed carriers were truckload carriers with operations based in one of the states surrounding Iowa.

Table 20 Top Observed Carriers

Carrier Name	Type	Base City	State	Number of Observations
Werner Enterprises Inc	TL	Omaha	NE	184
Schneider National Carriers Inc	TL	Green Bay	WI	155
United Parcel Service Inc	LTL	Downers Grove	IL	105
Wal-Mart Stores East Inc	Private	Bentonville	AR	99
J B Hunt Transport Inc	TL	Lowell	AR	96
Crete Carrier Corporation	TL	Lincoln	NE	83
Smithway Motor Xpress Inc	TL	Fort Dodge	IA	80
England Transportation	TL	Springfield	TN	80
U S Xpress Inc	TL	Chattanooga	TN	78
Swift Transportation Co Inc	TL	Phoenix	AZ	77
Yellow Freight System Inc	LTL	Overland Park	KS	74
Decker Truck Line Inc	TL	Fort Dodge	IA	55
Consolidated Freightways Corporation	LTL	Menlo Park	CA	54
Transport Corporation Of America Inc	TL	Eagan	MN	53

9.6.1 Matching

The detailed statistics of the data collection by location are shown in Table 21. The sites were divided into 4-lane divided, interstate, and rural for presentation in the table. Sites 1 and 2 were considered preliminary tests but were included in the analysis.

On the average, sites where the vehicles came to a stop in two or all directions had a much better overall matching rate than where the vehicles were in motion. All locations considered rural highways were at stop-control locations and had an average matching rate of 90.8%. One other location that was stop-controlled, location 3, also had a high overall matching rate of 88.7%. More importantly, the identification of the actual carrier was significantly better at these locations than locations where the vehicles were in-motion.

Table 21 Location Results

Location		Hrs	Number of Trucks Observed	Percentage of Carriers Observed: Not identified	Matched by: Carrier	Cargo	Both Cargo and Carrier	Total
4 lane divided								
2	In-motion	1.5	72	34.7%	23.6%	41.7%	0.0%	65.3%
3	4-way stop	5	151	11.3%	68.9%	7.9%	11.9%	88.7%
10	In-motion	7	395	20.8%	39.0%	33.2%	7.1%	79.2%
			Average	*22.2%*	*27.0%*	*27.6%*	*6.3%*	*77.8%*
Interstate								
1	In-motion	1.5	257	51.4%	35.8%	12.8%	0.0%	48.6%
6	In-motion	7	856	23.0%	50.6%	24.6%	1.8%	77.0%
12	In-motion	7	1416	20.2%	59.4%	16.6%	3.8%	79.8%
13	In-motion	7	1312	20.8%	57.5%	14.2%	7.5%	79.2%
14	In-motion	6	2150	29.0%	56.5%	11.8%	2.7%	71.0%
15	In-motion	6	2155	30.6%	56.8%	10.4%	2.3%	69.4%
			Average	*29.2%*	*52.8%*	*15.1%*	*3.0%*	*70.8%*
Rural Highway								
4	4-way stop	7	195	12.3%	53.3%	13.3%	21.0%	87.7%
5	2-way stop	7	442	12.2%	51.4%	19.7%	16.7%	87.8%
7	2-way stop	7	365	7.7%	58.9%	23.0%	10.4%	92.3%
8	4-way stop	7	832	8.2%	71.3%	15.4%	5.2%	91.8%
9	4-way stop	7	352	7.4%	67.6%	8.5%	16.5%	92.6%
11	4-way stop	7	477	7.3%	56.0%	22.9%	13.8%	92.7%
			Average	*9.2%*	*59.7%*	*17.1%*	*13.9%*	*90.8%*
Total		90	11,427	22.1%	56.7%	15.6%	5.6%	77.9%

Including matches of the “carrier” and “both cargo and carrier,” the total matching rate was 74%. At locations where the vehicle was in motion, the matching rate was 52.8% on the interstates and 27% on 4-lane divided roadways. This can be attributed to the fact that more information, such as the identification number or city/state, was consistently read on the vehicles while they were stopped (that helped in the matching process). The interstate matching rate was better than the 4-lane divided rate because carriers on the interstate are usually larger companies that have well marked tractors and trailers allowing for easier identification.

9.6.2 Vehicle Type and Configuration

The type and configurations of the highway vehicles observed are summarized by facility type in Table 22 and Table 23, respectively. The most common configuration for all highway types was the 3-S2 arrangement that accounted for approximately 95% of observations. The next most common configuration (2.9%) was the 2-S1-2 arrangement that was seen mostly on the interstate facilities. Single unit trucks (SU-2 and SU-3) accounted for 1.8% of total observations. The single unit trucks were much more common on the rural 4-lane and highways (5.7% and 2.8%, respectively) than on the interstate (1.2%). Iowa does not allow doubles or triples trailer combinations.

The most common observed trailer type was the dry van trailer. It was more common on the interstate facilities (51.8%) than on the rural highway (38.9%) or the 4-lane divided (37.2%). The refrigerated van was the next most common observation overall (15.8%). The third most common trailer overall was the flatbed (13.1%). Grain hopper trailers were more

Table 22 Percentage of Truck Trailer Type by Facility

Trailer Type	Rural highways	Rural Divided Highway	Interstate	All types
28' Doubles	1.1%	0.2%	3.7%	2.9%
Aggregate	0.4%	0.0%	1.3%	1.0%
Auto-carrier	0.5%	0.8%	0.9%	0.8%
Bulk tank	1.3%	2.6%	0.5%	0.8%
Container	0.6%	0.6%	1.1%	0.9%
Dry Van	38.9%	37.2%	51.8%	48.0%
Dump body	1.3%	1.3%	0.2%	0.5%
Flatbed	10.8%	16.5%	13.6%	13.1%
Grain hopper	11.9%	12.5%	3.5%	6.0%
Livestock	6.5%	4.7%	1.6%	2.9%
Other	0.9%	0.3%	0.4%	0.5%
Refrigerated	16.1%	12.9%	15.8%	15.8%
Single Van	0.8%	0.8%	0.3%	0.4%
Tank	9.0%	9.5%	5.3%	6.4%

Table 23 Percentage of Truck Configuration by Facility

Truck Configuration	Rural highways	Rural Divided Highway	Interstate	All types
2-S1	1.0%	0.2%	0.2%	0.4%
2-S1-2	0.9%	0.3%	3.7%	2.9%
3-S1	0.3%	-	0.1%	0.1%
3-S2	94.8%	93.4%	94.5%	94.5%
SU-2	2.8%	5.7%	1.2%	1.8%
SU-3	-	0.2%	0.2%	0.1%

common on the rural highways (11.9% and 12.5%) than on the interstate (3.5%). Likewise, tank trailers were more common on rural (9.0% and 9.5%) than on interstate (5.3%) facilities as well as livestock trailers (6.5% and 4.7%) versus (1.6%) interstate. Trailers in double combination (28' doubles) were more common on the interstate (3.7%) then on rural highways (1.1% and 0.2%).

9.7 Rail Vehicle Results

The rail data collection effort was not as extensive as the highway data collection effort. A summary of the results is presented in Table 24. The sites were divided into main and branch line for presentation in the table. Locations 1 and 2 on the Union Pacific and BNSF main lines yielded the majority of data. Two days of observation were made at the Ames location while the BNSF data were collected concurrently with the highway data collection at Osceola. A total of 38 trains were observed on the Union Pacific main line. Those trains consisted of 3,263 freight cars with an average train length of 86 cars. The longest train observed was an eastbound mixed freight that was 127 cars long. A total of 43% of all the cars observed could be considered to be transporting known commodities based upon car type or observation. The cargo of the remaining 57% of cars could not be determined.

On the Union Pacific main line there was a greater variation of the types of cars observed as shown in Table 25. Nearly 40% of all cars observed were either loaded or empty coal hoppers that traveled in unit trains. Intermodal car types including TOFC and COFC consisted of 20% of the total cars observed which also mostly always in unit trains. Grain

Table 24 Rail Data Summary

Location		Hrs	Number of Trains Observed	Average Train Consist	Not identified	Identified
Main line						
1	Ames	14	38	86	57%	43%
2	Osceola	7	3	96	21%	79%
Branch line						
3	Alton	7	2	94	27%	73%
4	Sloan	7	3	70	38%	62%
5	Lamont	7	0	-	-	-
	Total	42	42		52%	48%

Table 25 Percentage of Car Type by Location

Car Type	Union Pacific	BNSF	Union Pacific-Alton	Union Pacific-Sloan	All
Coal Hopper	19%	78%	-	-	21%
Empty Coal Hopper	21%	-	-	-	17%
Grain Hopper	13%	-	69%	57%	17%
Tank Car	4%	7%	9%	27%	5%
Two Cover Coil Steel	1%	1%	-	-	1%
Auto Carrier	3%	-	-	-	2%
Empty Auto Carrier	5%	-	-	-	4%
Open Gondola	1%	3%	7%	1%	1%
Boxcar	10%	11%	11%	-	1-
Empty Boxcar	-	-	-	10%	1%
Flatcar	-	-	-	-	-
Empty Flatcar	1%	-	-	-	1%
Lumber Rack	1%	-	4%	4%	1%
Empty Lumber Rack	2%	-	-	-	1%
TOFC 28'	2%	-	-	-	2%
TOFC 54'	5%	-	-	-	4%
COFC 20'	9%	-	-	-	7%
COFC 40'	4%	-	-	-	3%

hoppers made up 13% of the observed traffic and boxcar traffic made up another 10%.

Traffic on the BNSF main line was very low on the observation day. A total of three trains were observed, two of which were loaded unit coal trains. The third train was a mixed freight consisting of box and tank cars. For this reason, 79% of all cars on the BNSF line for the observed day were transporting known cargo. Traffic on the two Union Pacific branch lines that were observed consisted of mainly grain hoppers (69% and 57%). Other cars observed included tank, boxcar, and empty boxcars. No trains were observed at the Lamont site on the observation day.

9.8 Summary

This chapter documented the method used to collect data on freight transportation vehicles in Iowa. Data were collected at 15 locations during a three month locations. In this particular data collection, temporal aspects of freight distribution were not addressed. Most locations were only visited for a seven-hour period for one day. Cost was the primary limitation on collecting more data.

CHAPTER 10 - MODEL CALIBRATION

Calibration and validation of travel demand models are two important and distinct steps, and it is important to differentiate their processes. Sequential models are calibrated by adjusting parameters such that intermediate steps produce results observed in surveys of local trip making behavior. For example, a trip distribution model is calibrated to reflect observed origin-destination patterns. A mode split model may be calibrated to reflect user choice of transit or private automobile. Validation, on the other hand, is the process whereby a travel model is evaluated for its ability to represent the ultimate aim of the entire process, that is, to accurately represent flows of vehicles on transportation networks. Validation entails the comparison base-year model forecasts to observed traffic counts. It is important to note that in both calibration and validation, "truth" is never really known, as travel patterns, user choices and traffic flows vary significantly over time, may be misreported or otherwise under or overestimated, and are affected by many phenomena which are exogenous to the modeling process. In this model, two sets of parameters require calibration: 1) friction factors for the gravity model; and 2) link group costs that are used to model assignment and mode split. Validation is left for the next chapter.

10.1 Calibration Methodology

The calibration method used in this research is depicted in the flowchart shown in Figure 20. The objective of the calibration procedure is to adjust critical parameters (rail centroid connector costs and friction factors) for each commodity group such that the base year forecasts depict existing conditions represented by the TRANSEARCH data (for a discussion of the description and limitation of TRANSEARCH, see Chapter 4).

A series of sequential calibration "runs" were completed for each of the 14 commodity groups included in the model. In all, 94 calibration runs were made for the model. The calibration process was an iterative process for all commodity groups. The first step was to calibrate the gravity model based upon the freight patterns depicted by the TRANSEARCH data using the base link group costs. The calibration of the gravity model resulted in a set of friction factors, which were used in the model to produce an assignment of freight demand to the multimodal network. The mode split error was determined for each Commodity Analysis Zone (CAZ) and for the aggregate model. The results of this process were considered one calibration "run." Based on a process described in a later section, the rail centroid connector costs were adjusted and the entire process repeated using the new costs. After a number of calibration runs were made for each commodity group, the parameters that provided the best results were selected as the "final parameters." The following subsections describe this process in detail.

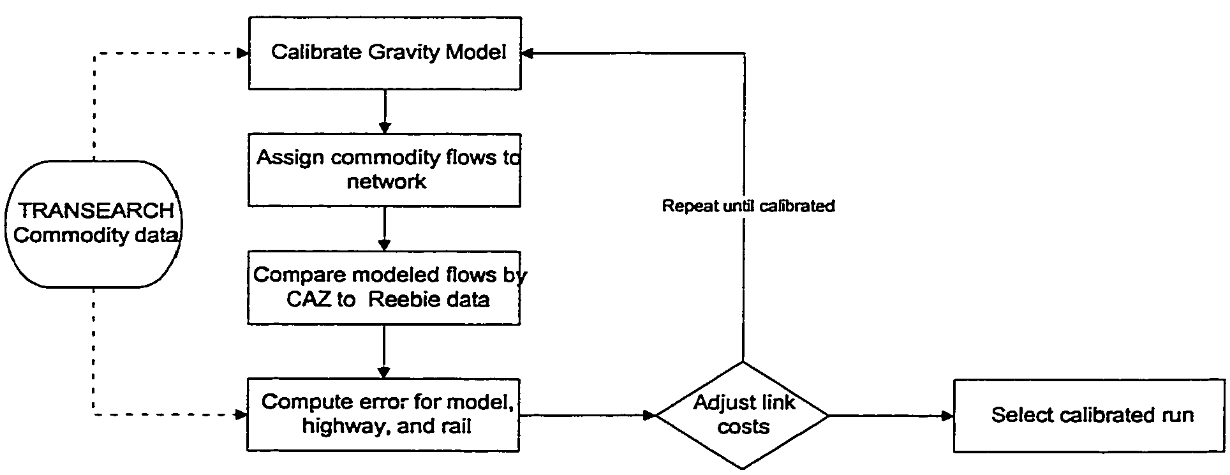


Figure 20 Flowchart for Calibration Process

10.2 Gravity Model Calibration

The primary parameter input of the gravity model is the friction factors. For passenger travel demand models, friction factors have been developed from extensive O/D surveys, updated and shared between models. This shared knowledge base is not available for statewide freight models. The friction factors for this model were developed by calibrating the gravity model to depict the commodity flows represented in the TRANSEARCH data.

Calibration of the gravity model was accomplished in a TRANPLAN routine $CALIBRATE GRAVITY MODEL (CGM). CGM performs an iterative process for calibrating gravity model parameters until the average trip length for each purpose is within a specified tolerance level of the average trip length of the survey data (in this case, the TRANSEARCH data) (*64*). Following an initial gravity model run, CGM iterates by adjusting the friction factors for each impedance increment by the following formula:

$$f_{new} = \frac{o/d\%}{gravity\%} f_{old}$$ where:

o/d% is the percentage of trips in each impedance increment in the survey data; and

gravity% is the percentage of trips in each impedance increment for the gravity model run.

The gravity model is run again using the adjusted friction factors and the average trip length is calculated. If the average trip length is within the specified range, the gravity model is considered calibrated. The output file of the CGM routine contains the calibrated friction factors. The graph shown in Figure 21 illustrates the calibration process by showing the trip length distributions for three iterations of one calibration run of commodity group STCC 201.

This gravity model calibration process was conducted for each commodity group and each calibration "run". For a three commodity groups, (STCC 112 (*Coal*), 324 (*Cement*), 331(*Steel mill products*), the CGM in TRANPLAN model was unable to create an inverse matrix to develop a friction factor solution. By inspection, this error only occurred for commodity groups where most of production was outside of Iowa and concentrated in one or two CAZs. This meant that there were no flows (zero in the flow matrix) for interzonal trips. The zeros in the survey file were changed to small non-zero value, which "solved" the indeterminate matrix problem. This added a relatively small number of trips (tons) to the freight flow matrix. Consideration was given to directly assigning the O/D flows for these commodity groups rather than calibrating the gravity model. The development of the friction factors so that the gravity model could be used for future analysis, however, was preferred.

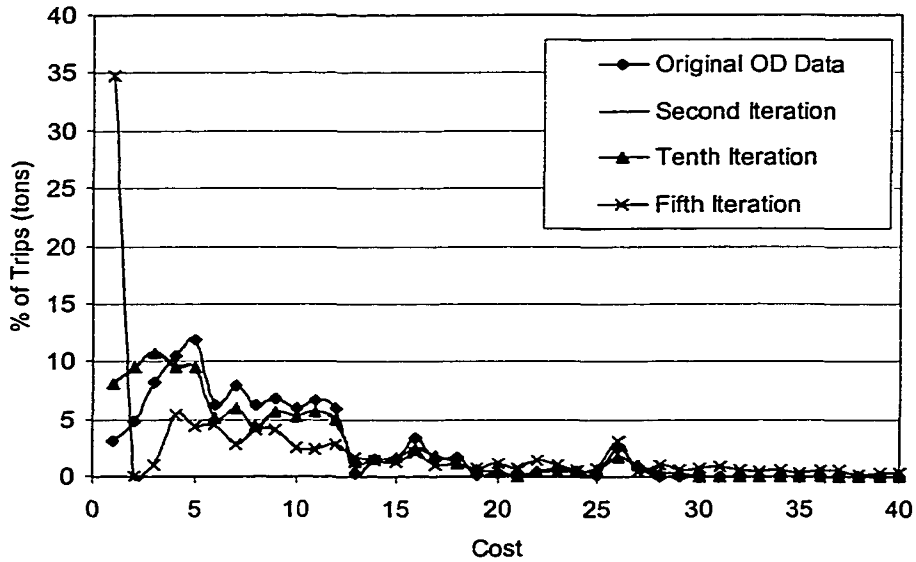


Figure 21 Trip Length Distribution - Calibration of STCC 201

10.3 Mode Split Calibration

For a model to be most useful, its forecasts must be sensitive to policy variables. For freight transportation, the ability to investigate the impact of decisions and trends on modal shifts is particularly relevant. To calibrate the mode split functions, total demand assigned to highway and rail links were adjusted to replicate observed values from TRANSEARCH, which depicts flows by the truck, rail, air and shipping/barge modes. Adjustments were made to the rail centroid connector costs to shift demand from one mode to another. No other link group costs were changed during the calibration process.

For each calibration "run" the modeled demand for each mode was compared to the aggregated mode split described by the TRANSEARCH data. The modeled mode split for each mode, error by mode, and error by CAZ were determined for each calibration run. Graphs were generated for each calibration run showing the TRANSEARCH demand in each CAZ and the modeled demand (for the rail mode). Based on the aggregate mode split error and these graphs, manual adjustments were made to rail centroid connectors costs and the calibration process was run again (calibrate gravity model, assign to network, determine mode split error). The objective of the calibration process for mode split was to generate a sufficient sample of runs, from which the "best" calibration run could be selected. The process by which the "best" run was selected is described in the next section.

From some of the initial calibration runs, it became clear that a single link group for all rail centroid connectors was not sufficient to accurately calibrate the model. The rail flows for the CAZs in and adjacent to Iowa were consistently low. To address the problem, an additional link group (link group 5) was added for the rail centroid connectors in the CAZs directly adjacent to and in Iowa. This additional link group was added because CAZ that are farther from Iowa are larger –and the centroid cost must reflect the greater distance for some trips to the railhead. The costs for these large CAZ have to be higher, so a separated link group structure was required.

10.4 Selection of Final Parameters

Selection of the calibrated parameters that were used to generate the base year model forecast was based on the following criteria: 1) minimize error in modeled mode split; 2) produce intuitive friction factors. The first criteria is straightforward. The rail centroid costs that were selected should represent the least error for both the aggregated mode split and the error in each CAZ. The process by which the selection of the minimum mode split error was selected is demonstrated in Figure 22 for STCC 204. The left axis in the graph represents the aggregate rail mode share for each rail centroid connector cost that was used in the calibration process (mode split for all zones in the model). The right axis is a measure of the absolute average error of all CAZs. The x-axis shows the combination of rail centroid connector costs used to calibrate the individual run. The mode split reported in TRANSEARCH (36%) is shown by the dashed line. As an example, calibration run with (45, 45) centroid connector costs resulted in a modeled rail share of 17%. The absolute average CAZ difference between the modeled rail tons and the TRANSEARCH reported tons for run was a 92,000 tons. The best combination of rail centroid connector costs was chosen based on the run that was closest to the TRANSEARCH reported split and had the minimum absolute average error for all 144 CAZ. In this case, calibration run (30, 30) was chosen as the "best" run based on the mode split parameters.

Following the selection of the rail centroid cost parameters, the friction factors for that set of link group costs was analyzed. For most of the calibration runs, the friction factors were relatively constant over the entire set of calibration runs. The set of friction factors for the selected rail centroid connector costs was selected unless the friction factors were increasing for that set of costs. The following sections describe the results of the selection process.

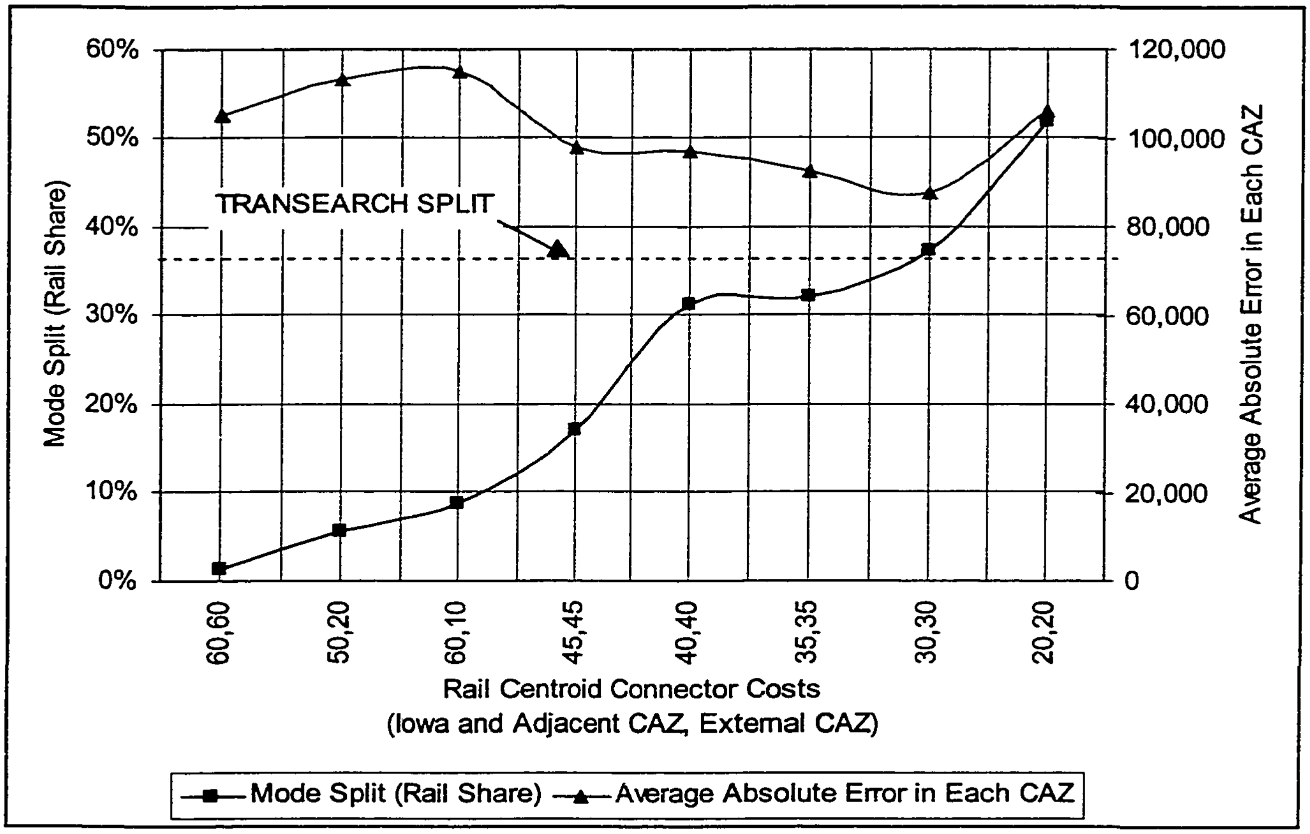


Figure 22 Selection of Optimal Calibration "Run" For STCC 204

10.4.1 Calibrated Friction Factors

As discussed in the chapter on the distribution of commodity flows, the model used three trip types:

1) internal, or Iowa-to-Iowa flows;
2) internal-external, or Iowa-to-external flows; and
3) external-internal, or external-to-Iowa flows.

For each of the commodity groups, the set of friction factors that were developed by the calibration process are displayed in Figure 23.

Upon inspection of the calibrated friction factors, it was found that several commodity groups had increasing friction factors for one or two trip types. The gravity model specifies, that friction factors should follow a decreasing trend with increasing impedance. Increasing friction factors implies that trips are likely to be attracted to zones that are farther away. Three of the commodity groups (STCC 11(*Coal*), 371 (*Automobiles*), 331(*Steel mill products*)) had friction factor that were increasing for one of the trip types. Three commodity groups had slightly increasing friction factors for trip types two or three (STCC 281 (*Chemicals*), 291 (*Petroleum*), 324 (*Cement*). Other calibration runs were examined for the commodity groups with increasing friction factors. All calibration runs for these commodity groups resulted in increasing friction factors. Eight of the 14 commodity groups have friction factors that are decreasing for all three trip types. The shape of the curves is exponential for Iowa to Iowa flows and relatively linear for the external-to-Iowa and Iowa-to-external flows. These curves are similar to friction factor curves from other models.

The counterintuitive friction factors can be attributed to market specific factors that cannot be captured in the model. For example, a farmer may have a contract with a grain processing plant that is not the nearest plant. The gravity model would distribute flows to the closest plant, while the farmer would ship crops to the processing plant that is farther away. Likewise, the commodity groups with counterintuitive friction factors are commodities that are largely produced in one CAZ. The majority of coal (90% by tons), for example, is originated in one CAZ that contains Wyoming. These market and commodity specific reasons are the explaination for the counterintuitive friction factors.

The primary concern with using the counterintuitive friction factors is 1) the reliability of using the friction factors in future forecasting; and 2) the portability of the friction factors to other states' models. Barring any significant shifts in production or consumption pattern of the commodity, the use of these friction factors in future forecasts should be acceptable. However, since the model is Iowa-specific, use of these friction factors in other models should be considered carefully. For adjacent states, the commodity distribution patterns may be similar enough that the use of the friction factors is appropriate. In any case, their use should be considered carefully.

10.4.2 Mode Split Errors

For the selected calibrated runs, the actual mode split, modeled mode split, the error in equivalent number of vehicles per day runs for each of the commodity groups were determined. The error in equivalent number of vehicles is a measure of the magnitude of the error for each commodity group and mode. The number was estimated by dividing the

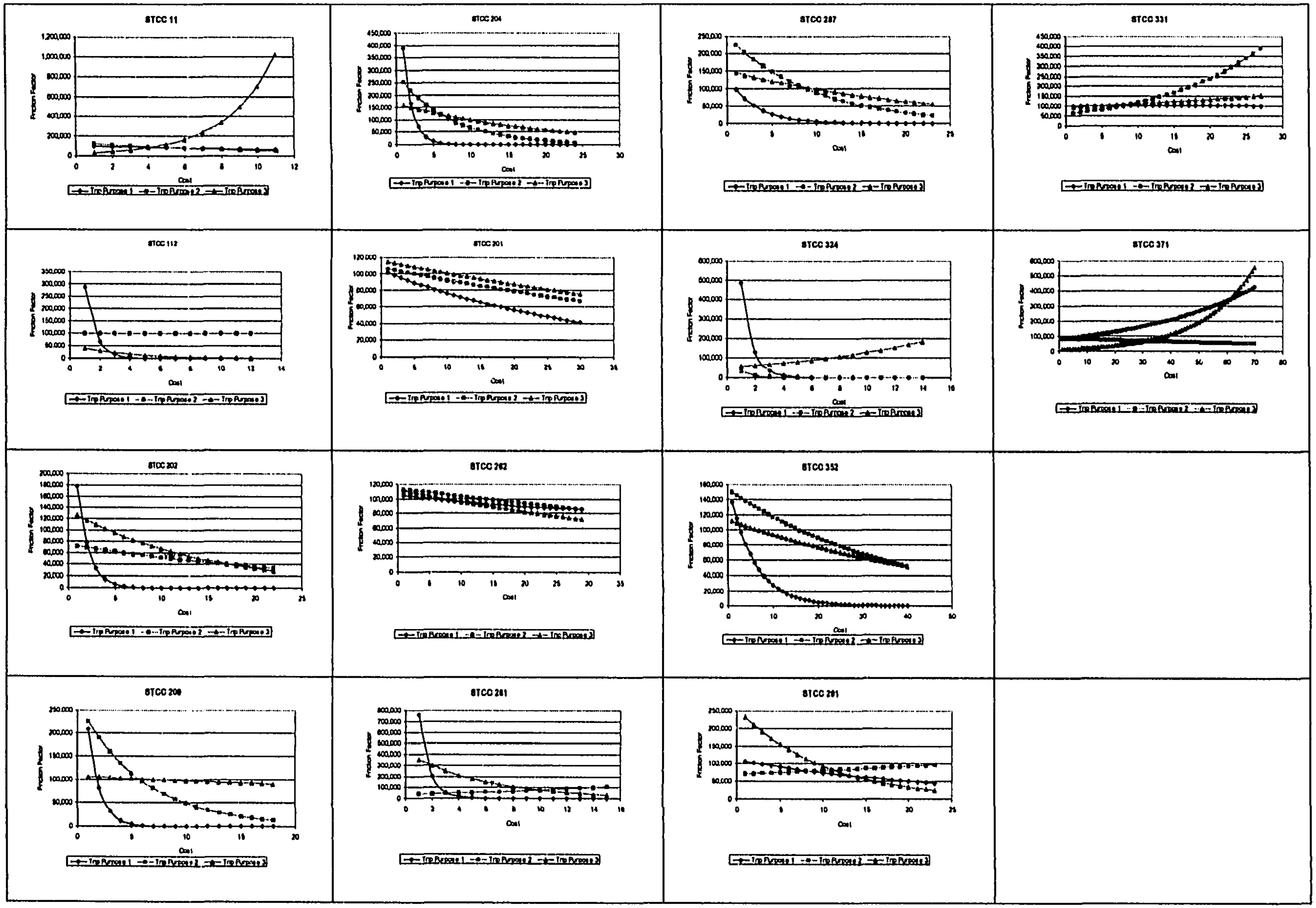


Figure 23 Calibrated Friction Factors for All Commodity Groups

aggregate error in tons by the average load per vehicle (24 tons for truck, 72 tons for rail). Summaries of these values are shown in Table 26.

The table clearly shows three commodity groups have large mode split errors, despite the calibration effort. Field crops were overestimated for the truck mode. The TRANSEARCH data did not include any movements from the farm to grainterminal or processing plant, so field crops were reported as 99% transported by rail. Even with low rail centroid penalties, some flow was assigned to the highway network that resulted in this error. This is because the shortest path between some zones will be on highway network, even with low rail centroid penalties. Similarly, STCC 112 (*Coal*) is almost exclusively (98 percent) transported by rail in Iowa. The selected parameters produced an overestimation of highway flows for similar reasons. STCC 324 (*Cement*) also could not be modeled reasonably by the mode split technique used in this model. The total error for this commodity group was 41%. Additional calibration runs of STCC 324, however, had a lower mode split error (20%) but the link costs produced gravity model parameters that were not satisfactory. This large error can be explained by the fact that the two largest producing and consuming CAZs are located less than 180 miles apart in northern Iowa and Minnesota. For this short distance, it was not possible to calibrate the model so that flow travels on rail without affecting other CAZs that are greater distances apart. Note that STCC 204 (*Grain mill products*) has an overestimated number of highway flows by approximately 425 trucks per day but modeled the mode split to within 4%. The reason for this error is the amount of flows for STCC 204 is large and a small error can result in the magnitude of 425 vehicles.

Table 26 Mode Spilt Error for Selected Calibration Run

		Rail Centroid Connector Costs ($/ ton-mile)		Highway Splits (%)		Rail Splits (%)		Error in Equivalent Number of Vehicles per Day	
STCC	**Commodity Description**	**LG[2] 5**	**LG[2] 6**	**Actual**	**Model**	**Actual**	**Model**	**Hwy**	**Rail**
11	Field Crops	10	10	0.5	6.5	99.6	93.5	293	-98
112[1]	Bituminous coal or lignite	20	20	1.7	16.5	98.2	83.5	629	17
201	Meat or poultry	50	40	89.1	91.4	10.9	8.6	41	-14
202	Dairy products	30	30	99.1	99.6	0.9	0.5	8	-1
204	Grain mill products	35	35	64.0	68.0	36.0	32.0	425	-30
209	Misc food preparations	20	20	68.0	73.6	32.1	26.4	165	-78
262	Paper	48	48	80.0	83.1	20.0	17.0	10	-2
281	Industrial chemicals	20	20	50.5	56.9	49.5	43.1	90	-29
287	Agricultural chemicals	40	40	61.5	48.8	38.5	51.2	-25	75
291	Products of petroleum	50	20	92.1	88.8	7.9	11.2	29	9
324[1]	Cement, hydraulic	10	10	51.8	93.4	48.2	6.6	419	-118
331[1]	Steel mill products	50	50	80.1	76.4	19.9	23.6	18	5
352	Farm machinery	60	60	97.9	94.1	2.1	5.9	-6	2
371	Motor vehicles	100	10	59.6	60.0	40.4	40.1	1	0

1) Program error encountered in calibration of gravity model – tons added to the flow matrix.

2) LG – Link Group

10.5 Summary

In summary, the model represented the mode splits described in the TRANSEARCH data within 10% over a broad range of actual mode splits except for the commodity groups discussed. Most of the mode splits, however, under represented rail share, and the least-cost approach produces less accurate results for those commodities that are dominated by rail transport. The reason for this is explored in the sensitivity analysis presented in Chapter 12.

The calibration process for the model adjusted the parameters of the gravity model and the mode split such that the base year model accurately represented the base year condition. Twelve of the fourteen commodities were calibrated to within 10% of the reported splits in the TRANSEARCH data with an intuitive (decreasing) set of friction factors. Six commodity groups had increasing friction factors for the selected rail centroid connector costs. The reasons for this and use of these friction factors in future forecasts and other models was discussed. One commodity group, STCC 324, could not be calibrated accurately for mode split because of the spatial proximity of the major production and attraction zones. Two other commodity groups overestimated the amount of freight assigned to the highway network (STCC 11 and 112). The following chapter documents the validation of the calibrated model.

CHAPTER 11 - MODEL VALIDATION

As discussed in the opening chapter, one of the primary objectives of the research is the evaluation of a new method to validate a statewide freight model. Current state of the practice is to validate freight models to known network volumes, or ground counts, after all steps of the model are performed. Validation to ground counts presents two methodological difficulties. First, the layered model does not include all freight demand, therefore, comparison to ground counts requires that exogenous freight demand be estimated. Second, validation to ground counts does not take advantage of intermediate model validation (i.e. each commodity), an important benefit of the layered approach.

In the Model Validation and Reasonableness Checking Manual, three procedures are recommended to validate models (*10*):

1) Compare observed versus estimated volumes by screen line;
2) Compare observed versus estimated volumes for all links with counts; and
3) Compare model vehicle miles traveled (VMT) to estimates of VMT.

In this chapter, two methods for each mode are presented. First, the state of the practice approach that compares the modeled highway and rail volumes to observed ground counts is described. For both modes, scatter plots of the modeled and estimated volumes are developed, the root mean square error (RMSE) is determined, and the percent error between the modeled and count data is determined. Second, the model is validated using data collected for this research. The development of the validation data set is also described in this chapter.

11.1 Validation of the Model with Ground Counts

In this section, validation using ground counts is presented for both highway and rail links. For both modes, only modeled links in Iowa were considered in the analysis (external links were not considered for validation). The aggregate model volumes, factored to include demand, are compared to the ground counts for the base year. The RMSE and percent error is determined for seven volume groups on the links. Error is determined by volume group, since the volume is an important decision variable in policy decisions. The link volume groups are comparable to the stratification used in the Iowa DOT truck average daily truck traffic (ADTT) and rail density maps.

11.1.1 Highway Model

Ground counts for the Iowa highway network were obtained from the Iowa DOT. The counts contain classification data and ADTT for the base year (the 1997 TRANSEARCH forecast). According to the TRANSEARCH data, the modeled commodity groups only account for 55% of the total demand for truck freight transportation. The modeled volumes were factored to account for this, then compared to the ground counts.

The scatter plot in Figure 24 shows a plot of ground count (ADTT) versus model volumes. A general trend of the figure is that the factored volumes compare to the ground counts. The modeled volumes, however, have substantial variation. A common measure of the variability in errors used in the validation of models is the root mean square error. The RMSE was calculated for all links with known ground counts by for the seven volumes, and RMSE was reported for each group:

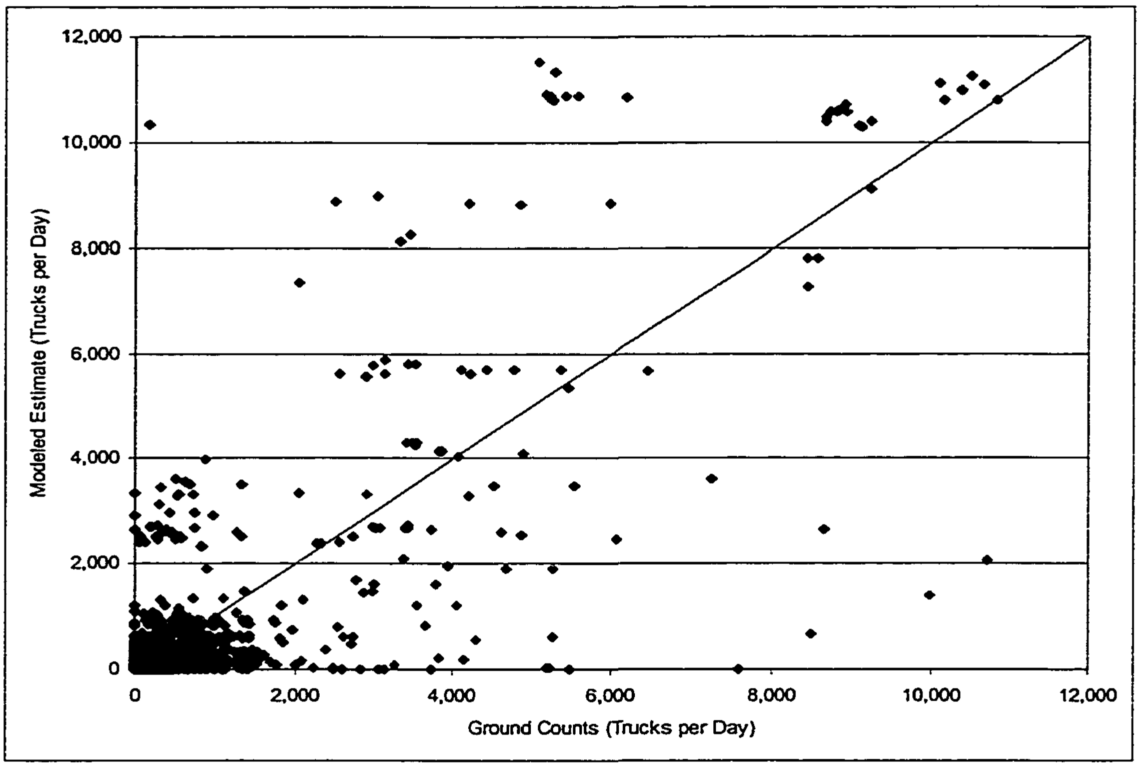


Figure 24 Scatter Plot of Ground Counts vs. Modeled Estimates (Highway Links)

$$RMSE = \frac{\sqrt{\sum_j (Model_j - Count_j)^2 / (NumofCounts - 1)} * (100)}{\sum_j Count_j / NumofCounts}$$, where:

RMSE	is the root mean square error;
$Model_j$	is the model count on link j;
$Count_j$	is the ground count on link j; and
NumofCounts	is the number of links with counts;

As shown in Table 27, the RMSE for the all links in Iowa was very poor – 180%. The lowest volume links had the highest RMSE – indicating a large, highly variable, error between the modeled volumes and ground counts. Large errors on low volume roads are usually acceptable, since these roads are not necessarily of interest for planning. For the higher volume roads, which are the principal freight distribution routes, the RMSE was lower, between 110 and 89%. As reference, Barton-Aschman presents RMSE by facility type for a typical urban 24-hour model. According to Barton-Aschman, freeways should have RMSE of near 18%, collectors near 77%. While the freight model will or may have greater variation, the model errors greatly exceed these values.

To facilitate comparison to the validation to the field collected data, the percent error for each link was calculated. The percent error between the modeled and ground counts was is:

$$\%error = \left(\frac{Model - Actual}{Actual}\right)(100) \quad \text{for all } i \text{ and } j\text{; where:}$$

Model is the volume estimated by the model;

Actual is the volume observed;

Again, the percent error was calculated and the average for each link volume group and is shown in Table 27. The percent error for the low volume roads, like the RMSE, is the largest. For links greater than 250 trucks per day, the percent error ranges from 94% to 57%. The high volume roads have the lowest error, at 57%.

Table 27 RMSE by Volume Group (Highway Links)

Link Group by ADTT				
Min	Max	Number of Links	RMSE	Average Percent Error[1] for Link Group
0	100	34	1,924	410
100	250	169	890	155
250	500	358	251	94
500	750	145	231	98
750	1,000	85	110	60
1,000	1,500	62	85	67
1,500	15,000	144	89	57
		997	180	104.56

1) Absolute Error

11.1.2 Rail Model

The ground count to validate the rail model was available in the form of gross ton-miles per mile (gtm/m) from the Iowa DOT rail density map for the base year (1997). Gross tons include the weight of cars and locomotives (in addition to the weight of the commodity). In order to compare the model estimates to counts, net tons were converted to gross tons. Rather than use the model output of railcars, the intermediate output of net tons was converted to gross tons for comparison. This was done for each link in Iowa by the following formula:

$$G_T = N_T + \frac{N_T}{W_{Com}}\left[\left(W_{Car}E_{RC}\right) + \left(\frac{1}{R_T}L_T W_{Loc}\right)\right], \text{ where:}$$

G_T is the modeled flows in gross tons;

N_T is the modeled flows in net tons;

W_{Com} is the average weight of commodity per carload;

W_{Car} is the average empty weight of railcar in tons;

E_{RC} is the average expansion factor for railcars over all STCC;

R_T is the average number of railcars in each consist;

L_T is the average number of locomotives per train; and

W_{Loc} is the average weight in tons of locomotive;

The average weight of commodity per carload was estimated from the data in Chapter 8 on the conversion of freight flows. The average empty car weight was assumed to be 65,000 lbs. (*65*). The average expansion factor of 1.5 was also developed in Chapter 8. Analysis of the field data found that the average length of a consist was 95 cars, with 2.5 power units. Locomotives were estimated to weigh 400,000 lbs. (*65*). The modeled tons, the weight of the cars, and the weight of the locomotives were summed to determine the modeled gross tons.

The commodity groups in the model represent 85% of the demand for rail transportation, as estimated by the TRANSEARCH data. The modeled gross tons were factored to account for the exogenous tons. The factored gross tonnage was then compared to the reported gross tonnage.

Figure 25 shows a scatter plot of the model estimates plotted against the reported gross tons. Except for a few links with low gtm/m, the model estimates are substantially lower than the reported gross ton miles/mile particularly for the high-volume links, even with the data factored for the exogenous demand.

Like the highway model, the RMSE was calculated for all rail links in Iowa. The links were grouped in seven gross ton mile/mile ranges. These ranges correspond to the ranges developed by the Iowa DOT for their rail density map. The RMSE was calculated for each group. The rail links with the lowest loading have the highest RMSE value, similar to the highway model. The higher volume links have a lower RMSE, within the range of 80–90%. The percent error was also calculated for each link. Summary of the results are shown in Table 28. Some of the error is clearly attributed to the conversion of the modeled net tons to gross tons. The base maps produced by the Iowa DOT are generated using the waybill sample – which makes comparing the model volumes to the base flow maps less desirable since the TRANSEARCH database also contains the waybill data.

11.1.3 Summary

As expected, validating the model to ground counts has proved less than conclusive. The source of the model error is unclear in the aggregate validation. One individual commodity group may be contributing to larger total of the error. Clearly, an improved validation methodology is required for the layered model. The RMSE of the total model compared to the ground counts is not within any acceptable range. The method of simply factoring all flows up from the modeled demand requires that all links be factored. The selected commodities may not necessarily account for the same amount of freight on each link. For example, since the major commodities are included in the model, the total flow on the interstate may only need to be factored by an amount less than the total exogenous demand. Lower volume links may actually be required to be factored more. This level of uncertainty makes validation difficult. The next section describes the process of developing

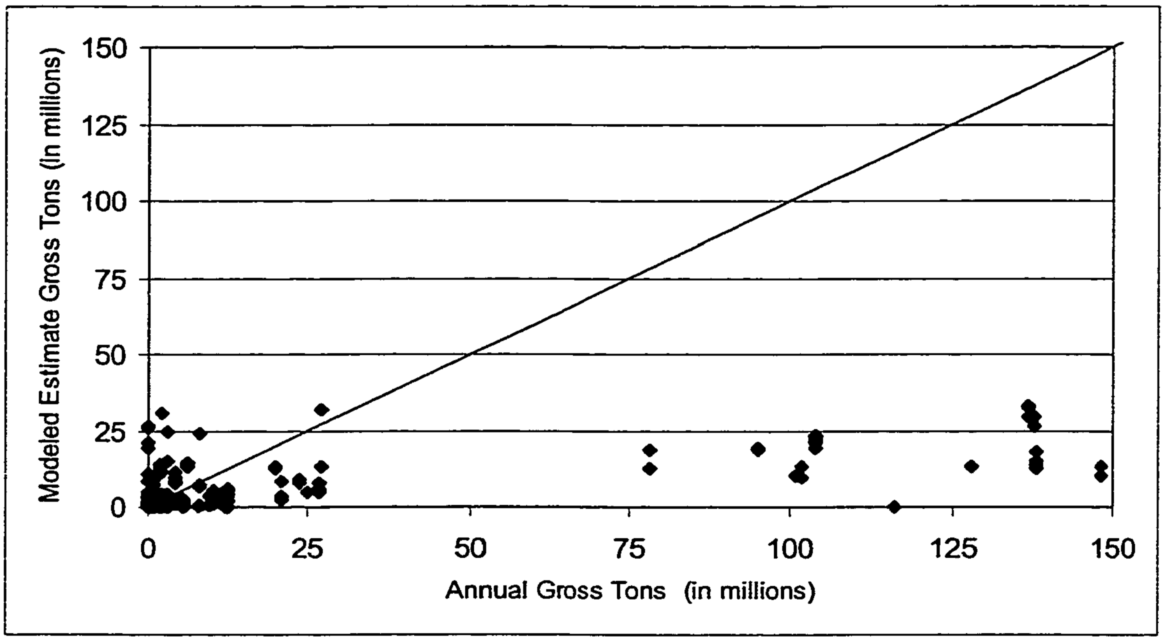


Figure 25 Scatter Plot of Modeled vs. Actual Volumes (Rail Links)

Table 28 RMSE by Volume Group (Rail Links)

Link Group Gross Ton-mile/mile in millions				
Min	**Max**	**Number of Links**	**RMSE**	**Average Percent Error[1] for Link Group**
0	1.0	52	3286	740
1	2.99	56	316	158
3	4.99	14	257	164
5	9.99	17	95	79
10	19.99	25	84	84
20	39.99	20	67	61
40	above	31	87	85
	Total Model	249	177	196

1) Absolute Error

the validation data set from the field data and is followed by the validation method.

11.2 Development of Validation Data Set from Field Data

This section describes the process for developing a validation data set from field observations. This effort produces truck and rail volumes by commodity group at each of the data collection locations. Recall from Chapter 9 that data were visually collected to include the type of vehicle (trailer type and railcar) and commodity type. These data were used to estimate commodity flows at each of the data collection locations. This section is divided into subsections describing the process for the truck and rail modes.

11.2.1 Development of Highway Validation Data

11.2.1.1 Comparison of MCMIS Data Set to Known Commodities

Commodities generally transported by carriers are indicated in the MCMIS data set. A carrier can report one or more commodity groups (including a description of a commodity that is not one of the categories). These commodity groups are shown in Table 29. Prior to developing the validation data set, a comparison was made between the declared commodity to known (observed) commodities. A total of 475 carriers (out of 11,427) in the field data had a known commodity (excluding empties) and were also matched to a carrier in the MCMIS database. This provided the opportunity to verify that the commodities indicated in the MCMIS database. This sample of observed vehicles was biased towards trailers where the commodity was actually observed (limiting it to grain hoppers, livestock, flatbeds, auto-carriers, and tanks with hazardous materials placards). The assumption was made that if the commodities observed compared to those commodities indicated by the MCMIS data set, it could be expected to predict the commodity in the observed field data.

The assumption was made that the commodity groups are generally transported by one or two trailer types. This assumption is certainly valid for most commodity groups (such as cars). A cross-reference was developed between the MCMIS commodity groups and the type of trailer generally used. This cross-reference is shown in Table 29.

To assess the accuracy of predictions made from the MCMIS data, a comparison was conducted to determine if the observed commodity matched the commodity predicted by the MCMIS data. Estimates were made of the probability of predicting the actual commodity based on the MCMIS data for the 475 records. For example, the MCMIS database indicated that Farmland Industries (USDOT Number 89238) transports liquids and gases, meat, chemicals, and dry bulk commodities. If the Farmland vehicle was observed with a tank trailer (which can transport both liquids and gases and chemicals), the actual commodity could be predicted with a probability of 50%. (In the field data, two Farmland Industries trucks were observed hauling tank trailers with hazardous materials placards 1203 (gasoline) and 1005 (anhydrous ammonia).

Each of the 475 records were analyzed in this manner. The pie graph in Figure 26 shows the results of this analysis. Nearly 52% of the 475 records predicted the commodity being transported (given the observed trailer type) with a probability of 100%. These records had either only a single commodity group declared or only a single commodity that could be carried by the observed trailer type. In addition, 15% of the records would have predicted the

Table 29 MCMIS Commodity Groups, STCC, and Assumed Trailer Types

STCC[1]	Commodity Group	Assumed Trailer Type	STCC[1]	Commodity Group	Assumed Trailer Type
461	General Freight	Any	11	Grain, Feed, Hay	Grain Hopper, Flatbed
—	Household Goods	Dry Van	112	Coal, Coke	Hopper, Dump
331	Metal, Sheets, Coils, Rolls	Flatbed	201	Meat	Refrigerated
371	Motor Vehicles	Auto-carrier	—	Garbage, Refuse, Trash	Dump
242	Logs, Poles, Beams, Lumber	Flatbed	430	U.S. Mail	Dry Van
—	Building Materials	Flatbed, Dry Van	281	Chemicals	Tank, Dry Van
—	Mobile Homes	Other	—	Commodities Dry Bulk	Bulk Tank, Hopper
—	Machinery, Large Objects	Flatbed	200-1	Refrigerated Food	Refrigerated
13	Fresh Produce	Refrigerated	208	Beverages	Other, Dry Van
281,291	Liquids/Gases	Tank	262	Paper Products	Dry Van
—	Intermodal Containers	Container	—	Utility	Flatbed
—	Oilfield Equipment	Flatbed	—	Farm Supplies	Dry Van, Flatbed
14	Livestock	Livestock	—	Construction	Flatbed
			—	Water – Well	Flatbed

1) Approximated

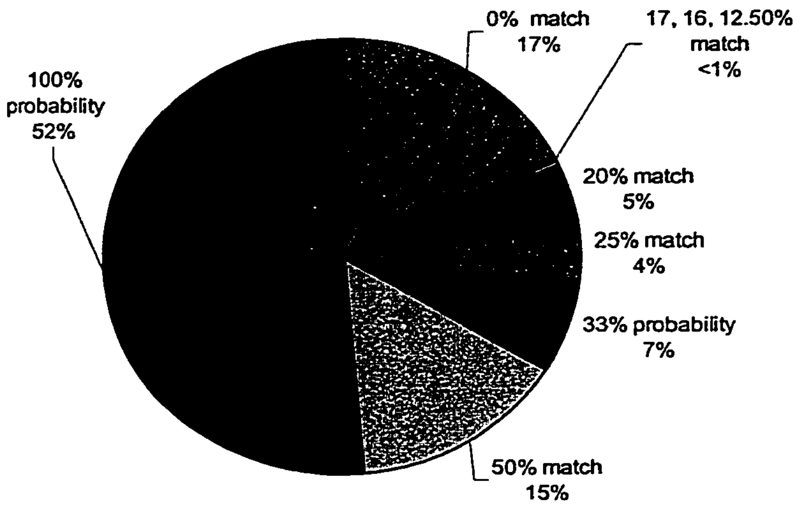


Figure 26 MCMIS Validation Results

commodity with a probability of 50% (two commodities possible with observed trailer type – one of which was the observed commodity) of the time and 7% would have predicted the commodity with a probability of 33%. In developing the validation set, only those records with a 50% chance of predicting the correct commodity were used. It can be concluded from this analysis, that if the trailer type and the carrier data are known, the commodity actually being transported can be estimated with a probability of approximately 88% (using only those records with a 50% or greater chance of predicting the commodity).

11.2.1.2 Analysis of Field Data

The first step to develop the validation data set was to select the trucks from observed data that could be used to estimate the commodity. Of the total 11,427 trucks observed, 6,444 (53%) met one of the following three criteria:

1) commodity was readily visible;

2) were considered matched by trailer type (grain hoppers, livestock trailers, auto-carriers); or

3) were matched to a carrier in the MCMIS data set.

The second step required classification of all field-observed commodities to a 3-digit STCC. For most part, this was easily accomplished by referencing an AAR Tariff that lists STCC for all commodities (*66*). For example, a truck observed carrying farm machinery (new) was assigned to STCC 352. Some observed cargoes could not be classified using the tariff because more information was required. For example, in order to classify the cargo of a truck observed carrying pipe, the material of the pipe must also be known since plastic pipe and steel pipe have different STCC 3-digit numbers. Trucks that displayed a hazardous material placard were also included in this step. By referring to the hazardous material data, the commodity related to the placard could be determined. The STCC was determined from the AAR tariff. If a commodity group could not be assigned for lack of information about the cargo – the truck was deleted from the subset. Trucks that were observed with a trailer type of grain hopper, auto carrier or livestock trailer were assumed to carry the commodity associated with the trailer type. No other analysis was required of these records. After steps one and two, 6,015 records remained.

The third step was to estimate the commodity for trucks that were "matched" to the MCMIS data. As discussed in the previous section, part of this process was to assume which trailer types were used to transport each of the MCMIS commodity groups. The commodity groups and the assumed trailer type for each MCMIS commodity group are shown in Table

29. Trucks with only one declared cargo for the trailer observed consisted of 72% of the 6,015 trucks (38% were general freight and 34% all other commodity groups). A STCC number was assigned to the MCMIS commodity groups, unless the group was too general to be assigned a STCC then, code "777" was used. For example, the MCMIS commodity group "household goods" could not be assigned an STCC because it is too general. Other MCMIS commodity groups like "meat" were more specific (assigned STCC 201). All of the trucks with one declared commodity group for the given trailer type were assigned an STCC. A small portion of these records (257) declared only one commodity group that had a description in the "other cargo" field of the MCMIS database. These descriptions were assigned an STCC using the AAR tariff if the description was adequate.

Records with two potential commodity groups for the observed trailer type accounted for only 16% of the records used. An STCC was assigned to these records on a random basis. For example, if a truck was observed with a refrigerated van and matched to a carrier that declared "produce" and "meat" as commodities carried – the STCC code 13 and 201 were assigned to the observations in a random pattern. Records with three or more commodities corresponding to the observed trailer type were not used.

Table 30 summarizes of the commodity estimation process by facility type. The table shows that of the 11,427 trucks observed, the method was able to estimate the commodity for nearly 50% of the observations (5,768). The ability to estimate the commodity was directly related to the matching rate described in Chapter 9. The facility type with the highest matching rate, rural highways, also had the highest estimation rate (65.6%). Interstate

Table 30 Summary of Commodity Estimation from Field Data (Highway)

Location	Type	Total Trucks Counted	Total Trucks with Commodity Estimated	MCMIS Commodity Group General Freight	Too General "777"	All Other STCC
2	4 lane divided	72	39	1	2	36
3	4 lane divided	151	85	22	5	58
10	4 lane divided	395	237	32	9	196
	Subtotal	618	361	55	16	290
% of total counted where commodity was estimated			*58.4%*			
1	Interstate	257	86	34	6	46
6	Interstate	856	436	78	13	345
12	Interstate	1416	684	254	24	406
13	Interstate	1312	646	215	42	389
14	Interstate	2150	948	404	44	500
15	Interstate	2155	859	310	40	509
	Subtotal	8146	3659	1295	169	2195
% of total counted where commodity was estimated			*44.9%*			
4	Rural highway	195	126	30	2	94
5	Rural highway	442	274	34	8	232
7	Rural highway	365	246	33	9	204
8	Rural highway	832	547	206	26	315
9	Rural highway	352	241	72	9	160
11	Rural highway	477	314	61	13	240
	Subtotal	2663	1748	436	67	1245
% of total counted where commodity was estimated			*65.6%*			
TOTAL		11,427	5,768	1,786	252	3730
% of total counted where commodity was estimated			*50.4%*			
% of trucks w/ commodity estimated in commodity group				*30%*	*4%*	*64%*

facilities had the lowest estimation levels for commodities (44.9%). It should be noted in the table that carriers reporting "general freight" as the primary commodity carried accounted for 30% of the total number of records where the commodity was estimated. Only 4% of the commodities estimated were in the MCMIS groups that were too general to match to an STCC.

To compare the commodity information to the model, the counts at the data collection site were expanded to an AADT volume. The Iowa DOT supplied vehicle classification, volume distribution data and truck factors by highway type. The hourly counts were expanded to 24-hour counts by:

$$V_{24hr} = V_c\left(\frac{1}{P_t}\right)(TF) \text{ where:}$$

V_{24hr}	is the total 24 hour volume for trucks at the data collection location;
V_c	is the total number of trucks counted from the start time to end time of data collection;
P_t	is the percentage of the total volume in the start time to end time of data collection;
TF	is the truck factor for day of week and month of data collection;

The statewide average of the 24-hour volume distributions are shown by highway type in Figure 27. The total percentage the 24-hour volume that occurred during the times of the data were collection were determined. The truck factor is used to convert the counted volumes on a particular day and month to the ADTT volume (truck factor of 0.88 means that 88% of the volume counted that day would be equal to the total ADTT). Table 31 shows the parameters

Table 31 Volume and Daily/Monthly Truck Factors

Location	Percent of 24 hour volume[1]	Monthly/Daily Truck Factor	Location	Percent of 24 hour volume[1]	Monthly/Daily Truck Factor
1	5%	0.88	9	48%	0.78
2	7%	0.88	10	48%	0.77
3	32%	0.78	11	48%	0.77
4	53%	0.8	12	37%	0.77
5	48%	0.77	13	41%	0.77
6	31%	0.78	14	39%	0.77
7	48%	0.77	15	39%	0.77
8	48%	0.77			

1) At count location

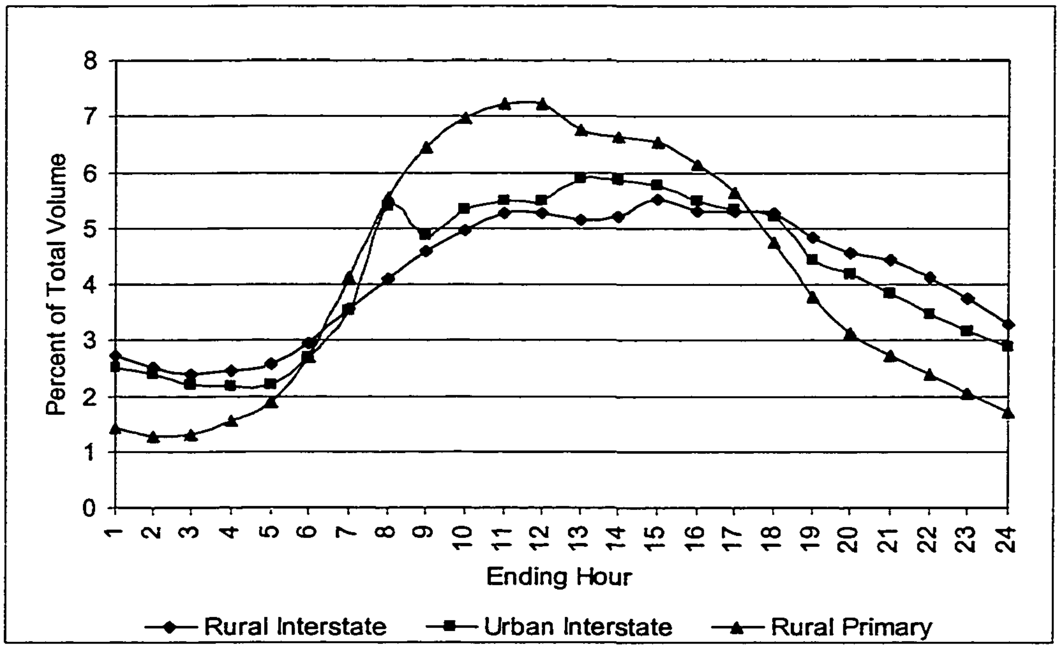


Figure 27 24-hour Volume Distribution of Combination Trucks on Iowa Highways

Source: Iowa DOT

used at each location to inflate the field data to ADTT for each commodity group. Recall that when the data were collected at an intersection, turning directions were also collected. This allowed the volumes on each of the intersection legs to be estimated.

The result was counts by commodity group for each link at the data collection site. In summary, the commodity groups identified by the data collection were consistent with the commodity groups identified in the Iowa Truck Survey (where vehicles were actually stopped). The top 20 most frequently observed commodity groups for both surveys are identified in Table 32. Twelve of the top 20 commodity groups were common to both surveys. If only the top 15 commodity groups in both surveys were included, 13 of the commodity groups were in both surveys.

The method produced predictions of commodities for approximately 50% of the observed trucks. By comparison, in a State of Washington survey that stopped trucks, only one in 10 trucks were stopped on interstate, (1 in 5 on lower volume facilities) (*11*). The Washington survey, however, would not have the bias observed in the sample collected in this research. The method used in this research could not identify the O/D of the trucks, but was able to predict the commodity being transported for 1 of every 2 trucks. Clearly, more uncertainty is associated with the method used in this research, as the "true" commodity can not usually be known for those vehicles whose cargo could not be visually identified.

11.2.2 Development of Rail Validation Data

Much less data were available to develop from rail observations. A total of 46 trains were observed (4,375 railcars). For rail data, no supplemental database such as the MCMIS,

Table 32 Comparison of the Iowa Truck Survey and Field Data

In Both

STCC	Commodity Description
11	Field Crops
14	Livestock or livestock products
200	Food or kindred products
201	Meat or poultry, fresh or chill
202	Dairy products
242	Sawmills and planing mills products
262	Paper
331	Steel mill products
352	Farm and garden machinery
353	Construction and related machinery
371	Motor vehicles and equipment
461/411	FAK shipments

In Iowa Truck Survey

STCC	Commodity Description
12	Fresh fruits or tree nuts
203	Canned or preserved food
204	Grain mill products
208	Beverages or flavor extracts
209	Misc food preparations
251	Household or office furniture
282	Plastics materials and synthetics fibres

In Field Data Observations

STCC	Commodity Description
13	Fresh vegetables
144	Gravel or sand
204	Grain mill products
281	Industrial chemicals
291	Products of petroleum refining
307	Miscellaneous plastics products
324	Cement, hydraulic
430	Mail or contract freight

was available that could be used to identify the commodity for railcars whose commodity could not be seen inferred by car type. Unfortunately, the quality of the video precluded the identification of hazardous material placards on tank cars in the data reduction phase. If a placard was identified in the field, it was recorded with a verbal note on the videotape. In summary, the rail commodities could only be estimated for those car types where: 1) the commodity was known because of the car type; and 2) the commodity was observed.

The most common railcar identified in the data collection was the coal hopper railcar, carrying coal. This commodity group was easily identified and assigned STCC 112 (*Coal*). The autorack car, also easily identified, was assigned STCC 371 (*Automobiles*). The two-cover coil car, used for carrying steel products, was assigned STCC 331. Finally, lumber rack cars carrying lumber products were assigned STCC 242 (*Wood products*). Covered hopper cars were assigned to STCC 011 (*Field Crops*). A large percentage of the traffic on the mainline was TOFC/COFC for which the commodity could not be identified visually. The remaining car types could not be assigned a commodity group – leaving only those identified to be developed at the data collection location.

The numbers of trains observed were expanded to 24-hour volumes for comparison to the model estimates. Train volumes were inflated to 24-hour volumes by estimating that 60% of the traffic occurred during the observed time. No 24-hour observations of rail were available, so this inflation factor was derived from using the observed counts on the Union Pacific main line in Ames and an estimate of the number of trains per day on the rail line. The Iowa DOT indicated that the Union Pacific is currently averages 60-70 trains per day through Ames (*67*). This factor was applied to all rail observation locations. Since only one day of observations at each location was available, the observed day was assumed to represent all other days. This assumption clearly limits the use of observed rail data to develop commodity flows for validation data set. The result of the rail data set was an estimate of commodity flows in railcars for those commodities that could be estimated at the four data collection sites (location 5 had no observations)

11.3 Validation of Model with Field Collected Data

In this section, the modeled volumes are compared to the validation data set. The validation is conducted for both the rail and highway modes. For both modes, only modeled links in Iowa were considered in the analysis (external links were not considered for validation). The first subsection highlights the limitations of the validation technique (this is applicable to both highway and rail). The second and third sections discuss the validation of the highway and rail modes by a technique developed in this research.

11.3.1 Limitations of Validation Technique

In the development of the field data collection sites, priority was given to collecting a sample of trucks from many locations in the state. Given the limited resources available, counts could only be made at each location once during the data collection period. These limitations of the data collection must be recognized when assessing the validation method tested in this research.

One significant limitation is that with only 15 locations for truck counts and 5 for rail data, the reporting of the RMSE for this technique would have little meaning. To demonstrate this limitation, a small model validation sample sets of the Des Moines Urban Area model was analyzed. Thirty tests with modeled volumes and ground counts of various sample sizes (10, 20, 30, 40, 50 and 100) were selected at random from the population of model links. For each sample selection, RMSE and standard deviation were calculated. Because the samples were chosen at random, the standard normal distribution could be used to estimate the confidence interval of the RMSE estimates. The true RMSE for the Des Moines model used is 36.4%. With a sample of 100 links, the confidence interval is 11.2% at the 5% significance level (within the range of 25.2% - 47.6%). For a sample size of 10, the RMSE calculated using the data collection sites would range from 4.6% - 68.2 at a 95% confidence interval, hardly a useful interval. This analysis demonstrates the limitation of reporting the RMSE for the number of count locations. Instead, the percent error at each location was determined.

11.3.2 Highway Model

Recall that the volumes by commodity group were developed for each leg at the data collection location. For intersections, this meant that volumes were developed on each link for the commodity groups. For example, at data collection location 11 - truck volumes for U.S. 63 west and east of the intersection and on U.S. 18 north and south of the intersection were developed. For each location, the error was determined for each leg individually, then averaged to estimate the model error at that location. As discussed in the previous section, the RMSE could not be reported because of the small sample size. In lieu of reporting the RMSE, the percent error was estimated for each commodity group.

The errors reported in Table 33 using a set of "screen lines" that were developed. The "screen lines" are not true screen lines (which would include all links that intersect the screen line); rather they are groups of data collection sites in a geographic area. The three "screen lines" are shown in Figure 26. The volume counts for each of the commodity groups were compared to the modeled estimate. Both were in number of trucks per day.

Analysis of the results reveal that for the commodity groups that were visually observed, rather than estimated by the MCMIS data, had the lowest average percent error.

Commodity group STCC 352 (*Farm Machinery*) had the lowest percent error of 32% (an average difference for at the three screen lines of 12 trucks per day). Commodities that were estimated by visually observing the hazardous material placards (STCC 281 and 291) had an average error of 50%. STCC 331 (*Steel mill products*) and STCC 371 (*Automobile*) had average model errors of -87% and -59% respectively. For commodity groups that were estimated by the MCMIS data set, the error between the model volumes and validation data were more significant. For STCC 201(*Meat and poultry*) and STCC 202 (*Dairy*) the error was 349% and 280%, respectively. There are two reasons for this large error in these commodity groups. First, because these commodities were estimated by matching to the MCMIS data the potential exists for the estimated flows to be off as much as 100% since only 50% of the trucks were matched to a carrier. However, even if only half the total flow was estimated the error would still be 160%. This also partially explains the lower errors for the commodities that were estimated by observations (meaning that all of the commodity could be observed). Second, the MCMIS commodity categories were general enough that "meat" could easily be carried by a carrier transporting "refrigerated food." This would also contribute to the under estimation of the validation data commodity flows.

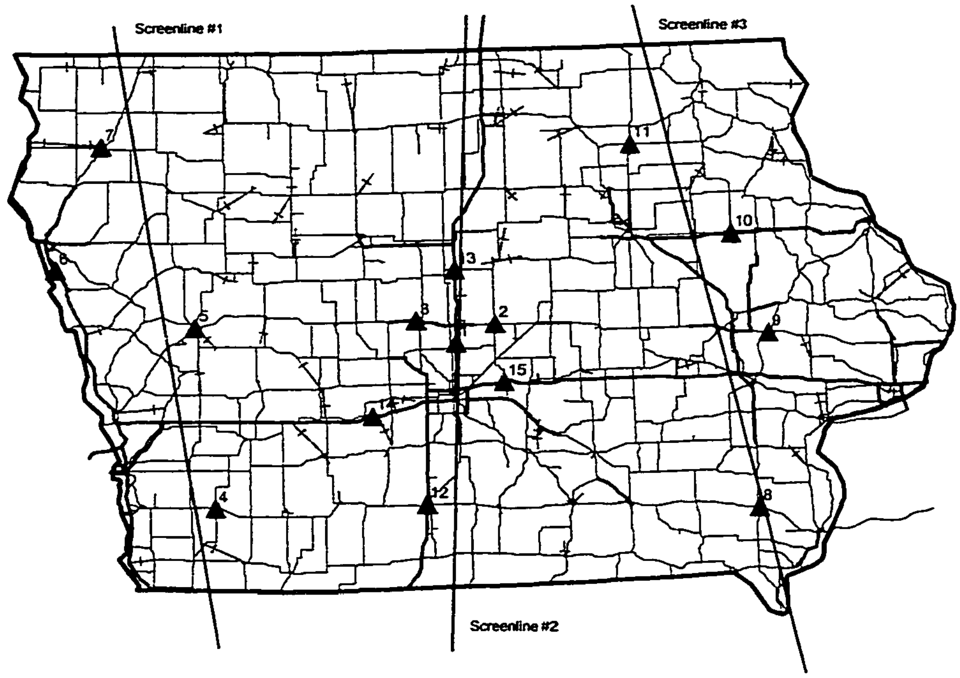


Figure 28 Location of Highway "Screen lines"

Table 33 Percent Error by Screen Line for Highway Model

		Percent Error			
STCC	**Description**	**Model**	**Screen line #1**	**Screen line #2**	**Screen line #3**
11	Field Crops	-94	-87	-94	-86
201	Meat or poultry	349	99	530	181
202	Dairy products	280	520	427	-4
262	Paper	21	-89	126	6
281	Industrial chemicals	52	-15	82	-8
291	Products of petroleum	51	-34	130	-9
324	Cement, hydraulic	131	-90	717	-8
331	Steel mill products	-87	-98	-85	-67
352	Farm and garden machinery	-32	-69	-9	-21
371	Motor vehicles and equipment	-59	-50	-76	-64
Average[1]		116%	115%	228%	45%
Average[1] w/o 201, 202		66%	67%	165%	33%

1) Absolute error

11.3.3 Rail Model

Because the rail data could only be used to estimate the commodity flows for select group of commodities, the validation of the rail model by this technique was not feasible. Nonetheless, the percent error for the identified commodity groups at each of the data collection locations are presented in Table 34. At the Union Pacific main line in Ames where the largest number of trains were observed, the average error for the four commodity groups was (–32%). The errors were higher at the other locations, but very few trains were observed at these locations (so very little confidence can be placed in the errors reported). Because of the resource limitations, the rail locations could only be counted for one day. At a location with one or two trains per day, the number of days needed to collect a sufficient sample is more than the one day that was available.

Table 34 Percent Error by STCC Group For Rail Model

		Percent Error at Rail Data Collection Location			
STCC	**Description**	**1**	**2**	**3**	**4**
11	Field Crops	20	-72	-83	-77
112	Bituminous coal	-46	42		
331	Steel mill products	-61	-89	-45	
371	Motor vehicles and equipment	-41			
Average		-32	-40	-64	-77

11.4 Summary

The results indicate that the validation of a STCC based model by the using the MCMIS data set to predict commodities would not produce validation results superior to simply comparing the model estimates to the ground counts. Without knowing the distribution patterns of the unmodeled freight demand, simply expanding the model estimates will not produce a more definitive validation. If all volumes on every link are expanded, this assumes that the unmodeled demand has similar distribution patterns of the modeled demand, which may not be the case. Alternatively, more commodity groups could be added to the model, increasing the demand included in the model and possibly reducing the error. The selection process insured that the important commodity groups were included, and by adding additional groups diminishing returns to accuracy after significant work to disaggregate the data, calibrate the mode split and gravity model, and assign the commodity flows to the network.

Both methods clearly have their advantages and disadvantages, and a combined approach would yield results superior to the individual approaches. Both methods did not appear to satisfactorily validate the modeled rail flows. However, the method for estimating commodity flows from observed data yielded commodity flows that were similar to the Iowa Truck Survey. In addition, the observed commodities matched well with those predicted by the MCMIS observations. The data collection technique could be used effectively if the commodity groups in the MCMIS data were sufficient for the analysis. Additional comparison could have been accomplished by comparing the MCMIS to a sample of carriers that declared their cargo in a survey where vehicles were stopped and the cargo being carried determined, much like the Iowa Truck Survey.

CHAPTER 12 - SENSTIVITY ANALYSIS AND CASE STUDY

Prior to this chapter, the potential impacts of the assumptions made in developing key parameters of the freight model on outputs have not been explicitly considered. The first part of this chapter reports the sensitivity of the results to changes in these parameters. The second section of this chapter demonstrates the use of the model in a simple case study. The model is used to forecast future freight distribution patterns and truck volumes based on 10-year growth forecasts and improvements to the transportation network that could be in place in 10 years. Additional applications are discussed in the conclusion.

12.1 Sensitivity Analysis

Sensitivity to several important model parameters is tested and described in this section. Three parameters were tested for their impact on the primary output (traffic volumes on links):

1) unit impedance values (link group costs);
2) average vehicle load (tons per vehicle for each commodity type); and
3) backhaul expansion factors.

To demonstrate, two different commodity groups were selected. Several logistical characteristics were considered in the selection of the two commodity groups:

1) high demand statewide;
2) decreasing (intuitive) friction factor curves;
3) low calibration error; and
4) different mode shares.

STCC 201 (*Meat and poultry*) and STCC 204 (*Grain mill products*) were selected for analysis. Relevant parameters are summarized in Table 35.

To test the sensitivity of mode share, line-haul link group costs for STCC204 and 201 were varied by 30 percent (plus and minus). The link costs for highway and interstate link groups and rail and branch link groups were changed by the 10 percent for each analysis. While testing the sensitivity of the model to one link group costs, the other was held constant. The results of this analysis are shown in Figure 29 to Figure 32. For STCC 201, which is dominated by trucking (90% truck and 10% rail by tons) in the calibrated base model, the mode share was relatively inelastic, until the cost increase was over 20%. Similarly, the mode share inelastic, except for a slight increase in rail share (decrease in truck share) for a 30% reduction in rail costs.

The mode share was more sensitive to changes in link group costs for STCC 204 (*Grain mill products*). The calibrated mode split for STCC 204 was 70% truck and 30% rail by tons. A 10 % decrease in highway link group costs resulted in a 4% increase in truck share. The model output was most sensitive to a 30% reduction in truck costs that resulted in a 25% gain in truck share to 95%. Mode share was inelastic to rail link cost. A 10% shift in rail costs

Table 35 Summary of STCC in Sensitivity Analysis

STCC	Tons of Demand (in millions)	Decreasing friction factors	Calibration Error	Mode Split (Truck/Rail)
201 Meat or poultry	7.6	Yes	2.3	65/35
204 Grain mill products	23.2	Yes	4.0	89/11

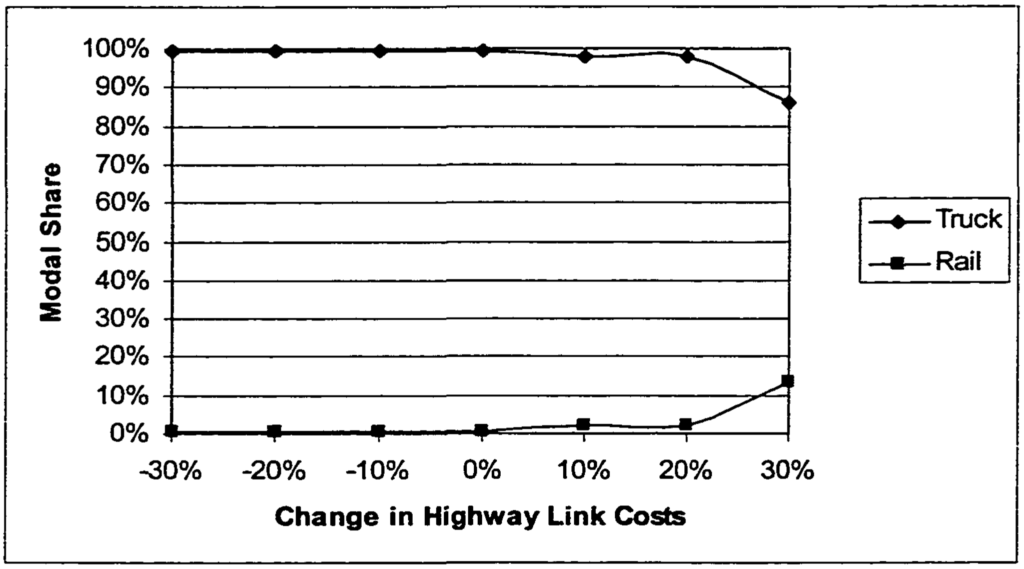


Figure 29 Sensitivity of Mode Share to Highway Link Costs for STCC 201

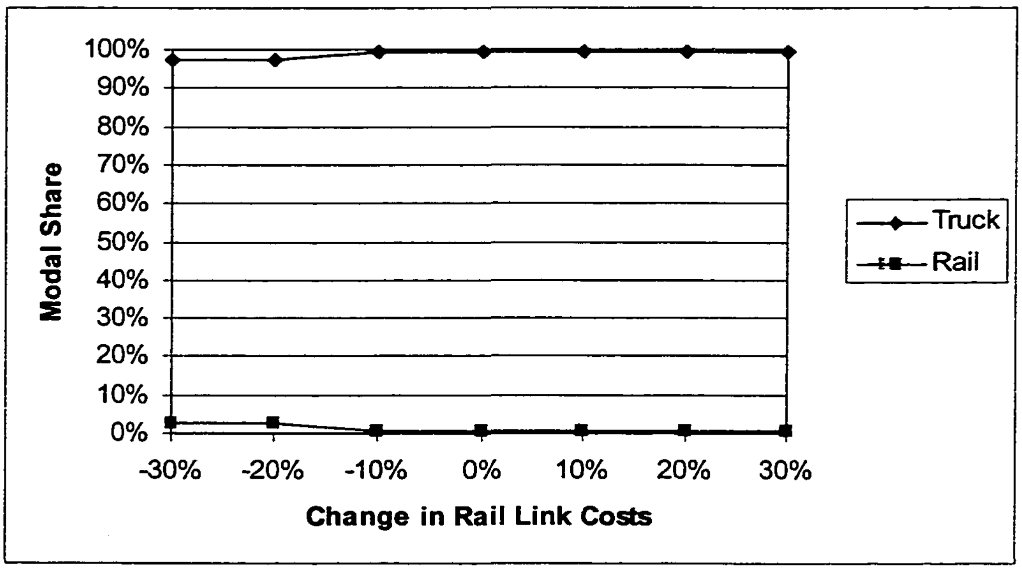


Figure 30 Sensitivity of Mode Share to Rail Link Costs for STCC 201

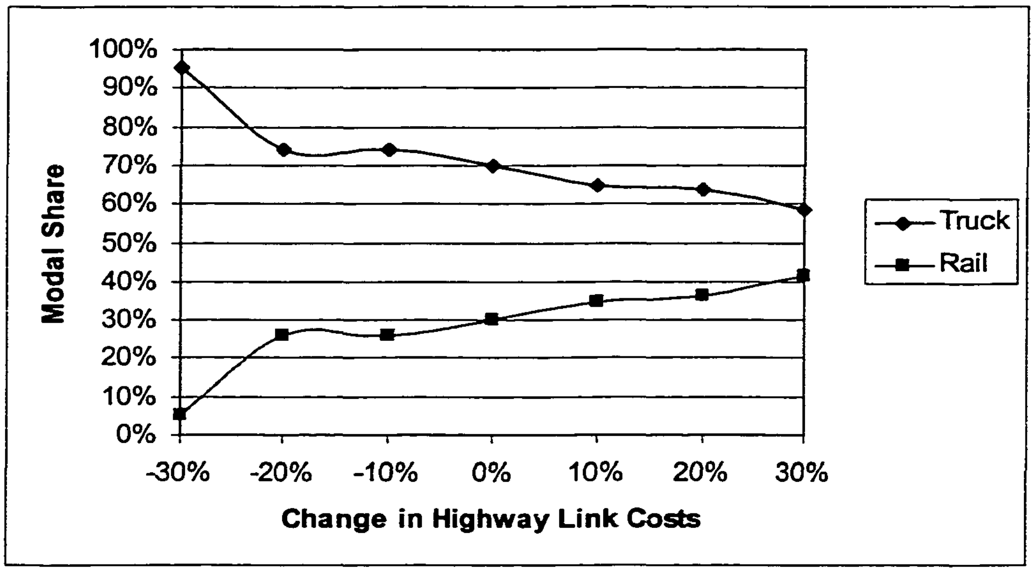


Figure 31 Sensitivity of Mode Share to Highway Link Costs for STCC 204

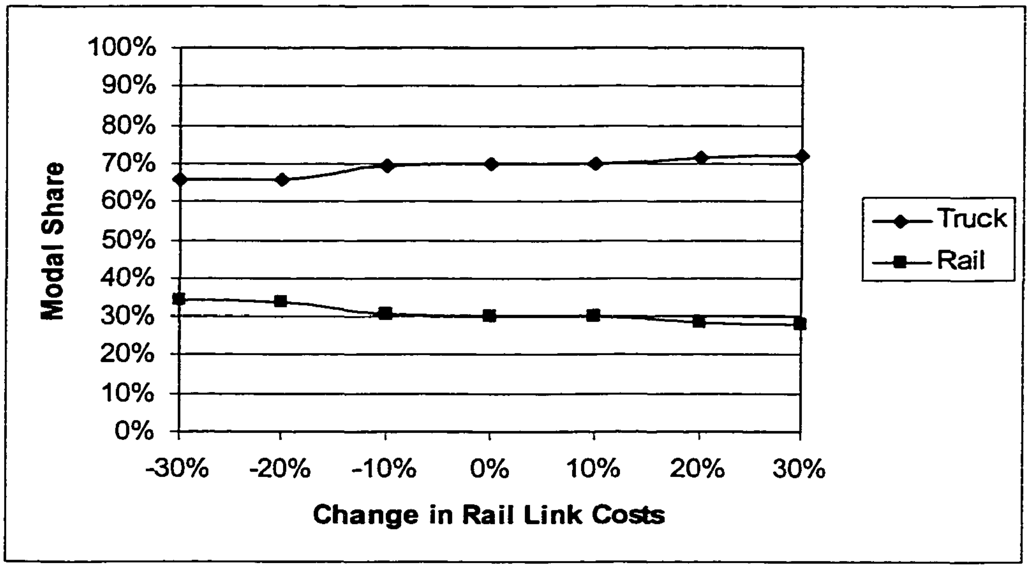


Figure 32 Sensitivity of Mode Share to Rail Link Costs for STCC 204

(either increase or decrease) resulted in no change in mode share and a 30%increase or decrease resulted in only a 2% shift in mode share.

The sensitivity analysis confirms what was observed during calibration. For commodities that are dominated by truck, the rail centroid connectors costs had to be calibrated with high costs and, as such, were less sensitive to changes in link group costs. For commodity groups that are more competitive for both modes, the calibrated model was sensitive to changes. It is important to note that for this sensitivity assessment, one link group cost was held constant. In an actual policy analysis, the costs for both modes would have to be changed. For example, if fuel costs caused an increase in line-haul costs for truck, rail costs would also increase but not at the same rate (since rail is more fuel efficient).

The second sensitivity test studies the impact of average load (tons per vehicle) on demand (vehicle-miles traveled (VMT) for truck and car-miles traveled (CMT) for rail). Average loads per truck and railcar were adjusted in a range of +/-30 percent. The sensitivity to changes in average load per vehicle is shown in Figure 33 to Figure 36. The daily VMT (CMT) is calculated for the entire network. Increases in average load were expected to result in fewer vehicles on both the rail and highway networks, as the model includes no provision to explicitly increase total demand for commodity shipment based on reduced transport costs.

The sensitivity of daily VMT was also analyzed for changes in vehicle expansion factors and are shown in shown in Figure 34 and Figure 36. Recall that the expansion factors account for empty vehicles. If a vehicle must return empty from a haul (no backhaul) the expansion factor is set to 2.0. A commodity with a backhaul is set to one. The expansion

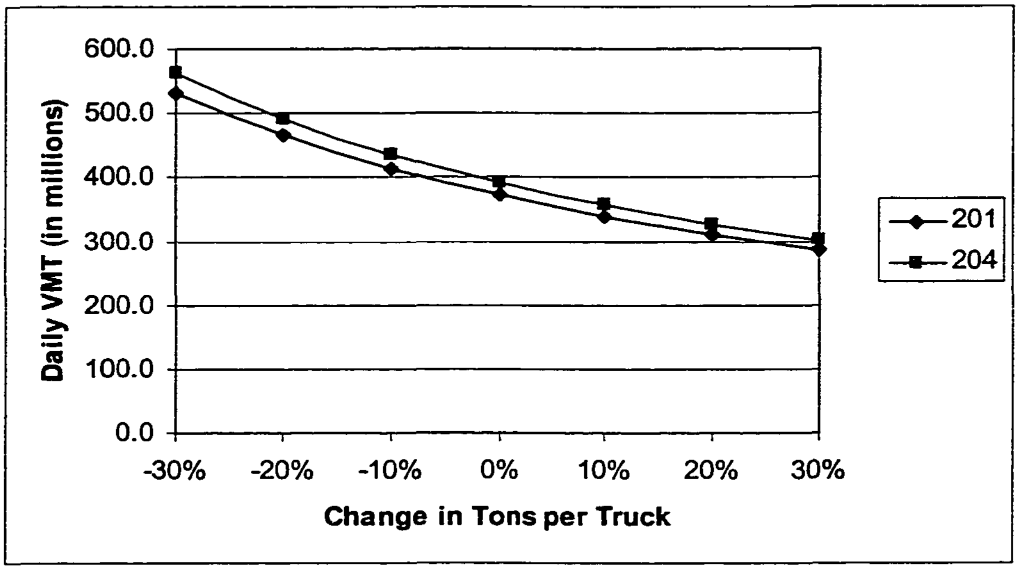


Figure 33 Sensitivity of VMT to Tons per Truck for STCC 201 and 204

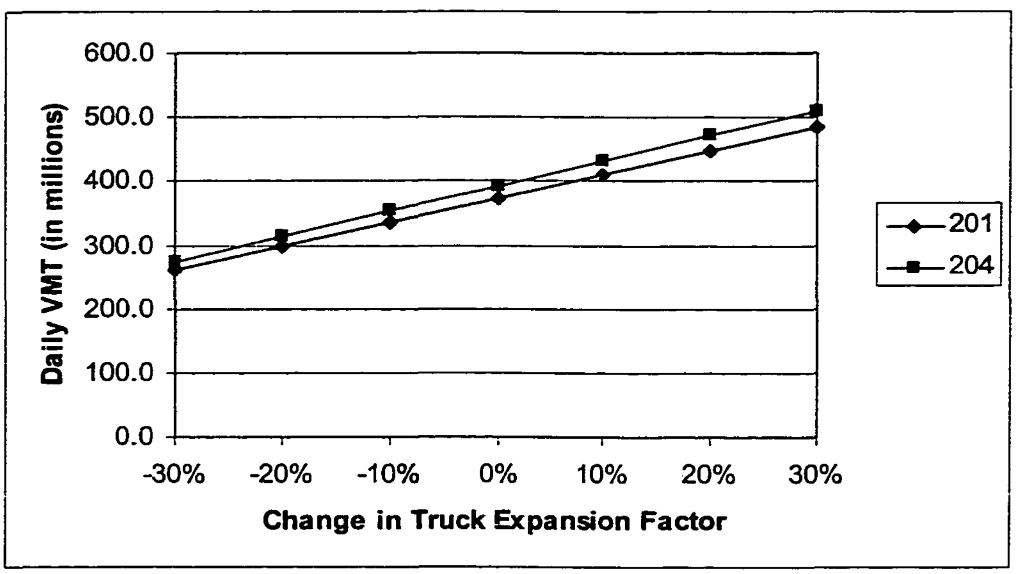


Figure 34 Sensitivity of VMT to Truck Expansion Factor for STCC 201 and 204

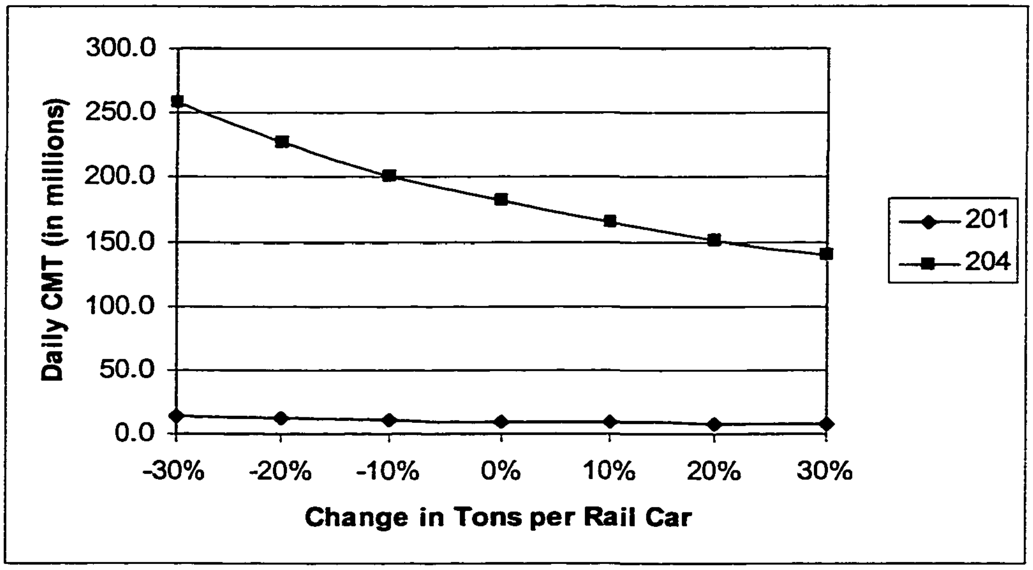


Figure 35 Sensitivity of CMT to Tons per Rail Car for STCC 201 and 204

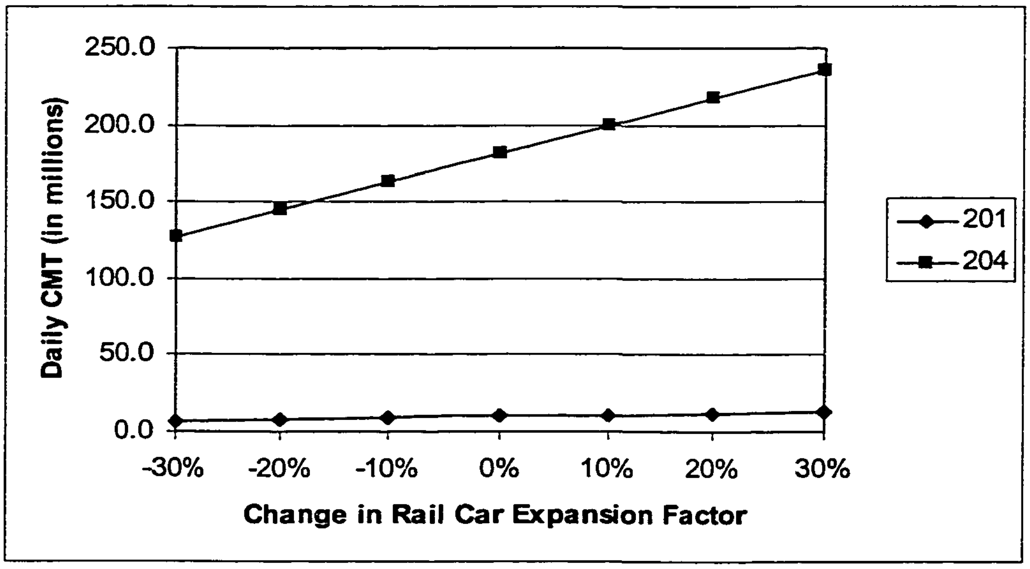


Figure 36 Sensitivity of CMT to Rail Car Expansion Factor for STCC 201 and 204

factor for 201 and 204 were set at 1.5 in the calibrated models. The analysis, show the relationship between VMT (or CMT) and the expansion factor. Again, the results are intuitive. Increasing the expansion factor increases the amount VMT in a linear fashion since the factor is applied after the model is output from the travel demand software.

12.2 Case Study

The purpose of the case study is to demonstrate the use of the model to forecast future freight distribution patterns based on predicted growth and network improvements. The model is used to forecast truck flows on Iowa highways by factoring the base model year demand by estimates of the annual growth for the next 10 years (1997-2007). The network is updated to 2007 using the *Iowa in Motion* state transportation plan. Most of the improvements to the network increased capacity and operational performance of the highways by increasing the number of lanes from two to four. The increased performance was captured in the updated network by changing the assignment group from "highway" to "interstate" (thereby lowering the line-haul costs on these facilities) The primary improvements coded to the network were:

1) the "Avenue of the Saints" corridor from south of Mt. Pleasant to Mason City;
2) the completion of a 4-lane U.S. 20 from Waterloo to Sac City;
3) U.S. 61 upgrade to four-lane facility from Davenport to Keokuk; and
4) IA 330 upgraded to four-lanes from Des Moines to Marshalltown.

The *Iowa in Motion* plan includes a number of super-two design criteria. Super-two's are two-lane facilities with enhanced safety and operational features on some sections such as wider shoulders, a center median,separated grade intersections, and passing lanes. No modifications were made to the network for super-two improvements. All other network link group costs were kept at their calibrated values for the 1997 model in the 2007 forecast. For this case study, it was assumed that no changes in cost structure would occur.

Each commodity group was forecast for a 10-year growth. Bridge traffic was not included in the case study forecast. Average annual commodity growth rates were obtained from a Standard and Poor's executive U.S. Freight Transportation Forecast to 2006 and are shown in Table 36 (*2*). The publication lists average annual growth rates for the top 10 and bottom 10 commodity groups. For commodity groups in the model not listed in the report, an average growth rate was assumed (2.5%). All of the modeled commodity groups were included in the future forecast except for STCC 11 (*Field Crops*) and STCC 112 (*Coal*), since they were dominated by rail.

The volume forecasts were compared to the base year volumes. A graphical representation of the comparison is shown in Figure 37. The gray highways are links with volumes that either increased slightly or decreased between the base year and the forecast year. The black highways are links where the volume increased between 260 and 1,400 trucks per day. The thickness of the line indicates the relative increase in volume. From the figure, it is clear that the improvements to the Waterloo to Mason City result in an increase in volumes along the entire corridor, as well as increased volumes on I-35 north of Mason City. Other improvement to four-lane facilities also show increased volumes. Table 37 shows the average increase in volume by link grouped by their 1997 ADTT (same as the link groups in the

Table 36 Average Annual Growth Rates by STCC

STCC	Description	Average Annual Growth (%)	STCC	Description	Average Annual Growth (%)
201	Meat or poultry	2.50	287	Agricultural chemicals	2.50
202	Dairy products	2.50	291	Products of petroleum refining	3.50
204	Grain mill products	2.50	307	Miscellaneous plastics products	2.50
209	Misc food preparations	2.50	324	Cement, hydraulic	1.60
262	Paper	1.50	331	Steel mill products	3.30
281	Industrial chemicals	2.50	352	Farm and garden machinery	3.50
			371	Motor vehicles and equipment	3.50

Source: U.S. Freight Transportation Forecast to 2006 (*2*)

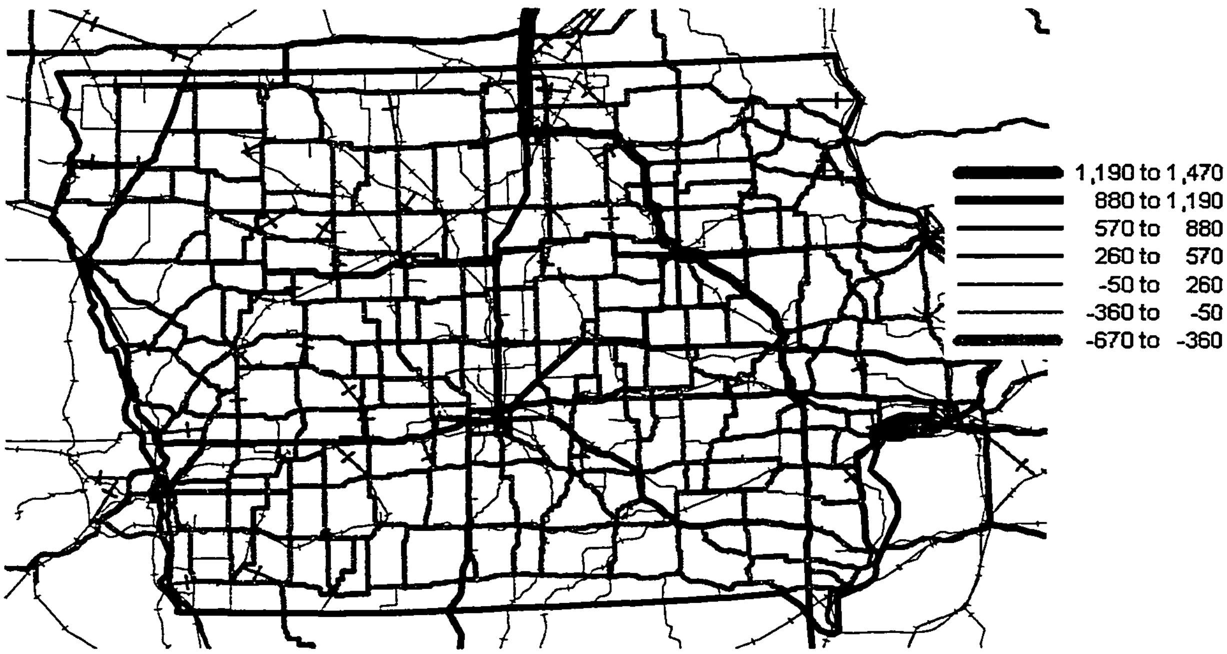


Figure 37 Difference in Flows For 10 year Case Study

Table 37 Change in Trucks per Day by Link Group

Link Group by ADTT		Change in Trucks per day		
Min	Max	Average	Max	Min
0	100	40.4	973.6	-569.2
100	250	21.9	775.7	-202.1
250	500	48.0	1,083.2	-230.8
500	750	177.2	1,255.4	-206.5
750	1,000	202.8	1,126.3	-166.6
1,000	1,500	293.2	1,275.4	-95.2
1,500	15,000	347.3	1,462.7	-646.5

validation chapter). The largest average increase is on the highest volume roads. The minimum and maximum increase in the link group are shown in the table as well. The large increase in low volume roads with large link increases is a result of the four-lane improvements on new alinements that were previously low volume roads.

12.3 Conclusion

This simple case study demonstrates how the model could be used for policy analysis. Analysis that is more complex could also be completed using the model. Since the model is layered, one of the chief benefits is the ability to analyze individual commodity groups. For those commodity groups that were competitive between truck and rail, mode shifts could be analyzed by changing link group costs and adjusting the rail centroid connector costs to model improvements in rail access or service quality. Effects of shifting population or employment centers on freight volumes could also be analyzed. By forecasting future freight demand similar to the case study, then changing the disaggregation measures for each CAZ (employment, population) to reflect the shifts, the model could be used to forecast future freight patterns.

The model could also be used to analyze the effect of changing truck size and weight laws on freight transportation in Iowa. Policy makers are considering raising the maximum allowable weight of trucks to 96,000 pounds from the current limit of 80,000 pounds. The increase could affect modal competition, restrict access to certain roads because of infrastructure limitation, and affect productivity.

CHAPTER 13 - CONCLUSIONS AND RECOMMENDATIONS

The development of a statewide freight model proved to be a substantial task. Many of the methods used in the model could easily be expanded to include much more detailed, complex analysis. Part of the development of planning model, however, is creating a model that will forecast freight flows that is not so overly complex or data intensive that the model cannot be used. This chapter summaries the development of the model, and presents some limitations of its use as currently developed and recommendations for future research.

13.1 Summary of Model Development, Validation and Application

A review of literature revealed that a broad range of models have been developed and applied, with varying degrees of success, for studying the freight transportation system. Early models of freight transportation were national in scope, and most focused on the rail mode. These large models were limited in application by data requirements and complexity. A second generation of models focused on explicitly modeling the decision-making process of the shipper-carrier interaction. For most applications of these disaggregate models, the data requirements were so significant that their application was limited. Subsequently, several state-level planning models were developed.

The model developed in this research was a refinement of an existing layered model developed by Souleyrette et al.(*7*). The model was implemented using the travel demand software, TRANPLAN, and the GIS software, MapInfo. A software tool developed in this research, the Freight Model Manager, automated an interface between these programs. Modeling tasks were operated from one program, greatly improving the usability of the model.

The model developed in this research requires commodity flow data (tonnage) in origin-destination (O/D) format. Reebie Associates' TRANSEARCH database was used to provide these data. The TRANSEACH data contains commodity flows at the U.S. Census Bureau of Economic Analysis (BEA) level (Iowa has six BEAs and parts of others) for shipments with origins or destinations in Iowa.

A basic version of a multimodal network for the U.S. (focusing on Iowa primary highways) was obtained from the researchers who conducted the earlier work. That version was refined (attributes and links added) to accommodate expanded model functionality added by this research. In addition, the network was stratified into ten link groups based on facility characteristics and use in the network. This allowed modeling intermodal shipments and railroad interline movements. Costs for each link group/commodity combination were developed using data from a variety of sources. In addition, a separate network and CAZ structure was developed to model bridge traffic, which is not otherwise treated in the base model.

To select the most appropriate commodity groups for inclusion in the layered model, an iterative process was used. First, commodity groups were evaluated by weight, value, employment, and a survey of truck commodities in Iowa. After the selection process, 15 commodity groups were selected at the 3-digit STCC level. These 15 groups represent 47% by value, 73% by weight, and 33% by employment (according to TRANSEARCH) for freight originating in or destined to Iowa. The TRANSEARCH data, as obtained from the Iowa

DOT, were aggregated to U.S. Census BEA, a level too coarse to support intrastate modeling purposes. Consequently, these data were disaggregated to the county level proportional to selected indicator variables chosen after careful inspection of input-output accounts. County employment by industry was used to disaggregate most freight production, while a mix of employment, population, and other measures were used to disaggregate freight attraction.

The 1997 CFS was used to generate flows for the bridge traffic model. The state-to-state flows of the CFS were modified based on the percentage of total flow from each state that corresponded to the layered commodities and the aggregate modal share in each state.

The disaggregated TRANSEARCH O/D data were synthesized into a production/attraction table. The production and attractions data were distributed with a gravity model and assigned to the network using an all-or-nothing assignment algorithm. The use of the gravity model allowed future forecasts of demand to be modeled. Mode-split was implicitly considered in assignment, as flows were assigned to least cost paths that included intermodal transfer penalties and cost functions for each mode. Calibration of two input parameters (gravity model friction factors and rail centroid connector costs) adjusted the model to work best for the Iowa case (and TRANSEARCH data).

Following calibration, the model was used to estimate 1997 network flows, by commodity. The flows were then converted to truck or carloads, as appropriate, using factors derived from the Iowa Truck Weight Survey and the Carload Waybill sample.

To support a new validation method developed in this research, an extensive data collection effort was undertaken. More that 11,000 trucks and 4,300 railcars were observed at

20 locations around the state. Observations of truck and rail cargo, configuration, trailer type, and carrier were made at several locations around Iowa. For trucks, carrier name and number were matched to carrier information in the MCMIS database, which was later used to estimate the commodity being carried.

The model was validated by two methods. First, the model flows were compared to ground counts for both truck and rail (a conventional technique). Second, the model was validated to the commodity flows estimated from the field data. As expected, model flows differed significantly from ground counts, as not all of freight demand was included in the model. Validating the model with the commodity flows estimated from the field data allowed validation of each individual commodity layer. Results of the validation were most accurate for those commodity groups transported by special equipment such as auto racks, chemical tank trailers/cars, etc.

Next, the sensitivity of model flows to changes in link cost, average load per vehicles, and backhaul expansion factors were examined. While not all commodity groups modeled were examined in detail the analysis, it was found that for commodities dominated by one mode, the model was inelastic to changes in link cost. For commodities that were split between the modes, the model volumes were sensitive to changes in link costs. Finally, to demonstrate the model's applicability, a simple case study was developed that forecasted the distribution patterns of the selected commodity groups ten years in the future. All commodities in the model were forecast ten years in the future with commodity-specific growth factors. Improvements to the transportation infrastructure, as specified in the *Iowa in*

Motion twenty-year plan were incorporated into the network. The model demonstrated the volume effects on certain facilities as a result of the improvement.

13.2 Conclusions and Limitations

The chief assumption of the model was that individual commodities could be modeled separately, then layered to create a composite picture of the freight transportation system in Iowa. This assumption facilitated both model development and overall utility. In a model of all freight demand, model parameters (link impedance, average cargo weight, friction factors, backhaul factors) would have to be average measures. With the layered approach, these parameters could be tailored to fit the unique characteristics of the commodity.

The layered approach also enables policy studies related to specific commodities or commodity groups, such as those related to economic development. For example, tax structures favoring a particular industry can be evaluated with respect to transportation system impacts. Conversely, large-scale transportation improvements such as upgrading of the "Avenue of the Saints" corridor could be modeled to demonstrate benefit to one particular commodity group.

While the layered approach reduces or eliminates some of the difficulties associated with conventional freight modeling – their principal impediment, data intensity, continues to limit application in this model. Consistency of data sources is particularly challenging to a method, which, by its nature, allows if not requires that each commodity be considered individually. Where data were available, often times the units of areal aggregation level or units which the data is grouped differed. For example, even though commodity-specific link impedances were developed, the commodity aggregation of the sources and the model aggregation did not match. The Transportation Technical Services data reported revenue per ton-mile for broad categories of motor carriers while the model required commodity groups at the 3-digit STCC level. While it was possible to draw conclusions between the data sources, it is a common limitation of freight data. In addition, the time reference of each data set was often different. For example, the 1997 TRANSEARCH, 1997 CFS, 1991 Iowa Truck Survey, 1991 Waybill Sample, and 2000 field collected data were all used in the model to develop, disaggregate, assign, and convert commodity flows. The modeler must be aware of the limitations these inconsistencies generate.

Another limitation of the model approach relates to the accuracy of the primary data source, TRANSEARCH. Errors in the O/D data propagate through the model. Error was also introduced through the process of disaggregating OD data from BEA to county level detail. If significant errors were a part of the TRANSEARCH data or the CFS, the model could not be validated, even with the technique developed for this model.

In general, use of a cost-only network to model freight distribution patterns and mode split is limited in its ability to model complex shipper carrier decisions. Special agreements between shippers and carriers are not explicitly considered by this approach. These and other simplifications resulted in counterintuitive friction factor calibration for some commodities. However, all travel demand and assignment models suffer from some degree of these limitations.

While the model was never expected to completely reproduce travel patterns that reflect a myriad of decisions and factors, the researchers had higher expectations for the validation procedure. However, with the exception of freight hauled by specialized equipment, the method did not provide enough data to recalibrate the model, or even to conclusively quantify the fidelity of the modeling process.

13.3 Recommendations

The results of this modeling attempt, and many of the others reviewed as part of this research reinforce the need for access to robust, accurate freight data before the models will be widely accepted and used. However, even the future of the most extensive national data collection effort, the Commodity Flow Survey, is in question. On a positive note, increased use of technology in freight transportation may reduce some of the current burden placed on shipper's during data collection efforts and result in more seamless, continuous data collection efforts. Development of data synthesis techniques and less intrusive forms of data collection such as remote sensing, are recommended to address some of the data limitations.

This study represents the only known attempt to validate a statewide travel model by data from direct observation coupled with truck counts and secondary data sources. And, while not completely successful, the technique may hold promise given sufficient dedication of resources. Additional data should be collected to verify that the commodities declared in the MCMIS data are actually being transported. Even though the MCMIS information was validated by a limited sample of observed cargo, the reliability of the data for the estimation of commodities could be increased to statistically valid levels. More data should be collected; both on a daily and seasonal basis, particularly in an agricultural state like Iowa where shipments like grain and livestock can vary considerably by day and season. A larger sample size would improve the quality of commodity flows generated by the model. Future deployments of ITS/CVO technologies may help researchers obtain carrier information without the labor-intensive process used in this research.

While much research was done in the development of this model, many components would benefit from increased consideration. The following list of recommendations for future research are provided:

- The level of commodity aggregation required for a successful model should be examined more closely. A more aggregate model would help rectify some of inconsistencies encountered while using the variety of data sources. Research in this area could quantify the tradeoffs between the aggregation level and performance of the model.
- The method for disaggregating commodity flows from the BEA to the county level could be validated by creating a sub-model of the area. Using the technique for data collection and commodity estimated developed in this research, the disaggregated flows could be validated.
- Prediction capabilities of the model could be improved if a more sophisticated submodel of mode split could be developed.
- As stated, even though commodity estimation using the MCMIS information was validated by a limited sample of observed cargo, the reliability of the data for the estimation of commodities could be increased to statistically valid

levels.

- The use observational data to predict commodity flows could be improved if a method was developed automate the collection of carrier identification numbers. This automation would improve the data entry and matching process.
- Even if the data collection and commodity estimation process developed in this method is considered to cumbersome in a statewide application, the use of the technique to develop flows in corridor study should be appropriate and relatively easy.

APPENDIX A – FREIGHT MODEL MANAGER CODE

```
'**************************************************************
'   Freight Model Manager
'   Code by:
'               Christopher Monsere
'               Iowa State University
'               Department of Civil and Construction Engineering
'               Transportation Engineering
'               Major Professors: Reginald Souleyrette and Tom Maze
'
'   Parts of code taken from R.Storm, J. Shadewald
'   Initially developed December 1999 for use in disseration research
'   Update 3.0 4/10/00
'   Update 4.0 5/20/00
'   Update 5.0 10/15/00
'   Update 5.1 11/13/00
'
'   Program requires the use of:
'       Microsoft Access
'       MapInfo v5.0
'       Tranplan v9.0
'       Freight.mbx v2.0
'
'   Requires Modeldir.txt in application directory
'
'   Sub headers contain detail on each sub
'**************************************************************

Option Explicit

Private Sub Browse_OD_Click()
CommonDialog.DialogTitle = "Open Survey OD Text File"
CommonDialog.Filter = "(*.txt) | *.txt"
CommonDialog.FileName = ""
CommonDialog.InitDir = Commodity_Dir.Path
CommonDialog.ShowOpen
OD_Textbox.Text = CommonDialog.FileName
End Sub

Private Sub Browse_Tons_Click()
CommonDialog.DialogTitle = "Open Tons Conversion Text File"
CommonDialog.Filter = "(*.txt) | *.txt"
CommonDialog.FileName = ""
CommonDialog.InitDir = Network_Dir.Path
CommonDialog.ShowOpen
Tons_Textbox.Text = CommonDialog.FileName
End Sub
Private Sub Calibrate_Click()
Select Case Calibrate.value

Case 1
SumPa_Textbox.Visible = False
FF_Textbox.Visible = False
Browse_SumPA.Visible = False
Browse_FF.Visible = False
```

```
GMwithSRV.value = 0
GMwithPA.value = 0
ControlFile_Textbox.Text = "calib.in"
outfilename_textbox.Text = "calib.out"
End Select
End Sub

Private Sub GMwithPA_Click()
Select Case GMwithPA.value

Case 1
SumPa_Textbox.Visible = True
FF_Textbox.Visible = True
Browse_SumPA.Visible = True
Browse_FF.Visible = True
Calibrate.value = 0
GMwithSRV.value = 0
ControlFile_Textbox.Text = "gmpa.in"
outfilename_textbox.Text = "gmpa.out"
End Select
End Sub

Private Sub GMwithSRV_Click()
Select Case GMwithSRV.value

Case 1
SumPa_Textbox.Visible = False
FF_Textbox.Visible = False
Browse_SumPA.Visible = False
Browse_FF.Visible = False
Calibrate.value = 0
GMwithPA.value = 0
ControlFile_Textbox.Text = "gmsrv.in"
outfilename_textbox.Text = "gmsrv.out"
End Select
End Sub

Private Sub CreateLogQuit_Click()
'*************************************************************
'   Sub CreateLogQuit compiles a file of the run of FMM and
'   saves the file in the ANALYSIS case directory, then quits
'*************************************************************

Dim msg, style, title, response
Dim logfile As String

msg = "Are you sure you want to quit? Log file will be saved to case
directory as 'log.txt'"   ' Define message.
style = vbYesNo + vbCritical + vbDefaultButton2 ' Define buttons.
title = "Quit Program"  ' Define title.
response = MsgBox(msg, style, title)
If response = vbYes Then    ' User chose Yes.
logfile = Case_Textbox.Text + "\log.txt"

Open logfile For Output As #99
```

```
Print #99, "FREIGHT MODEL MANAGER ROUTINES LOG"
Print #99, ""
Print #99, "ANALYSIS DIRECTORY = " + Case_Textbox.Text
Print #99, "NETWORK DIRECTORY = " + Network_Textbox.Text
Print #99, "COMMODITY DIRECTORY = " + Commodity_Textbox.Text
Print #99, ""

If Network_Pic.Visible = True Then
    Print #99, "4) Build Network Files = YES"
    Print #99, ""
    Print #99, Spc(4); "Links File = " + Links_TextBox.Text
    Print #99, Spc(4); "Nodes File = " + Nodes_TextBox.Text
    Print #99, Spc(4); "Exported TRANPLAN Formated Network File = " +
Case_Dir.Path + "\" + LinksEx_Textbox.Text
    Print #99, Spc(4); "Exported TRANPLAN Formated Nodes File = " +
Case_Dir.Path + "\" + NodesEx_Textbox.Text
    Print #99, ""
    Else
    Print #99, "4) Build Network Files = NO"
    Print #99, ""
End If


If NetworkCntrl_Pic.Visible = True Then
    Print #99, Spc(4); "Max Zones = " + NumZones_Textbox.Text; ", Max Nodes
= " + MaxNode_Textbox.Text; ", Max Time = " + maxtime_textbox.Text
    Print #99, Spc(4); "Link Costs Assigned"
    Print #99, Spc(8); "Link Group 1 = " + LG1_Textbox.Text
    Print #99, Spc(8); "Link Group 2 = " + LG2_Textbox.Text
    Print #99, Spc(8); "Link Group 3 = " + LG3_Textbox.Text
    Print #99, Spc(8); "Link Group 4 = " + LG4_Textbox.Text
    Print #99, Spc(8); "Link Group 5 = " + LG5_Textbox.Text
    Print #99, Spc(8); "Link Group 6 = " + LG6_Textbox.Text
    Print #99, Spc(8); "Link Group 7 = " + LG7_Textbox.Text
    Print #99, Spc(8); "Link Group 8 = " + LG8_Textbox.Text
    Print #99, Spc(8); "Link Group 9 = " + LG9_Textbox.Text
    Print #99, Spc(8); "Link Group 0 = " + LG0_Textbox.Text
    Print #99, ""
    Else
    Print #99, "4) Build Network Control File = NO"
    Print #99, ""
End If

If BuildPA_Pic.Visible = True Then
    Print #99, "1) Build Production Attractions = YES"
    Print #99, ""
    Print #99, Spc(4); "Production File = " + Production_Textbox.Text
    Print #99, Spc(4); "Attraction File = " + Attraction_Textbox.Text
    Print #99, Spc(4); "Exported All Flows File = " + Commodity_Dir.Path +
"\" + Allflows_Textbox.Text
    Print #99, Spc(4); "Exported Truck Only File =  " + Commodity_Dir.Path +
"\" + Trkflows_Textbox.Text
    Print #99, Spc(4); "Exported Rail Only File = " + Commodity_Dir.Path +
"\" + Railflows_Textbox.Text
    Print #99, ""
    Else
```

```
    Print #99, "1) Build Production Attractions = NO"
    Print #99, ""
End If

If BuildSurvey_Pic.Visible = True Then
    Print #99, "2) Build Survey Files = YES"
    Print #99, ""
    Print #99, Spc(4); "OD Survey File =" + OD_Textbox.Text
    Print #99, Spc(4); "Exported All Survey File =" +
SurveyAll_Textbox.Text
    Print #99, Spc(4); "Exported Truck Survey File =" +
SurveyTrk_Textbox.Text
    Print #99, Spc(4); "Exported Rail Survey File =" +
SurveyRail_Textbox.Text
    Print #99, ""
    Else
    Print #99, "2) Build Survey Files = NO"
    Print #99, ""
End If

If bldtrp_pic.Visible = True Then
    Print #99, "3) Build Trip Table and GMHFIL = YES"
    Print #99, ""
    Else
    Print #99, "3) Build Trip Table and GMHFIL = NO"
    Print #99, ""
End If

If Tp_Pic.Visible = True Then
    Print #99, "5) Build Control File = YES"
    Print #99, ""
    Print #99, Spc(4); "Control File =" + Case_Dir.Path + "\" +
ControlFile_Textbox.Text


    If Calibrate.value = True Then
        Print #99, Spc(4); "Calibrate Gravity Model only = YES"
        Else
        Print #99, Spc(4); "Calibrate Gravity Model only = NO"
    End If

    Print #99, Spc(4); "Header Text"
    Print #99, Spc(8); Header1_Textbox.Text

    If Calibrate.value = False Then
    Print #99, Spc(8); "PA File = " + SumPa_Textbox.Text
    Print #99, Spc(8); "FF File = " + FF_Textbox.Text
    End If


    Else
    Print #99, "5) Build Control File = NO"
    Print #99, ""
End If

If RunTp_Pic.Visible = True Then
```

```
    Print #99, "6) Run TRANPLAN = YES"
    Print #99, ""
    Else
    Print #99, "6) Run TRANPLAN = NO"
    Print #99, ""
End If

If Netcard_Pic.Visible = True Then
    Print #99, "7) Copy TRANPLAN Files and Run NETCARD = YES"
    Print #99, Spc(4); "Output File =" + Case_Dir.Path + "\" +
outfilename_textbox.Text
    Print #99, ""
    Else
    Print #99, "7) Copy TRANPLAN Files and Run NETCARD = NO"
    Print #99, ""
End If

If CopyKill_Pic.Visible = True Then
    Print #99, "8) Copy NETCARD output and delete files = YES"
    Print #99, ""
    Else
    Print #99, "8) Copy NETCARD output and delete files = NO"
    Print #99, ""
End If

If Format_Pic.Visible = True Then
    Print #99, "9) MAPINFO formatted output file created = YES"
    Print #99, ""
    Print #99, Spc(4); "Annual Conversion Factor = " + Annual_Textbox.Text
    Print #99, ""
    Print #99, Spc(4); "Import File = " + netcard_textbox.Text
    Print #99, Spc(4); "STCC Code = " + STCC_Textbox.Text
    Print #99, Spc(4); "Tons to Vehicles File = " + Tons_Textbox.Text
    Print #99, Spc(4); "Formated Output File = " + Output_textbox.Text
    Print #99, ""
    Print #99, Spc(4); "Truck Vehicle 1 = " + Label45.Caption
    Print #99, Spc(4); "Percent Truck Vehicle 1 = " + Text1.Text
    Print #99, Spc(4); "Tons per Truck Vehicle 1 = " + Text3.Text
    Print #99, Spc(4); "Truck Expansion Vehicle 1 = " + Text5.Text
    Print #99, ""
    Print #99, Spc(4); "Truck Vehicle 2 = " + Label46.Caption
    Print #99, Spc(4); "Percent Truck Vehicle 2 = " + Text2.Text
    Print #99, Spc(4); "Tons per Truck Vehicle 2= " + Text4.Text
    Print #99, Spc(4); "Truck Expansion Vehicle 2 = " + Text6.Text
    Print #99, ""
    Print #99, Spc(4); "Rail Vehicle 1 = " + Label47.Caption
    Print #99, Spc(4); "Percent Rail Vehicle 1 = " + Text7.Text
    Print #99, Spc(4); "Tons per Rail Vehicle 1 = " + Text9.Text
    Print #99, Spc(4); "Rail Expansion Vehicle 1 = " + Text11.Text
    Print #99, ""
    Print #99, Spc(4); "Rail Vehicle 2 = " + Label48.Caption
    Print #99, Spc(4); "Percent Rail Vehicle 2 = " + Text8.Text
    Print #99, Spc(4); "Tons per Rail Vehicle 2= " + Text10.Text
    Print #99, Spc(4); "Rail Expansion Vehicle 2 = " + Text12.Text
    Print #99, ""
    Else
```

```
    Print #99, "9) MAPINFO formated output file created = NO"
    Print #99, ""
End If


Close #99
Unload Mainfrm
Else    ' User chose No.
End If
End Sub

Private Sub Form_Load()
'************************************************************
'   Sub Form_Load specfies intial settings for form
'************************************************************
Dim directory As String
Dim rootdirectory As String
Dim prompt As String
Dim title As String
Dim tranplan As String

Tabform.Tab = 0
ProgressBar.value = 0
directory = App.Path + "\modeldir.txt" 'file that indicates root directory
of models. Must be in app directory
On Error GoTo Errorhandler
Open directory For Input As #1
Input #1, rootdirectory, tranplan
Close #1
Network_Dir.Path = rootdirectory + "network\"
Case_Dir.Path = rootdirectory
Commodity_Dir.Path = rootdirectory
Tp_Dir.Path = tranplan

Exit Sub

Errorhandler:
Dim response, style
If Dir(directory) = "" Then
    prompt = "File " + directory + " not found" + Chr(13) + "No default
directories will be set" ' Define message.
    title = "File not Found"  ' Define title.
    style = vbCritical ' Define buttons.
    response = MsgBox(prompt, style, title)
Else
    prompt = "Directory " + rootdirectory + " or " + tranplan + " specified
in modeldir.txt does not exist" + Chr(13) + "No default directories will be
set" ' Define message.
    title = "File not Found"  ' Define title.
    style = vbCritical ' Define buttons.
    response = MsgBox(prompt, style, title)
End If

End Sub
```

```
Private Sub Browse_Production_Click()
CommonDialog.DialogTitle = "Open Production Text File"
CommonDialog.Filter = "(*.txt) | *.txt"
CommonDialog.FileName = ""
CommonDialog.InitDir = Commodity_Dir.Path
CommonDialog.ShowOpen
Production_Textbox.Text = CommonDialog.FileName
End Sub

Private Sub Browse_Attraction_Click()
CommonDialog.DialogTitle = "Open Attraction Text File"
CommonDialog.Filter = "(*.txt) | *.txt"
CommonDialog.FileName = ""
CommonDialog.InitDir = Commodity_Dir.Path
CommonDialog.ShowOpen
Attraction_Textbox.Text = CommonDialog.FileName
End Sub

Private Sub Browse_netcard_Click()
CommonDialog.DialogTitle = "Open Netcard Output File"
CommonDialog.Filter = "(*.dat) | *.dat"
CommonDialog.FileName = ""
CommonDialog.InitDir = Case_Dir.Path
CommonDialog.ShowOpen
netcard_textbox.Text = CommonDialog.FileName
End Sub

Private Sub Browse_FF_Click()
CommonDialog.DialogTitle = "Open Friction Factor File"
CommonDialog.Filter = "(*.txt) | *.txt"
CommonDialog.FileName = ""
CommonDialog.InitDir = Commodity_Dir.Path
CommonDialog.ShowOpen
FF_Textbox.Text = CommonDialog.FileName
End Sub

Private Sub Browse_Links_Click()
CommonDialog.DialogTitle = "Open Links File"
CommonDialog.Filter = "(*.txt) | *.txt"
CommonDialog.FileName = ""
CommonDialog.InitDir = Network_Dir.Path
CommonDialog.ShowOpen
Links_TextBox.Text = CommonDialog.FileName
End Sub

Private Sub Browse_Nodes_Click()
CommonDialog.DialogTitle = "Open Nodes File"
CommonDialog.Filter = "(*.txt) | *.txt"
CommonDialog.FileName = ""
CommonDialog.InitDir = Network_Dir.Path
CommonDialog.ShowOpen
Nodes_TextBox.Text = CommonDialog.FileName
End Sub

Private Sub Browse_SumPA_Click()
CommonDialog.DialogTitle = "Open PA File"
```

```
CommonDialog.Filter = "(*.txt) | *.txt"
CommonDialog.FileName = ""
CommonDialog.InitDir = Commodity_Dir.Path
CommonDialog.ShowOpen
SumPa_Textbox.Text = CommonDialog.FileName
End Sub

Private Sub Browse_Control_Click()
CommonDialog.DialogTitle = "Open Control File"
CommonDialog.Filter = "(*.in) | *.in"
CommonDialog.FileName = ""
CommonDialog.InitDir = Case_Dir.Path
CommonDialog.ShowOpen
Control_Textbox.Text = CommonDialog.FileName
RunTp_Pic.Visible = False
CopyFile_Pic.Visible = False
Netcard_Pic.Visible = False
CopyKill_Pic.Visible = False

End Sub

Private Sub Commodity_Dir_Change()
Commodity_Textbox.Text = Commodity_Dir.Path
PAExport.Caption = "Saved in " + Commodity_Dir.Path + ":"
SurveyExport.Caption = "Saved in " + Commodity_Dir.Path + ":"
End Sub

Private Sub Drive_Change()
Case_Dir.Path = Drive.Drive
Network_Dir.Path = Drive.Drive
Commodity_Dir.Path = Drive.Drive
Tp_Dir.Path = Drive.Drive
End Sub

Private Sub Network_Dir_Change()
Network_Textbox.Text = Network_Dir.Path
Nodes_TextBox.Text = Network_Dir.Path + "\mi_nodes.txt"
Links_TextBox.Text = Network_Dir.Path + "\mi_links.txt"
Tons_Textbox.Text = Network_Dir.Path + "\tons.txt"
End Sub

Private Sub Case_Dir_Change()
Case_Textbox.Text = Case_Dir.Path
Output_textbox = Case_Dir.Path + "\new_data.txt"
netcard_textbox = Case_Dir.Path + "\out.dat"
RTOutputFile.Caption = "Saved in " + Case_Dir.Path + ":"
BNFControlFile.Caption = "Saved in " + Case_Dir.Path + ":"
BCFControlFile.Caption = "Saved in " + Case_Dir.Path + ":"
ExportNetwork.Caption = "Saved in " + Case_Dir.Path + ":"
TripTable.Caption = "Saved in " + Case_Dir.Path + ":"

End Sub

Private Sub NetworkCntrl_Click()
'**************************************************************
'   Sub BuildControlFile creates a TRANPLAN Control file with user
```

```
specified files
'   No dummy checks included, it is possible to overwrite files
'   or crash the program.
'   Options:
'       Network and Skims only
'       Calibrate GMModel only
'       Gravity Model with SRVDATA
'       Gravity Model with PA option
'*************************************************************

'*************************************************************
'   Variable Declarations for Sub BuildControlFile
'*************************************************************
On Error GoTo Errorhandler

Dim nodesfile As String
Dim linksfile As String
Dim outputfile As String

Dim taz As String  'For input varibles
Dim max_node As String
Dim max_time As String
Dim casepath As String
Dim networkpath As String
Dim compath As String
Dim lg1cost As String
Dim lg2cost As String
Dim lg3cost As String
Dim lg4cost As String
Dim lg5cost As String
Dim lg6cost As String
Dim lg7cost As String
Dim lg8cost As String
Dim lg9cost As String
Dim lg0cost As String

Dim msg As String  'For Dialog Boxes
Dim style As String
Dim title As String
Dim response As String
Dim prompt As String
Dim title2 As String

Dim EndBuild As Label

'*************************************************************
'Define variables
outputfile = Case_Dir.Path + "\" + NetworkControlFile.Text
linksfile = Case_Dir.Path + "\" + LinksEx_Textbox.Text
nodesfile = Case_Dir.Path + "\" + NodesEx_Textbox.Text
taz = NumZones_Textbox.Text
max_node = MaxNode_Textbox.Text
max_time = maxtime_textbox.Text
casepath = Case_Textbox.Text
networkpath = Network_Textbox.Text
compath = Commodity_Textbox.Text
```

```
lg1cost = LG1_Textbox.Text
lg2cost = LG2_Textbox.Text
lg3cost = LG3_Textbox.Text
lg4cost = LG4_Textbox.Text
lg5cost = LG5_Textbox.Text
lg6cost = LG6_Textbox.Text
lg7cost = LG7_Textbox.Text
lg8cost = LG8_Textbox.Text
lg9cost = LG9_Textbox.Text
lg0cost = LG0_Textbox.Text

'**************************************************************
'   Check for existing control file
'**************************************************************

If Dir(outputfile) <> "" Then
    msg = "Control File already exists do you want to overwrite ?"    '
Define message.
    style = vbYesNo + vbCritical + vbDefaultButton2 ' Define buttons.
    title = "File Exists"  ' Define title.
    response = MsgBox(msg, style, title)
    If response = vbNo Then     ' User chose No.
        Exit Sub
    End If
End If

ProgressBar.value = 0 'intial settings for progress bar and label18
ProgressBar.Max = 10

'**************************************************************
'   Write control file
'**************************************************************
Open outputfile For Output As #44

Print #44, "$BUILD HIGHWAY NETWORK"
Print #44, "$FILES"
Print #44, Spc(2); "OUTPUT FILE = HWYNET, USER ID = $" + casepath +
"\NETWORK.BIN$"
Print #44, "$HEADERS"
Print #44, Spc(2); Header1_Textbox.Text
Print #44, "$OPTIONS"
Print #44, Spc(2); "Large Coordinates"
Print #44, "$PARAMETERS"
Print #44, Spc(2); "Number of Zones = "; taz
Print #44, Spc(2); "Maximum Node = "; max_node
Print #44, "$DATA"
Print #44, "$INCLUDE "; nodesfile
Print #44, "$INCLUDE "; linksfile
Print #44, "$END TP FUNCTION"
Print #44, " "

ProgressBar.value = 4

Print #44, "$BUILD COST USER NETWORK"
Print #44, "$FILES"
```

```
    Print #44, Spc(2); "INPUT FILE = CUSIN, USER ID = $" + casepath +
"\NETWORK.BIN$"
    Print #44, Spc(2); "OUTPUT FILE = CUSOUT, USER ID = $" + casepath +
"\NETCOST.BIN$"
Print #44, "$HEADERS"
        Print #44, Spc(2); Header1_Textbox.Text
        Print #44, Spc(2); "1-Highway 2-Interstate 3-Rail Mainline 4-Rail
Shortline 5-Rail Centroid"
        Print #44, Spc(2); "6-Rail Centroid 7-Intermodal 8-Intermodal 9-
Interline 10-Interline 1/2"
Print #44, "$PARAMETERS"
    Print #44, Spc(2); "Cost Location = Cost"
Print #44, "$DATA"
    Print #44, Spc(2); "Linear Set = 1, Unit Time Cost = 0, Unit Distance
Cost = "; lg1cost
        Print #44, Spc(4); "Assignment Group = 1"
    Print #44, Spc(2); "Linear Set = 2, Unit Time Cost = 0, Unit Distance
Cost = "; lg2cost
        Print #44, Spc(4); "Assignment Group = 2"
    Print #44, Spc(2); "Linear Set = 3, Unit Time Cost = 0, Unit Distance
Cost = "; lg3cost
        Print #44, Spc(4); "Assignment Group = 3"
    Print #44, Spc(2); "Linear Set = 4, Unit Time Cost = 0, Unit Distance
Cost = "; lg4cost
        Print #44, Spc(4); "Assignment Group = 4"
    Print #44, Spc(2); "Linear Set = 5, Unit Time Cost = 0, Unit Distance
Cost = "; lg5cost
        Print #44, Spc(4); "Assignment Group = 5"
    Print #44, Spc(2); "Linear Set = 6, Unit Time Cost = 0, Unit Distance
Cost = "; lg6cost
        Print #44, Spc(4); "Assignment Group = 6"
    Print #44, Spc(2); "Linear Set = 7, Unit Time Cost = 0, Unit Distance
Cost = "; lg7cost
        Print #44, Spc(4); "Assignment Group = 7"
    Print #44, Spc(2); "Linear Set = 8, Unit Time Cost = 0, Unit Distance
Cost = "; lg8cost
        Print #44, Spc(4); "Assignment Group = 8"
    Print #44, Spc(2); "Linear Set = 9, Unit Time Cost = 0, Unit Distance
Cost = "; lg9cost
        Print #44, Spc(4); "Assignment Group = 9"
    Print #44, Spc(2); "Linear Set = 10, Unit Time Cost = 0, Unit Distance
Cost = "; lg0cost
        Print #44, Spc(4); "Assignment Group = 0"

Print #44, "$END TP FUNCTION"

Print #44, " "

ProgressBar.value = 10

Print #44, "$HIGHWAY SELECTED SUMMATION"
Print #44, "$FILES"
    Print #44, Spc(2); "INPUT FILE = HWYNET, USER ID = $" + casepath +
"\NETCOST.BIN$"
    Print #44, Spc(2); "OUTPUT FILE = HWYSKIM, USER ID = $" + casepath +
"\SKIM.DAT$"
```

```
Print #44, "$PARAMETERS"
    Print #44, Spc(2); "Impedance = Cost"
Print #44, "$DATA"
     Print #44, Spc(2); "Table = Cost"
Print #44, "$END TP FUNCTION"

Close #44

ProgressBar.value = 10
ProgressBar.value = 0
NetworkCntrl_Pic.Visible = True
outfilename_textbox.Text = "network.out"

Exit Sub

Errorhandler:
Dim response2, style2
prompt = "One or all of files specified are not found"
title = "File not Found"  ' Define title.
style2 = vbCritical ' Define buttons.
response2 = MsgBox(prompt, style2, title)

End Sub

Private Sub Quit_Click()
Dim msg, style, title, response
msg = "Are you sure you want to quit ?"    ' Define message.
style = vbYesNo + vbCritical + vbDefaultButton2 ' Define buttons.
title = "Quit Program"  ' Define title.
response = MsgBox(msg, style, title)
If response = vbYes Then    ' User chose Yes.
Unload Mainfrm
Else    ' User chose No.
End If
End Sub

Private Sub Reset_Click()
Network_Pic.Visible = False
NetworkCntrl_Pic.Visible = False
BuildPA_Pic.Visible = False
BuildSurvey_Pic.Visible = False
bldtrp_pic.Visible = False
GMHIST_Pic.Visible = False
Format_Pic.Visible = False
RunTp_Pic.Visible = False
CopyFile_Pic.Visible = False
Netcard_Pic.Visible = False
CopyKill_Pic.Visible = False
Tp_Pic.Visible = False
Frame22.Visible = False
Frame23.Visible = False

End Sub

Private Sub Run_Network_Click()
'*************************************************************
```

```
'   Sub Run_Network imports node and link files from
'   MapInfo export
'   to create TRANPLAN formated node and link files
'*************************************************************
'*************************************************************
'   Variable Declarations for Sub RunProgram
'*************************************************************
On Error GoTo Errorhandler

Dim nodesfile As String 'For file management
Dim linksfile As String

Dim outputnodesfile As String
Dim outputlinksfile As String

Dim msg As String  'For Dialog Boxes
Dim style As String
Dim title As String
Dim response As String
Dim prompt As String
Dim title2 As String


Dim node_numim As String 'For node file import
Dim x_nodeim As Long
Dim y_nodeim As Long
Dim x_node As Long
Dim y_node As Long
Dim tab_node As Long
Dim tab_x As Long
Dim tab_y As Long

Dim node_num As String  'For links file import
Dim x_node_str As String
Dim y_node_str  As String
Dim anode As String
Dim bnode As String
Dim assgn_group As String
Dim distance As String
Dim field_option As String
Dim field1 As String
Dim field2 As String
Dim direction_code As String
Dim linkgroup1 As String
Dim linkgroup2 As String
Dim linkgroup3 As String
Dim capacity As String
Dim capacity2 As String
Dim BA_option As String
Dim ax As String
Dim ay As String
Dim bx As String
Dim by As String
Dim tab_anode  As String
Dim tab_bnode  As String
Dim tab_distance  As String
```

```
Dim tab_field1  As String
Dim tab_field2  As String
Dim tab_direction_code  As String
Dim tab_linkgroup1  As String
Dim tab_linkgroup2  As String
Dim tab_linkgroup3  As String
Dim tab_capacity  As String
Dim tab_capacity2 As String

'**************************************************************

nodesfile = Nodes_TextBox.Text  'manage files and variables
linksfile = Links_TextBox.Text

outputnodesfile = Case_Dir.Path + "\" + NodesEx_Textbox.Text
outputlinksfile = Case_Dir.Path + "\" + LinksEx_Textbox.Text

If Dir(outputnodesfile) <> "" Then
    msg = "Nodes Export File already exists do you want to overwrite ?"    '
Define message.
    style = vbYesNo + vbCritical + vbDefaultButton2 ' Define buttons.
    title = "File Exists"   ' Define title.
    response = MsgBox(msg, style, title)
    If response = vbNo Then     ' User chose No.
        Exit Sub
    End If
End If

If Dir(outputlinksfile) <> "" Then
    msg = "Links Export File already exists do you want to overwrite ?"    '
Define message.
    style = vbYesNo + vbCritical + vbDefaultButton2 ' Define buttons.
    title = "File Exists"   ' Define title.
    response = MsgBox(msg, style, title)
    If response = vbNo Then     ' User chose No.
        Exit Sub
    End If
End If
ProgressBar.value = 0 'intial settings for progress bar and label18
ProgressBar.Max = 10


Open nodesfile For Input As #55
Open linksfile For Input As #33

Open outputnodesfile For Output As #44
Open outputlinksfile For Output As #45

'**************************************************************
'   Import Node Data from txt file, format, then print
'**************************************************************

    Do While Not EOF(55)
        Input #55, node_numim, x_nodeim, y_nodeim
        x_node = CLng(x_nodeim)
        y_node = CLng(y_nodeim)
```

```
        x_node_str = CStr(x_node)
        y_node_str = CStr(y_node)
        tab_node = 6 - Len(node_numim) + 1
        tab_x = 17 - Len(x_node_str) + 1
        tab_y = 28 - Len(y_node_str) + 1
        Print #44, "N "; Tab(tab_node); node_numim; Tab(tab_x); x_node_str;
Tab(tab_y); y_node_str
    Loop
    ProgressBar.value = 4
    Close #55
    Close #44
'***************************************************************
'   Import Link Data from txt file, format, then print
'***************************************************************

       Do While Not EOF(33)
        Input #33, anode, bnode, assgn_group, distance, field_option,
field1, field2, direction_code, linkgroup1, linkgroup2, linkgroup3,
capacity, capacity2, BA_option

        tab_anode = 5 - Len(anode) + 1
        tab_bnode = 10 - Len(bnode) + 1
        tab_distance = 15 - Len(distance) + 1
        tab_field1 = 20 - Len(field1) + 1
        tab_field2 = 24 - Len(field2) + 1
        tab_direction_code = 26 - Len(direction_code) + 1
        tab_linkgroup1 = 28 - Len(linkgroup1) + 1
        tab_linkgroup2 = 30 - Len(linkgroup2) + 1
        tab_linkgroup3 = 32 - Len(linkgroup3) + 1
        tab_capacity = 38 - Len(capacity) + 1
        tab_capacity2 = 44 - Len(capacity) + 1

        Print #45, Tab(tab_anode); anode; Tab(tab_bnode); bnode;
assgn_group; Tab(tab_distance); distance; field_option; Tab(tab_field1);
field1; Tab(tab_field2); field2; Tab(tab_direction_code); direction_code;
Tab(tab_linkgroup1); linkgroup1; Tab(tab_linkgroup2); linkgroup2;
Tab(tab_linkgroup3); linkgroup3; Tab(tab_capacity); capacity;
Tab(tab_capacity2); capacity2; BA_option
    Loop
    ProgressBar.value = 10
    Close #33
    Close #45
    Network_Pic.Visible = True
    ProgressBar.value = 0
Exit Sub

Errorhandler:
Dim response2, style2
prompt = "One or all of files specified are not found"
title = "File not Found"  ' Define title.
style2 = vbCritical ' Define buttons.
response2 = MsgBox(prompt, style2, title)


End Sub
```

```
Private Sub RunGMHIST_Click()
'************************************************************
'   Sub RunGMHIST builds batch file to run GMHIST misc utility
'   copies file back.
'************************************************************

Dim value As Double
Dim batch2 As String
Dim gmhfilin As String

On Error GoTo Errorhandler

gmhfilin = Tp_Dir.Path + "\gmhfil.in"
batch2 = Tp_Dir.Path + "\gmh.bat"

Open batch2 For Output As #3
Open gmhfilin For Output As #4

    Print #4, "Gravity Model Calibration GMHIST"
    Print #4, HeaderHist1_Textbox.Text
    Print #4, HeaderHist2_Textbox.Text

Close #4

    Print #3, "del gmhist.dat"
    Print #3, "del volume.dat"
    Print #3, "del skim.dat"
    Print #3, "copy " + Commodity_Dir.Path + "\volume.dat " + Tp_Dir.Path
    Print #3, "copy " + Case_Dir.Path + "\skim.dat " + Tp_Dir.Path
    Print #3, "gmhfil.exe"
    Print #3, "copy gmhist.dat " + Case_Dir.Path + "\gmhist.dat"
Close #3

ChDrive Drive.Drive
ChDir Tp_Dir.Path
value = Shell("command.com", vbNormalFocus)
GMHIST_Pic.Visible = True
Frame23.Visible = True
Exit Sub

Errorhandler:
Dim response, style, prompt, title
prompt = "File not found or Tranplan Directory not specified"
title = "File not Found"  ' Define title.
style = vbCritical ' Define buttons.
response = MsgBox(prompt, style, title)
End Sub

Private Sub RunPA_Click()
'************************************************************
'   Sub Run_PA imports p&a files exported from
'   MS Access
'   to create TRANPLAN formated gmpa files
'************************************************************

'******************************************************************
```

```
'   Variable Declarations
'*******************************************************************
On Error GoTo Errorhandler

Dim production As String
Dim attraction As String
Dim outputfile As String
Dim allflows As String
Dim trkflows As String
Dim railflows As String

Dim or_taz As Long
Dim de_taz As Long
Dim tot_wght As Long
Dim trk_wght As Long
Dim rail_wght As Long

Dim str_or_taz As String
Dim str_tot_wght As String
Dim str_trk_wght As String
Dim str_rail_wght As String

Dim tab_or As Long
Dim tab_de As Long
Dim tab_tot As Long
Dim tab_trk As Long
Dim tab_rail As Long

production = Production_Textbox.Text
attraction = Attraction_Textbox.Text
allflows = Commodity_Dir.Path + "\" + Allflows_Textbox.Text
trkflows = Commodity_Dir.Path + "\" + Trkflows_Textbox.Text
railflows = Commodity_Dir.Path + "\" + Railflows_Textbox.Text
ProgressBar.value = 0
ProgressBar.Max = 10

Open production For Input As #21
Open attraction For Input As #22

Open allflows For Output As #23
Open trkflows For Output As #24
Open railflows For Output As #25

Do While Not EOF(21)
    Input #21, or_taz, tot_wght, trk_wght, rail_wght
    str_or_taz = CStr(or_taz)
    str_tot_wght = CStr(tot_wght)
    str_trk_wght = CStr(trk_wght)
    str_rail_wght = CStr(rail_wght)
    tab_or = 7 - Len(str_or_taz) + 1
    tab_tot = 17 - Len(str_tot_wght) + 1
    tab_trk = 17 - Len(str_trk_wght) + 1
    tab_rail = 17 - Len(str_rail_wght) + 1
    Print #23, "GP"; Tab(tab_or); str_or_taz; Tab(9); "1"; Tab(tab_tot);
str_tot_wght
    Print #24, "GP"; Tab(tab_or); str_or_taz; Tab(9); "1"; Tab(tab_trk);
```

```
str_trk_wght
    Print #25, "GP"; Tab(tab_or); str_or_taz; Tab(9); "1"; Tab(tab_rail);
str_rail_wght
Loop
ProgressBar.value = 5

Do While Not EOF(22)
    Input #22, or_taz, tot_wght, trk_wght, rail_wght
    str_or_taz = CStr(or_taz)
    str_tot_wght = CStr(tot_wght)
    str_trk_wght = CStr(trk_wght)
    str_rail_wght = CStr(rail_wght)
    tab_or = 7 - Len(str_or_taz) + 1
    tab_tot = 17 - Len(str_tot_wght) + 1
    tab_trk = 17 - Len(str_trk_wght) + 1
    tab_rail = 17 - Len(str_rail_wght) + 1
    Print #23, "GA"; Tab(tab_or); str_or_taz; Tab(9); "1"; Tab(tab_tot);
str_tot_wght
    Print #24, "GA"; Tab(tab_or); str_or_taz; Tab(9); "1"; Tab(tab_trk);
str_trk_wght
    Print #25, "GA"; Tab(tab_or); str_or_taz; Tab(9); "1"; Tab(tab_rail);
str_rail_wght
Loop
ProgressBar.value = 10
BuildPA_Pic.Visible = True
ProgressBar.value = 0

Close #21
Close #22
Close #23
Close #24
Close #25
Exit Sub

Errorhandler:
Dim response2, style2, prompt, title
prompt = "One or all of files specified are not found"
title = "File not Found"  ' Define title.
style2 = vbCritical ' Define buttons.
response2 = MsgBox(prompt, style2, title)


End Sub

Private Sub BuildControlFile_Click()
'***************************************************************
'   Sub BuildControlFile creates a TRANPLAN Control file with user
specified files
'   No dummy checks included, it is possible to overwrite files
'   or crash the program.
'   Options:
'       Calibrate GMModel only
'       Gravity Model with SRVDATA
'       Gravity Model with PA option
'***************************************************************
```

```
'***********************************************************
'   Variable Declarations for Sub BuildControlFile
'***********************************************************
On Error GoTo Errorhandler

Dim sumpafile As String 'For file management
Dim fffile As String
Dim outputfile As String

Dim casepath As String
Dim networkpath As String
Dim compath As String

Dim msg As String  'For Dialog Boxes
Dim style As String
Dim title As String
Dim response As String
Dim prompt As String
Dim title2 As String

Dim EndBuild As Label

'***********************************************************
'Define variables
outputfile = Case_Dir.Path + "\" + ControlFile_Textbox.Text
sumpafile = SumPa_Textbox.Text
fffile = FF_Textbox.Text

casepath = Case_Textbox.Text
networkpath = Network_Textbox.Text
compath = Commodity_Textbox.Text


'***********************************************************
'   Check for existing control file
'***********************************************************

If Dir(outputfile) <> "" Then
    msg = "Control File already exists do you want to overwrite ?"    '
Define message.
    style = vbYesNo + vbCritical + vbDefaultButton2 ' Define buttons.
    title = "File Exists"  ' Define title.
    response = MsgBox(msg, style, title)
    If response = vbNo Then    ' User chose No.
        Exit Sub
    End If
End If

ProgressBar.value = 0 'intial settings for progress bar and label18
ProgressBar.Max = 10

'***********************************************************
'   Write control file
'***********************************************************
Open outputfile For Output As #44
```

```
If Calibrate.value = 1 Then 'Include this code if build required

    Print #44, "$CALIBRATE GRAVITY MODEL"
    Print #44, "$FILES"
        Print #44, Spc(2); "INPUT FILE = GMSKIM, USER ID = $" + casepath +
"\SKIM.DAT$"
        Print #44, Spc(2); "INPUT FILE = GMHIST, USER ID = $" + casepath +
"\GMHIST.DAT$"
        Print #44, Spc(2); "OUTPUT FILE = NEWDATA, USER ID = $" + compath +
"\SURVEY.DAT$"
    Print #44, "$HEADERS"
        Print #44, Spc(2); Header1_Textbox.Text
    Print #44, "$OPTIONS"
        Print #44, Spc(2); "Gravity Model History File"
        Print #44, Spc(2); "Output Data File"
        Print #44, Spc(2); "Print Trip Length Statistics"
    Print #44, "$PARAMETERS"
        Print #44, Spc(2); "F Factor Closure = 0.1"
        Print #44, Spc(2); "F Factor Iterations = 5"
        Print #44, Spc(2); "Maximum Time ="; maxtime_textbox.Text
        Print #44, Spc(2); "Impedance = Cost"
        Print #44, Spc(2); "Smooth Percentage = 100.00"
        Print #44, Spc(2); "Selected Purposes = 1-3"
        Print #44, Spc(2); "Skim Factor = 0.01"
    Print #44, "$END TP FUNCTION"
    GoTo EndBuild
End If

'*************************************************************
'   Gravity Model with SRVDATA Option
'*************************************************************
If GMwithSRV.value = 1 Then
    Print #44, "$GRAVITY MODEL"
    Print #44, "$FILES"
     Print #44, Spc(2); "INPUT FILE = GMSKIM, USER ID =$" + casepath +
"\SKIM.DAT$"
     Print #44, Spc(2); "INPUT FILE = GRVDATA, USER ID =$" + compath +
"\SURVEY.DAT$"
     Print #44, Spc(2); "OUTPUT FILE = GMTVOL, USER ID =$" + casepath +
"\GM92TOT.TRP$"
    Print #44, "$OPTIONS"
     Print #44, Spc(2); "Grvdata"
     Print #44, Spc(2); "Total Purpose File"
     Print #44, Spc(2); "Print Trip Ends"
     Print #44, Spc(2); "Print Trip Length Statistics"
    Print #44, "$PARAMETERS"
     Print #44, Spc(2); "Attraction Closure = 0.1"
     Print #44, Spc(2); "Iterations On Attractions = 10"
     Print #44, Spc(2); "Impedance = Cost"
     Print #44, Spc(2); "Maximum Purpose = 3"
     Print #44, Spc(2); "Maximum Time ="; maxtime_textbox.Text
     Print #44, Spc(2); "Selected Purposes = 1-3"
     Print #44, Spc(2); "Skim Factor = 0.01"
    Print #44, "$END TP FUNCTION"
    Print #44, " "
```

```
'***************************************************************
'   Gravity Model with PA Option
'***************************************************************
ElseIf GMwithPA.value = 1 Then

    Print #44, "$GRAVITY MODEL"
    Print #44, "$FILES"
     Print #44, Spc(2); "INPUT FILE = GMSKIM, USER ID =$" + casepath +
"\SKIM.DAT$"
     Print #44, Spc(2); "OUTPUT FILE = GMTVOL, USER ID =$" + casepath +
"\GM92TOT.TRP$"
    Print #44, "$OPTIONS"
     Print #44, Spc(2); "Total Purpose File"
     Print #44, Spc(2); "Print Trip Ends"
     Print #44, Spc(2); "Print Trip Length Statistics"
     Print #44, Spc(2); "Print Attractions"
    Print #44, "$PARAMETERS"
     Print #44, Spc(2); "Attraction Closure = 5.0"
     Print #44, Spc(2); "Iterations On Attractions = 3"
     Print #44, Spc(2); "Impedance = Cost"
     Print #44, Spc(2); "Maximum Purpose = 3"
     Print #44, Spc(2); "Maximum Time = "; maxtime_textbox.Text
    Print #44, "$DATA"
    Print #44, "$INCLUDE "; sumpafile
    Print #44, "$INCLUDE "; fffile
    Print #44, "$END TP FUNCTION"
    Print #44, " "

End If

Print #44, " "

Print #44, "$MATRIX TRANSPOSE"
Print #44, "$FILES"
     Print #44, Spc(2); "INPUT FILE = TRNSPIN, USER ID =$" + casepath +
"\GM92TOT.TRP$"
     Print #44, Spc(2); "OUTPUT FILE = TRNSPOT, USER ID =$" + casepath +
"\DUM.TRP$"
Print #44, "$END TP FUNCTION"

Print #44, " "

Print #44, "$MATRIX MANIPULATE"
Print #44, "$FILES"
     Print #44, Spc(2); "INPUT FILE = TMAN1, USER ID =$" + casepath +
"\GM92TOT.TRP$"
     Print #44, Spc(2); "INPUT FILE = TMAN2, USER ID =$" + casepath +
"\DUM.TRP$"
     Print #44, Spc(2); "OUTPUT FILE = TMAN3, USER ID =$" + casepath +
"\TOT92.TRP$"
Print #44, "$DATA"
     Print #44, Spc(2); "TMAN3 , T1 = TMAN1, T1 + TMAN2, T1"
Print #44, "$END TP FUNCTION"

Print #44, " "
```

```
Print #44, "$MATRIX UPDATE"
Print #44, "$FILES"
     Print #44, Spc(2); "INPUT FILE = UPDIN, USER ID =$" + casepath +
"\TOT92.TRP$"
     Print #44, Spc(2); "OUTPUT FILE = UPDOUT, USER ID =$" + casepath +
"\TOT92X.TRP$"
Print #44, "$DATA"
     Print #44, Spc(2); "T1,1-  144,1-  144, * .5"
Print #44, "$END TP FUNCTION"

Print #44, " "

Print #44, "$LOAD HIGHWAY NETWORK"
Print #44, "$FILES"
    Print #44, Spc(2); "INPUT FILE = HWYNET, USER ID =$" + casepath +
"\NETCOST.BIN$"
    Print #44, Spc(2); "INPUT FILE = HWYTRIP, USER ID =$" + casepath +
"\TOT92X.TRP$"
    Print #44, Spc(2); "OUTPUT FILE = LODHIST, USER ID =$" + casepath +
"\OUT.BIN$"
Print #44, "$PARAMETERS"
    Print #44, Spc(2); "Impedance = Cost"
Print #44, "$END TP FUNCTION"

Print #44, " "

Print #44, "$REPORT MATRIX"
Print #44, "$FILES"
    Print #44, Spc(2); "INPUT FILE = RTABIN, USER ID = $" + casepath +
"\TOT92X.TRP$"
Print #44, "$HEADERS"
    Print #44, Spc(2); "##***%%  TRIP TABLE REPORT %%***##"
Print #44, "$OPTIONS"
    Print #44, Spc(2); "PRINT Table"
Print #44, "$PARAMETERS"
    Print #44, Spc(2); "Selected Purposes = 1"
    Print #44, Spc(2); "Selected Zones = 1 - 144"
Print #44, "$END TP FUNCTION"

Print #44, " "

Print #44, "$DOS DEL  " + casepath + "\TOT92X.TRP"
Print #44, "$DOS DEL  " + casepath + "\DUM.TRP"
Print #44, "$DOS DEL  " + casepath + "\GM92TOT.TRP"

EndBuild:
Close #44

ProgressBar.value = 10
Tp_Pic.Visible = True
ProgressBar.value = 0

Exit Sub

Errorhandler:
Dim response2, style2
```

```
prompt = "One or all of files specified are not found"
title = "File not Found"  ' Define title.
style2 = vbCritical ' Define buttons.
response2 = MsgBox(prompt, style2, title)

End Sub

Private Sub RunSurvey_Click()
'**************************************************************
'   Sub Run_Survey imports OD files exported from
'   MS Access
'   to create TRANPLAN formated trip survey files
'   for use in Build Trip Table.
'
'   Tons divided by 10
'
'   Trips classified by purpose
'   Iowa to Iowa     = 1
'   Iowa to External = 2
'   External to Iowa = 3
'**************************************************************

'*********************************************************************
'   Variable Declarations
'*********************************************************************
On Error GoTo Errorhandler
Dim RunSurvey As Boolean
Dim od As String
Dim allfile As String
Dim truckfile As String
Dim railfile As String

Dim or_taz As Long
Dim de_taz As Long
Dim tot_wght As Long
Dim tot_wght10 As Long
Dim trk_wght As Long
Dim trk_wght10 As Long
Dim rail_wght As Long
Dim rail_wght10 As Long

Dim trip_purpose As String
Dim str_or_taz As String
Dim str_de_taz As String
Dim str_tot_wght As String
Dim str_trk_wght As String
Dim str_rail_wght As String

Dim tab_or As Long
Dim tab_de As Long
Dim tab_tot As Long
Dim tab_trk As Long
Dim tab_rail As Long
Dim tab_purpose As Long

'*********************************************************************
```

```
'   File Management
'*********************************************************************
od = OD_Textbox.Text
allfile = Commodity_Dir.Path + "\" + SurveyAll_Textbox.Text
railfile = Commodity_Dir.Path + "\" + SurveyTrk_Textbox.Text
truckfile = Commodity_Dir.Path + "\" + SurveyRail_Textbox.Text

ProgressBar.value = 0
ProgressBar.Max = 10

Open od For Input As #31
Open allfile For Output As #33
Open railfile For Output As #34
Open truckfile For Output As #35
ProgressBar.value = 5
'*********************************************************************
'   Import/Export Routine
'*********************************************************************
Do While Not EOF(31)
    Input #31, or_taz, de_taz, tot_wght, trk_wght, rail_wght
    'Classfy trips by purpose
    If or_taz <= 99 And de_taz <= 99 Then
        trip_purpose = 1
    ElseIf or_taz <= 99 And de_taz >= 100 Then
        trip_purpose = 2
    Else
        trip_purpose = 3
    End If

    tot_wght10 = tot_wght / 10
    trk_wght10 = trk_wght / 10
    rail_wght10 = rail_wght / 10

    str_or_taz = CStr(or_taz)
    str_de_taz = CStr(de_taz)
    str_tot_wght = CStr(tot_wght10)
    str_trk_wght = CStr(trk_wght10)
    str_rail_wght = CStr(rail_wght10)

    tab_or = 5 - Len(str_or_taz) + 1
    tab_de = 10 - Len(str_de_taz) + 1
    tab_tot = 20 - Len(str_tot_wght) + 1
    tab_trk = 20 - Len(str_trk_wght) + 1
    tab_rail = 20 - Len(str_rail_wght) + 1

    Print #33, Tab(tab_or); str_or_taz; Tab(tab_de); str_de_taz; Tab(13);
trip_purpose; Tab(tab_tot); str_tot_wght
    Print #34, Tab(tab_or); str_or_taz; Tab(tab_de); str_de_taz; Tab(13);
trip_purpose; Tab(tab_trk); str_trk_wght
    Print #35, Tab(tab_or); str_or_taz; Tab(tab_de); str_de_taz; Tab(13);
trip_purpose; Tab(tab_rail); str_rail_wght

    Loop

'*********************************************************************
'   End Management
```

```
'*********************************************************************
ProgressBar.value = 10
BuildSurvey_Pic.Visible = True
ProgressBar.value = 0
Close #31
Close #33
Close #34
Close #35
RunSurvey = True
Exit Sub

Errorhandler:
Dim response2, style2, prompt, title
prompt = "One or all of files specified are not found"
title = "File not Found"  ' Define title.
style2 = vbCritical ' Define buttons.
response2 = MsgBox(prompt, style2, title)


End Sub


Private Sub RunTranplan_Click()

'***************************************************************
'   Sub RunTranplan copys control file to tranplan directory, opens DOS
window
'***************************************************************
Dim value As Double
Dim batchfile As String
Dim tranfile As String

On Error GoTo Errorhandler

batchfile = Tp_Dir.Path + "\frt.bat"
Open batchfile For Output As #7
Print #7, "tranplan " + Control_Textbox.Text
Close #7

ChDir Tp_Dir.Path
value = Shell("command.com", vbNormalFocus)

RunTp_Pic.Visible = True
Tp_Pic.Visible = False
Exit Sub

Errorhandler:
Dim response, style, prompt, title
prompt = "Control file not found or Tranplan Directory not specified"
title = "File not Found"  ' Define title.
style = vbCritical ' Define buttons.
response = MsgBox(prompt, style, title)

End Sub
Private Sub CopyOut_Click()
On Error GoTo Errorhandler
```

```
FileCopy Tp_Dir.Path + "\trnpln.out", Case_Dir.Path + "\" +
outfilename_textbox.Text
Kill Tp_Dir.Path + "\trnpln.out"
CopyFile_Pic.Visible = True
Exit Sub

Errorhandler:
Dim response, style, prompt, title
prompt = "Output file not found or Tranplan Directory not specified"
title = "File not Found"  ' Define title.
style = vbCritical ' Define buttons.
response = MsgBox(prompt, style, title)

End Sub

Private Sub RunNetcard_Click()

'************************************************************
'   Sub RunNetcard copys out.bin to tranplan directory, opens DOS window
'************************************************************
Dim value
ChDir Tp_Dir.Path
On Error GoTo Errorhandler
FileCopy Case_Dir.Path + "\out.bin", Tp_Dir.Path + "\out.bin"
value = Shell("command.com", vbNormalFocus)
Netcard_Pic.Visible = True
CopyKill.Visible = True
Frame22.Visible = True
Exit Sub

Errorhandler:
Dim response, style, prompt, title
prompt = "Out.bin file not found or Tranplan Directory not specified"
title = "File not Found"  ' Define title.
style = vbCritical ' Define buttons.
response = MsgBox(prompt, style, title)

End Sub

Private Sub CopyKill_Click()

On Error GoTo Errorhandler
'************************************************************
'   Sub CopyKill copys output files to working directory, Kills old files
'************************************************************

FileCopy Tp_Dir.Path + "\out.dat", Case_Dir.Path + "\out.dat"


Dim msg, Msg1, Msg2, style, title, response
Msg1 = "Output file out.dat haf been copied to " + Case_Dir.Path + ". " +
Chr(13) + Chr(10)
Msg2 = "Delete file out.bin, out.dat in directory " + Tp_Dir.Path + "?" '
Define message.
msg = Msg1 + Msg2
```

```
style = vbYesNo + vbCritical + vbDefaultButton2 ' Define buttons.
title = "Confirm Delete"  ' Define title.
response = MsgBox(msg, style, title)
If response = vbNo Then    ' User chose No.
    Exit Sub
Else    ' User chose Yes.
End If

Kill Tp_Dir.Path + "\out.bin"
Kill Tp_Dir.Path + "\out.dat"

CopyKill_Pic.Visible = True

Exit Sub

Errorhandler:
Dim response2, style2, title2, prompt2
prompt2 = "Trnpln.out, trnpln.in, out.bin or out.dat not found in " +
Tp_Dir.Path
title2 = "File not Found"  ' Define title.
style2 = vbCritical ' Define buttons.
response2 = MsgBox(prompt2, style2, title2)

End Sub


Private Sub CreateMapInfoImport_Click()
On Error GoTo Errorhandler

'**************************************************************
'   This program takes output from NETCARD of TRANPLAN
'   sorts the data that was changed then prepares a text file
'   for import into MAPINFO, with freight.mbx
'
'   Also, added in v5.0 - Program reads in text file, converts
'   tons to vehicles using specified conversion factors.
'
'   IMPORTANT: For two-coded links only!
'
'**************************************************************

'*********************************************************************
'   Variable Declarations
'*********************************************************************

Dim netcardfile As String
Dim outputfile As String
Dim tonsfile As String
Dim anode As Long
Dim bnode As Long
Dim assgn_group As Long
Dim new_s2 As Long
Dim new_c2 As Long
Dim new_s4 As Long
Dim new_c4 As Long
Dim ba_opt As String
```

```
Dim total_loaded As Double
Dim total_vehicles As Double
Dim sub_vehicles1 As Double
Dim sub_vehicles2 As Double
Dim veh_type1 As Integer
Dim veh_type2 As Integer

Dim STCC As String
Dim tv1 As Long          'truck vehicle type 1
Dim pt1 As Double       '% of vehicle type 1
Dim tpt1 As Double       'tons per truck - vehicle type 1
Dim tef1 As Double       'truck vehicle type 1 empty expansion factor
Dim tv2 As Long
Dim pt2 As Double
Dim tpt2 As Double
Dim tef2 As Double
Dim rv1 As Long
Dim pr1 As Double
Dim tpr1 As Double
Dim ref1 As Double
Dim rv2 As Long
Dim pr2 As Double
Dim tpr2 As Double
Dim ref2 As Double
Dim ADT As Double
Dim match As Boolean

Dim eff_pt1 As Double        'effective rates
Dim eff_pt2 As Double
Dim eff_pr1 As Double
Dim eff_pr2 As Double

Dim j As Integer
Dim k As Integer

Dim netcardlabel As String
Dim netcard_input As String
Dim netcard_count As String
Dim ab_opt As String

Dim msg As String
Dim style As String
Dim title As String
Dim response As String
Dim Skip As Label


'**********************************************************************
'   File Management
'**********************************************************************
netcardfile = netcard_textbox.Text
outputfile = Output_textbox.Text
tonsfile = Tons_Textbox.Text

If Dir(outputfile) <> "" Then
    msg = "Export File already exists do you want to overwrite ?"
```

```
    style = vbYesNo + vbCritical + vbDefaultButton2
    title = "File Exists"
    response = MsgBox(msg, style, title)
    If response = vbNo Then
        Exit Sub
    End If
End If

'*********************************************************************
'   Read in Tons to Vehicle text file
'*********************************************************************
Open tonsfile For Input As #50
match = False
Do While Not EOF(50) And match = False
    Input #50, STCC, tv1, pt1, tpt1, tef1, tv2, pt2, tpt2, tef2, rv1, pr1,
tpr1, ref1, rv2, pr2, tpr2, ref2
    If STCC = STCC_Textbox.Text Then
        match = True
    End If
Loop
Close #50 'tons text file

'*********************************************************************
'   Notify user if no match made
'*********************************************************************
If match = False Then
    msg = "STCC code in specified tons-to-vehicles text file not found"
    style = vbCritical
    title = "No Match"
    response = MsgBox(msg, style, title)
    Exit Sub
End If

Label45.Caption = tv1
Label46.Caption = tv2
Label47.Caption = rv1
Label48.Caption = rv2

Text1.Text = pt1
Text2.Text = pt2
Text3.Text = tpt1
Text4.Text = tpt2
Text5.Text = tef1
Text6.Text = tef2

Text7.Text = pr1
Text8.Text = pr2
Text9.Text = tpr1
Text10.Text = tpr2
Text11.Text = ref1
Text12.Text = ref2


'*********************************************************************
'   Calculate eff. %'s, set tons per to one to avoid div 0
'*********************************************************************
```

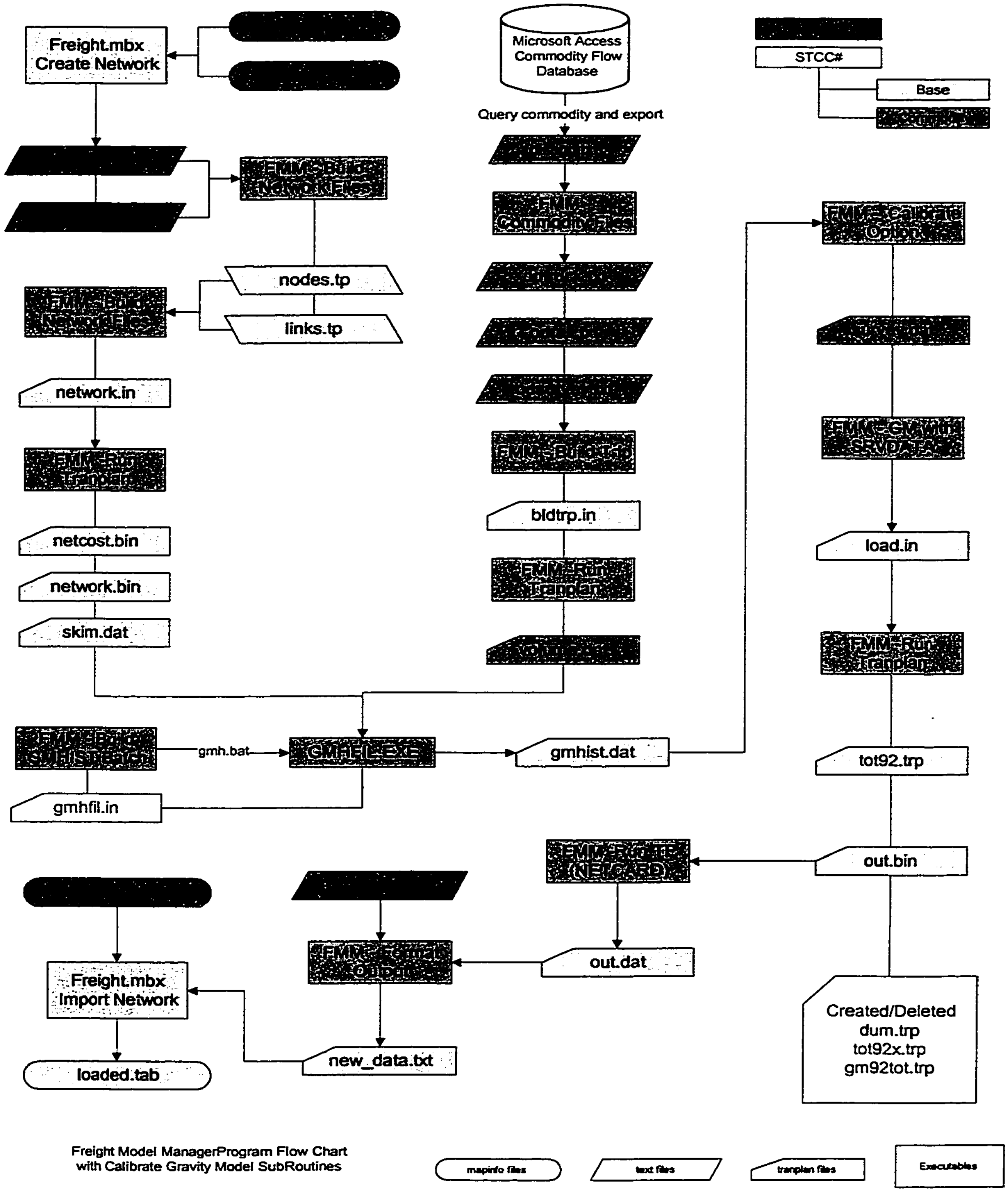
```
If pt2 = 0 Then
    tpt2 = 1
End If

If pr2 = 0 Then
    tpr2 = 1
End If

If pt1 = 0 Or pt2 = 0 Then
    eff_pt1 = pt1
    eff_pt2 = pt2
Else
    eff_pt1 = (1 - pt2) / ((tpt2 / tpt1) * (pt2) + (1 - pt2))
    eff_pt2 = (1 - pt1) / ((tpt1 / tpt2) * (pt1) + (1 - pt1))
End If

If pr1 = 0 Or pr2 = 0 Then
    eff_pr1 = pr1
    eff_pr2 = pr2
Else
    eff_pr1 = (1 - pr2) / ((tpr2 / tpr1) * (pr2) + (1 - pr2))
    eff_pr2 = (1 - pr1) / ((tpr1 / tpr2) * (pr1) + (1 - pr1))
End If

Open netcardfile For Input As #77
Open outputfile For Output As #30


'*********************************************************************
'   Read in NETCARD Output file for Progress Bar Length
'*********************************************************************
j = 1
Do While Not EOF(77)
    Line Input #77, netcard_count
    j = j + 1
Loop
Close #77
Open netcardfile For Input As #88
ProgressBar.Max = j
ProgressBar.value = 0


'*********************************************************************
'   Print MapInfo Output File header line
'*********************************************************************
Print #30, "STCC,ID,anode, bnode, assgn_group, new_s2, new_c2, ba_opt,
new_s4, new_c4, total_loaded, total_vehicles, adt, sub_vehicle1, veh_type1,
sub_vehicle2, veh_type2, netcardlabel"

'*********************************************************************
'   Read in NETCARD Output file, create output file
'*********************************************************************
k = 1

Do While Not EOF(88)
    Line Input #88, netcard_input 'Read in the entire line of Tranplan Data
```

Makes sure that the line just read in is not "Node" or "Turn Prohibitor" data.

```
    If Mid$(netcard_input, 1, 1) <> "N" And Mid$(netcard_input, 1, 1) <>
"T" Then 'Strip out the parts that may have changed or can be used as an
identifier.
        ab_opt = Mid$(netcard_input, 16, 1)
        anode = CInt(Mid$(netcard_input, 1, 5))
        bnode = CInt(Mid$(netcard_input, 6, 5))
        assgn_group = CInt(Mid$(netcard_input, 11, 1))

        If Mid$(netcard_input, 17, 4) = "****" Then
            new_s2 = 8888
        Else
            new_s2 = CLng(Mid$(netcard_input, 17, 4))
        End If

        new_c2 = CLng(Mid$(netcard_input, 39, 6))
        ba_opt = Mid$(netcard_input, 45, 1)

        If ba_opt = "2" Then
            new_s4 = new_s2
            new_c4 = new_c2
        ElseIf ba_opt = "S" Then
            new_s4 = CLng(Mid$(netcard_input, 46, 4))
            new_c4 = CLng(Mid$(netcard_input, 68, 6))
        End If

        If anode < bnode Then
            netcardlabel = anode & "-" & bnode
            Else
            netcardlabel = bnode & "-" & anode
        End If

'*********************************************************************
'   Convert tons flow to vehicle units.
'   Multiply volumes by 10 since flows are divided by 10 for TRANPLAN
requirements.
'*********************************************************************

        total_loaded = 10 * (new_c2 + new_c4)


        Select Case assgn_group
            Case Is = 1, 2
                sub_vehicles1 = ((total_loaded * eff_pt1) / tpt1) * tef1
                sub_vehicles2 = ((total_loaded * eff_pt2) / tpt2) * tef2
                veh_type1 = tv1
                veh_type2 = tv2
                total_vehicles = sub_vehicles1 + sub_vehicles2

            Case Is = 0, 3, 4, 5, 6, 7, 8, 9
                sub_vehicles1 = ((total_loaded * eff_pr1) / tpr1) * ref1
                sub_vehicles2 = ((total_loaded * eff_pr2) / tpr2) * ref2
                veh_type1 = rv1
                veh_type2 = rv2
```

```
                total_vehicles = sub_vehicles1 + sub_vehicles2

        End Select
        ADT = total_vehicless / Annual_Textbox.Text
        Write #30, STCC_Textbox.Text, run_textbox.Text, anode, bnode,
assgn_group, new_s2, new_c2, ba_opt, new_s4, new_c4, total_loaded,
total_vehicles, ADT, veh_type1, sub_vehicles1, veh_type2, sub_vehicles2,
netcardlabel

    End If
    k = k + 1 'add one to counter
    ProgressBar.value = k
Loop

Close #88 'NETCARD out.dat
Close #30 'output new_data.txt file


Format_Pic.Visible = True
ProgressBar.value = 0

Exit Sub

Errorhandler:
Dim response2, style2, title2, prompt2
prompt2 = "One or all of files specified are not found"
title2 = "File not Found"   ' Define title.
style2 = vbCritical ' Define buttons.
response2 = MsgBox(prompt2,  style2, title2)


End Sub

Private Sub RunTrp_Click()
'***************************** ***********************************
'   Sub RunTrp build trip table tranplan control file
'   and batch file to run, copy files
'***************************** ***********************************
Dim value As Double
Dim bldtrp As String
Dim batch As String
Dim batch2 As String
Dim allfile As String
Dim volume As String

On Error GoTo Errorhandler

bldtrp = Case_Dir.Path + "\bldtrp.in"
allfile = Commodity_Dir.Path + "\" + SurveyAll_Textbox.Text
volume = Commodity_Dir.Path + "\volume.dat"

Open bldtrp For Output As #1

    Print #1, "$BUILD TRIP TABLE"
    Print #1, "$FILES"
    Print #1, Spc(2); "INPUT FILE = SRVDATA, USER ID = $" + allfile + "$"
```

```
    Print #1, Spc(2); "OUTPUT FILE = VOLUME, USER ID = $" + volume + "$"
    Print #1, "$HEADERS"
    Print #1, Spc(2); "Build Trip Table"
    Print #1, "$OPTIONS"
    Print #1, Spc(2); "Print Trip Ends"
    Print #1, Spc(2); "Simple"
    Print #1, "$PARAMETERS"
    Print #1, Spc(2); "Number of Zones = " + TripZones_Textbox.Text
    Print #1, Spc(2); "Number of Purposes = " + TripPurposes_Textbox.Text
    Print #1, "$END TP FUNCTION"
Close #1
bldtrp_pic.Visible = True
outfilename_textbox.Text = "btrp.out"
Exit Sub

Errorhandler:
Dim response, style, prompt, title
prompt = "File not found or Tranplan Directory not specified"
title = "File not Found"  ' Define title.
style = vbCritical ' Define buttons.
response = MsgBox(prompt, style, title)

End Sub
```



Freight Model ManagerProgram Flow Chart
with Calibrate Gravity Model SubRoutines

APPENDIX B – TRANPLAN CODE

```
$BUILD HIGHWAY NETWORK
$FILES
  OUTPUT FILE = HWYNET, USER ID = $c:\work\201\calib2\NETWORK.BIN$
$HEADERS
  Enter text to write in headers
$OPTIONS
  Large Coordinates
$PARAMETERS
  Number of Zones = 144
  Maximum Node = 5907
$DATA
$INCLUDE c:\work\201\calib2\nodes.tp
$INCLUDE c:\work\201\calib2\links.tp
$END TP FUNCTION

$BUILD COST USER NETWORK
$FILES
  INPUT FILE = CUSIN, USER ID = $c:\work\201\calib2\NETWORK.BIN$
  OUTPUT FILE = CUSOUT, USER ID = $c:\work\201\calib2\NETCOST.BIN$
$HEADERS
  Enter text to write in headers
  1-Highway 2-Interstate 3-Rail Mainline 4-Rail Shortline 5-Rail
Centroid
  6-Rail Centroid 7-Intermodal 8-Intermodal 9-Interline 10-Interline
1/2
$PARAMETERS
  Cost Location = Cost
$DATA
  Linear Set = 1, Unit Time Cost = 0, Unit Distance Cost = 1.6
    Assignment Group = 1
  Linear Set = 2, Unit Time Cost = 0, Unit Distance Cost = 1.2
    Assignment Group = 2
  Linear Set = 3, Unit Time Cost = 0, Unit Distance Cost = 0.3
    Assignment Group = 3
  Linear Set = 4, Unit Time Cost = 0, Unit Distance Cost = 0.3
    Assignment Group = 4
  Linear Set = 5, Unit Time Cost = 0, Unit Distance Cost = 400.00
    Assignment Group = 5
  Linear Set = 6, Unit Time Cost = 0, Unit Distance Cost = 200.00
    Assignment Group = 6
  Linear Set = 7, Unit Time Cost = 0, Unit Distance Cost = 400.00
    Assignment Group = 7
  Linear Set = 8, Unit Time Cost = 0, Unit Distance Cost = 400.00
    Assignment Group = 8
  Linear Set = 9, Unit Time Cost = 0, Unit Distance Cost = 30.00
    Assignment Group = 9
  Linear Set = 10, Unit Time Cost = 0, Unit Distance Cost = 30.00
    Assignment Group = 0
```

```
$END TP FUNCTION

$HIGHWAY SELECTED SUMMATION
$FILES
  INPUT FILE = HWYNET, USER ID = $c:\work\201\calib2\NETCOST.BIN$
  OUTPUT FILE = HWYSKIM, USER ID = $c:\work\201\calib2\SKIM.DAT$
$PARAMETERS
  Impedance = Cost
$DATA
  Table = Cost
$END TP FUNCTION

$BUILD TRIP TABLE
$FILES
  INPUT FILE = SRVDATA, USER ID = $c:\work\cfs\com\odtruck.txt$
  OUTPUT FILE = VOLUME, USER ID = $c:\work\cfs\com\cfstrk.trp$
$HEADERS
  Build Trip Table
$OPTIONS
  Print Trip Ends
  Simple
$PARAMETERS
  Number of Zones = 122
  Number of Purposes = 3
$END TP FUNCTION

$CALIBRATE GRAVITY MODEL
$FILES
  INPUT FILE = GMSKIM, USER ID = $c:\work\201\calib2\SKIM.DAT$
  INPUT FILE = GMHIST, USER ID = $c:\work\201\calib2\GMHIST.DAT$
  OUTPUT FILE = NEWDATA, USER ID = $c:\work\201\com\SURVEY.DAT$
$HEADERS
  Enter text to write in headers
$OPTIONS
  Gravity Model History File
  Output Data File
  Print Trip Length Statistics
$PARAMETERS
  F Factor Closure = 0.1
  F Factor Iterations = 5
  Maximum Time =100
  Impedance = Cost
  Smooth Percentage = 100.00
  Selected Purposes = 1-3
  Skim Factor = 0.01
$END TP FUNCTION

$LOAD HIGHWAY NETWORK
$FILES
  INPUT FILE = HWYNET, USER ID =$c:\work\cfs\trk\NETCOST.BIN$
```

```
  INPUT FILE = HWYTRIP, USER ID =$c:\work\cfs\com\cfstrk.TRP$
  OUTPUT FILE = LODHIST, USER ID =$c:\work\cfs\trk\OUT.BIN$
$PARAMETERS
  Impedance = Cost
  Selected Purpose = 3
$END TP FUNCTION

$GRAVITY MODEL
$FILES
  INPUT FILE = GMSKIM, USER ID =$c:\work\201\calib2\SKIM.DAT$
  INPUT FILE = GRVDATA, USER ID =$c:\work\201\com\SURVEY.DAT$
  OUTPUT FILE = GMTVOL, USER ID =$c:\work\201\calib2\GM92TOT.TRP$
$OPTIONS
  Grvdata
  Total Purpose File
  Print Trip Ends
  Print Trip Length Statistics
$PARAMETERS
  Attraction Closure = 0.1
  Iterations On Attractions = 10
  Impedance = Cost
  Maximum Purpose = 3
  Maximum Time =100
  Selected Purposes = 1-3
  Skim Factor = 0.01
$END TP FUNCTION

$MATRIX TRANSPOSE
$FILES
  INPUT FILE = TRNSPIN, USER ID =$c:\work\201\calib2\GM92TOT.TRP$
  OUTPUT FILE = TRNSPOT, USER ID =$c:\work\201\calib2\DUM.TRP$
$END TP FUNCTION

$MATRIX MANIPULATE
$FILES
  INPUT FILE = TMAN1, USER ID =$c:\work\201\calib2\GM92TOT.TRP$
  INPUT FILE = TMAN2, USER ID =$c:\work\201\calib2\DUM.TRP$
  OUTPUT FILE = TMAN3, USER ID =$c:\work\201\calib2\TOT92.TRP$
$DATA
  TMAN3 , T1 = TMAN1, T1 + TMAN2, T1
$END TP FUNCTION

$MATRIX UPDATE
$FILES
  INPUT FILE = UPDIN, USER ID =$c:\work\201\calib2\TOT92.TRP$
  OUTPUT FILE = UPDOUT, USER ID =$c:\work\201\calib2\TOT92X.TRP$
$DATA
  T1,1-  144,1-  144, * .5
$END TP FUNCTION
```

```
$LOAD HIGHWAY NETWORK
$FILES
  INPUT FILE = HWYNET, USER ID =$c:\work\201\calib2\NETCOST.BIN$
  INPUT FILE = HWYTRIP, USER ID =$c:\work\201\calib2\TOT92X.TRP$
  OUTPUT FILE = LODHIST, USER ID =$c:\work\201\calib2\OUT.BIN$
$PARAMETERS
  Impedance = Cost
$END TP FUNCTION

$REPORT MATRIX
$FILES
  INPUT FILE = RTABIN, USER ID = $c:\work\201\calib2\TOT92X.TRP$
$HEADERS
  ##***%%  TRIP TABLE REPORT %%***##
$OPTIONS
  PRINT Table
$PARAMETERS
  Selected Purposes = 1
  Selected Zones = 1 - 144
$END TP FUNCTION

$DOS DEL  c:\work\201\calib2\TOT92X.TRP
$DOS DEL  c:\work\201\calib2\DUM.TRP
$DOS DEL  c:\work\201\calib2\GM92TOT.TRP
```

REFERENCES

1 Wilson, R. *Transportation in America, 16th Edition*. Eno Transportation Foundation, Washington D.C., 1998.

2 U.S. Freight Transportation Forecast ... to 2006. Prepared by Standard & Poor's DRI for the American Trucking Associations Foundation, Inc., Alexandria, Virginia, 1997.

3 Friesz, T. L., R. L. Tobin, and P. T. Harker. Predictive Interstate Freight Network Models: The State of the Art, In *Transportation Research-A*, Vol. 17A, No. 6, 1983, pp. 409-417.

4 Bronzini, M. Evolution of a Multimodal Freight Transportation Network Model. In the *Proceedings of the 21st Annual Meeting of the Transportation Research Forum,* Philadelphia, Pennsylvania, October 1980, pp 475-485.

5 *A Guidebook for Forecasting Freight Transportation Demand.* National Cooperative Highway Research Project, Report 388, National Research Council, Washington D.C., 1997.

6 Winston, C. The Demand for Freight Transportation: Models and Applications. In *Transportation Research Part A*, Vol. 17A, No. 6, 1983, pp.419-427.

7 Souleyrette, R., T.H. Maze, T. Strauss, D. Preissig, and A. Smadi, "Freight Planning Typology," In *Transportation Research Record 1613*, TRB, National Research Council, Washington D.C., pp. 12-19.

8 Smadi, A., and T.H. Maze. Statewide Truck Transportation Planning: Methodology and Case Study. In *Transportation Research Record 1522*, TRB, National Research Council, Washington D.C., 1996.

9 Ismart, D. *Calibrating and Adjustment of System Planning Models*. Publication FHWA-ED-90-015, FHWA, U.S. Department of Transportation, 1990.

10 Barton-Aschman Associates, Inc.; Cambridge Systematics, Inc., *Model Validation and Reasonableness Checking Manual.* Travel Model Improvement Program, Federal Highway Administration, Arlington, Texas, 1997.

11 Casavant, K. L., W. R. Gillis, D. Blankenship, and C. Howard. Survey Methodology for Collecting Freight Truck and Destination Data. In *Transportation Research Record 1477*, TRB, National Research Council, Washington D.C., 1995, pp. 7-14.

12 Weiner, E. *Urban Transportation Planning in the United States: An Historical Overview*. Fifth Edition. United States Department of Transportation, Washington D.C., 1997.

13 Intermodal Surface Transportation Efficiency Act. Public Law 120-240, 1991.

14 Transportation Equity Act for the Twenty First Century. Public Law No105-178, 1996.

15 Peyrebrune, H. *Multimodal Aspects of Statewide Transportation Planning, Synthesis of Highway Practice 286*. Transportation Research Board, Washington D.C. 2000

16 *Iowa in Motion. Part I: A Report on the Continuing Development of Iowa's Transportation Plan*. Iowa Department of Transportation, Ames, Iowa, 1994.

17 *Iowa Transportation Policy*. Iowa Department of Transportation, Ames, Iowa, 1993.

18 *Comprehensive Truck Size and Weight Study: Phase 1-Synthesis – Logistics and Truck Size and Weight Regulations*. Working Paper 8. United States Department of Transportation, Federal Highway Administration, Washington D.C.,1995.

19 Fiocco, M.J. *U.S. Freight: Economy in Motion*. United States Department of Transportation, Federal Highway Administration. FHWA-PL-98-034. Washington D.C., 1998.

20 Killkenny, M. *Class lecture notes from ECON 576-Regional Economics*, Iowa State University, Ames, Iowa. Spring 1999.

21 *Comprehensive Truck Size and Weight Study: Volume 3, Scenario Analysis (Draft)*. United States Department of Transportation. Washington D.C. December 1998.

22 Landry, M., and J. Ozmont. Short Line and Regional Railroads Executives Look at Their Industry. In *Transportation Quarterly*, Vol.55, No. 2, , Eno Transportation Foundation, Washington D.C., Spring 2001, pp.19-27.

23 HLB Decision Economics Inc., *Public Policy Impacts on Freight Productivity*. Prepared for the Federal Highway Administration, Silver Spring, Maryland, 1999.

24 Harker, P. *Predictive Intercity Freight Networks*. VNU Science Press. Utrecht, the Netherlands, 1987.

25 Holguin-Veras, J.,and E. Thorson. An Investigation of the Relationship Between the Trip Length Distributions in Commodity-based and Trip-based Freight Demand Modeling. *Transportation Research Board 78th Annual Meeting* (CD-ROM). January 2000.

26 Roberts, P. D. Kresge, and J. Meyer . *An Analysis of Investment Alternatives in the Colombian Transport System; Final Report*. Cambridge, Massachusetts, 1968.

27 Peterson, E.R. and H.V. Fullerton. *The Railcar Network Models*. Canadian Institute of Guided Ground Transport. Report No. 75-11. Kingston, Ontario, 1975.

28 Lansdowne, Z. F. Rail Freight Traffic Assignment. In *Transportation Research*. Vol. 15(A), 1981, pp. 183-190.

29 Kornhauser A.L., M. Hornung, Y. Hazony, and J. Lutin. *The Princeton Railroad Network Model: Application of Computer Graphics in the Analysis of a Changing Industry*. Presented at the 1979 Harvard Graphics Conference, Transportation Program, Princeton University, Princeton, N.J., 1979.

30 Sharp, G. A Multi-commodity, Intermodal Transportation Network Model. In the *Proceedings of the 20th Annual Meeting of the Transportation Research Forum*. Chicago, Illinois, October 1979, pp 399-407.

31 Friesz, T. L., J. A. Gottfried, and E. K. Morlok. A Sequential Shipper-Carrier Network Model for Predicting Freight Flows. In *Transportation Science*, Vol. 20, No. 2, May 1986, pp. 80-91.

32 Erlander S., S. Nguyen, and N.F.Stewart. On the Calibration of the Combined Distribution-Assignment Model. In *Transportation Research* . Vol. 13B, 1979, pp 259-267.

33 Smith D.P., and B.G. Hutchinson.Goodness of Fit Statistics for Trip Distribution Models. In *Transportation Research*. Vol 15A. 1981. pp. 295-303.

34 Rahman, M., and A.Radwan, Arizona Freight Network Evaluation Using Decision Support System. In *Journal of Transportation Engineering* Vol. 116, No. 2 March/April 1990. pp 227-243

35 Guelat, J., M. Florian, and T. G. Crainic. A Multimode Multiproduct Network Assignment Model for Strategic Planning of Freight Flows. In *Transportation Science*, Vol. 24, No. 1, February 1990, pp. 25-39.

36 Crainic, T.G., M. Florian, and J.Leal. A Model for the Strategic Planning of National Freight Transportation by Rail, *Transportation Science,* Vol. 24, No. 1, February 1990, pp. 1-25.

37 Mendoza, A., C. Gil, and J. Trejo. *A Multiproduct Network Analysis of Freight Land Transport Between Mexico and the USA*. Presented at the 1999 Transportation Research Board Annual Meeting. Washington D.C. January 1999.

38 Russell, E., L. Sorenson and R. Miller. *A Study Using Microcomputer Transportation Planning Models to Develop Highway Commodity Flows and Estimate ESAL Values*. Final Report, Midwest Transportation Center, Ames, Iowa, September 1992.

39 *Quick Response Freight Manual*. Report DOT-T-97-10. FHWA, U.S. Department of Transportation, 1996.

40 Ashtakala, B. and A. S. Murthy. Sequential Models to Determine Intercity Commodity Transportation Demand. In *Transportation Research-A*, Vol. 27A, No. 5, 1993, pp. 373-382.

41 Ashtakala, B., and A. S. Murthy. Optimized Gravity Models for Commodity Transportation. In *Journal of Transportation Engineering*, Vol. 114, No. 4, July 1988, pp. 393-408.

42 Murthy, A. S. and B. Ashtakala. Modal Split Analysis Using Logit Models, In *Journal of Transportation Engineering*, Vol. 113, No. 5, September 1987, pp. 502-519

43 Smadi, A. *Development of a Procedure for the Statewide Distribution and Assignment of Truck Commodity Flows: A Case Study of Iowa*. Ph.D. Dissertation, Iowa State University, Ames , Iowa, 1994.

44 Nellett, R., G. Robinson, J. McKinley, and L. Witherspoon. *Michigan's Statewide Travel Demand Model*. Presented at the 1996 Transportation Research Board Annual Meeting. Washington D.C., January 1996.

45 Wilbur Smith Associates. *Multimodal Freight Forecasts for Wisconsin*. Wisconsin Department of Transportation, 1996.

46 *Translink 21 Technical Report Series: Multimodal Freight Forecasts for Wisconsin.* Wisconsin Department of Transportation. Draft No. 2, Madison, Wisconsin, 1995.

47 Horowitz, A. *Guidebook on Statewide Travel Forecasting.* United States Department of Transportation, Federal Highway Administration. FHWA-HEP-99-007. Washington D.C., July 1999.

48 Black, W. *Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment: Phase 2.* Transportation Research Center, Indiana University, Bloomington. July 1997.

49 Krishnan, V., and K. Hancock. Highway Freight Flow Assignment in Massachusetts Using Geographic Information Systems. In *Transportation Research Record 1625*, TRB, National Research Council, Washington D.C., 1998.

50 Souyleyrette, R., and D. Preissig. Statewide Freight Transportation Planning Model Phase II Report. Center for Transportation Research and Education. Ames, Iowa. 1998.

51 Preissig, D. *Multimodal Statewide Freight Transportation Modeling Process.* Masters Thesis. Iowa State University, Ames, Iowa, 1993

52 *1997 Economic Census, 1997 Commodity Flow Survey.* U.S. Department of Transportation and U.S. Department of Commerce. December 1999.

53 *User Guide for the 1997 Surface Transportation Board Waybill Sample.* Association of American Railroads, Washington D.C., July 1998.

54 *Truck Weight Survey Field Instructions.* Iowa Department of Transportation, Ames, Iowa May 1987.

55 *Motor Carrier Management Information System (MCMIS).* U.S. Department of Transportation, Federal Motor Carrier Safety Administration. April 6, 2000.

56 *1997 Economic Census, Vehicle Inventory and Use Survey.* U.S. Department of Commerce. December 1999.

57 *Benchmark-Input Output Accounts.* U.S. Department of Commerce, Bureau of Economic Analysis. Washington D.C.

58 *Transportation Technical Services Bluebook.* Fredericksburg, Virginia, October 1996.

59 Garber, N.J., and L. Hoel. *Transportation Engineering.* West Publishing Company. St. Paul, Minnesota, 1988.

60 Park, M-B., Smith, R. Development of a Statewide Travel Demand Model With Limited O-D Survey Data. Presented at the 1997 Meeting of the Transportation Research Board

61 *Freight Data Requirements for Statewide Transportation Systems Planning.* National Cooperative Highway Research Program Report 177. Transportation Research Board, Washington D.C., 1977.

62 Federal Motor Carrier Safety Regulations. Markings of Commercial Vehicles. U.S. Departement of Transportation. Part 390.21.

63 Code of Federal Regulations, Title 49, Transportation, Parts 100-199. Hazardous Materials Table, (49 CFR 172.101(b)(1)).

64 TRANPLAN Manual, Version 9.0. Urban Analysis Group. Danville, California. 1998.

65 Armstrong, J.H. *The Railroad: What it is, What it Does. The Introduction to Railroading.* Simmons-Boardman Books, Omaha, Nebraska. December 1998.

66 *Standard Transportation Commodity Code Tariff STCC 6001-X,* Issued December 22, 1995. Association of American Railroads, Washington D.C.

67 Telephone conversation with Craig O'Riley, Office of Systems Planning, Iowa Department of Transportation, Ames, IA. June 12, 2001.