Final Report

# A MODEL FOR HEAVY TRUCK FREIGHT MOVEMENT ON EXTERNAL ROAD NETWORKS CONNECTING WITH FLORIDA PORTS, PHASE -I-

PB99-123184

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16. Abstract

This study focuses on development of models for heavy truck movements on external road networks connecting with Florida seaports. The objective of phase -I- of this study is to develop truck trip production and attraction models for the Port of Miami. Using regression analysis, it was found that the most significant parameters influencing truck trips were the daily imported/exported number of trailers/containers at the port and the particular day of the week. Days of the week were grouped together into three groups for each model and all possible scenarios were investigated to produce the best statistical fit truck trip production/attraction models. Preliminary analyses of various sources of data revealed that manually recorded gate pass cards, maintained by the Port of Miami, were the most accurate and detailed source of truck movements at the port. More than 73,000 cards were entered into the UCF database for a total of 57 days of gate pass data. This data was used to calibrate and validate truck trip generation models. Additionally, forecasting models for the number of imported/exported trailers/containers at the port were developed using two different approaches: time series and regression analysis. It was found that there is no statistically significant difference between forecasts obtained by the two approaches. However, the time series model is recommended because it captures seasonal variations in the port's vessel activities.

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# DISCLAIMER

The opinions, findings and conclusions in this publication are those of the authors and not necessarily those of the Florida Department of Transportation of the US Department of Transportation. This report does not constitute a standard, specification, or regulation. This report is prepared in cooperation with the State of Florida Department of Transportation.

# EXECUTIVE SUMMARY

Freight movement in the United States continues to evolve as a significant challenge to the transportation industry. Seaport operations dominated by container and trailer movements will have to make operational and infrastructure changes to maintain the growth of international cargo operations. Engineering research and analysis will assist transportation planners with the determination process of port and street network modifications. One such example is a truck trip generation model for heavy truck traffic related to cargo operations at the Port of Miami (Florida).

This report describes the research and initial development process of trip generation models for predicting the levels of cargo truck traffic moving inbound and outbound at the Port of Miami. It is restricted to container and trailer truck configurations that transport virtually all of the port's freight. Consequently, this associated truck traffic moves through the nearby street network in Downtown Miami.

The purpose of the trip generation models is to predict the daily volumes of large inbound and outbound trucks for specified time frames. The inbound truck model predicts truck trips attracted to the port while the outbound model predicts truck trips produced by the port activities. It was found in this study that the primary factors, which affect truck volume, are the amount and direction of cargo vessel freight (i.e., imported/exported freight units or trailers/containers) and the particular day of the week. The detailed gate pass card data were used to develop truck production and attraction models for the Port of Miami. More than 73,000 gate passes were

entered into the UCF computer database. Regression analysis was used to develop inbound and outbound truck trip generation models. Using this extensive database, both regression models were calibrated and validated successfully in this study. Truck weights were estimated using weights of freight units and observations of the port's scale readings for trucks entering the port at the security gate.

For long-term forecasts, two approaches were used to predict the monthly freight units (i.e., monthly Trailers/Containers). This is an important parameter for estimating the input to truck production/attraction models used to forecast truck volumes. The two approaches were: time series and regression. The time series approach has the advantage of predicting seasonal variations in vessel activity (or imported/exported freight units) at the port and consequently truck volumes on Port Boulevard, while the regression model is simpler to use. Surprisingly, there was no statistically significant difference between the forecasts of the two models. As such, planners can make a choice between the two models for future predictions. However, the time series model is recommended because it captures seasonal variations of the port's vessel activities.

The truck trip generation models developed in this study provide transportation planners with a foundation for transportation management decisions and infrastructure modifications. The user should be cautioned that long-term forecasts are only accurate if no major infrastructure developments have been introduced to the port. Otherwise, the models are best suited for short-term predictions of truck traffic as a function of the port's imported/exported freight units.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

There is great concern about whether or not the existing transportation infrastructure, and capacity of Florida Seaport's will be sufficient for accommodating the projected growth of the near future. Since 1988, import/ export cargo at the Port of Miami has increased 160 percent from 2.60 to 6.74 million tons *(1)*.

Port of Miami's freight operations are strongly influenced by the rapidly developing economies of the Caribbean and Latin American nations. In the last seven years, the annual TEUs (20-foot equivalent units) increased by 87% and annual cargo tonnage increased by 74%, see Figures 1.1 and 1.2. Economic projections indicate that the trading activity in Florida will continue to rapidly accelerate and require expansion and more efficiency of the port's operations. Figure 1.3 illustrates future economic projections in Florida forecasted by the Washington Economics Group and prepared for the Florida Trade Data Center *(2)*.

Exports represent the larger percentage of freight movement. Some of the higher volume export commodities produced in Florida include computer equipment, industrial machinery, transportation vehicles, apparel, and agricultural products.

Overall freight volume generally begins to accelerate in September, due mainly to Christmas season retail items and electronic equipment. Total freight volume begins to peak in

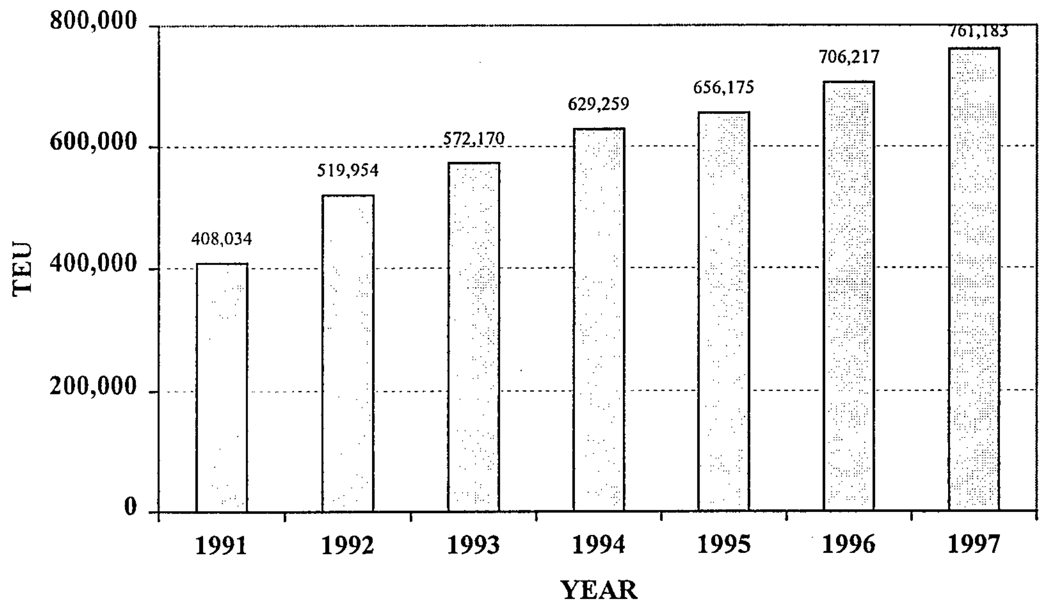



**Figure 1.1 Port of Miami Annual TEU Totals**

*T.E.U. = 20 foot equivalent units*
Source: Port of Miami Directory, 1998 *(1)*

October and remains busy through the retail season. In the middle of winter, citrus shipments begin to markedly increase and compensate for the gradual decrease in retail items. Thus, the peak season freight volume basically runs from October until April. In May, citrus product volume decreases and affects the overall total freight volume.

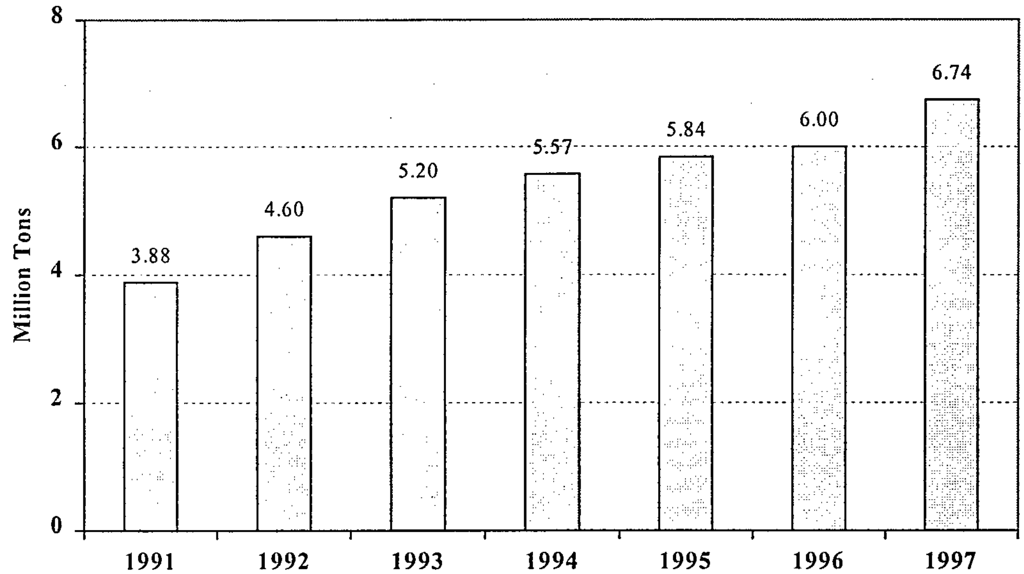



**Figure 1.2 Port of Miami Annual Cargo Tonnage Totals**
**Source: Port of Miami Directory, 1998** ***(1)***

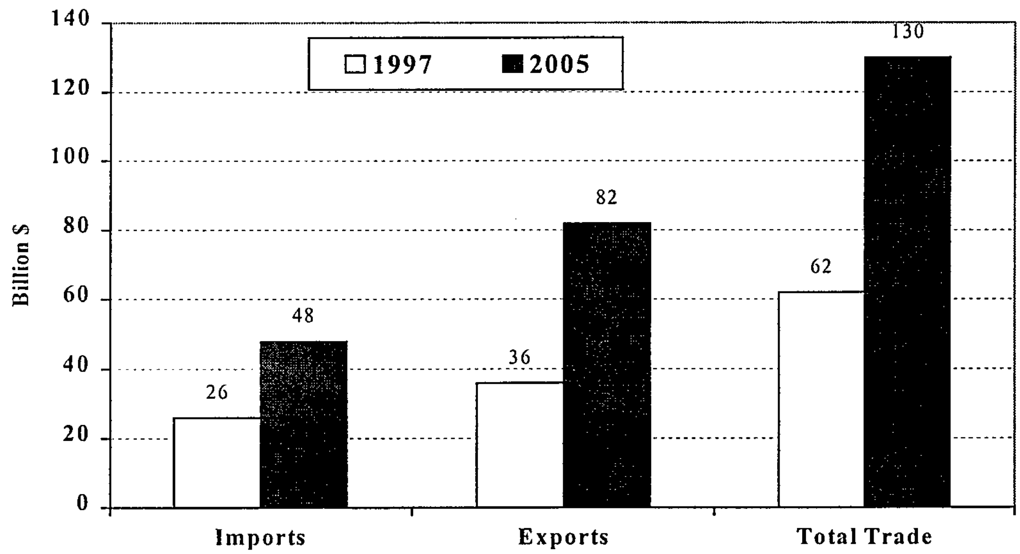



**Figure 1.3 Forecasts of Florida's Total Trade Performance (1997-2005)**

Source: Florida Trade Data Center - Washington Economics Group *(2)*

## 1.2 Problem Statement

The Florida Department of Transportation needs to accurately estimate the amount of truck freight movement on the external road networks connecting to large intermodal facilities. Florida's current estimation method of truck traffic entails overall traffic counts to be performed for only a few days in an area to determine Average Annual Daily Traffic (AADT). Statewide data for similar roadway classifications and regional characteristics of roadways are extrapolated to estimate truck percentages for the AADT figures. The statewide data is not specific enough to apply to a unique region such as a major freight port and its connecting road network.

The Port of Miami is one of the largest container cargo ports in the United States. It is the largest freight port in the state of Florida in terms of revenue and third largest by measure of tonnage. Although this study is confined to freight movement, it is worth noting here that the Port of Miami is the largest cruiseship port in the world by measures of both passenger volume and revenue. Cruiseship activity generates a tremendous amount of passenger vehicles which includes shuttle buses, motor coaches, courtesy vans, and taxi cabs.

## 1.3 Research Objectives

This research project's ultimate goal is to provide planners with a tool for developing near term and long term forecasts of freight traffic near the vicinity of Florida's major seaports. The intention is to provide this tool in the form of predictive traffic models.

Port of Miami was selected for the first phase of this research. It was initially considered to develop truck traffic generation models for truck trips produced from the port and truck trips attracted to the port. Different time intervals may be considered in these models such as weekly, daily, hourly, and during peak and off-peak periods.

Accurate long-term forecasts for the ten to twenty-year time periods are important input for major infrastructure investment decisions. This aspect was not defined in the original scope of this initial phase of the freight study. But with the application of time series analysis using long-term historical records, this study builds a foundation for the development of long-term forecasting tools.

The conventional strategic planning process of transportation modeling involves four sequential steps: trip generation, trip distribution, modal split, and traffic (or route) assignment. This process is widely accepted within the transportation industry and began and evolved primarily for transportation modeling of passenger trips. The function of trip generation analysis is to ultimately establish meaningful relationships between land use and trip-making activities, so that proposed changes in land use can be used to predict subsequent changes in transportation demand.

The three characteristics of land use that have been found to relate closely to trip generation are the intensity, character, and location of land use activities. Intensity of land usage is usually expressed in such terms as dwelling units per acre, employees per acre, and employees per 1000 square feet of retail floor space *(3)*. Character of land usage refers to the social and economic makeup of the land users. It typically includes measures such as average family income and car ownership per capita. Location is typically utilized as a variable that can encompass the combined effects of family size, stage in family life cycle, availability of parking, and level of street congestion.

It is apparent that for the situation of local freight movement generated by a cargo seaport, there needs to be a different approach from the traditional process, which is oriented towards passenger trips. There are no dwelling units, residing families, or retail space at the Port of Miami nor at any of the locations which directly exchange the truck freight.

Intermodal freight does not generally move with maximum efficiency. This is partly due to lack of cooperation among carriers and shippers. There are also operational problems with Electronic Data Interchange (EDI), terminal operations, freight container tracking, and capacity shortages. The Intermodal Surface Transportation Efficiency Act (ISTEA), and the more recent Transportation Equity Act (TEA21), provide metropolitan planning organizations (MPO's) a substantial grant of authority and an expanded role in making freight move efficiently *(4)*.

Trip destination, modal choice, and traffic assignment are not included in this Phase of the freight movement study at the Port of Miami. However, these important steps will be conducted in Phases –II- and –III- where other Florida seaports like Tampa and JAXPORT will be also studied.

## 1.4 Port Of Miami Situation

Port of Miami was selected for the first phase of this Florida freight port study, because it is the Florida port with the highest revenue and the largest container operation. Containers continue to be an increasingly growing and preferable method for freight movement throughout the United States and the international trading community. Containers can be processed and moved through intermodal facilities faster than trailers. The apparent advantage of containers is the capability of stacking these freight units. Stacking allows for a more efficient consumption of storage area.

A layout of the external road network surrounding the Port of Miami is shown in Figure 1-4. This small region extends for one mile from the port and is located within the Central Business District of Miami. The trip generation models will predict the heavy truck movement on Port Boulevard. The inbound and outbound truck traffic of this road is distributed among the remaining road segments defined below. The heavy truck traffic predictions moving on these auxiliary road segments can be determined from the Port Boulevard truck traffic using a traffic assignment model (to be developed in Phase-III- of this project).

The auxiliary segments consist of the following:

a. Biscayne Boulevard northbound and southbound, between the Port Boulevard entrance and exit.
b. NE 5th Street between NE 2nd Avenue and Biscayne Boulevard. This is a one-way, eastbound roadway.
c. NE 6th Street between Biscayne Boulevard and NE 2nd Avenue. This is a one-way, westbound roadway.
d. NE 2nd Avenue between NE 6th Street and NE 5th Street. This is a one-way, southbound roadway.

Truck movement at the Port of Miami is primarily on business days, Monday through Friday. Vessel berthing, loading, and unloading activities occur on all seven days of the week. Generally, a cargo vessel's berthing time is less than one day. The range is usually from a few hours to a day and a half. There is significant cargo vessel activity between Friday evenings and Monday mornings.

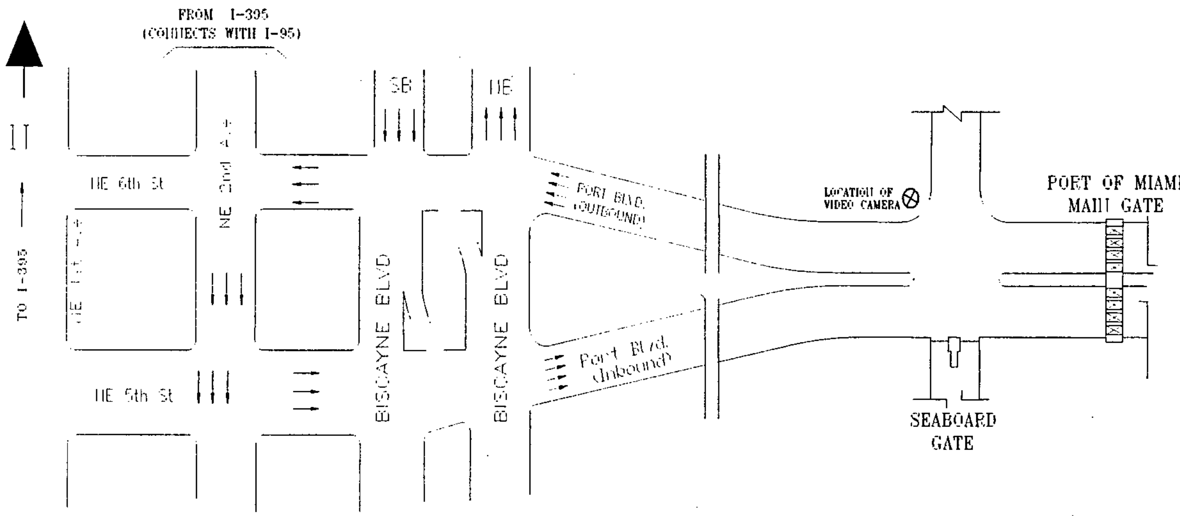



**Figure 1.4 Street Network in the Port of Miami Region.**

The Port of Miami has a slightly higher volume of exports versus imports. This implies that trucks are moving more freight into the port (to be exported by vessels) than out of the port (imports from the vessels). Thus, Thursday and Friday truck traffic tends to become heavier, because of the urgency to bring export cargo to the port and be loaded on the vessels scheduled for weekend departures.

Truck traffic tends to peak at any time between 9:30 AM and 3:30 PM on any of the five weekdays. Sometimes between the Noon to 1:00 PM lunch period, the truck traffic lightens. Most of the drivers are based locally and work primarily during daytime hours. These local drivers usually are not the same drivers who will move any freight ultimately destined for long-distance hauls. Thus, many port drivers take lunch at the regular noon hour.

On Mondays between 5:30 AM to 8:00 AM, or after any day when a very large cargo vessel has berthed, trucks usually begin forming a queue before the gate opens. This action forms a brief peak within the first hour of operation.

The late afternoons of Thursdays and Fridays (3:30 - 5:30) can sometimes experience heavy truck traffic, because exporters want to ensure their freight is placed on cargo vessels scheduled for weekend departures. Also, the terminals remain open an hour longer on Thursdays and Fridays to service the additional truck traffic. Night hour operations and weekends have very minimal truck operations.

This report is organized as follows. Chapter 2 provides a summary of literature review on heavy truck trip generation models in and outside of Florida. Chapter 3 briefly summarizes the data collection efforts in this project and presents the results of preliminary analyses of the collected data. Chapter 4 describes the detailed modeling process of trip generation and time series forecasting models. Finally, Chapter 5 documents conclusions and recommendations of the Phase-I- study.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Traditional Freight Modeling Attempts

As far back as 1977, FDOT initiated a program to develop a comprehensive statewide transportation plan encompassing all modes of transportation. As part of this program, FDOT sponsored the Statewide Multimodal Planning Process Project to develop and apply modeling techniques for forecasting future movements of persons and goods by mode. The research by Middendorf, Jelavich and Ellis *(5)* describes the development and application of the goods movement forecasting procedures resulting from the Statewide Multimodal Planning Process.

For truck shipments to ports, the origin zone was the zone of production and the destination zone was the Florida County containing the port. Similarly, for truck shipments from ports, the origin zone was the Florida County containing the port and the destination zone was the county of consumption.

However, the truck-to-port and truck-from-port freight flow O-D (origin and destination) tables included only domestic goods. Foreign imports and exports were excluded, because the true origin and destination zones of these goods could not be determined from the data that was available. With rapid regional economic development in Florida's port cities, it is difficult to make accurate long-term freight movement forecasts. The results of their freight movement forecasts for some commodity groups eventually resulted in large overestimates and underestimates for some other commodity groups.

Using this approach for a freight port within a large metropolitan area such as the Port of Miami would yield inaccurate results. The Bureau of Economic Analysis (BEA) region containing Miami extends as far north as Melbourne (Florida) and as far south as the Florida Keys.

An objective of the Port of Miami study is to examine movements within one of these regions, rather than between or among regions. Even though the Port of Miami is one of the largest generators of truck traffic in the state, the majority of truck freight crossing the borders of this BEA region would not be associated with the Port of Miami. This situation makes a traditional freight modeling approach very complicated or even inapplicable for this defined Port of Miami study.

## 2.2 State of Washington DOT Truck Survey

The work by Casavant, Gillis, Blankenship, and Howard *(6) & (7)* involved a massive freight truck origin and destination (O-D) study for the State of Washington DOT in 1993. This was the first study in the United States to collect statewide freight truck (O-D) data via direct personal interviews of truck drivers. A total of 30,000 truck drivers were interviewed to provide Washington with an extensive database on statewide freight and goods movements.

In addition to collecting information on truck characteristics and commodity type, the Washington State study documented specific highway routes utilized by the trucks.

However, our study concentrates on heavy freight truck movements in a local transportation corridor. Thus, a statewide survey or even a countywide survey may not provide enough specific information related to this transportation corridor of the Port of Miami region.

At the Port of Miami, a traffic circulation study to determine truck drivers most heavily used routes was recently conducted by the Corradino Group as part of a larger countywide study *(8)*. This local study involved brief interviews of truck drivers at the Port's security entrance gate to determine which connector roads and routes were most commonly used by the drivers to access the nearby main highway routes (i.e., Interstates 95, 395, State Routes 836, 968, U.S. Routes 1, 41, etc.). Although this was not an O-D study, the results may be more useful for our problem than those from a larger regional O-D study. But these results may not be immediately available for our usage.

If there is a future opportunity to conduct brief interviews of truck drivers at Florida weigh stations or other convenient survey sites, the questionnaire and procedure from the State of Washington study could potentially used as a guide.

## 2.3 Minnesota DOT Freight Flow Study

The Minnesota Department of Transportation (Mn/DOT) sponsored a study, which compiled and synthesized freight flow data within, through, into, and out of Minnesota for the year 1990. The study was performed by the University of Minnesota's Institute of Public Affairs *(9)* for the purpose of providing an understanding of commodity movement by mode, weight, and value and to also assist with the development of a statewide transportation plan, the Intermodal Management System and other planning efforts of Mn/DOT.

The primary data sources for this report were a series of Transearch files from Reebie Associates. These are specified for Bureau of Economic Analysis (BEA) economic regions. Reebie Associates produces data reports on tonnages of freight shipped from region to region by mode. There are 183 BEA regions in the United States.

Detailed origin and destination data on inbound and outbound freight flows were only obtained for one BEA region (No. 96) which contains Minneapolis-St. Paul. Trucks carry the most tonnage within this region. Only total inbound and outbound freight flow data were obtained for remaining regions.

As stated earlier, this approach for the Port of Miami would yield inaccurate results, because the BEA region containing Miami extends as far north as Melbourne (Florida) and as far south as the Florida Keys. The majority of truck freight crossing the borders of this BEA region would not be associated with the Port of Miami.

Data sources provided by the Seaway Port Authority of Duluth/Superior and the Minnesota Department of Transportation had also been used to examine waterborne flows from the Port of Duluth-Superior and three other ports. Similarly, the Port of Miami allows access to vessel movement data including sizes and types of vessels and arrival and departure times and dates.

For the Mn/DOT Study, many private freight carriers had provided data on freight movements within Minnesota as well as between Minnesota and other states, and between origin-destination pairs within the contiguous United States.

For our Port of Miami study, we were able to obtain gate movement activity (truck movements in and out) from the three private stevedoring companies, responsible for all of the freight berths at this port. Data on individual commodity movements was too difficult to obtain, because most of the freight is enclosed in box-type containers and trailers. These enclosed containers and trailers are not always opened for inspections. The descriptions of the contents written in the vessel reports are not always specific.

Since there are a few hundred trucking companies serving these three stevedoring terminals, data acquisition from the trucking companies would have been an insurmountable effort for this Port of Miami study.

## 2.4 Freight Movement Efficiency Study

This report by O'Rourke and Lawrence *(10)* discusses some positive and negative aspects among different modes for freight movement. Trucking is the most energy-intensive mode compared with pipeline, railroad, and waterborne transportation. Trucks consume more than 3000 Btu per ton-mile, whereas waterborne and rail transportation both use less than 500 Btu per ton-mile.

Intermodal containerized traffic has made it easier for rail and waterborne commerce to compete with trucks for freight. But intermodal traffic has been hampered in some regions of the country by a lack of intermodal facilities, and also by the inability of rail tunnels to accommodate double-stack container trains.

Alternative freight modes may have beneficial economic, environmental, and energy efficiency impacts. But the extent to which truck traffic can be diverted to other modes is often uncertain. Any analysis of freight movements must take into account that transportation and logistical decisions are made in a complex business environment where service, delivery time, and inventory management are important considerations for choice of mode. The fuel efficiencies of alternative freight movement can only be realized if alternative modes can effectively haul truck freight. Although important energy efficiencies may be achieved through multimodal and alternative freight movements, there are also many structural and geographical barriers to intermodal competition.

The Port of Miami layout is a prime example of such barriers. Although there is an existing rail line (Florida East Coast or FEC Railroad) connecting the port, the rail yard inside the port is not large enough to maneuver freight trains of significant length. With the Port being an island, there is limited land available for rail yard expansion.

Furthermore, this FEC rail line crosses Port Boulevard on the mainland. Since Port Boulevard is the only access road, long freight trains or frequently operating short trains would block truck movements. Expensive infrastructure modifications would be required to accommodate more freight train service directly with the port. Development of a large off site rail yard with a dedicated truck route connecting to the port could be a viable alternative.

This paper by O'Rourke and Lawrence also outlines some alternatives to increasing efficiency of truck freight movements such as using larger trucks, reducing empty backhauls, just-in-time delivery, and improved engine designs.

## 2.5 Port Authority of New York and New Jersey Truck Commodity Survey

List and Turnquist *(11)* presented a method for estimating multi-class truck trips from partial and fragmentary observations. The method was linked to a geographic information system. Trip matrices were estimated for the three truck classes of vans, medium and heavy trucks with the study area focusing on the Bronx in New York City.

It is becoming more common to treat truck flows explicitly, instead of mere percentages of estimated automobile flows. This is because different agencies may use different sampling bases. For example, certain truck classes, origins, or destinations may be included or excluded. Different definitions of items may be employed (i.e., heavy truck versus medium truck). Data may have been acquired during different time frames (i.e., different seasons, starting and ending times during the day).

A method for synthesizing truck flow patterns from partial and fragmentary observations is presented in this paper by List and Turnquist *(12)*. The method estimates such matrices from typically available data such as link volumes, classification counts, and cordon counts of trucks exiting and entering the study area.

The paper examines the 1991 Port Authority of New York and New Jersey (PANYNJ) Truck Commodity Survey and the 1988 Triborough Bridge and Tunnel Authority (TBTA) Truck Survey. These surveys contain data about flows between a given bridge and a location within the study area.

This idea of focusing on interregional freight movement could potentially be applied to our research. There is only one road (Port Boulevard) connecting the port to the external road network that primarily consists of one-way streets. Acquiring truck link volumes and cordon counts is feasible for future project phases.

## 2.6 Texas Department of Transportation Research

The research performed by Easley and Walton of the University of Texas (Austin) Transportation Research Center *(13)* investigated and analyzed certain operating procedures at the Barbours Cut Container Terminal at the Port of Houston. An in-depth study was made of the delays associated with these operating procedures related to trucking operations. Some general internal and external problems analyzed by the Port of Houston study are generic problems that also exist at the Port of Miami.

The research also involved a nationwide study with field visits at various terminals. Selection of these other terminals was based on technological enhancements of operations, size of facilities, and associated problems characteristic of large terminals. The Port of Miami terminals were not among those in the study. However, their research and recommendations can be useful and analogous, because focus was on large ports with substantial container terminal operations.

One of the most expensive transfer points in intermodal operation is the idle time between the unloading of containers from the ship and the time when the truck or the rail car with the loaded container departs. The transfer of cargo between ports and inland transport is one of the weakest, least efficient links in the intermodal transportation chain.

Internal problems include paperwork processing delays, lost time trying to locate a container, lack of priority given to "hot hatch" (high priority) containers, and communication problems between truck operators and clerks. It is common to find truck operators who do not read or speak English which delays the order-processing time.

External problems include unnecessary trips because of insufficient information or communication, no dedicated truck routes to container terminal or port facilities, no coordination between roadway and seaport terminal traffic serving trucking operations, and no dissemination of real-time traffic conditions available at the terminal.

## 2.7 Florida's Standard Urban Transportation Modeling Structure

Florida's specific transportation planning model is the Florida Standard Urban Transportation Modeling Structure (FSUTMS). This computer program is a derivative of the nationally utilized TRANPLAN software program. The FSUTMS is not currently structured to specifically incorporate the truck traffic impact of the states fourteen seaports. Therefore, good freight forecasting models, which could be incorporated into FSUTMS, can benefit many communities throughout the state.

The FSUTMS currently accounts for seaports as "special generators" of traffic. This special generator category additionally includes facilities such as airports, universities, large shopping malls, and stadiums *(14)*. However, this special generator module has been developed primarily from a passenger trip standpoint. Perhaps a seaport trip generation model, which includes all vehicle traffic (rather than only heavy trucks), will be compatible with this FSUTMS module. Otherwise, the module will have to be modified or a new module will need to be created.

## 2.8 Current Freight Forecasting Efforts in Florida

In Florida, 19 of the 25 Metropolitan Planning Organizations (MPO's) are currently addressing freight and goods movement planning *(15)*. These efforts are being handled through either the long-range planning processes or by development of specialized freight modeling procedures to assist the planning processes. Freight forecasting has been identified as a high priority issue in Dade County (Florida) for the purpose of improving regional and economic planning efforts.

The FDOT presently has two regional models that incorporate sophisticated techniques to forecast freight truck traffic models, using the Florida Standard Urban Transportation Modeling Structure (FSUTMS). These models are the Southeast Regional Planning Model (SERPM) and the Tampa Bay Regional Transportation Analysis Model (14)

The Southeast Regional Planning Model (SERPM) is a regional model that includes the southeast Florida counties of Dade, Broward, and Palm Beach. A new approach to freight modeling was created during the development of SERPM. Similar freight modeling techniques are under consideration by three Metropolitan Planning Organizations (MPO's) corresponding to these three counties for use in their travel demand forecasting models.

The SERPM model incorporates truck modeling to reflect how trucks exhibit different characteristics than passenger vehicles with respect to trip generation, origin/destination patterns, and route selection (14). Trucks are a major consideration in the analysis of roadway capacity and pavement design. The SERPM separates truck trips throughout the entire model stream (i.e., trip generation through assignment).

The SERPM initially utilized freight modeling parameters from outside the state of Florida, due to budgetary limitations on data collection. The model was calibrated to be consistent with Florida freight movement. The trip generation module uses the following predictor variables:

- population
- wholesale employment
- non-wholesale employment
- manufacturing employment

The SERPM separates truck trips from passenger trips in the external and internal trip generation modules. External trip modeling is the process of predicting the travel behavior of trips with at least one trip end outside of the transportation study area.

The SERPM provides reasonable freight estimates when used for the system level. However, additional truck counts and surveys are necessary to make the model more functional at the corridor and sub-area levels. Local surveys and studies such as Port of Miami's are needed to develop local truck trip generation rates for large special generators such as cargo ports.

The Tampa Bay Regional Goods Movement study identifies and addresses major issues related to goods movement in the Tampa Bay area. Objectives of this study are to address current problems and future needs concerning goods movement in the region to enhance safety, efficiency, and effectiveness of goods movement. The study will provide recommendations on changes in policies, standards, and design plans to FDOT and other planning and regulatory agencies.

# CHAPTER 3

# METHODOLOGY AND DATA COLLECTION

## 3.1 Methodology

The methodology of developing truck trip generation model(s) for the Port of Miami consisted of the following steps:

1. Examining the road network map surrounding the port, making field observations, and reviewing general traffic information.

2. Recording sample truck traffic volumes and classifications (type, number of axles, configurations, etc.) during different peak and off-peak periods at specific locations of the road network shown in Figure 1.4.

3. Interviewing local port personnel who are familiar with the many facets of the overall operation. This includes personnel from administration, field operations, shipping companies, private terminals, trucking companies, security, accounting, and marketing.

4. Collecting limited data samples for analysis from various sources. Selection of data sources was prioritized according to quality, availability, and feasibility. Data was entered into electronic databases in stages, coordinated with various preliminary analyses. These stages of preliminary analyses allowed us to check preliminary results and more efficiently prioritize time on future data selection for entry. Verifying availability of data was important

for developing a robust model. The FDOT would like to have a model with minimum input data that is collected routinely.

5. Determine the independent variables for formulating models to correlate the volume of freight truck movement with internal port activity. The focus was on the main road, Port Boulevard, the *only road* available for port access.

6. Trip generation model development was achieved by applying regression analysis. Port Boulevard's daily truck volumes are the dependent variables to be predicted by the models. There are models for each direction, inbound and outbound. Inbound refers to truck trips entering the port (trip attraction model), outbound refers to truck trips leaving the port (trip production model).

7. Validation of the models. This was accomplished by inputting actual data that was not used during the model formulation process. Then, the predicted values of truck volumes can be compared with the actual volumes.

8. Estimate gross weight of heavy truck movement generated on Port Boulevard by applying regression model(s) with the monthly gross weight of cargo as the dependent variable and the cargo vessel freight unit volume.

9. Time series analysis to examine long-term and seasonal trends. Time series analysis was applied to the monthly totals of the main independent variable, cargo vessel freight unit volume (containers + trailers). This independent variable was determined in Step 6. Historical data was obtained for this variable from 1978 to 1998. It could not be applied to

the dependent variable of truck volumes, because historical totals were not available before 1996.

10. Determine hourly distribution of truck movements from gate pass data.

11. Interpret the results to establish conclusions and make recommendations for future analyses.

## 3.2 Introduction

This section documents the process of data acquisition of relevant parameters for modeling and describes preliminary analysis of the data. Table 3-1 summarizes the different types of data collected during this project. Also, it shows the resolution of each type of data.

**Table 3-1 Summary of Data Collected.**

| Source Of Data | Resolution | Period |
| --- | --- | --- |
| Terminal Company Gate Movements | Daily Truck Movements | Jan 1996 – Dec 1997 |
| Port of Miami Gate Passes | Individual Truck Movements | Jan 1997 – May 1997* |
| Video Counts | Individual Truck Movements | 10/31, 11/3,and 11/6/97 |
| Gantry Crane Activities | Start Time and End Time | Jan 1996 – Dec 1997 |
| Dock Reports | Individual Vessel Arrival and Departure Times | Jan 1996 – Dec 1997 |
| Trailer/Container Reports | Daily Trailer/Container Totals | Jan 1996 – Dec 1997 |
| Monthly Performance Reports | Monthly Trailer/Container Totals | Oct 1978 – Apr 1998 |

* Only 57 days were collected.

### *3.2.1 Terminal Companies' Truck data*

There are four terminal operating companies, which collectively account for all of the heavy truck gate movements of the port. The matrix below (as shown in Table 3-2) identifies all of the gates used by trucks to access these different companies. Figure 3-1 illustrates the locations of the gates.

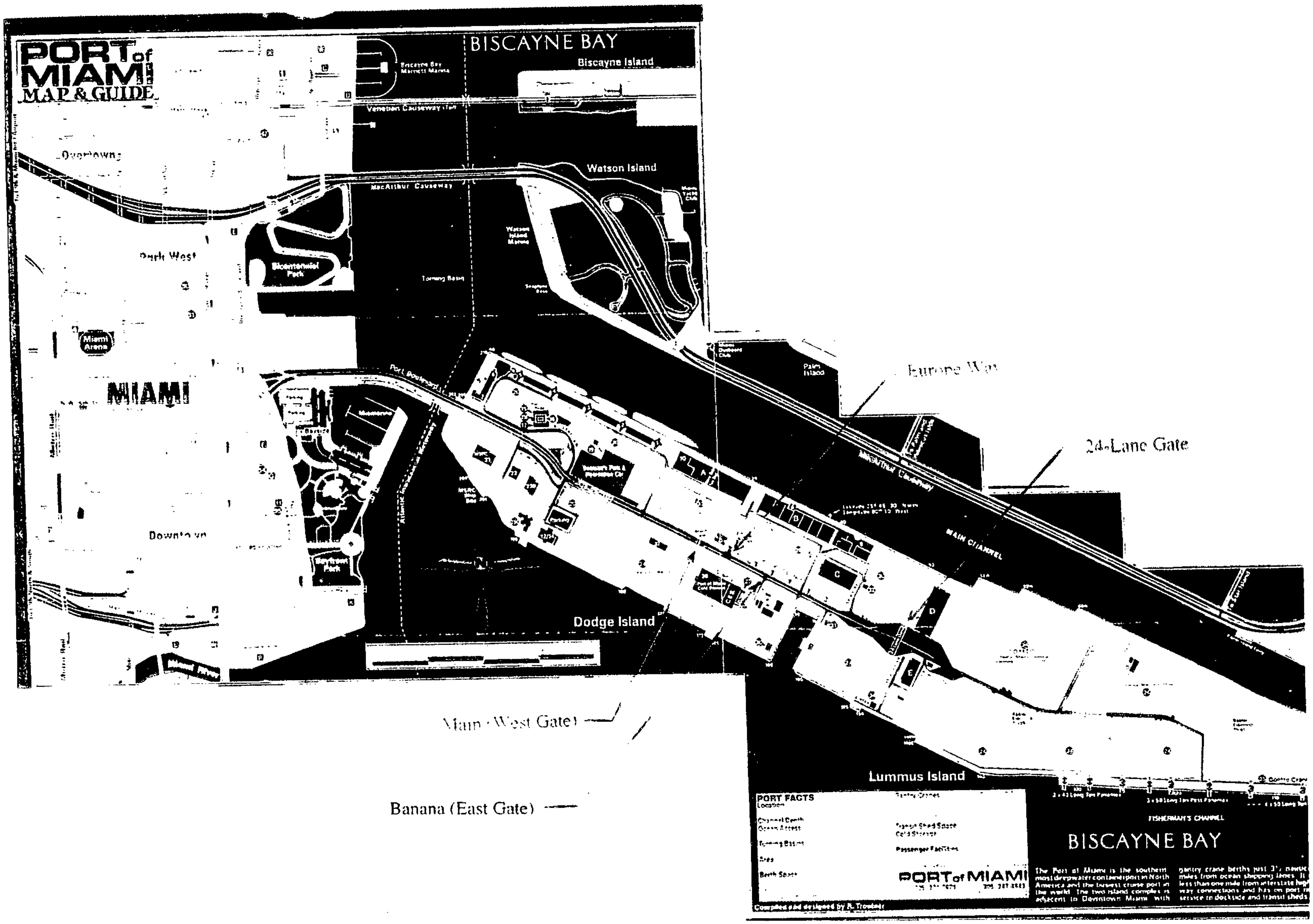
**Table 3-2 Terminal Operating Companies and Their Respective Gates.**

| **Terminal Operating Company** | **Accessible Gates** | | |
|---|---|---|---|
| Seaboard Marine | Main (West Gate) | Banana (East Gate) | FEC-36th Street Yard (Not at Port) |
| Universal (Maersk) | 24-Lane Gate | N/A | N/A |
| POMTOC | 24-Lane Gate | N/A | N/A |
| Chiquita Banana | Europe Way | N/A | N/A |

N/A = Not Applicable

Daily truck movements for trucks going into and out of the port were obtained from Seaboard, Universal, and POMTOC daily truck reports. Only POMTOC data showed total gate movements without separating data into trucks going into the Port (inbound) and trucks going out of the Port (outbound). Both Seaboard and Universal separated their truck movement data into inbound and outbound records. Because of this problem, terminal data may not be accurate for developing the production/attraction models. However, terminal data could be used to study the general overview in daily truck movements.

## Figure 3.1 Accessible Gates at Port of Miami



Daily movements for Chiquita Banana were unavailable. The percentage of the trucks visiting Chiquita Banana was less than 1% of the ports overall total. This amount was small enough to neglect during model development.

Table 3-3 illustrates the volume percentages and amounts of truck gate movements corresponding to the respective terminal operating companies. These total movements are inbound and outbound truck movements combined together. This data relates to 113 selected days of operation between 1-1-96 and 7-31-96. It was obtained from the terminal operating companies.

**Table 3-3 Distribution of Truck Movements (113 Selected Days, from 1/1/96 to 7/31/96).**

| Company | POMTOC | | Seaboard | | Universal | | Total |
|---|---|---|---|---|---|---|---|
| Day | No. | % | No. | % | No. | % | No. |
| Monday | 16,644 | 41.43% | 12,585 | 31.33% | 10,944 | 24.24% | 40,173 |
| Tuesday | 17,568 | 43.13% | 13,670 | 33.56% | 9,491 | 23.30% | 40,729 |
| Wednesday | 19,973 | 45.93% | 13,628 | 31.34% | 9,883 | 22.73% | 43,484 |
| Thursday | 19,525 | 42.83% | 14,263 | 31.29% | 11,797 | 25.88% | 45,585 |
| Friday | 19,149 | 37.66% | 17,547 | 34.51% | 14,148 | 27.83% | 50,844 |
| Saturday | 0 | 0 | 1,383 | 97.88% | 30 | 2.12% | 1,413 |
| Sunday | 0 | 0 | 580 | 99.83% | 1 | 0.17% | 581 |
| Total | 92,859 | 41.68% | 73,656 | 33.06% | 56,294 | 25.27% | 222,809 |

From this table, it is clear that PMOTOC had the largest contribution to total truck activity at the port. Also, with the exception of Seaboard trucks, very minimal truck activity occurs at the port during the weekends.

### *3.2.2 Gate Pass Data*

The daily truck movement data obtained from the terminal operating companies are not broken down to hourly bi-directional data (inbound and outbound). As such, another source of data was needed. Port of Miami collects and stores gate pass cards which record entering and exiting times of trucks, general vehicle configurations, the terminal operating companies visited, and the inbound gross weights of the vehicles (see sample gate passes in Appendix A). Gate pass information allowed the UCF research team to focus more on hourly volumes, and it provided the most detailed information about truck movements in and out of the port.

The gate pass cards represent trucks visiting all of the terminals except Seaboard Marine. Most of the Seaboard traffic passes through a gate checkpoint that is separate from the Port of Miami main gate. This terminal company has its own security system at this gate. Therefore, the Port of Miami gate pass records do not represent most of seaboard's truck traffic data.

Seaboard's truck gate movements were not made available to the UCF research team. The regression model formulation processes had to exclude Seaboard's truck and cargo data. As shown in Table 3-3, Seaboard accounts for about 33% of the port's truck traffic. Most of the remaining 67% are distributed among POMTOC and Universal.

The research team selected complete 57 completed days of gate passes out of 70 days collected from the Port of Miami. The selected dates were chosen to maintain an equal balance of business days (e.g., 8 Mondays, 8 Tuesdays, etc.) and to cover at least one week per month during six consecutive months. Also, some of the days collected did not have complete data because of cards misplaced in the Port of Miami archives. The port informed the UCF research team about days with misplaced cards after data collection. Table 3-4 provides the list of all 57 days of gate pass data that have been entered into the UCF database within the period from January 17, 1997 to May 1, 1997.

**Table 3-4 Gate Pass Data Entered into UCF Database.**

| Date | | No. of Cards |
|---|---|---|
| 17-Jan-97 | Friday | 1501 |
| 21-Jan-97 | Tuesday | 1307 |
| 22-Jan-97 | Wednesday | 910 |
| 23-Jan-97 | Thursday | 1701 |
| 24-Jan-97 | Friday | 2128 |
| 18-Feb-97 | Tuesday | 504 |
| 19-Feb-97 | Wednesday | 966 |
| 20-Feb-97 | Thursday | 1536 |
| 21-Feb-97 | Friday | 1608 |
| 24-Feb-97 | Monday | 1213 |
| 25-Feb-97 | Tuesday | 1328 |
| 26-Feb-97 | Wednesday | 1283 |
| 27-Feb-97 | Thursday | 1297 |
| 28-Feb-97 | Friday | 1721 |
| 03-Mar-97 | Monday | 1515 |
| 04-Mar-97 | Tuesday | 1174 |
| 05-Mar-97 | Wednesday | 1288 |
| 06-Mar-97 | Thursday | 1574 |
| 07-Mar-97 | Friday | 1186 |
| 10-Mar-97 | Monday | 1302 |
| 11-Mar-97 | Tuesday | 1060 |
| 12-Mar-97 | Wednesday | 1224 |
| 13-Mar-97 | Thursday | 1311 |
| 14-Mar-97 | Friday | 1424 |
| 17-Mar-97 | Monday | 716 |
| 18-Mar-97 | Tuesday | 1400 |
| 19-Mar-97 | Wednesday | 1073 |
| 20-Mar-97 | Thursday | 2003 |
| 21-Mar-97 | Friday | 1459 |
| 24-Mar-97 | Monday | 1246 |
| 25-Mar-97 | Tuesday | 1257 |
| 26-Mar-97 | Wednesday | 1272 |
| 27-Mar-97 | Thursday | 1517 |
| 31-Mar-97 | Monday | 1189 |
| 01-Apr-97 | Tuesday | 1203 |
| 02-Apr-97 | Wednesday | 1128 |
| 03-Apr-97 | Thursday | 1190 |
| 04-Apr-97 | Friday | 1432 |
| 07-Apr-97 | Monday | 1278 |
| 08-Apr-97 | Tuesday | 1176 |
| 09-Apr-97 | Wednesday | 1111 |
| 10-Apr-97 | Thursday | 1329 |
| 11-Apr-97 | Friday | 1493 |
| 14-Apr-97 | Monday | 1232 |
| 15-Apr-97 | Tuesday | 1239 |
| 16-Apr-97 | Wednesday | 1204 |
| 17-Apr-97 | Thursday | 1370 |
| 18-Apr-97 | Friday | 1024 |
| 21-Apr-97 | Monday | 1073 |
| 22-Apr-97 | Tuesday | 1145 |
| 23-Apr-97 | Wednesday | 1236 |
| 24-Apr-97 | Thursday | 1806 |
| 25-Apr-97 | Friday | 1468 |
| 28-Apr-97 | Monday | 703 |
| 29-Apr-97 | Tuesday | 1206 |
| 30-Apr-97 | Wednesday | 1188 |
| 01-May-97 | Thursday | 760 |
| **Total** | | **73187** |

A gate pass card has seven data entry cells. These cells are the date and time the truck gets to the port, the date and time the truck leaves the port, the configuration of the truck getting in and out of the port (e.g., container, chassis, bobtail), the company that the truck visits, and the truck weight. With an average of approximately 1200 gate pass cards per day, and seven data entry items per gate pass, this indicates that there are nearly 500,000 spreadsheet cells containing data in the UCF database. Since there are several researchers entering the data, quality of the data entered and the entry process has been monitored by sample checks. The purpose of these checks is to ensure consistency in interpretation of subjective items and to minimize data entry errors. Table 3-5 illustrates a sample result of this review. As shown in this table, only 5.78% of the cards have one or more cells that are defected. For 900 sample cards, only 52 cards have defects and/or human errors. These cards have been modified and corrected accordingly.

**Table 3-5 Quality Control Check of Gate Pass Data Entry.**

| No. of Sample Cards | No. of Defected Cards | % of Defected Cards | Type of Defect |
|---|---|---|---|
| 900 | 30 | 3.33% | Configuration Type |
| | 11 | 1.22% | Company Name |
| | 7 | 0.78% | Item Not Entered |
| | 4 | 0.44% | Time Not Clear |
| **900** | **52** | **5.78%** | |

### *3.2.3 Videotape Counts*

Port Boulevard traffic was videotaped on three days (Friday 10/31/97, Monday 11/3/97, and Thursday 11/6/97). The corresponding truck gate passes maintained by Port Security for the selected days were counted to ensure the reliability of gate passes as a substitute data source for traffic counting. One important reason for videotaping was to have a visual record of some observed traffic. Another reason was to compare the observations from the videotapes with Port Security's gate pass records.

### *3.2.4 Vessel Movements*

Vessel movement data corresponding to time frames when truck movement data were collected from the gate passes and terminal companies were obtained. Detailed records of vessel berthing were obtained from the "Daily Dock Reports". These reports provide the entry and exit times and dates and various other data associated with the berthing. This data was acquired for all of 1996 and 1997. A sample page of the "Daily Dock Reports" is shown in Appendix B.

### *3.2.5 Gantry Crane Activities*

The UCF research team obtained gantry crane data corresponding to time frames during which truck movement data were collected. Detailed records of crane activities (start time and end time of service for each vessel individually) were extracted from the "Gantry Crane Activity By Shipline Reports" maintained by the port. This data was acquired for all of 1996 and 1997. A sample page of the "Gantry Crane Activity Reports" is shown in Appendix C.

### *3.2.6 Trailer/Container Activity Reports*

"Trailer/Container Reports" were obtained from Port Accounting office. These reports provide the number of freight units (trailers and containers) moved on and off each vessel (see sample sheet in Appendix D). This data was entered into the UCF database for the first six months of 1997. These reports provide more detailed data source of vessel cargo. This data source was not available during earlier months of this research project. These reports were obtained for the period of January 96 through December 97. However, gate passes were only available to research team for the first six months of 97.

### *3.2.7 Statistical Monthly Trailer/Container Performance Reports*

"Monthly Trailer/Container Performance Reports" were obtained for the period of October 78 through April 98. These reports provide a monthly summary of the activities listed in the "Trailer/Container Reports". This data may be useful for determining a historical trend (time series) of the trip generation model input for long-term forecasts (e.g., 15 to 20 years). A sample of this data is shown in Appendix E.

## 3.3 Preliminary Data Analysis

Using the 1996 truck traffic volumes obtained from the various terminal operating companies, a statistical test (Scheffe's test) was used to determine if there are significant differences in volumes among different weekdays. A brief explanation of the application of Scheffe's Test is located in Appendix F. The results of this test are shown in Table 3-6.

**Table 3-6 Scheffe's Test for Daily Truck Movements**

| Group | F Value (Statistic) |
|---|---|
| Monday, Tuesday, Wednesday, Thursday, and Friday | 50.853 |
| Monday and Tuesday | 1.246 |
| Monday and Wednesday | 9.397 |
| Monday and Thursday | 50.181 |
| Monday and Friday | 150.254 |
| Tuesday and Wednesday | 3.848 |
| Tuesday and Thursday | 36.694 |
| Tuesday and Friday | 127.632 |
| Wednesday and Thursday | 17.584 |
| Wednesday and Friday | 90.155 |
| Thursday and Friday | 26.770 |

Having F Critical = 9.88, the test results indicate that at 95% confidence level, there are no significant differences in heavy truck traffic among the following three weekdays: Mondays, Tuesdays, and Wednesdays. Thursdays, as well as Fridays are significantly different (higher volumes) from those first three weekdays. Additionally, there appears to be some difference between Thursday and Friday volumes. The test was performed for a sample of 94 days. The data for POMTOC, Universal, and Seaboard were available for these 94 days.

A statistical test (t-test) was performed to compare between heavy truck traffic volumes obtained from the terminal companies and truck volumes obtained from gate passes. Since a gate pass identified the terminal company, the test was performed twice, once for POMTOC data and once for Universal data. Table 3-7 illustrates the mean value for the gate pass data and the terminal companies' data. The table also shows the results of the t-test performed. There is a significant difference, at the 95% confidence level ($P<0.05$), between the daily truck movements obtained from gate passes as compared to daily truck movements obtained from terminal companies. Although the UCF research team has presented these findings to terminal companies, there was no clear answer as to what caused this discrepancy in reporting truck volumes.

**Table 3-7 Comparison Between Gate Pass Data and Terminal Companies' Data.**

**For POMTOC**

| | *Gate Passes Data* | *Terminal Data* |
|---|---|---|
| Mean | 861 | 1082 |
| Variance | 11031 | 47348 |
| Observations | 18 | 18 |
| Pearson Correlation | 0.63 | |
| Hypothesized Mean Difference | 0 | |
| df | 17 | |
| t Stat | -5.43 | |
| P(T<=t) one-tail | **2.23E-05** | |
| t Critical one-tail | 1.74 | |
| P(T<=t) two-tail | **4.466E-05** | |
| t Critical two-tail | 2.11 | |

**For UNIVERSAL**

| | *Gate Passes Data* | *Terminal Data* |
|---|---|---|
| Mean | 526 | 293 |
| Variance | 19562 | 8176 |
| Observations | 18 | 18 |
| Pearson Correlation | 0.89 | |
| Hypothesized Mean Difference | 0 | |
| df | 17 | |
| t Stat | 13.73 | |
| P(T<=t) one-tail | **6.27E-11** | |
| t Critical one-tail | 1.74 | |
| P(T<=t) two-tail | **1.25E-10** | |
| t Critical two-tail | 2.11 | |

Two different statistical tests (Wilcoxon Rank Sum Test and t-Test) were performed to statistically demonstrate reasonable reliability of the gate pass data. Appendix G illustrates the equation and the hypothesis used for the Wilcoxon Rank Sum test. Both Wilcoxon Rank Sum

Test and t-Test revealed that there is no significant difference, at the 95% confidence level ($Z<1.96$ and $P>0.05$), between the actual traffic counts (extracted from videotapes) and counts obtained from the gate pass information. Tables 3-8 and Figures 3-2 through 3-5 show the comparison and testing of gate passes with video counts for inbound and outbound truck traffic for Friday 10/31/97. Table 3-9 and Figures 3-6 through 3-9 show the comparison and testing of gate passes with video counts for inbound and outbound truck traffic for Monday 11/03/97.

## Table 3-8 Tabular Comparison and Testing of Gate Passes with Video Counts for Friday 10/31/97.

| DATE : | 10/31/97 | | | | | | DAY : | | FRIDAY | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME | INBOUND | | | | | | OUTBOUND | | | | | |
| | Video Count | Cum. | Rating | Gate | Cum. | Rating | Video Count | Cum. | Rating | Gate | Cum. | Rating |
| 10:00 - 11:00 | 162 | 162 | 13 | 154 | 154 | 11 | 144 | 144 | 9 | 130 | 130 | 5 |
| 11:00 - 12:00 | 159 | 321 | 12 | 133 | 287 | 8 | 150 | 294 | 11 | 150 | 280 | 12 |
| 12:00 - 1:00 | 133 | 454 | 7 | 141 | 428 | 10 | 135 | 429 | 6 | 136 | 416 | 7 |
| 1:00 - 2:00 | 132 | 586 | 6 | 125 | 553 | 3 | 156 | 585 | 14 | 137 | 553 | 8 |
| 2:00 - 3:00 | 125 | 711 | 2 | 125 | 678 | 4 | 126 | 711 | 2 | 127 | 680 | 3 |
| 3:00 - 4:00 | 145 | 856 | 1 | 162 | 840 | 14 | 128 | 839 | 4 | 124 | 804 | 1 |
| 4:00 - 5:00 | 127 | 983 | 5 | 135 | 975 | 9 | 147 | 986 | 10 | 153 | 957 | 13 |
| TOTAL | 983 | | 46 | 975 | | 59 | 986 | | 56 | 957 | | 49 |

**Inbound — Wilcoxon Rank Sum Test**

| | | | |
|---|---|---|---|
| | n1 | = | 7 |
| | n2 | = | 7 |
| | T1 | = | 46 |
| | T2 | = | 59 |
| 95% | $Z_{.025}$ | = | 1.96 |
| | Z | = | -0.83 |

**Inbound — t-Test: Two-Samples Assuming Equal Variances**

| | *Variable 1* | *Variable 2* |
|---|---|---|
| Mean | 137 | 139 |
| Variance | 275 | 200 |
| Observations | 7 | 7 |
| Hypothesized Mean Difference | 0 | |
| df | 12 | |
| t Stat | -0.28 | |
| P(T<=t) one-tail | 0.39 | |
| t Critical one-tail | 1.78 | |
| P(T<=t) two-tail | 0.79 | |
| t Critical two-tail | 2.18 | |

**Outbound — Wilcoxon Rank Sum Test**

| | | | |
|---|---|---|---|
| | n1 | = | 7 |
| | n2 | = | 7 |
| | T1 | = | 56 |
| | T2 | = | 49 |
| 95% | $Z_{.025}$ | = | 1.96 |
| | Z | = | 0.45 |

**Outbound — t-Test: Two-Samples Assuming Equal Variances**

| | *Variable 1* | *Variable 2* |
|---|---|---|
| Mean | 141 | 137 |
| Variance | 130 | 124 |
| Observations | 7 | 7 |
| Hypothesized Mean Difference | 0 | |
| df | 12 | |
| t Stat | 0.69 | |
| P(T<=t) one-tail | 0.25 | |
| t Critical one-tail | 1.78 | |
| P(T<=t) two-tail | 0.50 | |
| t Critical two-tail | 2.18 | |

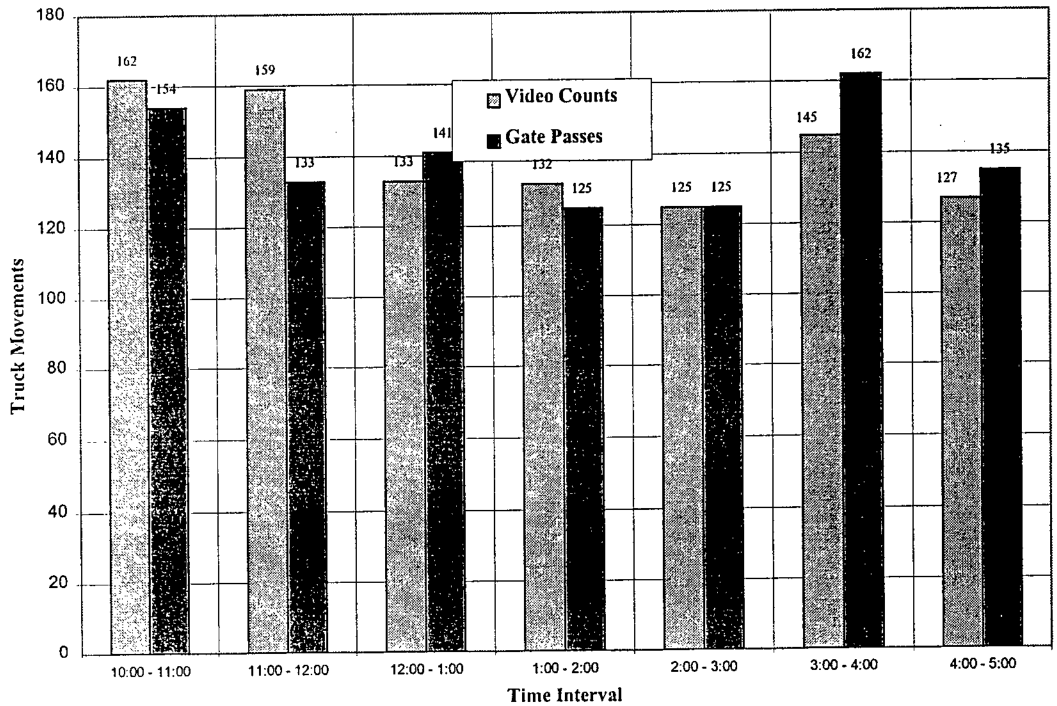



**Figure 3.2 Graphical Comparison of Gate Passes with Video Counts (Friday, Inbound).**

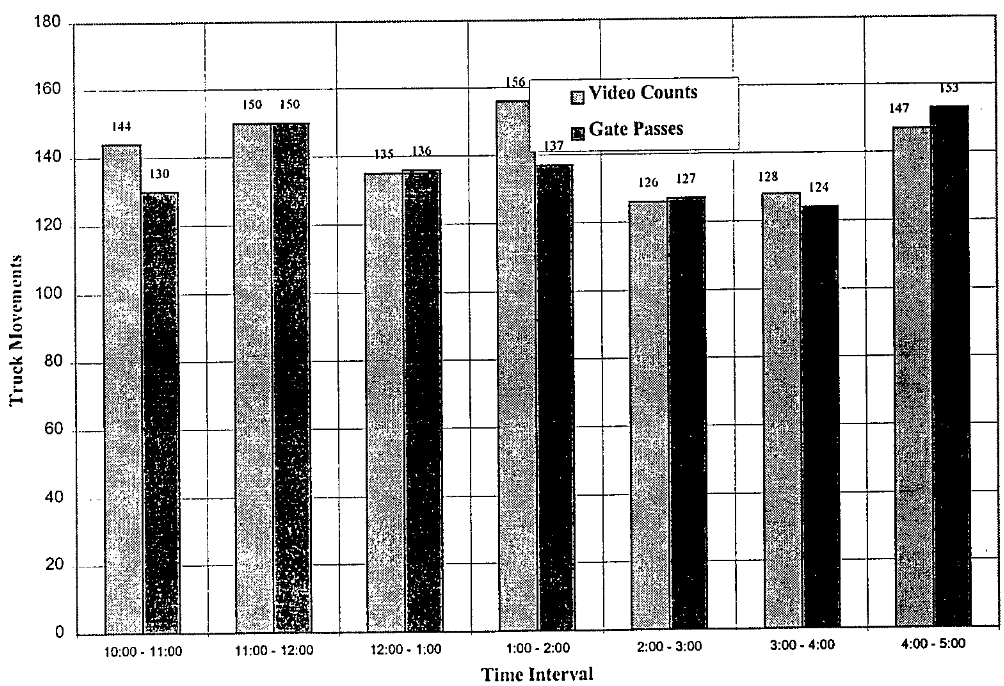



**Figure 3.3 Graphical Comparison of Gate Passes with Video Counts (Friday, Outbound).**

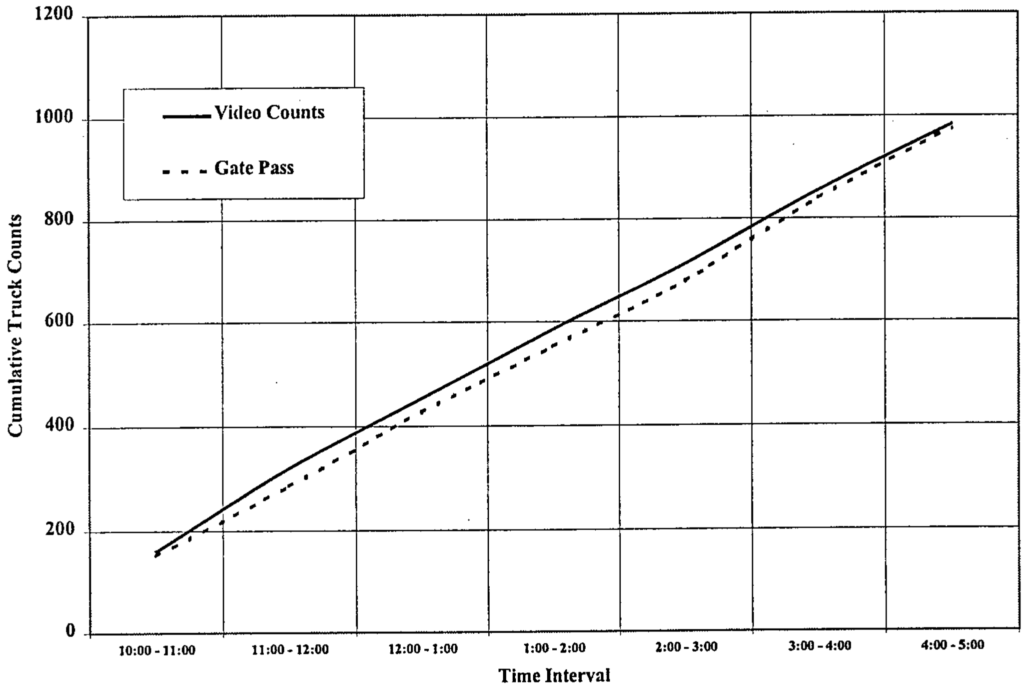



**Figure 3.4 Cumulative Comparison of Gate Passes with Video Counts (Friday, Inbound).**

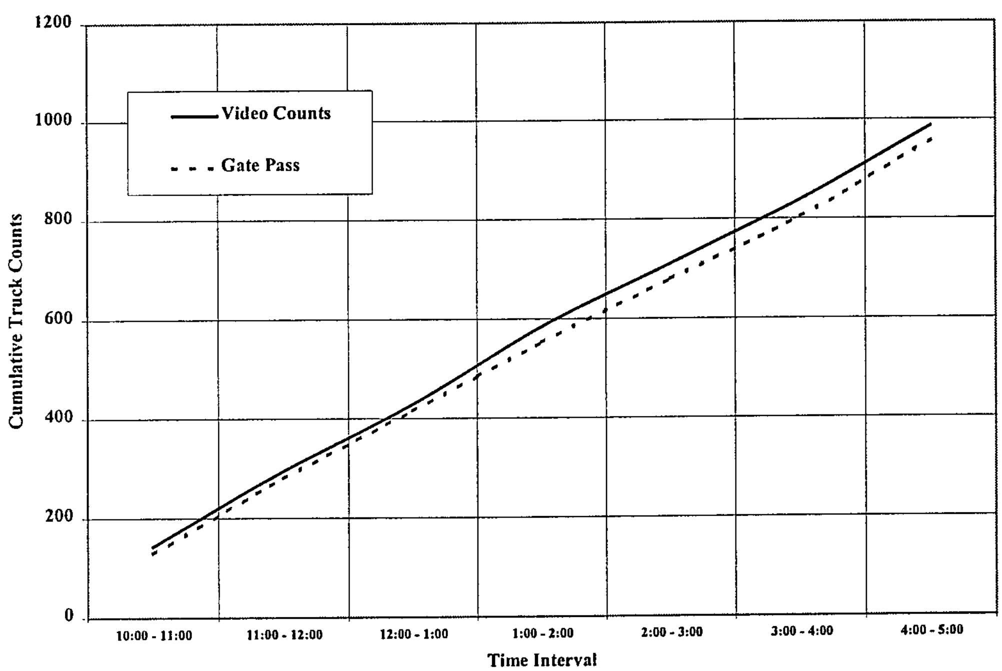



**Figure 3.5 Cumulative Comparison of Gate Passes with Video Counts (Friday, Outbound).**

## Table 3-9 Tabular Comparison and Testing of Gate Passes with Video Counts for Monday 11/3/97.

| DATE : | 11/3/97 | | | | | | DAY : | | MONDAY | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME | INBOUND | | | | | | OUTBOUND | | | | | |
| | Video Count | Cum. | Rating | Gate | Cum. | Rating | Video Count | Cum. | Rating | Gate | Cum. | Rating |
| 6:00 - 7:00 | 27 | 27 | 1 | 42 | 42 | 4 | 1 | 1 | 1 | 2 | 2 | 2 |
| 7:00 - 8:00 | 80 | 107 | 6 | 72 | 114 | 5 | 19 | 20 | 3 | 25 | 27 | 4 |
| 8:00 - 9:00 | 106 | 213 | 12 | 97 | 211 | 9 | 79 | 99 | 7 | 65 | 92 | 5 |
| 9:00 - 10:00 | 93 | 306 | 8 | 88 | 299 | 7 | 100 | 199 | 9 | 77 | 169 | 6 |
| 10:00 - 11:00 | 121 | 427 | 16 | 112 | 411 | 14 | 103 | 302 | 10 | 87 | 256 | 8 |
| 11:00 - 12:00 | 133 | 560 | 22 | 126 | 537 | 21 | 108 | 410 | 13 | 104 | 360 | 11 |
| 12:00 - 1:00 | 123 | 683 | 18 | 116 | 653 | 15 | 107 | 517 | 12 | 115 | 475 | 14 |
| 1:00 - 2:00 | 103 | 786 | 11 | 125 | 778 | 20 | 136 | 653 | 22 | 117 | 592 | 15 |
| 2:00 - 3:00 | 122 | 908 | 17 | 124 | 902 | 19 | 131 | 784 | 19 | 121 | 713 | 17 |
| 3:00 - 4:00 | 108 | 1016 | 13 | 98 | 1000 | 10 | 129 | 913 | 18 | 120 | 833 | 16 |
| 4:00 - 5:00 | 36 | 1052 | 3 | 32 | 1032 | 2 | 132 | 1045 | 20 | 135 | 968 | 21 |
| TOTAL | 1052 | | 127 | 1032 | | 126 | 1045 | | 134 | 968 | | 119 |

**Wilcoxon Rank Sum Test** (Inbound)

| | | | |
|---|---|---|---|
| | n1 | = | 11 |
| | n2 | = | 11 |
| | T1 | = | 127 |
| | T2 | = | 126 |
| 95% | $Z_{.025}$ | = | 1.96 |
| | Z | = | 0.03 |

**t-Test: Two-Samples Assuming Equal Variances** (Inbound)

| | Variable 1 | Variable 2 |
|---|---|---|
| Mean | 96 | 94 |
| Variance | 1232 | 1079 |
| Observations | 11 | 11 |
| Hypothesized Mean Difference | 0 | |
| df | 20 | |
| t Stat | 0.13 | |
| P(T<=t) one-tail | 0.45 | |
| t Critical one-tail | 1.72 | |
| P(T<=t) two-tail | 0.90 | |
| t Critical two-tail | 2.09 | |

**Wilcoxon Rank Sum Test** (Outbound)

| | | | |
|---|---|---|---|
| | n1 | = | 11 |
| | n2 | = | 11 |
| | T1 | = | 134 |
| | T2 | = | 119 |
| 95% | $Z_{.025}$ | = | 1.96 |
| | Z | = | 0.49 |

**t-Test: Two-Samples Assuming Equal Variances** (Outbound)

| | Variable 1 | Variable 2 |
|---|---|---|
| Mean | 95 | 88 |
| Variance | 2077 | 1816 |
| Observations | 11 | 11 |
| Hypothesized Mean Difference | 0 | |
| df | 20 | |
| t Stat | 0.37 | |
| P(T<=t) one-tail | 0.36 | |
| t Critical one-tail | 1.72 | |
| P(T<=t) two-tail | 0.71 | |
| t Critical two-tail | 2.09 | |

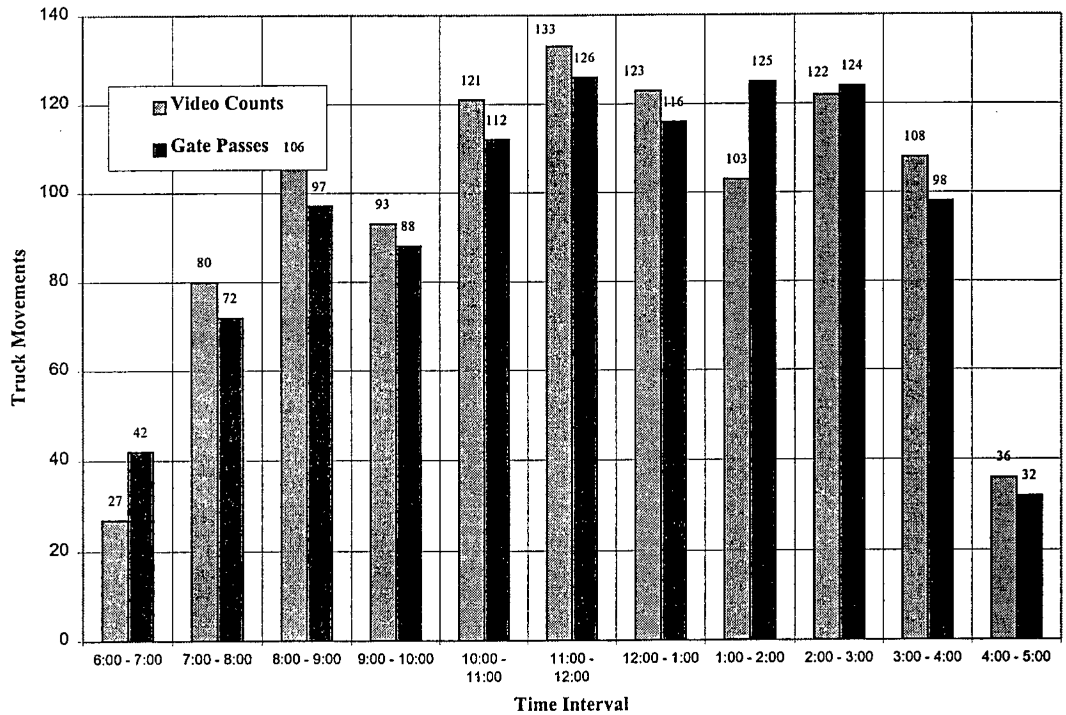



Figure 3.6 Graphical Comparison of Gate Passes with Video Counts (Monday, Inbound).

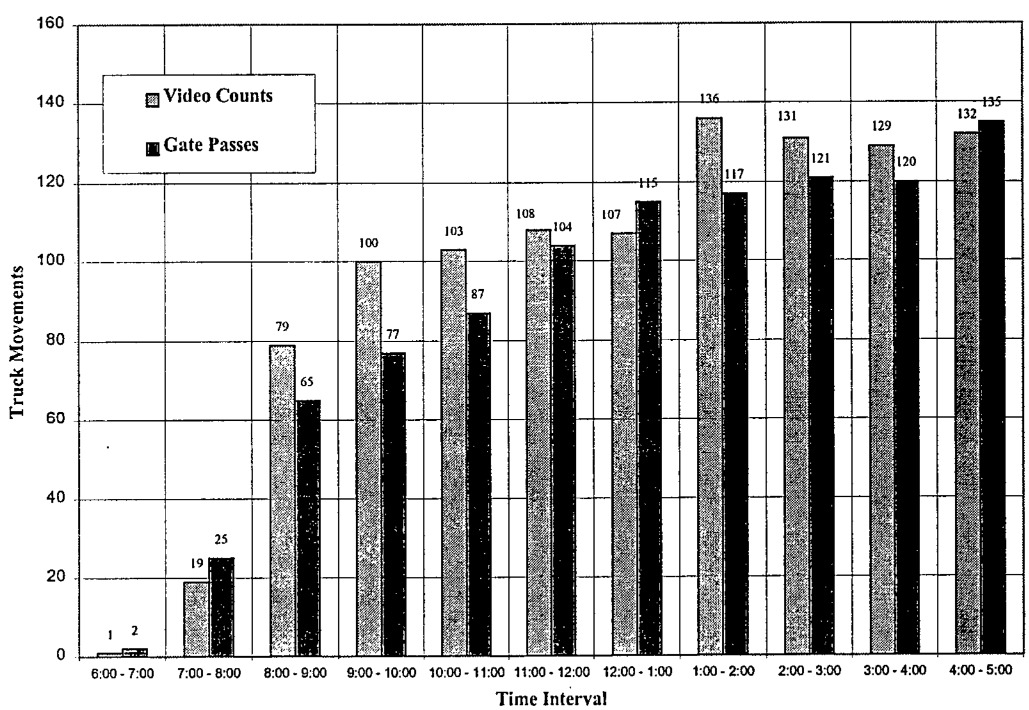



Figure 3.7 Graphical Comparison of Gate Passes with Video Counts (Monday, Outbound).

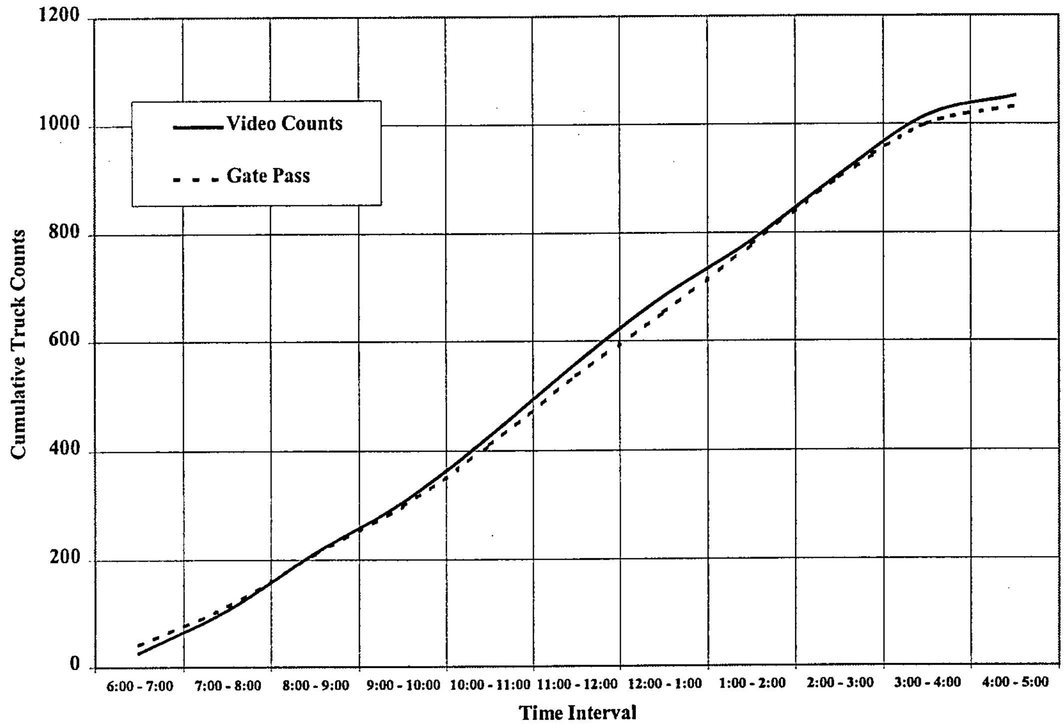



**Figure 3-8 Cumulative Comparison of Gate Passes with Video Counts (Monday, Inbound).**

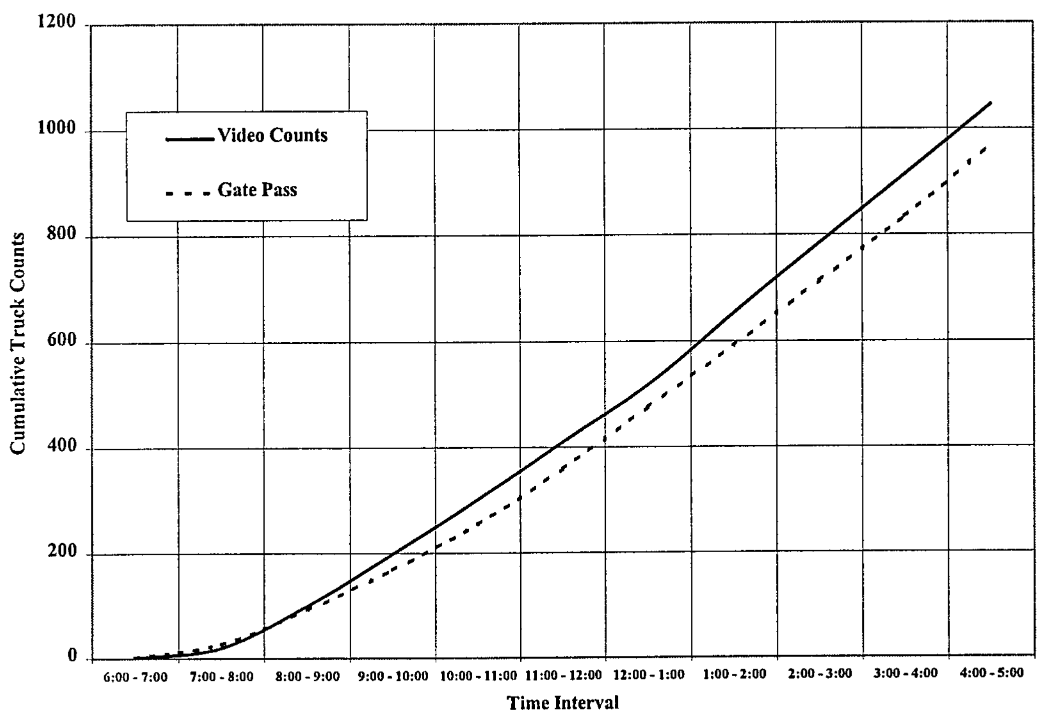



**Figure 3-9: Cumulative Comparison of Gate Passes with Video Counts (Monday, Outbound).**

## 3.4 Summary

With this reliability established for gate passes. These records are now being utilized as the primary source of traffic records. Extracting traffic records from the gate passes is a much quicker process than manual traffic counting or counting traffic as displayed from video tapes. Other data collected in this project will serve as input to the trip generation model(s).

In the next chapter, attempts will be made to identify the input variable(s) to the trip generation model. This variable(s) are related to truck traffic obtained from gate passes.

# Chapter 4

# MODELING AND FORECASTING

This chapter presents the process of developing trip generation (production/attraction) models to estimate the amount of truck freight movement generated at the Port of Miami. This chapter also describes the development of time series models that can be used to predict the amount of monthly truck freight movement generated at the port for short term (5 years) and long term (20 years) forecasting.

## 4.1 Truck Freight Movement Models

### *4.1.1 Introduction To Regression Modeling*

Regression Analysis is a statistical technique used to attain models with best fit based on a set of observations. The fitted model represents the relationship between a dependent variable (Y) and one or more independent variable(s) ($X_1, X_2, \ldots X_n$). By developing such model we can predict the value of the dependent variable corresponding to certain values of the independent variable(s). Regression models can be either linear or nonlinear. The linear regression model indicates that the relationship between the dependent variable and the independent variable(s) could be represented as a straight line. However, in nonlinear regression models this relationship is more complex. In any regression model both the dependent variable and the independent variable(s) should be randomly distributed, also all independent variable(s) should be independent of each other (i.e., there should be no multicolinarity between the independent variables). The general simple linear regression model (one independent variable) can be represented in the following format:

$$Y=\beta_o + \beta_1 X$$

Where Y is the dependent variable, X is the independent variable, $\beta_o$ is the Y-intercept for the fitted straight line, and $\beta_1$ is the slop of this line.

A linear regression model is expected to yield good prediction of roadway freight movement using the readily available data of vessel traffic and the associated cargo volumes as independent variable(s).

### *4.1.2 Characteristics of the Dependent Variable*

The main goal of this research is to develop trip generation (production/attraction) model(s) for predicting the daily truck freight movements generated from the port of Miami. Therefore, total daily truck movements should be used as the dependent variable in the developed regression model. Total daily truck movements are randomly distributed among days and each day is independent of previous days. Gate passes obtained from the port of Miami for a total of 57 business days during the first six months of 1997 were the main source of the daily number of truck movements data set used in the model. As mentioned before, the Port of Miami issues gate passes for only two main terminal truck companies (UNIVERSAL and POMTOC). Gate passes data did not include the daily truck volumes generated from the SEABOARD terminal. As such, the developed regression model(s) in this study was based only on UNIVERSAL and POMTOC data. Therefore, an upward adjustment of the model prediction will be necessary. Based on Table 3-3, total truck movements generated from the SEABOARD terminal was calculated as 33% of total truck movements generated by the port of Miami.

### *4.1.3 Characteristics of the Independent Variable(s)*

Several attempts were made to identify the most significant variable(s) that can truly represent the daily vessel activity. Initially, the UCF research team started by using daily total vessels berthed in the Port of Miami as an independent variable. Analysis showed a very weak correlation (0.24) between the daily number of vessels and the daily truck traffic data as shown in Figure 4.1.

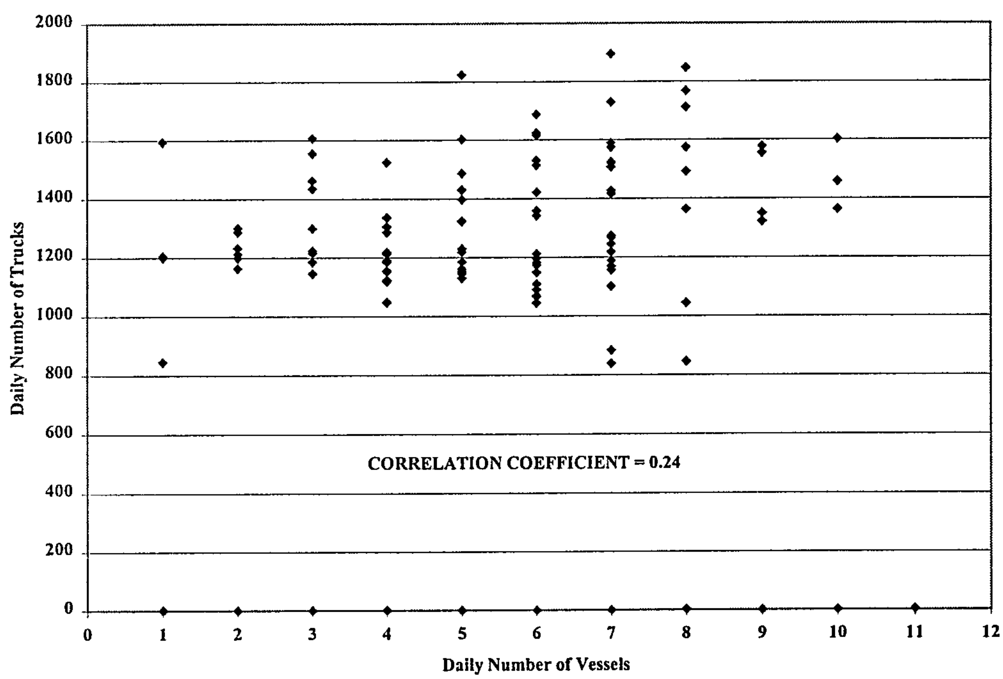



**Figure 4.1 Daily Truck Movements and Daily Number of Vessels.**

Using maximum rated cargo carrying capacities (gross tons) as an independent variable to represent the port activity was the second attempt. Daily truck volume did not correlate well with the maximum capacity (correlation coefficient = 0.08) as shown in Figure 4.2. This is due to the fact that the gross tonnage represents a maximum cargo weight capacity rating for respective vessels and not the actual cargo weight of the shipment.

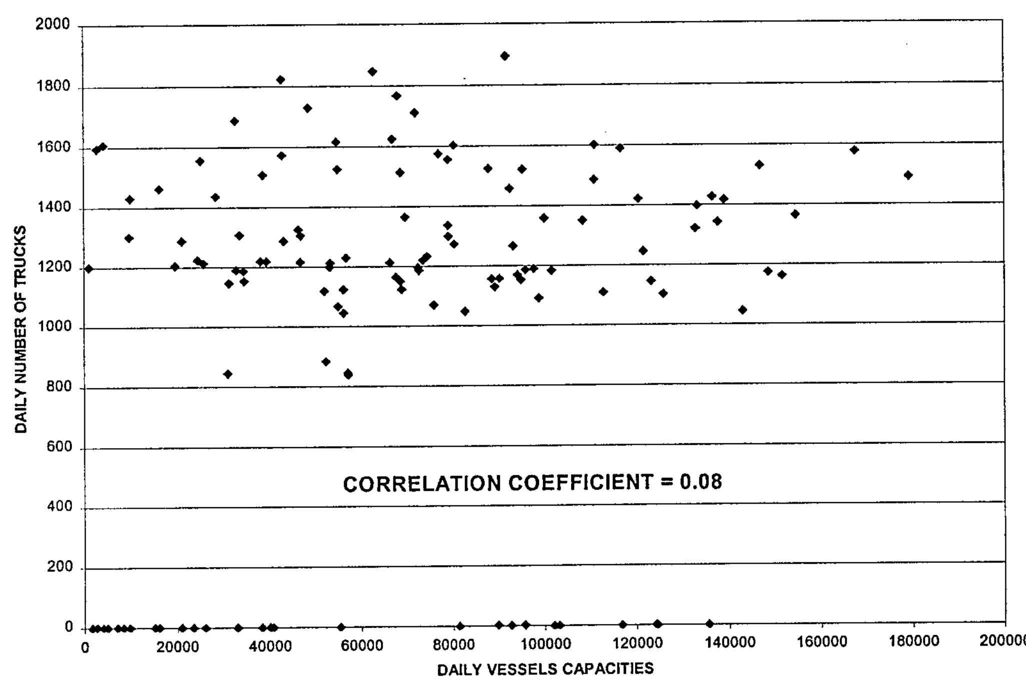



**Figure 4.2 Daily Truck Movements and Maximum Rated Vessel Capacity.**

The third attempt was to test if daily gantry crane operation hours and/or daily number of freight units (containers + trailers) can be a good indicator of the Port of Miami activity. Figure 4.3 shows that total daily gantry crane hours have a strong correlation (correlation coefficient 0.7) with the daily total freight units moved by the gantry cranes. To prevent multicolinearity of the independent variable(s) in the model, either gantry crane hours or number of freight units will be selected as the independent variable in the model.

Gantry crane hours reports do not distinguish between the inbound and outbound freight units. This reflects the problem of aggregating inbound and outbound truck freight volumes in the model. Also, about 25% of the daily freight units is moved by other methods besides gantry cranes which could create a significant source of error in the model. Therefore, the daily number of freight units was believed to be a better truck volume predictor than the gantry crane hours. In conclusion, the daily freight units was considered as the main independent variable in the model.

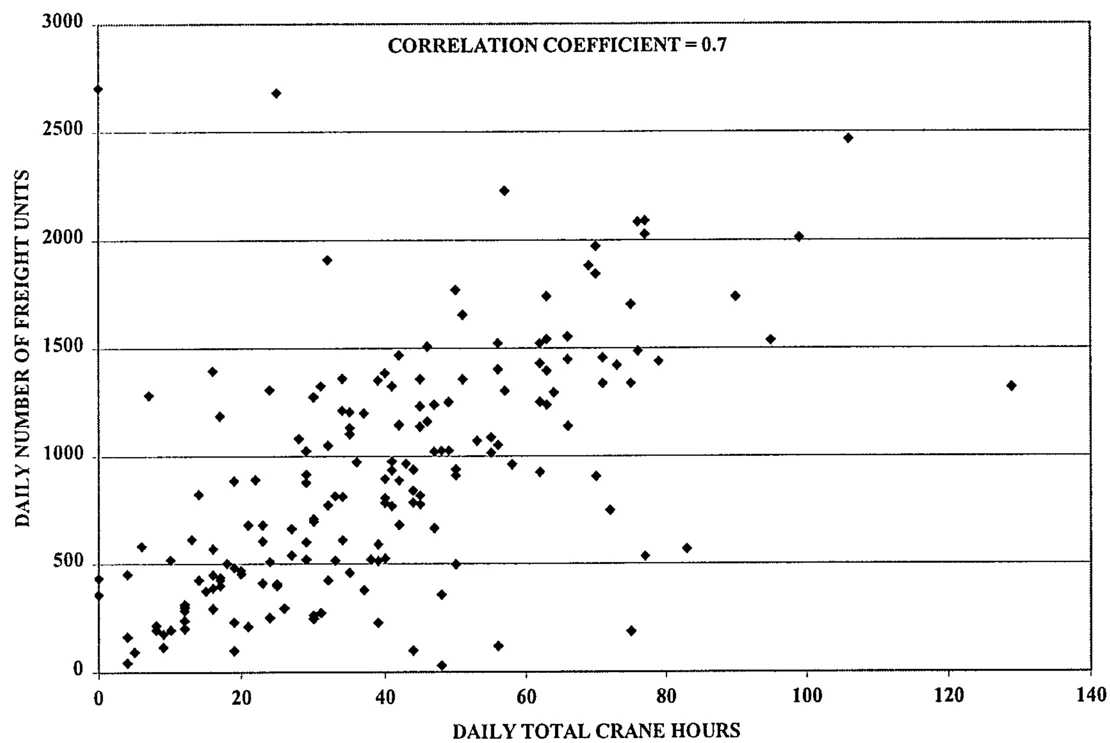



**Figure 4.3 Daily Gantry Crane Hours and Daily Number of Freight Units.**

### *4.1.4 Inbound Model Versus Outbound Model*

The Port of Miami has a slightly higher volume of exports than imports. This implies that trucks are moving more freight into the port (inbound direction) than out of the port (outbound direction). Therefore, it is essential to distinguish between the inbound direction and the outbound direction in the model. The inbound loaded trucks that arrive on Friday are loaded with containers that will be exported on Friday or the *following* Saturday or Sunday. However, for outbound trucks leaving the port on Monday, they are loaded with imported containers that arrived on Monday or the *previous* Saturday or Sunday. So, developing only one model that represents both inbound and outbound truck volumes is inaccurate in representing the port's activity. This implies that two separate regression models are essential. This is intuitive as trip production or attraction at the port does not have to be symmetrical and a model is needed for each. One model would represent the daily inbound truck movements based on number of exported freight units (attraction model) and the other would represent the daily outbound truck movements based on imported freight units (production model).

As discussed earlier, the most important independent variable is daily imported/exported freight units. An initial attempt was conducted to identify the correlation between the daily truck volume and the daily freight units. Figure 4.4 shows a very weak correlation (correlation coefficient of 0.08) between the daily truck volume and the daily freight units. However, grouping of days could be a good approach to improve this correlation.

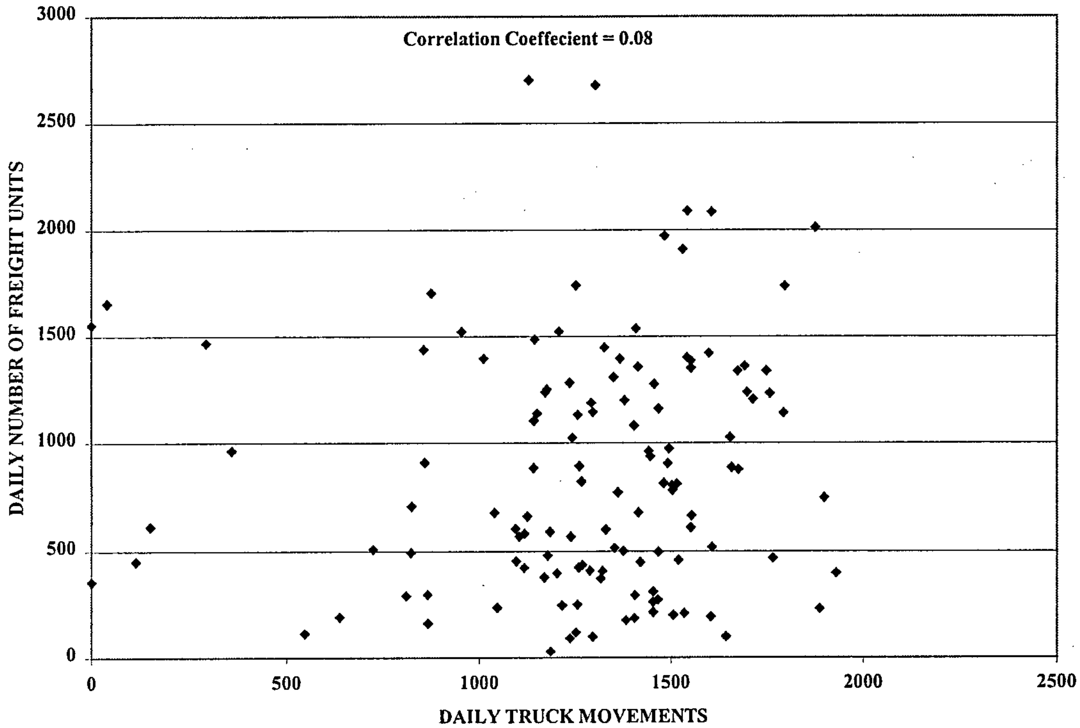



**Figure 4.4 Daily Truck Volume and Daily Freight Units Volume.**

### *4.1.5 Grouping of Days*

Truck movement at the Port of Miami occurs primarily on weekdays (Monday through Friday). However, cargo vessel loading operations are very active during the weekends (Saturday and Sunday). Correlating seven days of vessel loading activity with five weekdays of truck traffic is a challenging task that should be attempted before developing the model. Grouping of days was the ideal solution to solve this problem. Truck traffic aggregated over a few weekdays was associated with vessel cargo aggregated over a few weekdays and/or weekend days. At the same time, this grouping concept reduced the variability in both the dependent and the independent variable(s) and produced a good fit model. As a result of this grouping, the final model correlated the total number of freight units for a specific group of days with the total number of trucks for same or different group of business days. For example, as shown in Figure 4.5, we can predict the total number of inbound trucks generated on Monday from the total number of exported freight units arrived to the Port of Miami on Monday (Group 1). Also, we will be able to predict the summation of total number of inbound trucks generated on Tuesday, Wednesday, Thursday from the summation of total number of exported freight units arrived to the Port of Miami on Tuesday, Wednesday, Thursday, and Friday (Group 2). Finally, by aggregating the total number of exported freight units on Saturday and Sunday (Group 3), we can predict the total number of inbound trucks generated on Friday. Afterwards, the distribution of daily truck movements (Monday through Friday) can be used to calculate truck movements for each day within this group as will be discussed in detail in section 4.4, Step 5. All possible combinations of these groups of days were considered. A total of 131 grouping scenarios for the inbound freight truck model and 140 grouping scenarios for the outbound freight truck model are shown in Appendices H and I, respectively.

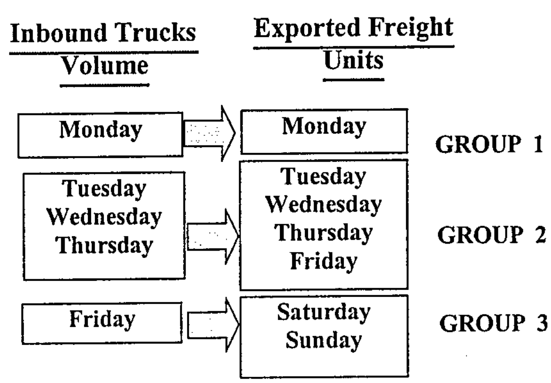



**Figure 4.5 Sample of Grouping of Days Concept for the Attraction Model.**

### *4.1.6 Modeling Assumptions*

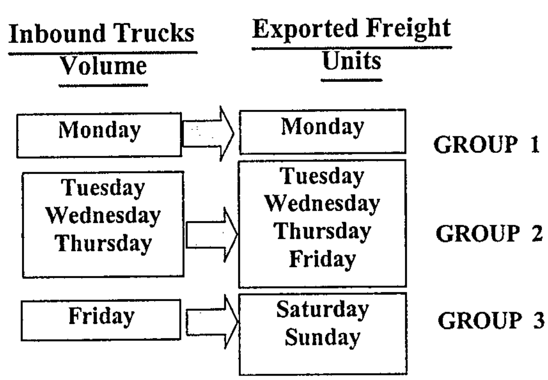
- Holidays were excluded from the analysis.
- Routine delivery trucks and service vehicles were neglected. These were not counted as heavy trucks.
- Auto wreckers were considered as heavy trucks (whether loaded or empty).
- The effect of cruiseships on cargo truck generation was neglected.
- The model did not include unloaded truck volumes (chassis or bobtail). The cargo vessel activity handled by the port generates more trucks loaded with freight units. Therefore, the dependent variable used in the model is the total number of daily ***loaded*** trucks. Model adjustments are needed for bobtail and chassis configurations as described later in section 4.4, Step 7.

### *4.1.7 Models Formulation*

The proposed inbound and outbound models are simple linear regressions formulated to correlate the daily volume of ***loaded*** truck freight movements generated from the Port of Miami with the daily number of freight units (containers and trailers) handled by the Port of Miami. For the purpose of this analysis, the term ***loaded*** refers to any truck configuration that contains a trailer or a container. The trailer or container units do not necessarily have filled contents.

The grouping concept mentioned earlier in this study introduces many combinations of (day-groups) to be tested before reaching the final regression models. All possible grouping scenarios were performed in this study. Regression analyses were conducted for a total of 140 grouping scenarios for the outbound freight truck model and 131 grouping scenarios for the inbound freight truck model. Appendices H and I summarize the scenarios and the statistical regression results for all combination scenarios for inbound and outbound models, respectively. The best models were selected based on the following criteria: high R-squared value, lower percentage of outlier observations, large sample size, and lower SSE/Mean Ratio. Finally, one model was selected for inbound ***loaded*** trucks (attraction model) and one for the outbound ***loaded*** trucks (production model). These attraction/production models are illustrated in the following sections:

#### 4.1.7.1 Attraction Model: Inbound Freight Truck Movement



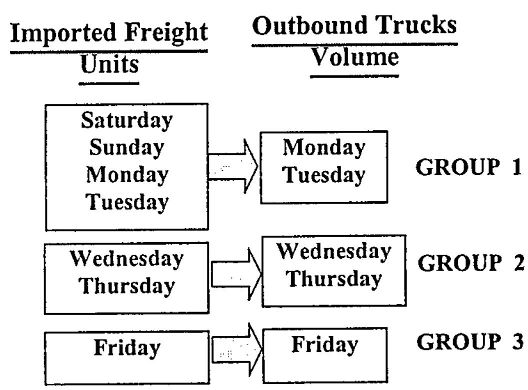

$$INTK_g = 1.197\ (EXPFU) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: **$INTK_g$**: Inbound Loaded Freight Truck Volume for Group "g"

**EXPFU** : Total number of Exported Freight Units Per Group "g"

A total of 28 data points were available for this model. Each data point represents a day or a group of days. Only 20 data points were used for building the model and 8 points were used for validating the developed model. The developed model indicates that we can predict the total number of ***loaded*** trucks entering the Port of Miami (for UNIVERSAL and POMTOC companies) (INTK) on Monday (Group 1) by multiplying the total number of exported freight units (EXPFU) handled by these two companies on Monday by a factor of 1.197. Also, by aggregating the daily exported freight units handled by these two companies on Tuesday, Wednesday, Thursday and Friday (Group 2), and multiplying these day totals by a factor of 1.197, we can estimate the total number of ***loaded*** trucks on Tuesday, Wednesday and Thursday. Finally, we can predict the total number of inbound ***loaded*** trucks generated on Friday by multiplying the summation of exported freight units for these two companies on Saturday and Sunday (Group 3) by a factor of 1.197.

### 4.1.7.2 Production Model: Outbound Freight Truck Movement




$$OUTTK_g = 310.079 + 0.698\,(IMPFU) \qquad (2)$$

Where: $OUTTK_g$: Outbound Loaded Freight Truck Volume for Group "g"

IMPFU : Total number of Imported Freight Units Per Group "g"

Similarly to the attraction model, a total of 28 data points were available for the production model. Each data point represents one day or a group of days. Only 20 data points were used for building the model and 8 points were used for validating the developed model. The developed model indicates that we can predict the total number of ***loaded*** trucks leaving the Port of Miami (OUTTK) (for UNIVERSAL and POMTOC companies) on Monday and Tuesday (Group 1) by multiplying the total number of imported freight units handled by these two companies on Saturday, Sunday, Monday and Tuesday (IMPFU) by 0.698 and adding 310.079 to the resulted value. Also, by aggregating the total number of imported freight units handled by these two companies on Wednesday and Thursday and multiplying this summation by 0.698 and adding 310.079 to the resulted value, we can estimate total number of outbound ***loaded*** trucks on Wednesday and Thursday. Finally, we can predict the total number of outbound ***loaded*** trucks generated on Friday by multiplying 0.698 by the total number of imported freight units for these two companies on Friday and adding 310.079 to this value (Group 3). The intercept value of 310.079 in this model indicates a backlog in the number of imported freight units at the Port of Miami. This backlog may be due to time needed for U.S. Customs clearance. Figures 4.6 and 4.7 illustrate the actual data collected and the fitted regression models for both inbound and outbound directions.

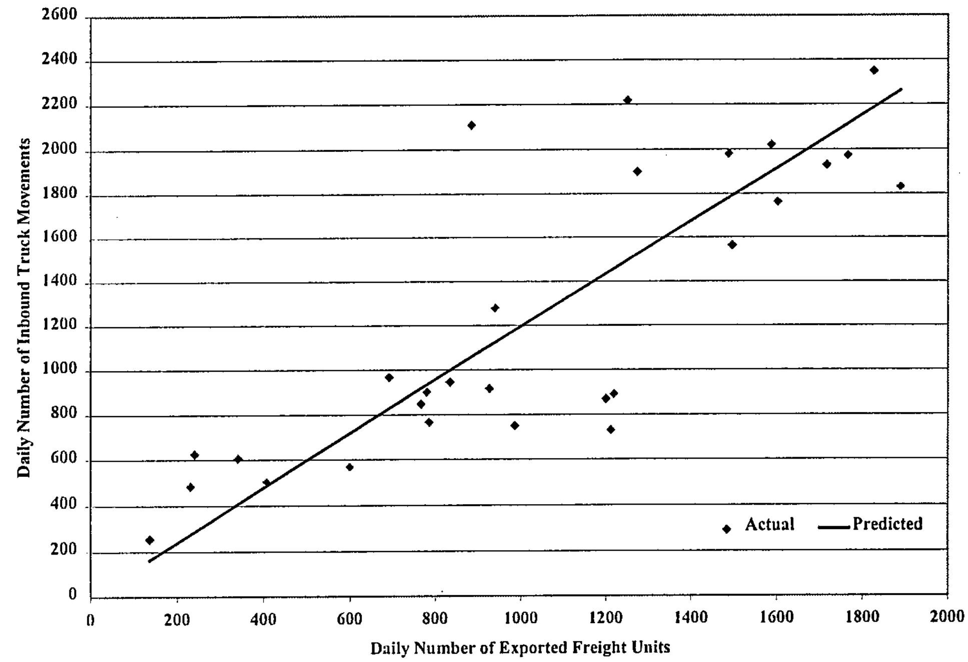



**Figure 4.6 Inbound Loaded Freight Trucks and Exported Freight Units.**

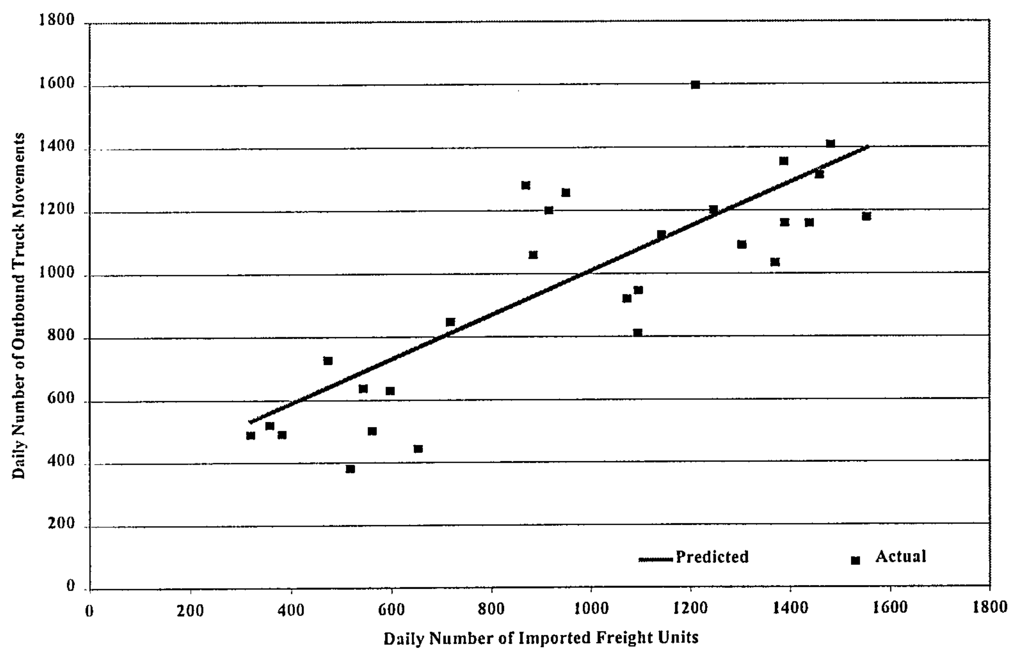



**Figure 4.7 Outbound Loaded Freight Trucks and Imported Freight Units.**

### *4.1.8 Model Testing and Validation*

Figures 4.8 and 4.9 present the inbound and outbound linear regression models summary statistics. The R-squared value for the inbound (attraction) model indicated that almost 80% of the variability in the number of inbound ***loaded*** truck movements (dependent variable) was explained by the model. Also, the number of exported freight units is significant for this model at 95% confidence level. The R-squared value for the outbound (production) model indicated that almost 70% of the variability in the number of outbound ***loaded*** truck movements (dependent variable) was explained by the model. Also, the number of exported freight units is significant for this model at 95% confidence level. The intercept was significant only for the outbound (production model).

It appears that these two models are adequate to represent the relationship between the number of ***loaded*** truck movements and the number freight units. However, one more step is needed before they can be used, that is validation.

SUMMARY OUTPUT

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.8855865 |
| R Square | 0.7842635 |
| Adjusted R Square | 0.7316319 |
| Standard Error | 303.59594 |
| SSE / Mean | 0.2392403 |
| Observations | 20 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 6366254 | 6366254 | 69.07041 | 1.41801E-07 |
| Residual | 19 | 1751239 | 92170.49 | | |
| Total | 20 | 8117493 | | | |

| | *Coefficients* | *andard Erro* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0 | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A | #N/A |
| Exported Containers | 1.1972237 | 0.058542 | 20.45058 | 2.12E-14 | 1.074693224 | 1.319754183 | 1.074693224 | 1.319754183 |

**Figure 4.8 Inbound Loaded Freight Trucks Regression Model Statistics.**

SUMMARY OUTPUT

| Regression Statistics | |
|---|---|
| Multiple R | 0.82805933 |
| R Square | 0.68568225 |
| Adjusted R Square | 0.66822015 |
| Standard Error | 203.248744 |
| SSE / Mean | 0.20846025 |
| Observations | 20 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 1622117.269 | 1622117.27 | 39.26689027 | 6.56215E-06 |
| Residual | 18 | 743580.9313 | 41310.0517 | | |
| Total | 19 | 2365698.2 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 310.089987 | 115.4757536 | 2.68532551 | 0.015115137 | 67.48424288 | 552.69573 | 67.4842429 | 552.6957302 |
| Imported Containers | 0.69757761 | 0.111321559 | 6.26632989 | 6.56215E-06 | 0.463699516 | 0.93145571 | 0.46369952 | 0.931455713 |

**Figure 4.9 Outbound Loaded Freight Trucks Regression Model Statistics.**

A model must be validated in order to insure that it can predict real life data. To validate these models a total of 20 observations for each model (71% of the total available observations) were used to fit the regression model and 8 observations (29% of the total available observations) were used to validate the developed model. A paired t-test was used to compare the total number of loaded freight trucks predicted by the developed model and their actual values. Figures 4.10 and 4.11 show the results of these tests for both the inbound and outbound models, respectively. The results from these tests indicated that there is no significant difference between the predicted values and the observed values for both models at the 95% confidence level (P>0.05).

Paired t-Test:

| | Actual | Predicted |
|---|---|---|
| Mean | 1148 | 1225 |
| Variance | 417489 | 417474 |
| Observations | 8 | 8 |
| Pearson Correlation | 0.81 | |
| Hypothesized Mean Difference | 0 | |
| df | 7 | |
| t Stat | -0.55 | |
| P(T<=t) one-tail | **0.30** | |
| t Critical one-tail | 1.89 | |
| P(T<=t) two-tail | 0.60 | |
| t Critical two-tail | 2.36 | |

**Figure 4.10 Statistical Comparison between the Observed Total Number of Inbound Loaded Freight Trucks and the Predicted Values by the Attraction Regression Model.**

Paired t-Test:

| | Predicted | Actual |
|---|---|---|
| Mean | 1004 | 906 |
| Variance | 57150 | 104258 |
| Observations | 8 | 8 |
| Pearson Correlation | 0.86 | |
| Hypothesized Mean Difference | 0 | |
| df | 7 | |
| t Stat | 1.61 | |
| P(T<=t) one-tail | **0.08** | |
| t Critical one-tail | 1.89 | |
| P(T<=t) two-tail | 0.15 | |
| t Critical two-tail | 2.36 | |

**Figure 4.11 Statistical Comparison between the Observed Total Number of Outbound Loaded Freight Trucks and the Predicted Values by the Production Regression Model**

### *4.1.9 Sources of Randomness in Truck Traffic*

This section discusses some limitations of the developed model. There is some movement of freight directly into and out of the port via railroad. It comprises less than one percent of the annual total truck movements. This freight was neglected by our modeling steps.

Some heavy trucks (1 to 1 1/2 %) are generated by cruiseships. Cruiseship cargo activities are not included in the Trailer/Container Activity Reports utilized by our analysis.

There is minimal truck traffic on weekend days which usually comprises between one-half to one percent of the week's total. This traffic was neglected by the analysis.

Auto carriers or wreckers are considered as heavy trucks by our definition. These vehicles are either transporting one or two automobiles or are empty. Approximately one percent of the cargo freight consists of automobiles. However, the T/C Report's trailer and container totals do not correspond with all of the automobile cargo. Some of the automobiles are shipped on the vessels as open cargo.

There can be some trucks making unnecessary trips to the port. For example, a driver may come in and find out his load was unavailable until another day. Also, the driver could be bringing a load that gets rejected at the terminal, perhaps for failure to pass a load inspection or because of being over the weight limit. In each case, the driver departs producing two moves on Port Boulevard which were not associated with any internal freight movement activity, the main independent variable.

Occasionally, truck drivers who are doing business unrelated to the port will bring their vehicles to the Security Plaza weigh stations simply to check their vehicle weights for a modest service fee. Thus, these movements on Port Boulevard are unrelated to internal freight movement activity. Internal factors can complicate the correlation between vessel traffic and Port Boulevard truck traffic. There are direct vessel-to-vessel transshipments, which will not generate any truck gate moves. An example of a transshipment would be a group of containers brought into the port from a vessel arriving from Europe. The containers are placed in the storage yard and later loaded on a vessel bound for a Caribbean destination. These situations occur rather frequently, since Port of Miami also serves as a transfer hub as well as an origin and a destination port. Freight units may also remain in the port longer than usual for other reasons, such as special inspections or problems with shipping companies.

Thus, the amount of stored freight units inside the port can vary moderately during short time intervals, such as a few days or shorter. For periods longer than a few days, the storage level closely resembles a steady flow condition. We assumed that the freight flow remains at a steady state condition for all periods in order to simplify the analysis.

## 4.2 Weight Models

Gross weight of freight units is important for both the Port of Miami and the shipping companies. A model relating the expected total weight in tonnage and the number of freight units could be a good tool for both parties to predict the expected daily, weekly or monthly total tonnage that can be handled by the port. Data for monthly total weight were obtained from the "Trailer/Container Reports" provided by the Port of Miami for the period from November 1978 to April 1998. Figures 4.12 and 4.13 show the relationship between the imported and exported number of freight units and the gross weight in tons handled by the Port of Miami for each month. It is clear that this relationship can be presented as a simple linear regression model. The following section presents the estimated linear regression models for both imported and exported freight units to estimate the gross weight of the total number of freight units handled by the Port of Miami.

### *4.2.1 Models Formulation*

#### 4.2.1.1 Linear Regression Model for Weight of Imported Freight Units

$$\mathbf{WGHT_{IMP} = 14.34\ (IMPFU)} \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where:

**$WGHT_{IMP}$** = Gross weight for imported freight units in tons.

**IMPFU** = Total number of imported freight units.

A total of 135 observations of monthly number of imported freight units and monthly gross weight of the imported freight units were used to fit this regression model. The developed model indicates that the average weight of an imported freight unit (averaged over full and empty containers) is about 14.34 tons. Therefore, we can predict the total daily, weekly or monthly gross weight for imported freight units by multiplying the total daily, weekly or monthly imported freight units by 14.34 tons.

#### 4.2.1.2 Linear Regression Model for Weight of Exported Freight Units

$$\mathbf{WGHT_{EXP} = 13.936\ (EXPFU)} \quad \ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where:

**$WGHT_{EXP}$** = Gross weight of exported freight units in tons.

**EXPFU** = Total number of exported freight units.

Similarly, a total of 135 observations of monthly number of exported freight units and monthly gross weight of the exported freight units were used to fit this regression model. The developed model indicates that the average weight of an exported freight unit (averaged over full and empty containers) is about 13.936 tons. Therefore, we can predict the total daily, weekly or monthly gross weight for exported freight units by multiplying the total daily, weekly or monthly exported freight units by 13.936 tons.

### *4.2.2 Models Testing and Validation*

Figures 4.14 and 4.15 show the linear regression models statistics. The R-squared values for both models indicated that 90% of the variability in the gross weight (dependent variable) were explained by the models. Also, the weight of the total monthly number of freight units is significant for both models at 95% confidence level. In conclusion, there is enough evidence that these two models are adequate to represent the relationship between the number of freight units and the total gross weight. Also, it can be concluded from both models that the average weight of one freight unit (averaged over full and empty containers) is around 14 tons.

Average vehicle gross weights were also estimated by two different approaches. One method utilized the gross container weight totals from the "Trailer/Container (T/C) Reports". The second method utilized the gross vehicle weights from the gate pass records. Table 4.1 summarizes the results of these two methods.

For the T/C Report method, an average gross container weight of 30,440 lbs (15.2 tons). was calculated from a sample size of 1211 shipping company activities, which represents hundreds of thousands of containers. An average chassis weight without a bobtail was calculated to be 6575 lbs. (3.3 tons) from a sample size of 61 vehicles. An average bobtail weight was calculated to be 16,785 lbs. (8.4 tons) from a sample size of 26 vehicles. Thus, the average truck weight is the total of the three averages - 53,800 lbs. (26.9 tons). This figure represents inbound and outbound container trucks, carrying both long and short containers.

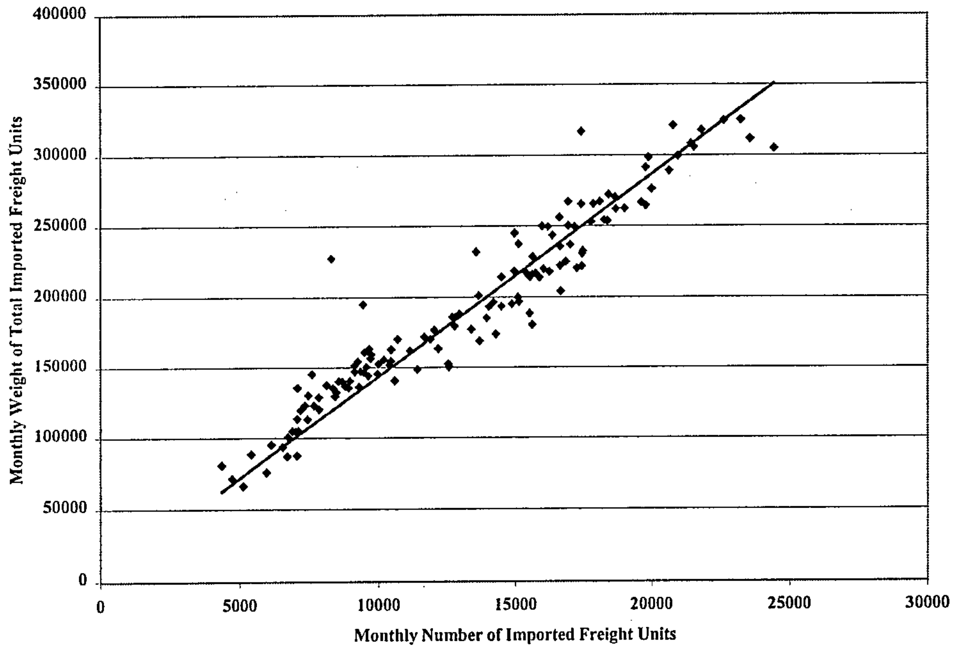



Figure 4.12 Monthly Number of Imported Freight Units and Gross Weight.

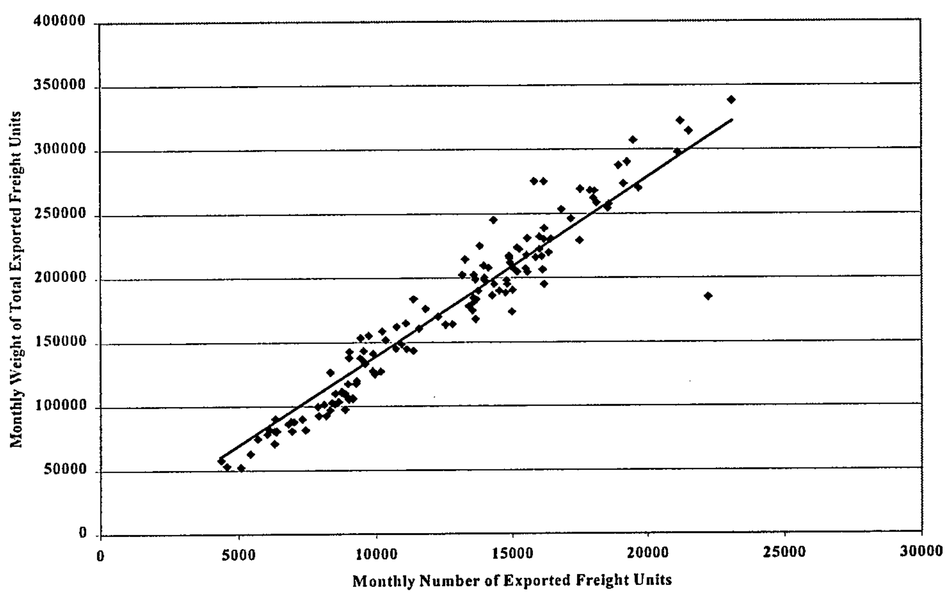



Figure 4.13 Monthly Number of Exported Freight Units and Gross Weight.

SUMMARY OUTPUT

| Regression Statistics | |
|---|---|
| Multiple R | 0.94955147 |
| R Square | 0.90164799 |
| Adjusted R Square | 0.89418531 |
| Standard Error | 20171.0487 |
| SSE / Mean | 0.10491656 |
| Observations | 135 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 4.99822E+11 | 5E+11 | 1228.453 | 4.85431E-69 |
| Residual | 134 | 54520741784 | 4.07E+08 | | |
| Total | 135 | 5.54343E+11 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Number of Imported Freight Units | 14.3406491 | 0.123457065 | 116.159 | 2.2E-136 | 14.09647278 | 14.5848254 | 14.09647278 | 14.58482536 |

**Figure 4.14 Regression Model Statistics for Weight of Imported Freight Units.**

SUMMARY OUTPUT

| Regression Statistics | |
|---|---|
| Multiple R | 0.9577576 |
| R Square | 0.91729963 |
| Adjusted R Square | 0.90983694 |
| Standard Error | 19190.9625 |
| SSE / Mean | 0.11111475 |
| Observations | 135 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 5.47397E+11 | 5.47E+11 | 1486.307 | 4.71262E-74 |
| Residual | 134 | 49351267652 | 3.68E+08 | | |
| Total | 135 | 5.96748E+11 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | pper 95.0% |
|---|---|---|---|---|---|---|---|---|
| o. Of Exported Freight Units | 13.9367658 | 0.125051712 | 111.448 | 5.4E-134 | 13.68943558 | 14.18409602 | 13.68943558 | 14.184096 |

**Figure 4.15 Regression Model Statistics for Weight of Exported Freight Units.**

The average weight of 60,787 lbs (30.39 tons) calculated from a sample of 17,800 gate passes only represents inbound trucks. Weigh station apparatus is only installed on the inbound lanes at the Port of Miami Security Plaza.

It is optional for drivers to have their vehicle weights recorded. Drivers with light loads or empty containers often decline weight checks. This pattern is one reason for the higher average truck weight from the gate pass estimate over the T/C Report method. Although most of the heavy truck traffic primarily consists of container configurations, the gate pass records also include trailers. Trailer configurations tend to weigh slightly more than container configurations.

**Table 4-1 Summary Of Average Weights.**

| CONFIGURATION | AVERAGE WEIGHT (tons) | SAMPLE SIZE (vehicles) |
|---|---|---|
| BOBTAIL | 8.4 | 26 |
| CHASSIS (without a bobtail) | 3.3 | 61 |
| FREIGHT UNITS (From T/C Reports) | 15.2 | 1211 |
| FREIGHT UNITS (From Gate Passes) | 18 | 17800 |
| LOADED TRUCK(from T/C) (Bobtail + Chassis + Container) | 26.9 | 1211 |
| LOADED TRUCK(from Gate Passes) (Bobtail + Chassis + Container) | 30.4 | 17800 |

## 4.3 Forecasting Number of Freight Units (Independent Variable)

### *4.3.1 Background*

Time Series analysis is a statistical approach to understand the special role played by time in the relationship between time-ordered variables. Time series is a collection of data obtained by observing a response variable at equal spaced points in time. The main goal of time series analysis is to produce a model which can express a time-structured relationship among some variables or events. After developing the time series model, it can be used to forecast the response variable. A single equation ARIMA (Auto Regressive Integrated Moving Average) model states how any value in a single time series is linearly related to its own past values. If a model is a good approximation of a process the model tends to mimic the behavior of the process. Thus, forecasts from the model may provide useful information about future values of the series *(16)*.

To examine long-term and seasonal trends of the freight unit volumes, time series analysis was the ideal approach to present such trends.

### *4.3.2 Modeling for the Number of Freight Units*

The number of freight units handled by the Port of Miami every month can be used as a good indicator for the port activities. The input of trip generation models can be estimated from this section. Then trip generation models can be used to predict truck traffic. Any increase in freight units will generate more freight truck movements in the area around the Port of Miami.

Developing a model to predict the future monthly number of freight units based on the past and current volume of the freight units could help in forecasting truck volumes used in conjunction with the tip generation models developed in section 4.1.7. The number of monthly imported and exported freight units was obtained from the "Trailer/Container Reports for the period from October 1978 to April 1998 for the Port of Miami", see Appendix E. Figures 4.16 and 4.17 illustrate the time series trends for both imported and exported monthly freight units, respectively. These figures show that the imported and exported monthly freight units follow the same trend. By looking at the two trends, we can detect that a change in the trend had occurred around November 1986. It is clear that the period from October 1978 to November 1986 is not stable in showing the trend in volume of monthly freight units. However, the period from November 1986 to April 1998 (11.5 years) showed a constant growing trend throughout that period. Therefore, the period from October 1978 to November 1986 was excluded from the time series analysis and the developed time series models in this study focused on the historical monthly freight units starting from November 1986 to April 1998.

Using this historical data for the monthly freight units, an adequate ARIMA model for the imported and exported freight units can be used by the port to forecast the expected future monthly volume of freight units. Then by using the developed regression models in section 4.2.1, it will be possible to predict the total expected weight and the number of truck movement volumes associated with the predicted number of freight units from the ARIMA models.

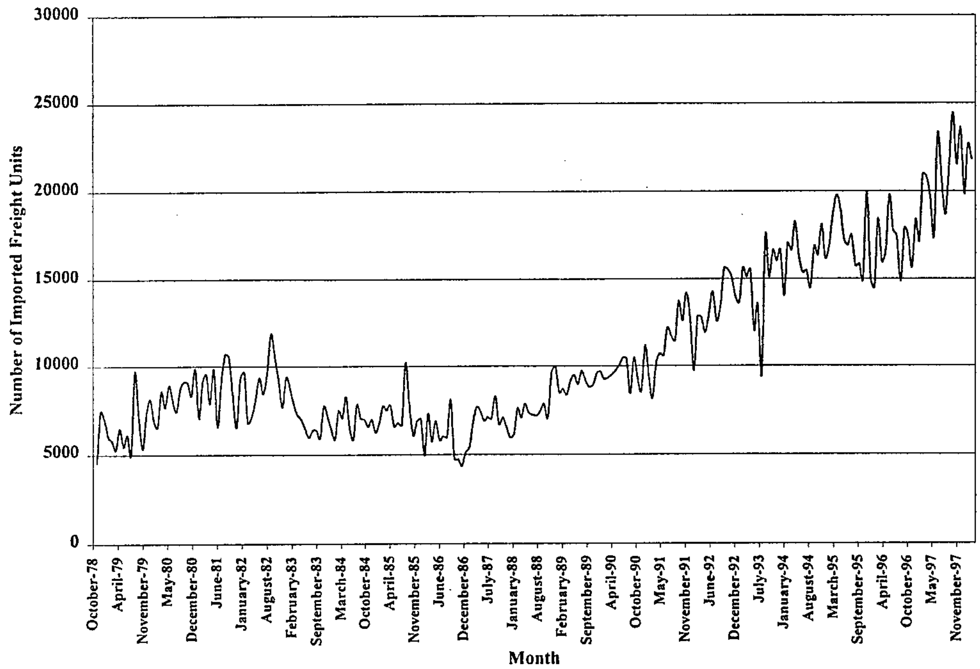



**Figure 4.16 Time Series of Number of Imported Freight Units.**

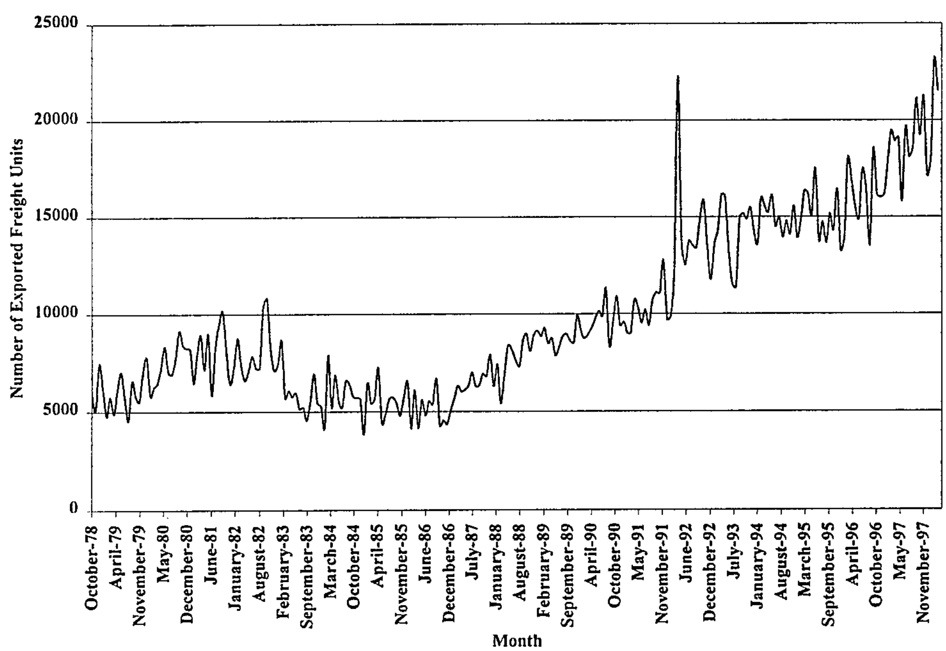



**Figure 4.17 Time Series of Number of Exported Freight Units.**

#### *4.3.3 Models Formulation*

Several steps were conducted to formulate an adequate time series ARIMA model, e.g. removing the data variability, achieving a stationary constant. Appendix J describes the process used in developing this ARIMA model in details. A time series model for both imported and exported natural logarithm of the number of freight units was developed. The following sections present the formulation of imported and exported freight units' time series models.

##### 4.3.3.1 Time Series Model for Imported Freight Units

Let $IMPFU_m$ be the total number of imported freight units handled by the port of Miami in month "m" and Ln be the natural logarithm function, then

$$\mathbf{Ln(IMPFU_{m}) = 0.0135 + Ln(IMPFU_{m-1}) - 0.218\ (\ (Ln\ (IMPFU_{m-9}) - Ln((IMPFU_{m-10}))} \ldots \ (5)$$

A total of 135 observations for the monthly volume of imported freight units were used in developing this model. The time series model for imported freight units indicates that the number of freight units of this month ($IMPFU_m$ ) is a natural logarithm function of the number of imported freight units in the last month ($IMPFU_{m-1}$), the number of imported freight units nine months ago ($IMPFU_{m-9}$), and the number of imported freight units ten months ago(($IMPFU_{m-10}$). This represents the seasonal variation in the number of imported freight units.

##### 4.3.3.2 Time Series Model for Exported Freight Units

Let $EXPFU_m$ be the total number of exported freight units handled by the port of Miami in month "m" and Ln be the natural logarithm function, then

$$\mathbf{Ln(EXPFU_m) = 0.01275 + Ln(EXPFU_{m-1}) - 0.18\ ((Ln\ (EXPFU_{m-9}) - Ln((EXPFU_{m-10}))} \quad \ldots\ldots \mathit{(6)}$$

Similarly, a total of 135 observations for the monthly volume of exported freight units were used in developing this model. The time series model for exported freight units indicates that the number of exported freight units of this month ($EXPFU_m$ ) is a natural logarithm function of the number of exported freight units in the last month ($EXPFU_{m-1}$), the number of exported freight units nine months ago ($EXPFU_{m-9}$), and the number of exported freight units ten months ago(($EXPFU_{m-10}$) which represents the seasonality in the number of exported freight units.

Figures J.11 and J.12 in Appendix J, respectively represent the imported and exported monthly freight unit models statistics in detail.

### *4.3.4 Models Testing and Validation*

If the developed models are an adequate time series representations of the imported and exported freight unit volumes, then there should be no future significant auto-correlation pattern left in the residual series. The auto-correlation residual plots (Figures J.13 and J.14 in Appendix J) indicated that all residual Auto-Correlation Function (ACF) fall within the two standard error limits. The residual Partial Auto-Correlation Function (PACF) for the proposed models (Figures J.15 and J.16 in Appendix J) also indicated that each residual partial auto-correlation is small relative to its standard error limits (the dashed line). This suggests that the developed models adequately represent the auto correlation pattern in the data for both series. Chi-square tests were performed to determine if the first 20 residuals auto correlation is not equal to zero (Null Hypothesis) for both models. The Chi-square values for the inbound and outbound models are

19.088 and 18.274, respectively. These two values are less than the critical chi-square value for 17 degrees of freedom (27.587 for 95% confidence level). The results of these joint tests for both models suggest that the two models have adequately captured the auto-correlation patterns in the data.

The normal probability plots for the residuals for the imported and the exported freight units volume time series models shown in Figures J.17 and J.18 in Appendix J are very close to straight lines, suggesting that the residuals are approximately normal. All of these residuals fall well within two standard deviations from zero. Thus we have no outliers that call for special attention.

Also, the P values for the parameters are less than 0.05 which indicated that all parameters are significant at the 95% confidence level (Figures J.11, J.12, J.19 and J.20 in Appendix J).

### *4.3.5 Alternative Approach: Regression Models*

Another approach was conducted to predict the monthly number of freight units volume. Using the same monthly data for imported and exported monthly freight units obtained from the monthly "Trailer/Container Reports", non-linear regression models for predicting both imported and exported freight units (on the basis of the month index) were developed. Figures 4.16 through 4.19 illustrate the original data and the non-linear fitted models. Also, Figures 4.20 and 4.21 present the two non-linear regression models statistics.

#### 4.3.5.1 Regression Model for Monthly Imported Freight Units

**IMPFU = Exp (8.771+ 0.009506 (Month Index)) .........................*(7)***

Where;

IMPFU = Total number of imported freight units handled by the Port of Miami in a specific month.

Month Index=1,2,3,4,5...etc. for Nov 86, Dec 86, Jan 87, Feb 87,.....etc

Exp: is the exponential function.

#### 4.3.5.2 Regression Model for Monthly Exported Freight Units

**EXPFU =Exp (8.767 + 0.00885 (Month Index)......................*(8)***

Where;

EXPFU = Total number of exported freight units handled by the Port of Miami in a specific month.

Month Index =1,2,.3,4,.5...etc. for Nov 86, Dec 86, Jan 87, Feb 87,.....etc

Exp: is the exponential function.

### *4.3.6 Models Testing and Validation*

The R-squared values for both models indicated that almost 90% of the variability in the monthly number of freight units (dependent variable) were explained by the model. Also, the "Month Index" variable is significant for both models at the 95% confidence level. These results indicate that both non-linear regression models are adequate for representation of the actual operation.

### *4.3.7 Comparison of ARIMA Time Series Models and Non-Linear Regression Models*

After calculating the monthly number of freight units by both Time Series and Regression approaches, a test to check if there is a significant difference between the results of the two approaches was performed. Figures 4.22 and 4.23 show the forecasted values for 60 points using both methods. Also, Figures 4.24 and 4.25 show the results of t- statistical tests to check if there is any significant difference between the two models for the 60 points. It is clear that at the 95% confidence level, there is no significant difference between both methods (P-value >0.05). In conclusion, using either approach will yield almost the same forecasts of monthly freight units.

The nonlinear regression models developed in Section 4.3.5 could be easier to use for predicting the monthly freight units. However, these models do not identify the ***seasonal patterns*** in monthly freight units. Time series models identify the seasonal pattern. Therefore, time series models are the recommended approach in forecasting monthly freight units.

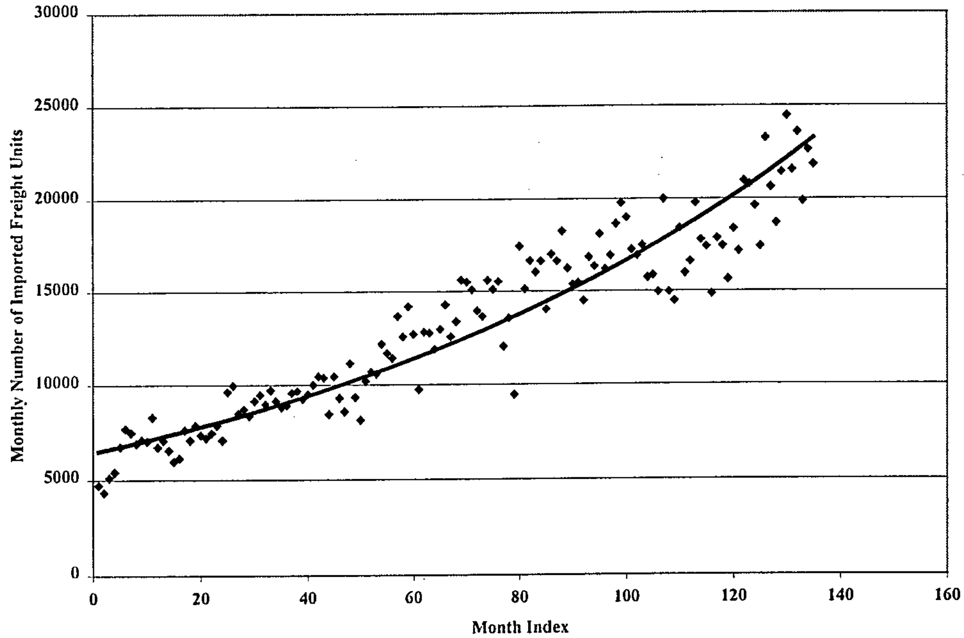



**Figure 4.18 Monthly Number of Imported Freight Units and the Fitted Regression Model.**

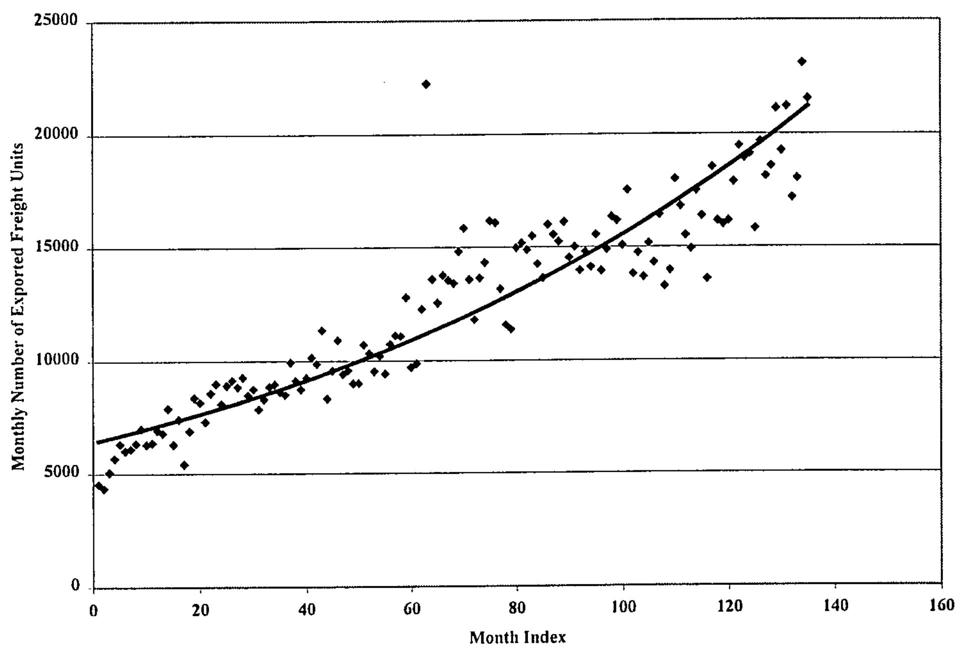



**Figure 4.19 Monthly Number of Exported Freight Units and the Fitted Regression Model.**

SUMMARY OUTPUT

| Regression Statistics | |
|---|---|
| Multiple R | 0.94479652 |
| R Square | **0.89264047** |
| Adjusted R Square | 0.89183325 |
| Standard Error | 0.12943618 |
| SSE / Mean | 0.01374 |
| Observations | 135 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 18.52673953 | 18.52674 | 1105.828 | 2.59641E-66 |
| Residual | 133 | 2.228245463 | 0.016754 | | |
| Total | 134 | 20.75498499 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 8.77131315 | 0.022404541 | 391.4971 | 1.7E-205 | 8.72699786 | 8.815628432 | 8.72699786 | 8.815628432 |
| Month Point | 0.00950608 | 0.000285863 | 33.25399 | 2.6E-66 | 0.008940653 | 0.010071503 | 0.008940653 | 0.010071503 |

**Figure 4.20 Monthly Number of Imported Freight Units Regression Model Statistics.**

SUMMARY OUTPUT

| Regression Statistics | |
|---|---|
| Multiple R | 0.931405485 |
| R Square | **0.867516178** |
| Adjusted R Square | 0.866520059 |
| Standard Error | 0.135795952 |
| SSE / Mean | 0.014494178 |
| Observations | 135 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 16.05979604 | 16.059796 | 870.896161 | 3.11457E-60 |
| Residual | 133 | 2.452591905 | 0.01844054 | | |
| Total | 134 | 18.51238794 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 8.767161748 | 0.023505375 | 372.985402 | 1.03E-202 | 8.720669057 | 8.81365444 | 8.72066906 | 8.813654439 |
| Month Point | 0.008850583 | 0.000299908 | 29.5109498 | 3.1146E-60 | 0.008257376 | 0.00944379 | 0.00825738 | 0.00944379 |

**Figure 4.21 Monthly Number of Exported Freight Units Regression Model Statistics.**

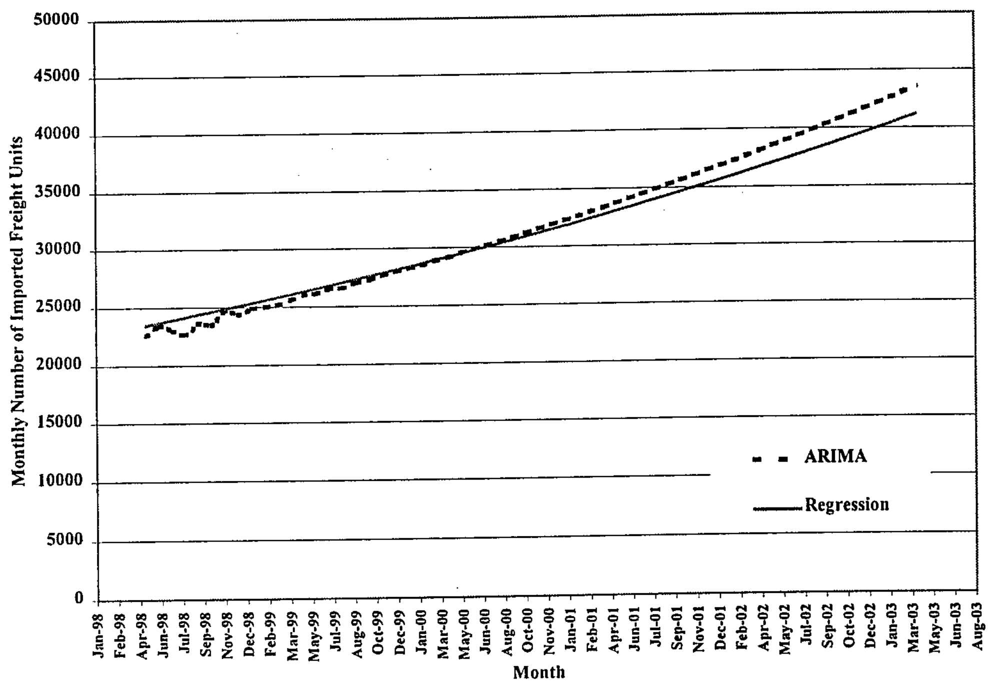



**Figure 4.22 ARIMA Time Series Forecasts and Regression Model Forecasts for Monthly Imported Freight Units.**

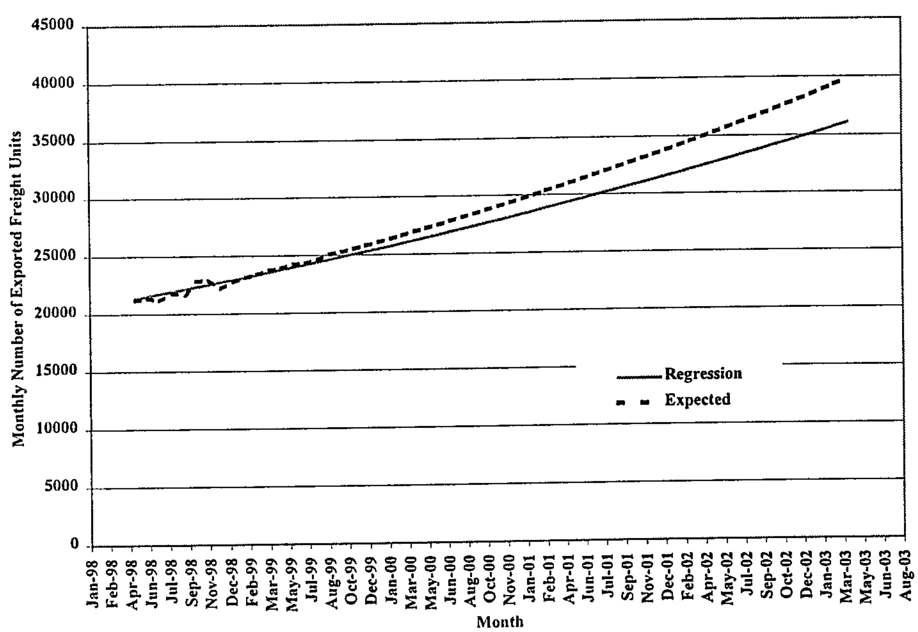



**Figure 4.23 ARIMA Time Series Forecasts and Regression Model Forecasts for Monthly Exported Freight Units.**

t-Test: Two-Sample Assuming Unequal Variances

| | ARIMA | egression |
|---|---|---|
| Mean | 31965 | 31500 |
| Variance | 38119378 | 27200840 |
| Observations | 60 | 60 |
| Hypothesized Mean Difference | 0 | |
| df | 115 | |
| t Stat | 0.445181 | |
| P(T<=t) one-tail | **0.328513** | |
| t Critical one-tail | 1.658211 | |
| P(T<=t) two-tail | 0.657026 | |
| t Critical two-tail | 1.980807 | |

**Figure 4.24 Statistical Test for Number of Imported Freight Units (ARIMA Time Series Forecasts versus the Regression Model Forecasts).**

t-Test: Two-Sample Assuming Unequal Variances

| | ARIMA | Regression |
|---|---|---|
| Mean | 29443 | 28106 |
| Variance | 30550705 | 18785950 |
| Observations | 60 | 60 |
| Hypothesized Mean Difference | 0 | |
| df | 112 | |
| t Stat | 1.48 | |
| P(T<=t) one-tail | **0.07** | |
| t Critical one-tail | 1.66 | |
| P(T<=t) two-tail | 0.14 | |
| t Critical two-tail | 1.98 | |

**Figure 4.25 Statistical Test for Number of Exported Freight Units (ARIMA Time Series Forecasts versus the Regression Model Forecasts).**

## 4.4 Forecasting For Daily Truck Movements

A challenging task in this study is to forecast the daily and hourly truck movements for the next 5 years. The following sections present the steps to be conducted in forecasting daily truck volumes.

***Step 1: Forecast of the Monthly Imported/Exported Freight Units***

Tables 4-2 and 4-3 present the forecast values for Imported and exported monthly freight units with 95% confidence limits for 5 years based on the results of the time series ARIMA models discussed earlier in section 4.3.

***Step 2: Forecast for the Weekly Imported/Exported Freight Units***

Table 4-4 presents the distribution of the total number of weekly imported and exported freight units based on the first 6 months of the year 1997. This resulted in 6 observations with each observation representing one month, as shown in Table 4-4. By multiplying the monthly number of freight units from Step 1 by the average percentage of each week of the month, we can estimate the total number of weekly imported and exported number of freight units.

**Table 4-2 Forecasts of Monthly Imported Freight Units with 95% Confidence Limits for 5 years Using the Time Series ARIMA Model.**

| Month | Lower Limit | Expected | Upper Limit |
|---|---|---|---|
| May-98 | 18029 | 22594 | 28316 |
| Jun-98 | 18454 | 23405 | 29686 |
| Jul-98 | 17944 | 23020 | 29532 |
| Aug-98 | 17485 | 22676 | 29409 |
| Sep-98 | 18027 | 23625 | 30961 |
| Oct-98 | 17736 | 23479 | 31082 |
| Nov-98 | 18480 | 24703 | 33021 |
| Dec-98 | 18037 | 24339 | 32842 |
| Jan-99 | 18259 | 24864 | 33857 |
| Feb-99 | 18353 | 25017 | 34101 |
| Mar-99 | 18360 | 25163 | 34487 |
| Apr-99 | 18578 | 25597 | 35270 |
| May-99 | 18793 | 26031 | 36055 |
| Jun-99 | 18782 | 26150 | 36408 |
| Jul-99 | 18966 | 26541 | 37141 |
| Aug-99 | 18917 | 26605 | 37418 |
| Sep-99 | 19142 | 27054 | 38238 |
| Oct-99 | 19218 | 27295 | 38766 |
| Nov-99 | 19323 | 27629 | 39504 |
| Dec-99 | 19458 | 27969 | 40203 |
| Jan-00 | 19546 | 28243 | 40810 |
| Feb-00 | 19638 | 28523 | 41427 |
| Mar-00 | 19785 | 28882 | 42161 |
| Apr-00 | 19889 | 29180 | 42810 |
| May-00 | 20049 | 29561 | 43584 |
| Jun-00 | 20149 | 29853 | 44231 |
| Jul-00 | 20286 | 30201 | 44963 |
| Aug-00 | 20417 | 30530 | 45654 |
| Sep-00 | 20544 | 30863 | 46364 |
| Oct-00 | 20685 | 31216 | 47108 |
| Nov-00 | 20827 | 31572 | 47861 |
| Dec-00 | 20959 | 31914 | 48595 |
| Jan-01 | 21104 | 32276 | 49362 |
| Feb-01 | 21238 | 32622 | 50110 |
| Mar-01 | 21388 | 32995 | 50901 |
| Apr-01 | 21531 | 33359 | 51683 |
| May-01 | 21679 | 33732 | 52487 |
| Jun-01 | 21830 | 34110 | 53299 |
| Jul-01 | 21980 | 34488 | 54115 |
| Aug-01 | 22132 | 34871 | 54941 |
| Sep-01 | 22289 | 35262 | 55786 |
| Oct-01 | 22445 | 35653 | 56635 |
| Nov-01 | 22606 | 36054 | 57502 |
| Dec-01 | 22765 | 36454 | 58372 |
| Jan-02 | 22929 | 36861 | 59258 |
| Feb-02 | 23094 | 37271 | 60153 |
| Mar-02 | 23260 | 37686 | 61059 |
| Apr-02 | 23429 | 38107 | 61979 |
| May-02 | 23600 | 38532 | 62911 |
| Jun-02 | 23772 | 38961 | 63854 |
| Jul-02 | 23947 | 39396 | 64809 |
| Aug-02 | 24123 | 39834 | 65776 |
| Sep-02 | 24302 | 40278 | 66757 |
| Oct-02 | 24482 | 40727 | 67750 |
| Nov-02 | 24665 | 41181 | 68757 |
| Dec-02 | 24849 | 41640 | 69777 |
| Jan-03 | 25036 | 42104 | 70809 |
| Feb-03 | 25224 | 42573 | 71855 |
| Mar-03 | 25415 | 43048 | 72915 |
| Apr-03 | 25607 | 43528 | 73989 |
| May-03 | 25802 | 44013 | 75077 |
| Jun-03 | 25999 | 44504 | 76179 |
| Jul-03 | 26198 | 45000 | 77296 |
| Aug-03 | 26399 | 45501 | 78427 |
| Sep-03 | 26602 | 46008 | 79573 |
| Oct-03 | 26807 | 46521 | 80734 |
| Nov-03 | 27014 | 47040 | 81910 |
| Dec-03 | 27224 | 47564 | 83102 |

**Table 4-3 Forecasts of Monthly Exported Freight Units with 95% Confidence Limits for 5 years Using the Time Series ARIMA Model.**

| Month | Lower Limit | Expected | Upper Limit |
|---|---|---|---|
| May-98 | 16879 | 21231 | 26705 |
| Jun-98 | 16861 | 21409 | 27184 |
| Jul-98 | 16535 | 21187 | 27148 |
| Aug-98 | 16881 | 21821 | 28207 |
| Sep-98 | 16658 | 21716 | 28310 |
| Oct-98 | 17384 | 22850 | 30034 |
| Nov-98 | 17314 | 22940 | 30395 |
| Dec-98 | 16640 | 22218 | 29667 |
| Jan-99 | 16940 | 22791 | 30662 |
| Feb-99 | 17183 | 23143 | 31169 |
| Mar-99 | 17292 | 23404 | 31678 |
| Apr-99 | 17461 | 23749 | 32302 |
| May-99 | 17508 | 23927 | 32699 |
| Jun-99 | 17664 | 24255 | 33305 |
| Jul-99 | 17645 | 24342 | 33580 |
| Aug-99 | 17777 | 24636 | 34143 |
| Sep-99 | 18027 | 25097 | 34939 |
| Oct-99 | 18094 | 25303 | 35383 |
| Nov-99 | 18172 | 25557 | 35942 |
| Dec-99 | 18282 | 25832 | 36500 |
| Jan-00 | 18383 | 26095 | 37041 |
| Feb-00 | 18510 | 26394 | 37637 |
| Mar-00 | 18617 | 26667 | 38198 |
| Apr-00 | 18760 | 26992 | 38836 |
| May-00 | 18877 | 27279 | 39422 |
| Jun-00 | 18973 | 27537 | 39967 |
| Jul-00 | 19106 | 27850 | 40595 |
| Aug-00 | 19238 | 28156 | 41208 |
| Sep-00 | 19367 | 28462 | 41829 |
| Oct-00 | 19500 | 28775 | 42462 |
| Nov-00 | 19630 | 29084 | 43093 |
| Dec-00 | 19766 | 29403 | 43740 |
| Jan-01 | 19896 | 29715 | 44380 |
| Feb-01 | 20034 | 30039 | 45041 |
| Mar-01 | 20178 | 30373 | 45719 |
| Apr-01 | 20317 | 30701 | 46391 |
| May-01 | 20458 | 31033 | 47074 |
| Jun-01 | 20602 | 31370 | 47767 |
| Jul-01 | 20747 | 31710 | 48466 |
| Aug-01 | 20895 | 32055 | 49177 |
| Sep-01 | 21044 | 32403 | 49894 |
| Oct-01 | 21195 | 32756 | 50623 |
| Nov-01 | 21348 | 33112 | 51359 |
| Dec-01 | 21501 | 33470 | 52102 |
| Jan-02 | 21657 | 33834 | 52858 |
| Feb-02 | 21815 | 34202 | 53622 |
| Mar-02 | 21975 | 34573 | 54395 |
| Apr-02 | 22136 | 34949 | 55178 |
| May-02 | 22299 | 35328 | 55971 |
| Jun-02 | 22464 | 35712 | 56774 |
| Jul-02 | 22630 | 36100 | 57587 |
| Aug-02 | 22799 | 36492 | 58410 |
| Sep-02 | 22969 | 36889 | 59244 |
| Oct-02 | 23141 | 37289 | 60087 |
| Nov-02 | 23315 | 37694 | 60942 |
| Dec-02 | 23491 | 38104 | 61807 |
| Jan-03 | 23668 | 38517 | 62683 |
| Feb-03 | 23848 | 38936 | 63570 |
| Mar-03 | 24029 | 39359 | 64469 |
| Apr-03 | 24212 | 39786 | 65378 |
| May-03 | 24397 | 40218 | 66300 |
| Jun-03 | 24584 | 40655 | 67232 |
| Jul-03 | 24773 | 41097 | 68177 |
| Aug-03 | 24964 | 41543 | 69133 |
| Sep-03 | 25157 | 41994 | 70102 |
| Oct-03 | 25352 | 42451 | 71083 |
| Nov-03 | 25548 | 42912 | 72076 |
| Dec-03 | 25747 | 43378 | 73081 |

### Table 4-4 Percentages of Freight Units Volumes by Week of the Month

| Observation | First week of the month | | Second week of the month | | Third week of the month | | Fouth week of the month | |
|---|---|---|---|---|---|---|---|---|
| | Imported | Exported | Imported | Exported | Imported | Exported | Imported | Exported |
| 1 | 26.79% | 19.42% | 26.91% | 32.09% | 22.56% | 26.24% | 23.74% | 22.25% |
| 2 | 27.20% | 25.91% | 22.11% | 21.74% | 24.59% | 26.81% | 26.10% | 25.54% |
| 3 | 22.50% | 25.22% | 19.03% | 23.46% | 31.19% | 26.53% | 27.28% | 24.80% |
| 4 | 23.88% | 23.18% | 24.24% | 28.02% | 31.10% | 29.08% | 20.78% | 19.71% |
| 5 | 19.12% | 20.41% | 33.47% | 30.21% | 25.41% | 26.80% | 22.00% | 22.58% |
| 6 | 21.19% | 20.67% | 30.56% | 28.44% | 25.56% | 23.22% | 22.69% | 27.66% |
| Average | 23% | 22% | 26% | 27% | 27% | 26% | 24% | 24% |
| Stdev | 3% | 3% | 5% | 4% | 4% | 2% | 2% | 3% |

Exported freight units should be used for day-groups in the attraction model
Imported freight units should be used for day-groups in the production model

### *Step 3: Forecast for Each Group of Days*

Table 4-5 presents the distribution of the total number of imported and exported freight units for each group within the week. By multiplying the weekly number of freight units resulting from Step 2 by the average percentage of each group, we can predict the total number of freight units for each group.

### Table 4-5 Percentages of Freight Units Volumes by the Day-Groups of the Week.

| Observation | Group 1 of the week | | Group 2 of the week | | Group 3 of the week | |
|---|---|---|---|---|---|---|
| | Imported | Exported | Imported | Exported | Imported | Exported |
| 1 | 22.81% | 10.21% | 65.16% | 58.03% | 12.03% | 31.77% |
| 2 | 37.19% | 18.43% | 40.64% | 54.70% | 22.17% | 26.87% |
| 3 | 33.19% | 8.90% | 50.28% | 65.46% | 16.53% | 25.65% |
| 4 | 58.45% | 14.38% | 28.93% | 52.90% | 12.63% | 32.72% |
| 5 | 40.55% | 4.33% | 42.74% | 66.00% | 16.71% | 34.00% |
| 6 | 59.78% | 4.57% | 34.47% | 57.73% | 5.75% | 37.95% |
| 7 | | 14.20% | | 56.63% | | 38.80% |
| 8 | | 17.57% | | 53.06% | | 32.74% |
| 9 | | 11.85% | | 46.92% | | 35.50% |
| 10 | | | | 65.70% | | 34.30% |
| 11 | | | | 45.38% | | 42.77% |
| Average | 42% | 12% | 44% | 57% | 14% | 34% |
| Stdev | 15% | 5% | 13% | 7% | 6% | 5% |

Exported freight units should be used for day-groups in the attraction model
Imported freight units should be used for day-groups in the production model

*Step 4: Forecast of Loaded Trucks for Each Group of Days*

By applying the attraction and the production models developed in section 4.1, we can predict the total number of ***loaded*** trucks generated by the Port of Miami for each group of days for each direction.

*Step 5: Forecast for Each Day of The Week Within Each Group*

Gate passes indicated that truck volumes generated from the Port of Miami on Saturday and Sunday are very low and can be neglected. Tables 4-6 and 4-7 present the distribution of inbound and outbound loaded freight truck volumes for each day within each group. By multiplying the regression model results for the number of loaded truck for each group by the average of truck movements percentage shown in Tables 4-6 and 4-7, we can estimate the daily number of inbound and outbound ***loaded*** freight trucks.

**Table 4-6 Daily Percentages of Inbound Loaded Trucks per Group (Attraction Model).**

GROUP 1

| Observation | Monday |
|---|---|
| 1 | 100.00% |
| 2 | 100.00% |
| 3 | 100.00% |
| 4 | 100.00% |
| 5 | 100.00% |
| 6 | 100.00% |
| 7 | 100.00% |
| 8 | 100.00% |
| 9 | 100.00% |
| 10 | 100.00% |
| 11 | 100.00% |
| AVERAGE | 100% |
| STDEV | 0% |

GROUP 2

| Observation | Tuesday | Wednesday | Thursday |
|---|---|---|---|
| 1 | 34.23% | 26.15% | 39.62% |
| 2 | 22.79% | 31.54% | 45.67% |
| 3 | 31.05% | 34.14% | 34.80% |
| 4 | 32.14% | 31.69% | 36.17% |
| 5 | 33.05% | 30.73% | 36.23% |
| 6 | 30.40% | 18.90% | 50.70% |
| 7 | 28.69% | 32.79% | 38.52% |
| 8 | 33.46% | 32.77% | 33.77% |
| 9 | 31.01% | 31.46% | 37.53% |
| 10 | 32.39% | 31.62% | 35.99% |
| 11 | 25.34% | 32.31% | 42.35% |
| AVERAGE | 30% | 30% | 39% |
| STDEV | 4% | 4% | 5% |

GROUP 3

| Observation | Friday |
|---|---|
| 1 | 100.00% |
| 2 | 100.00% |
| 3 | 100.00% |
| 4 | 100.00% |
| 5 | 100.00% |
| 6 | 100.00% |
| 7 | 100.00% |
| 8 | 100.00% |
| 9 | 100.00% |
| 10 | 100.00% |
| 11 | 100.00% |
| AVERAGE | 100% |
| STDEV | 0% |

**Table 4-7 Daily Percentages of Outbound Loaded Trucks per Group (Production Model).**

GROUP 1

| Observation | Monday | Tuesday |
|---|---|---|
| 1 | 47.69% | 52.31% |
| 2 | 58.24% | 41.76% |
| 3 | 53.59% | 46.41% |
| 4 | 32.22% | 67.78% |
| 5 | 45.49% | 54.51% |
| 6 | 48.70% | 51.30% |
| 7 | 45.93% | 54.07% |
| 8 | 52.87% | 47.13% |
| 9 | 46.48% | 53.52% |
| 10 | 53.07% | 46.93% |
| 11 | | |
| 12 | | |
| AVERAGE | 48% | 52% |
| STDEV | 7% | 7% |

GROUP 2

| Observation | Wednesday | Thursday |
|---|---|---|
| 1 | 33.11% | 66.89% |
| 2 | 36.47% | 63.53% |
| 3 | 48.23% | 51.77% |
| 4 | 55.38% | 44.62% |
| 5 | 44.50% | 55.50% |
| 6 | 35.15% | 64.85% |
| 7 | 49.89% | 50.11% |
| 8 | 44.22% | 55.78% |
| 9 | 41.97% | 58.03% |
| 10 | 44.57% | 55.43% |
| 11 | 42.51% | 57.49% |
| 12 | 51.37% | 48.63% |
| AVERAGE | 44% | 56% |
| STDEV | 7% | 7% |

GROUP 3

| Observation | Fiday |
|---|---|
| 1 | 100.00% |
| 2 | 100.00% |
| 3 | 100.00% |
| 4 | 100.00% |
| 5 | 100.00% |
| 6 | 100.00% |
| 7 | 100.00% |
| 8 | 100.00% |
| 9 | 100.00% |
| 10 | 100.00% |
| 11 | 100.00% |
| 12 | 100.00% |
| AVERAGE | 100% |
| STDEV | 0% |

***Step 6: Adjustment for SEABOARD Freight Truck Volumes***

As mentioned in Chapter 3, daily number of loaded trucks for inbound and outbound direction produced from Step 5 includes only truck movements generated from the two terminal companies UNIVERSAL & POMTOC. Therefore, an adjustment is needed to factor up these values and reflect the truck movements generated from the SEABOARD terminal company. Daily truck volumes generated from the SEABOARD terminal were estimated from terminal company data to be 33% of the total truck movements generated by the Port of Miami (see Table 3-3, page 3-6).

***Step 7: Forecast of Total Daily Truck Volumes***

The completion of Step 6 provides the inbound (attraction) and outbound (production) ***loaded*** trucks. Final adjustments are required to compute all daily generated trucks, including chassis and bobtail configurations. Constant daily percentages of the total daily ***loaded*** truck configurations for both inbound and outbound directions are shown in Table 4-8. These percentages were based on 57 days of gate pass data. Finally, by multiplying these daily percentages by the total daily number of loaded trucks provided by Step 6 we can predict the total daily inbound and outbound freight truck movement volumes.

**Table 4-8 Daily Percentages of Bobtails and Chassis Trucks from Total *Loaded* Truck Volume.**

| Day | BOBTAIL | | CHASSIS | |
|---|---|---|---|---|
| | Inbound | Outbound | Inbound | Outbound |
| Monday | 32% | 31% | 30% | 30% |
| Tuesday | 25% | 36% | 27% | 33% |
| Wednesday | 23% | 25% | 30% | 38% |
| Thursday | 27% | 27% | 32% | 36% |
| Friday | 18% | 50% | 19% | 55% |

Finally, using the time series ARIMA model, the regression models, and steps 1 through 6, Table 4-9 present forecasts of daily truck volumes for the year 2003.

# Table 4-9 Forecasts of the Daily Truck Volumes for the Year 2003.

| Day | | Inbound | Outbound |
|---|---|---|---|
| Wednesday | 01-Jan-03 | 3856 | 3374 |
| Thursday | 02-Jan-03 | 4770 | 4352 |
| Friday | 03-Jan-03 | 5960 | 3659 |
| Saturday | 04-Jan-03 | 0 | 0 |
| Sunday | 05-Jan-03 | 0 | 0 |
| Monday | 06-Jan-03 | 2958 | 3613 |
| Tuesday | 07-Jan-03 | 3955 | 4108 |
| Wednesday | 08-Jan-03 | 3981 | 3496 |
| Thursday | 09-Jan-03 | 5378 | 3946 |
| Friday | 10-Jan-03 | 6462 | 3396 |
| Saturday | 11-Jan-03 | 0 | 0 |
| Sunday | 12-Jan-03 | 0 | 0 |
| Monday | 13-Jan-03 | 3495 | 4037 |
| Tuesday | 14-Jan-03 | 4674 | 4591 |
| Wednesday | 15-Jan-03 | 4704 | 3909 |
| Thursday | 16-Jan-03 | 6355 | 4411 |
| Friday | 17-Jan-03 | 7636 | 3728 |
| Saturday | 18-Jan-03 | 0 | 0 |
| Sunday | 19-Jan-03 | 0 | 0 |
| Monday | 20-Jan-03 | 3227 | 4178 |
| Tuesday | 21-Jan-03 | 4314 | 4751 |
| Wednesday | 22-Jan-03 | 4342 | 4046 |
| Thursday | 23-Jan-03 | 5867 | 4566 |
| Friday | 24-Jan-03 | 7049 | 3839 |
| Saturday | 25-Jan-03 | 0 | 0 |
| Sunday | 26-Jan-03 | 0 | 0 |
| Monday | 27-Jan-03 | 2958 | 3754 |
| Tuesday | 28-Jan-03 | 3955 | 4269 |
| Wednesday | 29-Jan-03 | 3981 | 3634 |
| Thursday | 30-Jan-03 | 5378 | 4101 |
| Friday | 31-Jan-03 | 6462 | 3507 |
| Saturday | 01-Feb-03 | 0 | 0 |
| Sunday | 02-Feb-03 | 0 | 0 |
| Monday | 03-Feb-03 | 3669 | 3235 |
| Tuesday | 04-Feb-03 | 4906 | 3679 |
| Wednesday | 05-Feb-03 | 4938 | 3131 |
| Thursday | 06-Feb-03 | 6672 | 3985 |
| Friday | 07-Feb-03 | 8016 | 3424 |
| Saturday | 08-Feb-03 | 0 | 0 |
| Sunday | 09-Feb-03 | 0 | 0 |
| Monday | 10-Feb-03 | 3534 | 3616 |
| Tuesday | 11-Feb-03 | 4724 | 4112 |
| Wednesday | 12-Feb-03 | 4756 | 3501 |
| Thursday | 13-Feb-03 | 6425 | 4456 |
| Friday | 14-Feb-03 | 7720 | 3761 |
| Saturday | 15-Feb-03 | 0 | 0 |
| Sunday | 16-Feb-03 | 0 | 0 |
| Monday | 17-Feb-03 | 3262 | 3743 |
| Tuesday | 18-Feb-03 | 4361 | 4256 |
| Wednesday | 19-Feb-03 | 4390 | 3625 |
| Thursday | 20-Feb-03 | 5930 | 4613 |
| Friday | 21-Feb-03 | 7126 | 3873 |
| Saturday | 22-Feb-03 | 0 | 0 |
| Sunday | 23-Feb-03 | 0 | 0 |
| Monday | 24-Feb-03 | 2990 | 3362 |
| Tuesday | 25-Feb-03 | 3998 | 3823 |
| Wednesday | 26-Feb-03 | 4024 | 3255 |
| Thursday | 27-Feb-03 | 5436 | 4142 |
| Friday | 28-Feb-03 | 6532 | 3536 |

| Day | | Inbound | Outbound |
|---|---|---|---|
| Saturday | 01-Mar-03 | 0 | 0 |
| Sunday | 02-Mar-03 | 0 | 0 |
| Monday | 03-Mar-03 | 3709 | 3268 |
| Tuesday | 04-Mar-03 | 4959 | 3716 |
| Wednesday | 05-Mar-03 | 4992 | 3163 |
| Thursday | 06-Mar-03 | 6744 | 4026 |
| Friday | 07-Mar-03 | 8104 | 3453 |
| Saturday | 08-Mar-03 | 0 | 0 |
| Sunday | 09-Mar-03 | 0 | 0 |
| Monday | 10-Mar-03 | 3572 | 3653 |
| Tuesday | 11-Mar-03 | 4776 | 4154 |
| Wednesday | 12-Mar-03 | 4807 | 3537 |
| Thursday | 13-Mar-03 | 6494 | 4502 |
| Friday | 14-Mar-03 | 7803 | 3793 |
| Saturday | 15-Mar-03 | 0 | 0 |
| Sunday | 16-Mar-03 | 0 | 0 |
| Monday | 17-Mar-03 | 3297 | 3781 |
| Tuesday | 18-Mar-03 | 4408 | 4299 |
| Wednesday | 19-Mar-03 | 4437 | 3662 |
| Thursday | 20-Mar-03 | 5995 | 4660 |
| Friday | 21-Mar-03 | 7203 | 3907 |
| Saturday | 22-Mar-03 | 0 | 0 |
| Sunday | 23-Mar-03 | 0 | 0 |
| Monday | 24-Mar-03 | 3022 | 3396 |
| Tuesday | 25-Mar-03 | 4041 | 3862 |
| Wednesday | 26-Mar-03 | 4068 | 3288 |
| Thursday | 27-Mar-03 | 5495 | 4184 |
| Friday | 28-Mar-03 | 6603 | 3566 |
| Saturday | 29-Mar-03 | 0 | 0 |
| Sunday | 30-Mar-03 | 0 | 0 |
| Monday | 31-Mar-03 | 3750 | 3301 |
| Tuesday | 01-Apr-03 | 5013 | 3754 |
| Wednesday | 02-Apr-03 | 5046 | 3195 |
| Thursday | 03-Apr-03 | 6817 | 4067 |
| Friday | 04-Apr-03 | 8191 | 3482 |
| Saturday | 05-Apr-03 | 0 | 0 |
| Sunday | 06-Apr-03 | 0 | 0 |
| Monday | 07-Apr-03 | 3611 | 3690 |
| Tuesday | 08-Apr-03 | 4828 | 4196 |
| Wednesday | 09-Apr-03 | 4859 | 3573 |
| Thursday | 10-Apr-03 | 6565 | 4548 |
| Friday | 11-Apr-03 | 7888 | 3826 |
| Saturday | 12-Apr-03 | 0 | 0 |
| Sunday | 13-Apr-03 | 0 | 0 |
| Monday | 14-Apr-03 | 3333 | 3819 |
| Tuesday | 15-Apr-03 | 4456 | 4343 |
| Wednesday | 16-Apr-03 | 4486 | 3699 |
| Thursday | 17-Apr-03 | 6060 | 4708 |
| Friday | 18-Apr-03 | 7281 | 3941 |
| Saturday | 19-Apr-03 | 0 | 0 |
| Sunday | 20-Apr-03 | 0 | 0 |
| Monday | 21-Apr-03 | 3055 | 3819 |
| Tuesday | 22-Apr-03 | 4085 | 4343 |
| Wednesday | 23-Apr-03 | 4112 | 3699 |
| Thursday | 24-Apr-03 | 5555 | 4708 |
| Friday | 25-Apr-03 | 6675 | 3941 |
| Saturday | 26-Apr-03 | 0 | 0 |
| Sunday | 27-Apr-03 | 0 | 0 |
| Monday | 28-Apr-03 | 3055 | 3430 |
| Tuesday | 29-Apr-03 | 4085 | 3901 |
| Wednesday | 30-Apr-03 | 4112 | 3321 |

| Day | | Inbound | Outbound |
|---|---|---|---|
| Thursday | 01-May-03 | 5555 | 4227 |
| Friday | 02-May-03 | 6675 | 3597 |
| Saturday | 03-May-03 | 0 | 0 |
| Sunday | 04-May-03 | 0 | 0 |
| Monday | 05-May-03 | 3790 | 3334 |
| Tuesday | 06-May-03 | 5068 | 3791 |
| Wednesday | 07-May-03 | 5101 | 3227 |
| Thursday | 08-May-03 | 6891 | 4107 |
| Friday | 09-May-03 | 8280 | 3511 |
| Saturday | 10-May-03 | 0 | 0 |
| Sunday | 11-May-03 | 0 | 0 |
| Monday | 12-May-03 | 3650 | 3727 |
| Tuesday | 13-May-03 | 4880 | 4238 |
| Wednesday | 14-May-03 | 4912 | 3610 |
| Thursday | 15-May-03 | 6636 | 4594 |
| Friday | 16-May-03 | 7974 | 3859 |
| Saturday | 17-May-03 | 0 | 0 |
| Sunday | 18-May-03 | 0 | 0 |
| Monday | 19-May-03 | 3369 | 3858 |
| Tuesday | 20-May-03 | 4505 | 4388 |
| Wednesday | 21-May-03 | 4534 | 3737 |
| Thursday | 22-May-03 | 6126 | 4756 |
| Friday | 23-May-03 | 7360 | 3975 |
| Saturday | 24-May-03 | 0 | 0 |
| Sunday | 25-May-03 | 0 | 0 |
| Monday | 26-May-03 | 3088 | 3465 |
| Tuesday | 27-May-03 | 4129 | 3940 |
| Wednesday | 28-May-03 | 4156 | 3355 |
| Thursday | 29-May-03 | 5615 | 4270 |
| Friday | 30-May-03 | 6747 | 3627 |
| Saturday | 31-May-03 | 0 | 0 |
| Sunday | 01-Jun-03 | 0 | 0 |
| Monday | 02-Jun-03 | 3831 | 3367 |
| Tuesday | 03-Jun-03 | 5123 | 3829 |
| Wednesday | 04-Jun-03 | 5156 | 3260 |
| Thursday | 05-Jun-03 | 6966 | 4149 |
| Friday | 06-Jun-03 | 8370 | 3541 |
| Saturday | 07-Jun-03 | 0 | 0 |
| Sunday | 08-Jun-03 | 0 | 0 |
| Monday | 09-Jun-03 | 3690 | 3765 |
| Tuesday | 10-Jun-03 | 4933 | 4282 |
| Wednesday | 11-Jun-03 | 4965 | 3647 |
| Thursday | 12-Jun-03 | 6708 | 4641 |
| Friday | 13-Jun-03 | 8060 | 3893 |
| Saturday | 14-Jun-03 | 0 | 0 |
| Sunday | 15-Jun-03 | 0 | 0 |
| Monday | 16-Jun-03 | 3406 | 3898 |
| Tuesday | 17-Jun-03 | 4554 | 4432 |
| Wednesday | 18-Jun-03 | 4584 | 3775 |
| Thursday | 19-Jun-03 | 6192 | 4805 |
| Friday | 20-Jun-03 | 7440 | 4010 |
| Saturday | 21-Jun-03 | 0 | 0 |
| Sunday | 22-Jun-03 | 0 | 0 |
| Monday | 23-Jun-03 | 3406 | 3500 |
| Tuesday | 24-Jun-03 | 4554 | 3980 |
| Wednesday | 25-Jun-03 | 4584 | 3389 |
| Thursday | 26-Jun-03 | 6192 | 4313 |
| Friday | 27-Jun-03 | 7440 | 3658 |
| Saturday | 28-Jun-03 | 0 | 0 |
| Sunday | 29-Jun-03 | 0 | 0 |
| Monday | 30-Jun-03 | 3443 | 3535 |

# Table 4-9 Forecasts of the Daily Truck Volumes for the Year 2003 (continued).

| Day | Inbound | Outbound |
|---|---|---|
| Tuesday 01-Jul-03 | 4603 | 4020 |
| Wednesday 02-Jul-03 | 4633 | 3423 |
| Thursday 03-Jul-03 | 6259 | 4357 |
| Friday 04-Jul-03 | 7521 | 3690 |
| Saturday 05-Jul-03 | 0 | 0 |
| Sunday 06-Jul-03 | 0 | 0 |
| Monday 07-Jul-03 | 3156 | 3401 |
| Tuesday 08-Jul-03 | 4219 | 3868 |
| Wednesday 09-Jul-03 | 4247 | 3293 |
| Thursday 10-Jul-03 | 5738 | 4191 |
| Friday 11-Jul-03 | 6894 | 3571 |
| Saturday 12-Jul-03 | 0 | 0 |
| Sunday 13-Jul-03 | 0 | 0 |
| Monday 14-Jul-03 | 3873 | 3804 |
| Tuesday 15-Jul-03 | 5178 | 4325 |
| Wednesday 16-Jul-03 | 5212 | 3684 |
| Thursday 17-Jul-03 | 7042 | 4689 |
| Friday 18-Jul-03 | 8461 | 3927 |
| Saturday 19-Jul-03 | 0 | 0 |
| Sunday 20-Jul-03 | 0 | 0 |
| Monday 21-Jul-03 | 3730 | 3938 |
| Tuesday 22-Jul-03 | 4987 | 4478 |
| Wednesday 23-Jul-03 | 5019 | 3814 |
| Thursday 24-Jul-03 | 6781 | 4854 |
| Friday 25-Jul-03 | 8148 | 4045 |
| Saturday 26-Jul-03 | 0 | 0 |
| Sunday 27-Jul-03 | 0 | 0 |
| Monday 28-Jul-03 | 3443 | 3535 |
| Tuesday 29-Jul-03 | 4603 | 4020 |
| Wednesday 30-Jul-03 | 4633 | 3423 |
| Thursday 31-Jul-03 | 6259 | 4357 |
| Friday 01-Aug-03 | 7521 | 3690 |
| Saturday 02-Aug-03 | 0 | 0 |
| Sunday 03-Aug-03 | 0 | 0 |
| Monday 04-Aug-03 | 3190 | 3436 |
| Tuesday 05-Aug-03 | 4265 | 3907 |
| Wednesday 06-Aug-03 | 4293 | 3326 |
| Thursday 07-Aug-03 | 5800 | 4234 |
| Friday 08-Aug-03 | 6969 | 3602 |
| Saturday 09-Aug-03 | 0 | 0 |
| Sunday 10-Aug-03 | 0 | 0 |
| Monday 11-Aug-03 | 3915 | 3842 |
| Tuesday 12-Aug-03 | 5235 | 4369 |
| Wednesday 13-Aug-03 | 5269 | 3722 |
| Thursday 14-Aug-03 | 7118 | 4737 |
| Friday 15-Aug-03 | 8553 | 3961 |
| Saturday 16-Aug-03 | 0 | 0 |
| Sunday 17-Aug-03 | 0 | 0 |
| Monday 18-Aug-03 | 3770 | 3978 |
| Tuesday 19-Aug-03 | 5041 | 4524 |
| Wednesday 20-Aug-03 | 5074 | 3853 |
| Thursday 21-Aug-03 | 6855 | 4904 |
| Friday 22-Aug-03 | 8236 | 4081 |
| Saturday 23-Aug-03 | 0 | 0 |
| Sunday 24-Aug-03 | 0 | 0 |
| Monday 25-Aug-03 | 3480 | 3571 |
| Tuesday 26-Aug-03 | 4653 | 4061 |
| Wednesday 27-Aug-03 | 4684 | 3458 |
| Thursday 28-Aug-03 | 6327 | 4401 |
| Friday 29-Aug-03 | 7603 | 3721 |
| Saturday 30-Aug-03 | 0 | 0 |
| Sunday 31-Aug-03 | 0 | 0 |

| Day | Inbound | Outbound |
|---|---|---|
| Monday 01-Sep-03 | 3225 | 3471 |
| Tuesday 02-Sep-03 | 4312 | 3947 |
| Wednesday 03-Sep-03 | 4340 | 3360 |
| Thursday 04-Sep-03 | 5863 | 4277 |
| Friday 05-Sep-03 | 7045 | 3632 |
| Saturday 06-Sep-03 | 0 | 0 |
| Sunday 07-Sep-03 | 0 | 0 |
| Monday 08-Sep-03 | 3958 | 3471 |
| Tuesday 09-Sep-03 | 5291 | 3947 |
| Wednesday 10-Sep-03 | 5326 | 3360 |
| Thursday 11-Sep-03 | 7196 | 4277 |
| Friday 12-Sep-03 | 8646 | 3632 |
| Saturday 13-Sep-03 | 0 | 0 |
| Sunday 14-Sep-03 | 0 | 0 |
| Monday 15-Sep-03 | 3811 | 3882 |
| Tuesday 16-Sep-03 | 5095 | 4414 |
| Wednesday 17-Sep-03 | 5129 | 3760 |
| Thursday 18-Sep-03 | 6929 | 4785 |
| Friday 19-Sep-03 | 8326 | 3996 |
| Saturday 20-Sep-03 | 0 | 0 |
| Sunday 21-Sep-03 | 0 | 0 |
| Monday 22-Sep-03 | 3518 | 4019 |
| Tuesday 23-Sep-03 | 4704 | 4570 |
| Wednesday 24-Sep-03 | 4734 | 3893 |
| Thursday 25-Sep-03 | 6396 | 4955 |
| Friday 26-Sep-03 | 7685 | 4117 |
| Saturday 27-Sep-03 | 0 | 0 |
| Sunday 28-Sep-03 | 0 | 0 |
| Monday 29-Sep-03 | 3260 | 3644 |
| Tuesday 30-Sep-03 | 4358 | 4144 |
| Wednesday 01-Oct-03 | 4387 | 3529 |
| Thursday 02-Oct-03 | 5927 | 4492 |
| Friday 03-Oct-03 | 7121 | 3786 |
| Saturday 04-Oct-03 | 0 | 0 |
| Sunday 05-Oct-03 | 0 | 0 |
| Monday 06-Oct-03 | 4001 | 3506 |
| Tuesday 07-Oct-03 | 5349 | 3987 |
| Wednesday 08-Oct-03 | 5384 | 3394 |
| Thursday 09-Oct-03 | 7274 | 4320 |
| Friday 10-Oct-03 | 8740 | 3663 |
| Saturday 11-Oct-03 | 0 | 0 |
| Sunday 12-Oct-03 | 0 | 0 |
| Monday 13-Oct-03 | 3852 | 3921 |
| Tuesday 14-Oct-03 | 5151 | 4459 |
| Wednesday 15-Oct-03 | 5185 | 3799 |
| Thursday 16-Oct-03 | 7004 | 4834 |
| Friday 17-Oct-03 | 8416 | 4031 |
| Saturday 18-Oct-03 | 0 | 0 |
| Sunday 19-Oct-03 | 0 | 0 |
| Monday 20-Oct-03 | 3556 | 4060 |
| Tuesday 21-Oct-03 | 4755 | 4617 |
| Wednesday 22-Oct-03 | 4786 | 3933 |
| Thursday 23-Oct-03 | 6466 | 5006 |
| Friday 24-Oct-03 | 7769 | 4153 |
| Saturday 25-Oct-03 | 0 | 0 |
| Sunday 26-Oct-03 | 0 | 0 |
| Monday 27-Oct-03 | 3260 | 3644 |
| Tuesday 28-Oct-03 | 4358 | 4144 |
| Wednesday 29-Oct-03 | 4387 | 3529 |
| Thursday 30-Oct-03 | 5927 | 4492 |
| Friday 31-Oct-03 | 7121 | 3786 |

| Day | Inbound | Outbound |
|---|---|---|
| Saturday 01-Nov-03 | 0 | 0 |
| Sunday 02-Nov-03 | 0 | 0 |
| Monday 03-Nov-03 | 3295 | 3541 |
| Tuesday 04-Nov-03 | 4406 | 4027 |
| Wednesday 05-Nov-03 | 4435 | 3429 |
| Thursday 06-Nov-03 | 5991 | 4364 |
| Friday 07-Nov-03 | 7199 | 3695 |
| Saturday 08-Nov-03 | 0 | 0 |
| Sunday 09-Nov-03 | 0 | 0 |
| Monday 10-Nov-03 | 4044 | 3962 |
| Tuesday 11-Nov-03 | 5407 | 4505 |
| Wednesday 12-Nov-03 | 5443 | 3838 |
| Thursday 13-Nov-03 | 7353 | 4884 |
| Friday 14-Nov-03 | 8835 | 4066 |
| Saturday 15-Nov-03 | 0 | 0 |
| Sunday 16-Nov-03 | 0 | 0 |
| Monday 17-Nov-03 | 3894 | 4102 |
| Tuesday 18-Nov-03 | 5207 | 4664 |
| Wednesday 19-Nov-03 | 5241 | 3974 |
| Thursday 20-Nov-03 | 7081 | 5057 |
| Friday 21-Nov-03 | 8508 | 4190 |
| Saturday 22-Nov-03 | 0 | 0 |
| Sunday 23-Nov-03 | 0 | 0 |
| Monday 24-Nov-03 | 3595 | 3681 |
| Tuesday 25-Nov-03 | 4806 | 4186 |
| Wednesday 26-Nov-03 | 4838 | 3565 |
| Thursday 27-Nov-03 | 6536 | 4537 |
| Friday 28-Nov-03 | 7853 | 3819 |
| Saturday 29-Nov-03 | 0 | 0 |
| Sunday 30-Nov-03 | 0 | 0 |
| Monday 01-Dec-03 | 3331 | 3577 |
| Tuesday 02-Dec-03 | 4454 | 4068 |
| Wednesday 03-Dec-03 | 4483 | 3464 |
| Thursday 04-Dec-03 | 6056 | 4408 |
| Friday 05-Dec-03 | 7277 | 3727 |
| Saturday 06-Dec-03 | 0 | 0 |
| Sunday 07-Dec-03 | 0 | 0 |
| Monday 08-Dec-03 | 4088 | 3577 |
| Tuesday 09-Dec-03 | 5466 | 4068 |
| Wednesday 10-Dec-03 | 5502 | 3464 |
| Thursday 11-Dec-03 | 7433 | 4408 |
| Friday 12-Dec-03 | 8931 | 3727 |
| Saturday 13-Dec-03 | 0 | 0 |
| Sunday 14-Dec-03 | 0 | 0 |
| Monday 15-Dec-03 | 3937 | 4002 |
| Tuesday 16-Dec-03 | 5263 | 4551 |
| Wednesday 17-Dec-03 | 5298 | 3877 |
| Thursday 18-Dec-03 | 7157 | 4934 |
| Friday 19-Dec-03 | 8600 | 4102 |
| Saturday 20-Dec-03 | 0 | 0 |
| Sunday 21-Dec-03 | 0 | 0 |
| Monday 22-Dec-03 | 3634 | 4144 |
| Tuesday 23-Dec-03 | 4858 | 4712 |
| Wednesday 24-Dec-03 | 4890 | 4015 |
| Thursday 25-Dec-03 | 6607 | 5110 |
| Friday 26-Dec-03 | 7938 | 4228 |
| Saturday 27-Dec-03 | 0 | 0 |
| Sunday 28-Dec-03 | 0 | 0 |
| Monday 29-Dec-03 | 3402 | 4497 |
| Tuesday 30-Dec-03 | 4788 | 4720 |
| Wednesday 31-Dec-03 | 4820 | 4986 |

*Step 8: Forecasts of Hourly Truck Volumes*

Finally, we can predict the total hourly volume of trucks by using the results from Step 7 and multiplying these figures by the percentages of trucks for each hour. Table 4-10 presents a sample of the 24-hourly distribution for inbound truck volumes on Mondays. Figures K.1 through K.10 in Appendix K illustrate a complete list of inbound and outbound hourly truck volume distributions for each day.

**Table 4-10 Hourly Distributions of Inbound Truck Volume (Attraction Model) on Mondays.**

| Time | Mon 3/17/97 | Mon 3/24/97 | Mon 3/31/97 | Mon 4/7/97 | Mon 4/14/97 | Mon 4/21/97 | Mon 4/28/97 | Average - One Stdev | Average | Average + One Stdev |
|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 1:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 2:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 3:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 4:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 5:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 6:00 | 3% | 1% | 0% | 1% | 2% | 0% | 1% | 0% | 1% | 2% |
| 7:00 | 8% | 2% | 3% | 4% | 6% | 6% | 5% | 3% | 5% | 7% |
| 8:00 | 9% | 8% | 7% | 9% | 8% | 10% | 10% | 8% | 9% | 10% |
| 9:00 | 9% | 11% | 9% | 10% | 9% | 11% | 8% | 8% | 10% | 11% |
| 10:00 | 11% | 11% | 11% | 8% | 11% | 9% | 8% | 8% | 10% | 11% |
| 11:00 | 10% | 10% | 11% | 12% | 11% | 7% | 11% | 9% | 10% | 12% |
| 12:00 | 10% | 9% | 10% | 8% | 13% | 11% | 13% | 9% | 11% | 13% |
| 13:00 | 7% | 11% | 11% | 11% | 9% | 10% | 11% | 8% | 10% | 11% |
| 14:00 | 7% | 11% | 10% | 8% | 10% | 9% | 11% | 8% | 9% | 11% |
| 15:00 | 10% | 13% | 10% | 11% | 9% | 11% | 11% | 10% | 11% | 12% |
| 16:00 | 8% | 10% | 10% | 10% | 9% | 10% | 9% | 8% | 9% | 10% |
| 17:00 | 5% | 2% | 3% | 3% | 2% | 3% | 2% | 2% | 3% | 4% |
| 18:00 | 1% | 1% | 2% | 1% | 0% | 1% | 0% | 0% | 1% | 1% |
| 19:00 | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 1% |
| 20:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 21:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 22:00 | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% |
| 23:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

# Chapter 5

## CONCLUSIONS AND RECOMMENDATIONS

The immediate implementation of the developed trip generation models in this study is for short-term prediction of heavy truck volumes. The regression models forecast current or near-term (5 years or less) truck trip generation, based primarily on internal port activity.

There is a potential benefit for planners and other users of the model for predicting truck traffic even for very short time horizons, e.g., few weeks in the future. Although no infrastructure modifications could be applied for this time frame, transportation system management (TSM) solutions can be implemented to alleviate anticipated traffic problems, e.g., traffic signal adjustments.

The implementation of time series and production/attraction models for long-term prediction should be applied with caution. Truck volumes over the long term are expected to be vastly higher than the present period. For this latter situation, truck traffic over the long term needs to be quantified in the near future to assist with long-term planning solutions, such as infrastructure improvements and roadway expansions.

A much more extensive and complicated analysis is required for long-range forecasting. The developed and validated regression models for near-term truck trip generation at the port combined with the time series analysis for long-term prediction of the independent variable (freight units) provide the foundation for a potential long-term forecasting tool.

The success from these truck trip generation models for this small urban region can be utilized to build a freight movement model for a larger region, which might also include effects on the interstate highways (I-95 and I-395). This is planned for Phase III of this study.

It cannot be assumed for the long-term (20 years) that the dependent variable of truck trip generation will necessarily be related to the independent variable of internal freight activity according to the regression models. Unexpected variables can significantly alter the long-term trend. For example, demand for port usage can be a function of economic activities in regions several thousand miles outside of the United States. This is applicable to the Port of Miami's situation with its freight activity being dominated by international imports and exports.

Another influencing scenario could emerge from the continuing development and competition of nearby ports (i.e., Freeport, Everglades, Canaveral, Jacksonville, etc.). A third major influence might be from cruiseship service. Port of Miami is currently the world's largest cruise port by passenger volume and revenue. Cruiseship service could become more profitable in the future and affect the financial viability of maintaining or expanding cargo operations.

A viable alternative has been proposed by Beiswenger, Hoch, and Associates *(17)* for relieving truck traffic from the street network that is destined for the nearby intermodal rail yard. The proposal is to build an elevated, dedicated truck route over the railroad's (Florida East Coast's) right-of-way. This would be a long-term solution involving a major infrastructure change. However, this alternative may be resisted by the local community. A trip distribution and modal split analysis would be required to model this scenario. As the main goal of this multi-phase study is to develop a statewide heavy truck model on road networks connecting with Florida seaports, the future tasks will focus on mode choice, trip distribution, and trip assignment models. These are planned in Phases II and III of this study.

# REFERENCES


1. Port of Miami 1998 Official Directory

2. Florida Trade Data Center; Villamil, Antonio and Cruz, Robert; A Forecast of Florida's International Trade in 2005: Opportunities and Challenges, The Washington Economics Group, January 1998.

3. Wright and Ashford, Transportation Engineering, Planning and Design, published by Wiley and Sons, 1989.

4. Jackson, Michael P., Perspectives on the Research Framework: Freight Stakeholders National Network, American Trucking Associations Foundation, National Conference on Setting an Intermodal Transportation Research Framework, Washington, D.C., March 4-5, 1996.

5. Middendorf, David; Jelavich, Mark; Ellis, Raymond; Development and Application of Statewide, Multimodal Freight Forecasting Procedures for Florida, TRB, Washington, D.C., 1982.

6. Casavant, Kenneth; Blankenship, Gillis; Howard, Charles Jr.; "Survey Methodology for Collecting Freight Truck and Destination Data", Transportation Research Board, National Academy Press, Washington, D.C., 1995.

7. Casavant, Kenneth; Arnis, Amy; Gillis, William; Nell, Waynette; Jessup, Eric; "Modeling Washington State Truck Freight Flows Using GIS-T: Data Collection and Design", Transportation Research Record No. 1497, TRB National Research Council, National Academy Press, Washington, D.C., 1995.

8. Dade County Freight Movement Study, The Corradino Group, Louisville, Kentucky, 1995.

9. Minnesota Freight Flows - 1990, prepared by Hubert H. Humphrey Institute of Public Affairs at the University of Minnesota for the Minnesota Department of Transportation, February 1995.

10. O'Rourke, Laurence; Lawrence, Michael F., "Strategies for Goods Movement in a Sustainable Transportation System", published by the American Council for an Energy-Efficient Economy (ACEEE), 1995.

11. List, George F., Turnquist, Mark A., "A GIS-Based Approach for Estimating Truck Flow Patterns in Urban Settings, Journal of Advanced Transportation, Vol. 29, No. 3, pp. 281-298, 1994.

12. List, George F., Turnquist, Mark A., "Estimating Truck Travel Patterns in Urban Areas", Transportation Research Record 1430, TRB National Research Council, National Academy Press, Washington, D.C., 1994.

13. Texas Department of Transportation; Easley, Richard B. and Walton, Michael; Applicability of the Technologies of ITS in Commercial Vehicle Operations at the Port of Houston's Intermodal Marine Container Terminal with Case Studies of Existing Systems, Center for Transportation Research, University of Texas at Austin, February 1995.

14. Florida Department of Transportation Central Office Systems Planning, FSUTMS Basic Workshop Participants Workbook, August 31 - September 4, 1998.

15. Florida Department of Transportation Central Office Systems Planning, Draft to Statewide Model Task Force on Freight Modeling and Forecasting Techniques, Tallahassee, Florida, February 1998.

16. Pankratz, Alan; asting with Dynamic Regression Models", Wiley and Sons, 1991.

17. Beiswenger, Hoch and Associates, Inc., Port of Miami Proposed Truck Viaduct Routes, May 1997.

# APPENDIX A

## Sample of Gate Pass Cards

## Figure A-1: A Gate Pass Card With Weight Information

**PORT of MIAMI**

# GATE PASS

SCALE FILE COPY S264773

REGISCOPE NO.

METRO-DADE

**METROPOLITAN DADE COUNTY FLORIDA**
**SEAPORT DEPARTMENT**

DATE & TIME IN ............ DATE & TIME OUT ............

CARRIER (Trucking Co.) ............ TRAC./LIC. No. ............ STATE ............ DRIVER 97 FEB 20 PM 12:04

| | | |
|---|---|---|
| **IN** | ☐ EMPTY | TRAILER/CONTAINER No. |
| | ☐ LOAD | TRAILER/CONTAINER No. |
| | ☐ CHASIS/FLATBED | CHASSIS/FLATBED No. |
| **OUT** | ☐ EMPTY | TRAILER/CONTAINER No. |
| | ☐ LOAD | TRAILER/CONTAINER No. |
| | ☐ CHASIS/FLATBED | CHASSIS/FLATBED No. |
| **IN** | ☐ EMPTY | TRAILER/CONTAINER No. |
| | ☐ LOAD | TRAILER/CONTAINER No. |
| | ☐ CHASIS/FLATBED | CHASSIS/FLATBED No. |
| **OUT** | ☐ EMPTY | TRAILER/CONTAINER No. |
| | ☐ LOAD | TRAILER/CONTAINER No. |
| | ☐ CHASIS/FLATBED | CHASSIS/FLATBED No. |

**SEAPORT SCALE**
WEIGHT GROSS

11:44AM 21FEB97 GROSS 66300 LB

RECEIVED

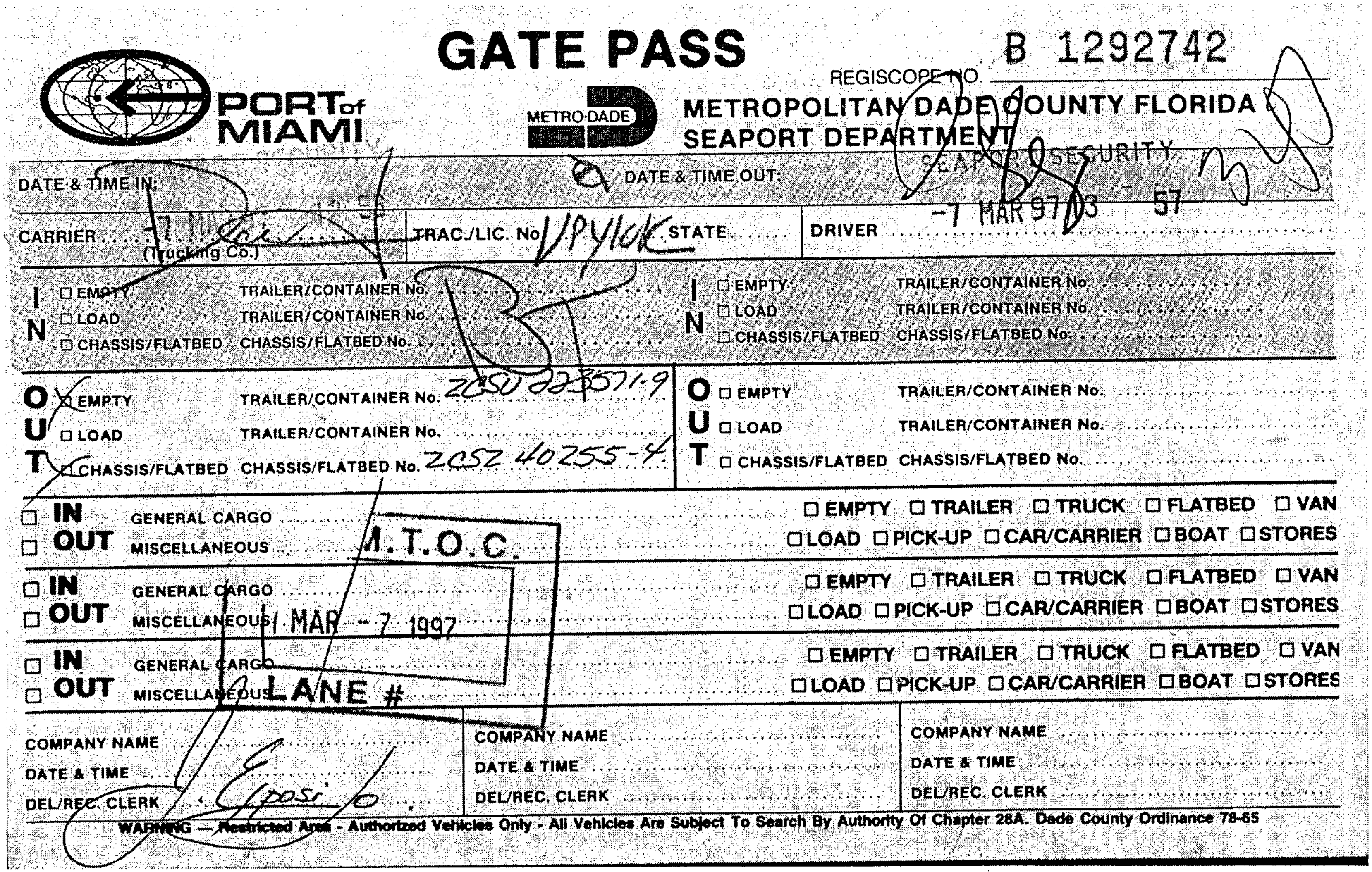
| | |
|---|---|
| COMPANY NAME ............ | COMPANY NAME ............ |
| DATE & TIME ............ | DATE & TIME ............ |
| DEL/REC. CLERK ............ | DEL/REC. CLERK ............ |

PRINT DRIVER'S NAME

DRIVER'S SIGNATURE

**WARNING: • Restricted Area • Authorized Vehicles Only • All Vehicles Are Subject To Search By Authority of Chapter 28A. Dade County Ordinance 78-65**

**Figure A-2: A Gate Pass Card Without Weight Information**


GATE PASS

B 1292742

REGISCOPE NO.

PORT of MIAMI

METRO-DADE

METROPOLITAN DADE COUNTY FLORIDA
SEAPORT DEPARTMENT

SEAPORT SECURITY

DATE & TIME IN:

DATE & TIME OUT: -7 MAR 97 03 57

CARRIER (Trucking Co.)

TRAC./LIC. No. VPY10K

STATE

DRIVER

IN: ☐ EMPTY ☐ LOAD ☐ CHASSIS/FLATBED — TRAILER/CONTAINER No. / TRAILER/CONTAINER No. / CHASSIS/FLATBED No.

IN: ☐ EMPTY ☐ LOAD ☐ CHASSIS/FLATBED — TRAILER/CONTAINER No. / TRAILER/CONTAINER No. / CHASSIS/FLATBED No.

OUT: ☒ EMPTY ☐ LOAD ☒ CHASSIS/FLATBED — TRAILER/CONTAINER No. ZCSU 223571-9 / TRAILER/CONTAINER No. / CHASSIS/FLATBED No. ZCSZ 40255-4

OUT: ☐ EMPTY ☐ LOAD ☐ CHASSIS/FLATBED — TRAILER/CONTAINER No. / TRAILER/CONTAINER No. / CHASSIS/FLATBED No.

☐ IN ☐ OUT GENERAL CARGO / MISCELLANEOUS — ☐ EMPTY ☐ TRAILER ☐ TRUCK ☐ FLATBED ☐ VAN ☐ LOAD ☐ PICK-UP ☐ CAR/CARRIER ☐ BOAT ☐ STORES

☐ IN ☐ OUT GENERAL CARGO / MISCELLANEOUS — ☐ EMPTY ☐ TRAILER ☐ TRUCK ☐ FLATBED ☐ VAN ☐ LOAD ☐ PICK-UP ☐ CAR/CARRIER ☐ BOAT ☐ STORES

☐ IN ☐ OUT GENERAL CARGO / MISCELLANEOUS — ☐ EMPTY ☐ TRAILER ☐ TRUCK ☐ FLATBED ☐ VAN ☐ LOAD ☐ PICK-UP ☐ CAR/CARRIER ☐ BOAT ☐ STORES

M.T.O.C.
MAR - 7 1997
LANE #

COMPANY NAME / DATE & TIME / DEL/REC. CLERK

COMPANY NAME / DATE & TIME / DEL/REC. CLERK

COMPANY NAME / DATE & TIME / DEL/REC. CLERK

WARNING — Restricted Area - Authorized Vehicles Only - All Vehicles Are Subject To Search By Authority Of Chapter 28A. Dade County Ordinance 78-65

# APPENDIX B

## Sample of Daily Dock Reports

TIDES: HIGH 1025-2257
LOW 0434-1657

PORT OF MIAMI
DAILY DOCK REPORT
07/31/96
07:49

SUNRISE: 0649 PAGE:
SUNSET: 2011

| | FLAG/ BERTH | INBOUND DATE/TIME | OUTBOUND DATE/TIME | VESSEL LENGTH/WT | AGENT/ STEVEDORE | PURPOSE & CARGO | PORT OF CAL LAST/NEXT |
|---|---|---|---|---|---|---|---|
| **VESSELS IN PORT** | | | | | | | |
| MSRC 451 | UNITED STATES | 07/01/96 | 07/31/96 | 300 | MARINE SPILL RE | | MIAMI |
| (WCB770)MARINE SPILL RESPONC | NOAA-E | 0001 | 2400 | 869 | NONE | | MIAMI |
| NORDSEE | ANTIGUA & BARBUD | 07/27/96 | 07/31/96 | 291 | SEABOARD MARINE | CONT. | SEA |
| (V2NW )SEABOARD MARINE LTD | 93 | 1845 | 2100 | 2579 | CONTINENTAL | CONT. | PORT AU PRINC |
| SEABOARD VENTURE | NORWAY | 07/29/96 | 08/01/96 | 373 | SEABOARD MARINE | CONT | MONTEGO BAY |
| (LATJ2 )SEABOARD MARINE LTD. | 74 | 1550 | 1500 | 6991 | CONTINENTAL | CONT | KINGSTON |
| TROPICANA | BAHAMAS | 07/29/96 | 07/31/96 | 385 | TROPICANA CRUIS | | FREEPORT |
| (C6DQ5 )JUBILEE OF THE BAHAM | 6 (6-8) PST | 1745 | 1930 | 4548 | OCEANIC | PASSENGERS | SEA |
| MAYVIEW MAERSK | DENMARK | 07/31/96 | 07/31/96 | 965 | MAERSK LINE AGE | CONT | MANZANILLO |
| (OWEB2 )MAERSK LINE | G/C 102-1/2W | 0605 | 1800 | 52181 | UNIVERSAL MARIT | CONT | CHARLESTON, S |
| THORKIL MAERSK | SINGAPORE | 07/31/96 | 07/31/96 | 529 | MAERSK LINE AGE | CONT | MANZANILLO |
| (9VFE )MAERSK LINE | G/C 111-1/2W | 0645 | 1700 | 17700 | UNIVERSAL | CONT | CHARLESTON, S |
| SEABOARD UNIVERSE | LIBERIA | 07/31/96 | 07/31/96 | 527 | SEABOARD MARINE | TRLS./CONT | SANTO THOMAS D |
| (ELRU3 )SEABOARD MARINE LTD | 91 | 0715 | 2130 | 15375 | CONTINENTAL | TRLS./CONT | PUERTO CORTES |
| **VESSELS DUE IN PORT WITHIN 1 DAY** | | | | | | | |
| JAMAICA PROVIDER | BELIZE | 07/31/96 | 07/31/96 | 301 | SEABOARD MARINE | TRLS./CONT | NASSAU |
| (V3NY4 )SEABOARD MARINE LTD | 76 | 0900 | 1800 | 2676 | CONTINENTAL | TRLS./CONT | NASSAU |
| CSAV RENGO | GERMANY | 07/31/96 | 08/01/96 | 603 | CHILEAN LINE | CONT. | BALBOA |
| (DIKV )CHILEAN LINE | G/C 111W | 2000 | 1900 | 16800 | FLA. STEVEDORES | CONT. | NEW YORK |
| MSC CHIARA | PANAMA | 07/31/96 | 08/01/96 | 683 | MEDITERRANEAN S | CONT. | CHARLESTON, S. |
| (3EZQ8 )MEDITERRANEAN SHIPPI | G/C 116-1/2W | 2000 | 1600 | 26699 | FL. STEVEDORES | CONT. | NEW ORLEANS, |
| TROPICANA | BAHAMAS | 07/31/96 | 08/01/96 | 385 | TROPICANA CRUIS | PASSENGERS | SEA |
| (C6DQ5 )JUBILEE OF THE BAHAM | 6 (6-8) PST | 2400 | 1930 | 4548 | OCEANIC | PASSENGERS | SEA |
| BELGRANO | CYPRUS | 08/01/96 | 08/01/96 | 425 | FAROVI SHIPPING | CONT | HOUSTON, TEXAS |
| (P3HR2 )FROTA AMAZONICA | TBA | 0500 | 2000 | 7240 | FL.STEVE. | CONT | MANAUS |
| NOBLEZA | LIBERIA | 08/01/96 | 08/01/96 | 539 | WILHELMSEN LINE | CONT | JACKSONVILLE, |
| (ELDF7 )NYK/NOS | 55-W | 0600 | 2100 | 29933 | OCEANIC | CONT | RIO HAINA |
| ROYAL SEAS | UKRAINE | 08/01/96 | 08/02/96 | 513 | SUNSHINE SHIPPI | PASSENGERS | TAMPA, FLORIDA |
| (ELSH9 )DISCOVERY CRUISES, I | 10 (10-2) SST | 0800 | 1000 | 15409 | CONTINENTAL | PASSENGERS | SEA |
| ATLANTIS | ANTIGUA & BARBUD | 08/01/96 | 08/01/96 | 291 | SEABOARD MARINE | CONT. | KINGSTON |
| (V2CT )SEABOARD MARINE LTD | 183W | 0930 | 2100 | 2563 | CONTINENTAL | CONT. | PORT AU PRINC |
| HOOD ISLAND | BAHAMAS | 08/01/96 | 08/01/96 | 586 | ECUADORIAN LINE | CONT. | GUAYAQUIL |
| (C6LU4 )ECUADORIAN LINE | G/C 123W | 1000 | 1900 | 14061 | CONTINENTAL | CONT. | ZEEBRUGGE |

# APPENDIX C

## Sample of Ganty Crane Activities Reports

PGM: FISB590
RUN DATE: 04/08/97

FISCAL OPERATIONS
CRANE ACTIVITY BY SHIPLINE

| SHIPLINE /VESSEL NAME | SERVICE DATE | S/T HRS. | O/T HRS. | D/T MINS |
|---|---|---|---|---|
| *** VACANT *** | | | | |
| MEHMET KALKAVAN | 03/03/97 | 5 | 1 | |
| CURRENT MONTH LINE TOTALS --------------------> | | 5 | 1 | |
| *** CCNI *** | | | | |
| CCNI ANAKENA | 01/12/97 | | -2 | |
| CCNI ANAKENA | 03/28/97 | | 6 | |
| CCNI ARAUCO | 03/14/97 | 5 | 1 | |
| CCNI ARAUCO | 03/22/97 | | 11 | |
| CURRENT MONTH LINE TOTALS --------------------> | | 5 | 16 | |
| *** CHILEAN LINE (CSAV) *** | | | | |
| CSAV LONQUIMAY | 03/07/97 | | 9 | |
| CSAV LONQUIMAY | 03/15/97 | | 13 | |
| CSAV RANCO | 03/13/97 | 6 | | |
| CSAV RENGO | 03/08/97 | | 8 | |
| CSAV ROMERAL | 03/03/97 | | 16 | |
| CSAV RUNGUE | 03/23/97 | | 9 | |
| CSAV RUNGUE | 03/31/97 | 7 | 5 | |
| CSAV RUPANCO | 03/07/97 | 8 | 2 | 30 |
| CSAV RUPANCO | 03/07/97 | | | -15 |
| CURRENT MONTH LINE TOTALS --------------------> | | 21 | 62 | 15 |
| *** CHO YANG *** | | | | |
| HANSA CARRIER | 03/18/97 | 2 | 9 | |
| HAVELLAND | 02/22/97 | | | |
| HAVELLAND | 03/28/97 | | 4 | |
| CURRENT MONTH LINE TOTALS --------------------> | | 2 | 13 | |
| *** COLUMBIA COASTAL *** | | | | |
| COLUMBIA MIAMI (BARGE) | 03/05/97 | | 4 | |
| COLUMBIA MIAMI (BARGE) | 03/12/97 | | 3 | |
| COLUMBIA MIAMI (BARGE) | 03/19/97 | | 11 | |
| COLUMBIA MIAMI (BARGE) | 03/27/97 | | 1 | |
| CURRENT MONTH LINE TOTALS --------------------> | | | 19 | |
| *** COLUMBUS LINE *** | | | | |
| HEICON | 03/16/97 | | 12 | |

S/T = Standard Time
O/T = Over Time

# APPENDIX D

## Sample of Trailer/Container Activity Reports

FOREIGN <---- INBOUND ACTIVITY ----> <---- OUTBOUND ACTIVITY -->

| SHIPPING LINE/ VESSEL NAME | ARRIVAL DATE | INBOUND -GROSS WEIGHTS- CNTNRS | INBOUND -GROSS WEIGHTS- TRAILERS | INBOUND QUANTITIES CONTAINERS 20" FUL | INBOUND CONTAINERS 20" EMP | INBOUND CONTAINERS 40" FUL | INBOUND CONTAINERS 40" EMP | INBOUND TRAILERS FUL | INBOUND TRAILERS EMP | OUTBOUND -GROSS WEIGHTS- CNTNRS | OUTBOUND -GROSS WEIGHTS- TRAILERS | OUTBOUND QUANTITIES CONTAINERS 20" FUL | OUTBOUND CONTAINERS 20" EMP | OUTBOUND CONTAINERS 40" FUL | OUTBOUND CONTAINERS 40" EMP | OUTBOUND TRAILERS FUL | OUTBOUND TRAILERS EMP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAMAICA PROVIDER | 50896 | 18 | 88 | | 8 | | | 2 | 9 | 83 | 331 | 6 | | | | 14 | |
| JAMAICA PROVIDER | 51096 | 2 | 90 | | 1 | | | 1 | 11 | 80 | 358 | 6 | | | | 16 | |
| JAMAICA PROVIDER | 51296 | 23 | 50 | | 10 | | | 1 | 5 | 73 | 256 | 4 | | | | 12 | |
| JAMAICA PROVIDER | 51596 | 9 | 110 | | 4 | | | 1 | 14 | 120 | 469 | 9 | | | | 18 | |
| JAMAICA PROVIDER | 51796 | | 40 | | | | | | 6 | 89 | 203 | 6 | | | | 9 | |
| JAMAICA PROVIDER | 52096 | 20 | 84 | | 9 | | | 1 | 9 | 113 | 156 | 6 | | | | 7 | |
| VESSEL TOTAL -------------> | | 148 | 876 | 1 | 60 | | | 13 | 101 | 905 | 3464 | 58 | | | | 148 | |
| KIRK.CHALLENGER | 42696 | 72 | 193 | | 32 | | | | 29 | 355 | 874 | 32 | | | | 39 | |
| KIRK CHALLENGER | 50396 | 9 | 596 | | 4 | | | 23 | 18 | 466 | 984 | 24 | | | | 41 | |
| KIRK CHALLENGER | 51096 | 61 | 130 | | 27 | | | | 20 | 217 | 994 | 17 | | | | 45 | |
| KIRK CHALLENGER | 51796 | 23 | 195 | 1 | 9 | | | | 29 | 297 | 930 | 17 | | | | 40 | |
| VESSEL TOTAL -------------> | | 165 | 1114 | 1 | 72 | | | 23 | 96 | 1335 | 3782 | 90 | | | | 165 | |
| KIRK MARINER | 42596 | 81 | 807 | | 36 | | | 41 | 18 | 119 | 1775 | 10 | | | | 79 | |
| KIRK MARINER | 50396 | 94 | 367 | 2 | 38 | | | 3 | 42 | 280 | 1369 | 19 | | | | 63 | |
| KIRK MARINER | 50996 | 63 | 661 | | 28 | | | 18 | 40 | 273 | 1568 | 21 | | | | 69 | |
| KIRK MARINER | 51696 | 65 | 817 | 3 | 16 | | | 26 | 32 | 336 | 1281 | 29 | | | | 62 | |
| VESSEL TOTAL -------------> | | 303 | 2652 | 5 | 118 | | | 88 | 132 | 1008 | 5993 | 79 | | | | 273 | |
| SEABOARD CARIBE | 42896 | 20 | 3118 | | 9 | | | 143 | | 199 | 2520 | 23 | | | | 124 | 13 |
| SEABOARD CARIBE | 50596 | 27 | 2666 | 12 | | | | 108 | | 101 | 2538 | 15 | | | | 124 | 18 |
| SEABOARD CARIBE | 51296 | 267 | 2147 | 16 | | | | 83 | 55 | 107 | 2506 | 20 | | | | 124 | 16 |
| SEABOARD CARIBE | 51996 | 242 | 2031 | 9 | 30 | | | 92 | 41 | 70 | 2596 | 8 | | | | 125 | 6 |
| VESSEL TOTAL -------------> | | 556 | 9962 | 37 | 39 | | | 426 | 96 | 477 | 10160 | 66 | | | | 497 | 53 |
| SEABOARD EXPRESS | 50896 | | | | | | | | | 341 | 1683 | 27 | | | | 84 | |
| SEABOARD EXPRESS | 51596 | 114 | 1505 | 14 | 14 | | | 55 | 98 | 519 | 2054 | 33 | 1 | | | 100 | 26 |
| VESSEL TOTAL -------------> | | 114 | 1505 | 14 | 14 | | | 55 | 98 | 860 | 3737 | 60 | 1 | | | 184 | 26 |
| SEABOARD SUN | 43096 | 71 | 1595 | 2 | 28 | | | 25 | 108 | 580 | 2600 | 62 | | | | 115 | |
| SEABOARD SUN | 51296 | 348 | 1780 | 19 | 33 | | | 61 | 26 | 601 | 2360 | 48 | | | | 102 | |
| VESSEL TOTAL -------------> | | 419 | 3375 | 21 | 61 | | | 86 | 134 | 1181 | 4960 | 110 | | | | 217 | |
| SHIPLINE TOTAL -------> | | 2471 | 19484 | 87 | 480 | 2 | 73 | 691 | 657 | 7917 | 32146 | 549 | 1 | 64 | | 1485 | 79 |

# APPENDIX E

## Sample of Monthly Trailer/Container Performance Reports

METROPOLITAN DADE COUNTY SEAPORT DEPARTMENT MONTH : AUGUST YEAR : 1997

PERFORMANCE REPORT (STATISTICAL) PAGE 1

| PERSONNEL: | THIS MONTH | LAST MONTH | SAME MONTH LAST YEAR |
|---|---|---|---|
| BUDGETED | 212 | 202 | 214 |
| EMPLOYED | 197 | 202 | 214 |

| | THIS MONTH | | LAST MONTH | | SAME MONTH LAST YEAR | | THIS YEAR TO DATE | | LAST YEAR TO DATE | |
|---|---|---|---|---|---|---|---|---|---|---|
| SHIPS DOCKED: | U.S. | FOREIGN | U.S. | FOREIGN | U.S. | FOREIGN | U.S. | FOREIGN | U.S. | FOREIG |
| CARGO | 25 | 196 | 18 | 193 | 16 | 199 | 182 | 2,074 | 187 | 2,133 |
| PASSENGER | | 109 | | 93 | | 117 | 1 | 1,286 | | 1,598 |
| TOTAL | 25 | 305 | 18 | 286 | 16 | 316 | 183 | 3,360 | 187 | 3,731 |

| | THIS MONTH | LAST MONTH | SAME MONTH LAST YEAR | THIS YEAR TO DATE | LAST YEAR TO DATE |
|---|---|---|---|---|---|
| NO. BERTH DAYS: | | | | | |
| CARGO SHIPS | 321 | 311 | 321 | 3,226 | 3,313 |
| PASSENGER SHIPS | 90 | 83 | 102 | 1,155 | 1,306 |
| TOTAL | 411 | 394 | 423 | 4,381 | 4,619 |
| SHIPS TONNAGE: | | | | | |
| CARGO SHIPS | 2,897,179 | 2,811,531 | 2,966,468 | 30,999,202 | 31,276,426 |
| PASSENGER SHIPS | 4,135,452 | 3,649,229 | 3,480,277 | 44,552,660 | 42,074,163 |
| TOTAL SHIPS TONNAGE | 7,032,631 | 6,460,760 | 6,446,745 | 75,551,862 | 73,350,589 |
| PASSENGERS: | | | | | |
| U.S. FLAG SHIPS | | | | | |
| FOREIGN FLAG SHIPS | 324,236 | 283,429 | 246,039 | 3,010,462 | 2,877,479 |
| TOTAL | 324,236 | 283,429 | 246,039 | 3,010,462 | 2,877,479 |
| PARKING LOT VEHICLES | 16,832 | 14,287 | 14,239 | 153,733 | 142,300 |
| CARGO TONNAGE: | | | | | |
| U.S. FLAG SHIPS: | | | | | |
| INBOUND IN TRAILERS | 5,351 | 5,206 | 1,537 | 44,469 | 14,599 |
| INBOUND IN CONTAINERS | 45,746 | 29,985 | 15,330 | 267,349 | 148,263 |
| INBOUND OTHERS | 2 | | | 7 | 936 |
| OUTBOUND IN TRAILERS | 1,837 | 1,277 | 1,069 | 15,391 | 15,558 |
| OUTBOUND IN CONTAINERS | 10,007 | 11,049 | 6,492 | 72,734 | 83,991 |
| OUTBOUND OTHERS | | | | 11 | 99 |
| TOTAL U.S. FLAG-SHIPS | 62,943 | 47,517 | 24,428 | 399,961 | 263,446 |
| FOREIGN SHIPS: | | | | | |
| INBOUND IN TRAILERS | 61,372 | 65,287 | 55,971 | 808,297 | 709,983 |
| INBOUND IN CONTAINERS | 176,841 | 224,681 | 192,686 | 1,927,417 | 1,835,843 |
| INBOUND OTHERS | 4,177 | 4,067 | 7,853 | 58,368 | 51,983 |
| OUTBOUND IN TRAILERS | 100,847 | 102,773 | 81,678 | 1,182,867 | 968,493 |
| OUTBOUND IN CONTAINERS | 145,811 | 155,000 | 140,752 | 1,661,002 | 1,451,331 |
| OUTBOUND OTHERS | 12,023 | 13,014 | 13,480 | 158,791 | 167,327 |
| TOTAL FOREIGN SHIPS | 501,071 | 564,822 | 492,420 | 5,796,742 | 5,184,960 |
| GRAND TOTAL ALL CARGO | 564,014 | 612,339 | 516,848 | 6,196,703 | 5,448,406 |
| NUMBER OF TRAILERS: | | | | | |
| INBOUND | 5,585 | 6,313 | 3,809 | 62,317 | 52,589 |
| OUTBOUND | 5,332 | 5,937 | 4,295 | 65,557 | 53,429 |
| TOTAL | 10,917 | 12,250 | 8,104 | 127,874 | 106,018 |
| NUMBER OF CONTAINERS: | | | | | |
| INBOUND | 15,065 | 16,950 | 13,609 | 146,902 | 133,713 |
| OUTBOUND | 12,790 | 13,729 | 12,085 | 130,304 | 118,870 |
| TOTAL | 27,855 | 30,679 | 25,694 | 277,206 | 252,583 |

# APPENDIX F

## Shceffe's Test

# EXPLANATION OF SCHEFFE'S STATISTICAL TEST

Scheffe's Equation determines whether there are significant differences between mean values. Scheffe's method is rigorous. In other words, it reduces the probability of making a Type I error versus less rigorous methods. Application of Scheffe's involves a series of statistical F-tests.

$$F = \frac{(N_1 * N_2) * (\overline{X}_1 - \overline{X}_2)^2}{(N_1 + N_2) * S^2}$$

$\overline{X}_1$ = Mean value of data set $X_1$

$\overline{X}_2$ = Mean value of data set $X_2$

S = Sum of squares/ degrees of freedom of groups added together

$N_1$ = Number of values in data set $X_1$

$N_2$ = Number of values in data set $X_2$

Each of the following comparisons of data sets A, B, and C would represent a different F-test:

$\overline{A}$ versus $\overline{B}$

$\overline{A}$ versus $\overline{C}$

$\overline{B}$ versus $\overline{C}$

These tests are used to evaluate the differences between two variances in order to decide if it is practical to pool the two together.

# APPENDIX G

## Wilcoxon Rank Sum test

**The Wilcoxon Rank Sum Test for Large Samples**

**(n1 >= 10 and n2 >= 10)**

---

Ho: Relative frequency distributions for populations 1 and 2 are identical.

Ha: Relative frequency distribution for population 1 is shifted either to the left or to the right of the distribution of population 2.

Test Statistic :

$$Z = \frac{T1 - [\frac{n1 * n2 + n1 * (n1 + 1)}{2}]}{\sqrt{\frac{n1 * n2 * (n1 + n2 + 1)}{12}}}$$

n1 = Size of Sample 1

n2 = Size of Sample 2

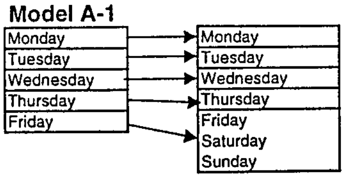
T1 = Sum of Rank of Sample 1

Rejection Region : $Z > Z_{\alpha/2}$ or $Z < -Z_{\alpha/2}$

# APPENDIX H

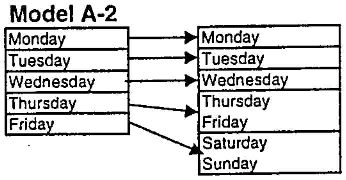
## Inbound Freight Truck Movement Combinations
## (Attraction Model)

## Model A-1



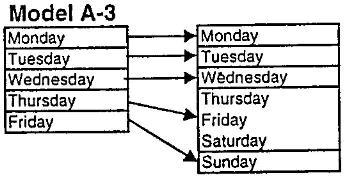

| | |
|---|---|
| Total sample Size | *57* |
| % of outlier | *22.81* |
| Model sample Size | *44* |
| R square Value | *0.412* |
| SSE/Mean | *0.22* |

## Model A-2



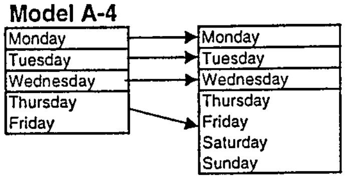

| | |
|---|---|
| Total sample Size | *57* |
| % of outlier | *17.54* |
| Model sample Size | *47* |
| R square Value | *0.16* |
| SSE/Mean | *0.31* |

## Model A-3



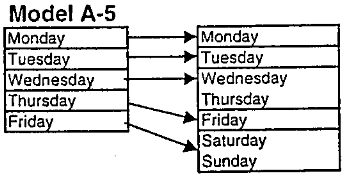

| | |
|---|---|
| Total sample Size | *57* |
| % of outlier | *21.05* |
| Model sample Size | *45* |
| R square Value | *0.054* |
| SSE/Mean | *0.28* |

## Model A-4



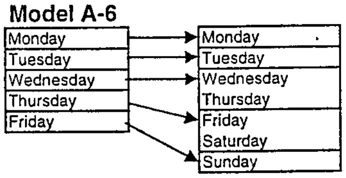

| | |
|---|---|
| Total sample Size | *48* |
| % of outlier | *22.92* |
| Model sample Size | *37* |
| R square Value | *0.723* |
| SSE/Mean | *0.32* |

## Model A-5



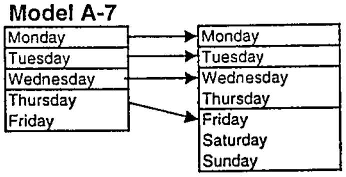

| | |
|---|---|
| Total sample Size | *57* |
| % of outlier | *19.30* |
| Model sample Size | *46* |
| R square Value | *0.04* |
| SSE/Mean | *0.27* |

## Model A-6



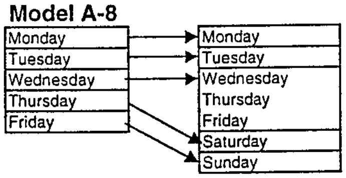

| | |
|---|---|
| Total sample Size | *57* |
| % of outlier | *17.54* |
| Model sample Size | *47* |
| R square Value | *0.03* |
| SSE/Mean | *0.28* |

## Model A-7



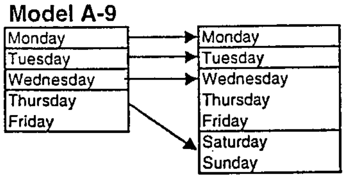

| | |
|---|---|
| Total sample Size | *57* |
| % of outlier | *35.09* |
| Model sample Size | *37* |
| R square Value | *0.56* |
| SSE/Mean | *0.4* |

## Model A-8



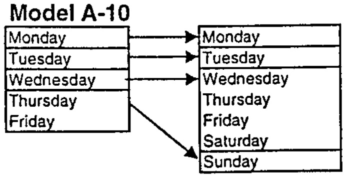

| | |
|---|---|
| Total sample Size | *57* |
| % of outlier | *17.54* |
| Model sample Size | *47* |
| R square Value | *0.017* |
| SSE/Mean | *0.318* |

## Model A-9



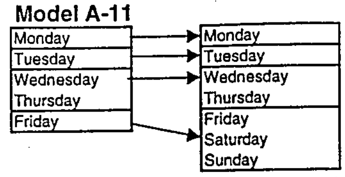

| | |
|---|---|
| Total sample Size | *48* |
| % of outlier | *22.92* |
| Model sample Size | *37* |
| R square Value | *0.04* |
| SSE/Mean | *0.59* |

## Model A-10



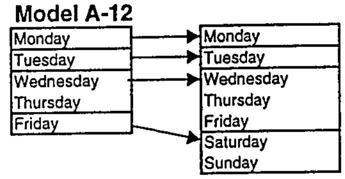

| | |
|---|---|
| Total sample Size | *48* |
| % of outlier | *25.00* |
| Model sample Size | *36* |
| R square Value | *0.03* |
| SSE/Mean | *0.59* |

## Model A-11



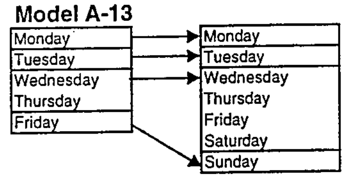

| | |
|---|---|
| Total sample Size | *48* |
| % of outlier | *18.75* |
| Model sample Size | *39* |
| R square Value | *0.138* |
| SSE/Mean | *0.39* |

## Model A-12



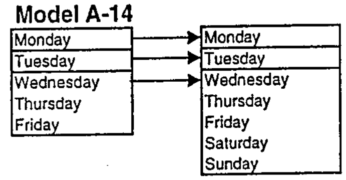

| | |
|---|---|
| Total sample Size | *48* |
| % of outlier | *25.00* |
| Model sample Size | *36* |
| R square Value | *0.582* |
| SSE/Mean | *0.26* |

## Model A-13



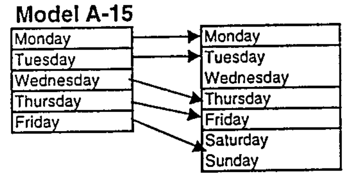

| | |
|---|---|
| Total sample Size | *48* |
| % of outlier | *25.00* |
| Model sample Size | *36* |
| R square Value | *0.63* |
| SSE/Mean | *0.25* |

## Model A-14



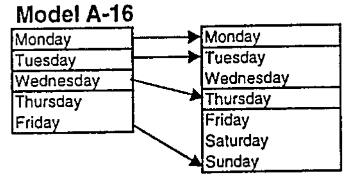

| | |
|---|---|
| Total sample Size | *36* |
| % of outlier | *25.00* |
| Model sample Size | *27* |
| R square Value | *0.87* |
| SSE/Mean | *0.25* |

## Model A-15



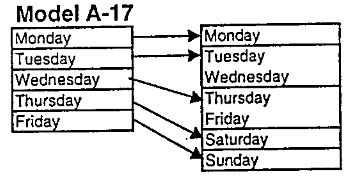

| | |
|---|---|
| Total sample Size | *57* |
| % of outlier | *-10.53* |
| Model sample Size | *63* |
| R square Value | *0.106* |
| SSE/Mean | *0.29* |

## Model A-16



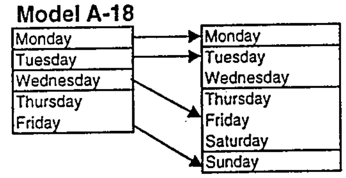

| | |
|---|---|
| Total sample Size | *48* |
| % of outlier | *18.75* |
| Model sample Size | *39* |
| R square Value | *0.668* |
| SSE/Mean | *0.35* |

## Model A-17



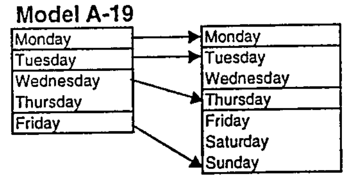

| | |
|---|---|
| Total sample Size | *57* |
| % of outlier | *7.02* |
| Model sample Size | *53* |
| R square Value | *0* |
| SSE/Mean | *0.27* |

## Model A-18



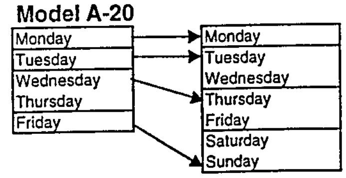

| | |
|---|---|
| Total sample Size | *48* |
| % of outlier | *12.50* |
| Model sample Size | *42* |
| R square Value | *0.016* |
| SSE/Mean | *0.57* |

## Model A-19



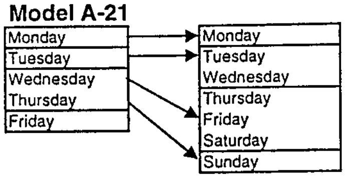

| | |
|---|---|
| Total sample Size | *48* |
| % of outlier | *18.75* |
| Model sample Size | *39* |
| R square Value | *0.015* |
| SSE/Mean | *0.4* |

## Model A-20



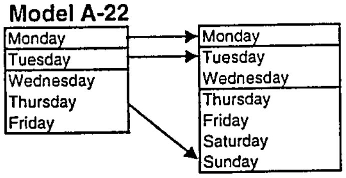

| | |
|---|---|
| Total sample Size | *48* |
| % of outlier | *0.00* |
| Model sample Size | *41* |
| R square Value | *0.136* |
| SSE/Mean | *0.39* |

## Model A-21



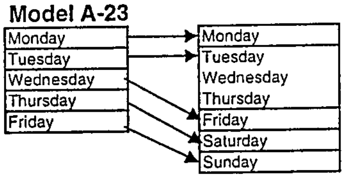

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.315 |
| SSE/Mean | 0.38 |

## Model A-22



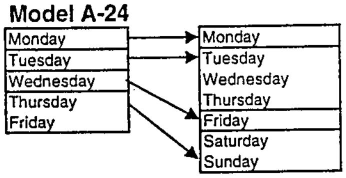

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.767 |
| SSE/Mean | 0.35 |

## Model A-23



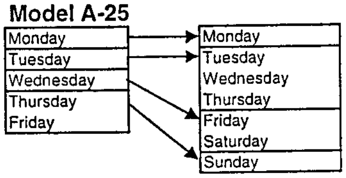

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 8.77 |
| Model sample Size | 52 |
| R square Value | 0.002 |
| SSE/Mean | 0.27 |

## Model A-24



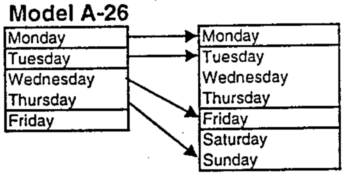

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.127 |
| SSE/Mean | 0.55 |

## Model A-25



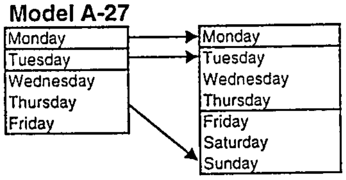

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.034 |
| SSE/Mean | 0.57 |

## Model A-26



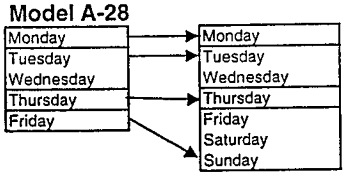

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.067 |
| SSE/Mean | 0.44 |

## Model A-27



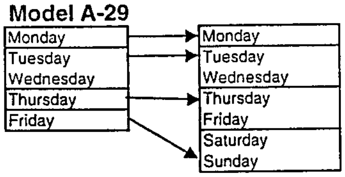

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.459 |
| SSE/Mean | 0.52 |

## Model A-28



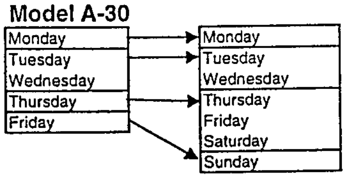

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.1 |
| SSE/Mean | 0.31 |

## Model A-29



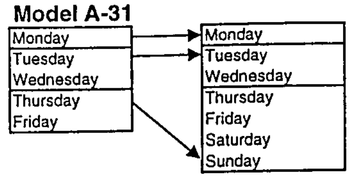

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.035 |
| SSE/Mean | 0.31 |

## Model A-30



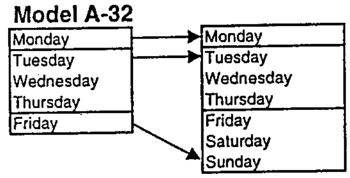

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.006 |
| SSE/Mean | 0.33 |

## Model A-31



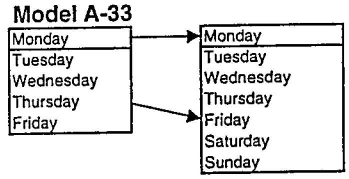

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 25.00 |
| Model sample Size | 27 |
| R square Value | 0.602 |
| SSE/Mean | 0.25 |

## Model A-32



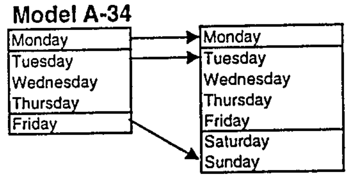

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.025 |
| SSE/Mean | 0.55 |

## Model A-33



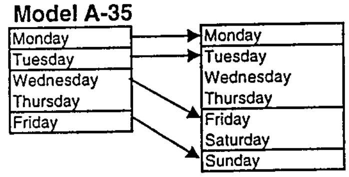

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 29.17 |
| Model sample Size | 17 |
| R square Value | 0.88 |
| SSE/Mean | 0.21 |

## Model A-34



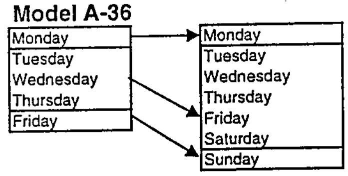

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.28 |
| SSE/Mean | 0.24 |

## Model A-35



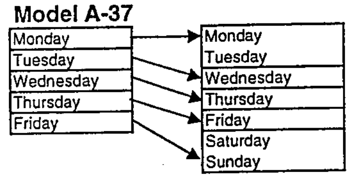

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 20.83 |
| Model sample Size | 38 |
| R square Value | 0.041 |
| SSE/Mean | 0.42 |

## Model A-36



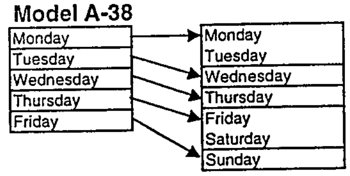

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 22.22 |
| Model sample Size | 28 |
| R square Value | 0.75 |
| SSE/Mean | 0.26 |

## Model A-37



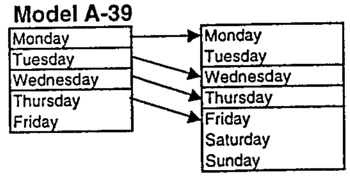

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 7.02 |
| Model sample Size | 53 |
| R square Value | 0.08 |
| SSE/Mean | 0.3 |

## Model A-38



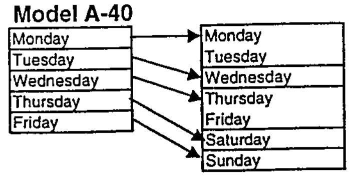

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 7.02 |
| Model sample Size | 53 |
| R square Value | 0.025 |
| SSE/Mean | 0.3 |

## Model A-39



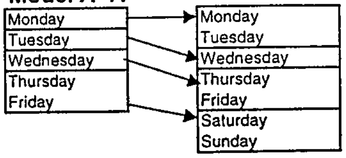

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 10.42 |
| Model sample Size | 43 |
| R square Value | 0.64 |
| SSE/Mean | 0.35 |

## Model A-40



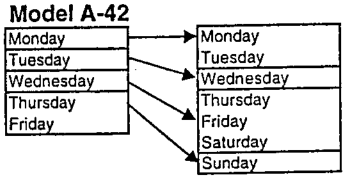

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 7.02 |
| Model sample Size | 53 |
| R square Value | 0.006 |
| SSE/Mean | 0.17 |

## Model A-41



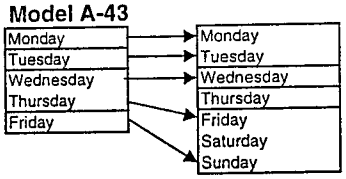

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0.175 |
| SSE/Mean | 0.53 |

## Model A-42



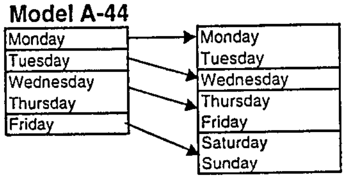

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.0195 |
| SSE/Mean | 0.56 |

## Model A-43



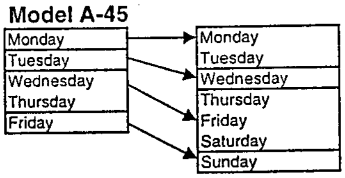

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 29.82 |
| Model sample Size | 40 |
| R square Value | 0.012 |
| SSE/Mean | 0.4 |

## Model A-44



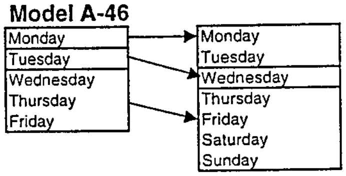

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.139 |
| SSE/Mean | 0.39 |

## Model A-45



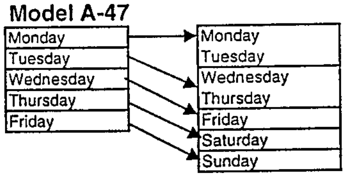

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.39 |
| SSE/Mean | 0.34 |

## Model A-46



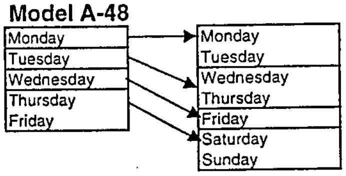

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.786 |
| SSE/Mean | 0.33 |

## Model A-47



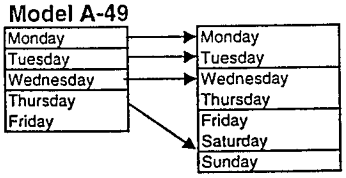

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 10.53 |
| Model sample Size | 51 |
| R square Value | 0.012 |
| SSE/Mean | 0.27 |

## Model A-48



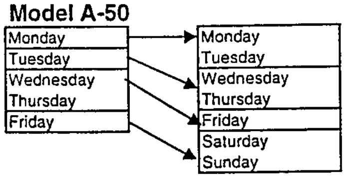

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.165 |
| SSE/Mean | 0.53 |

## Model A-49



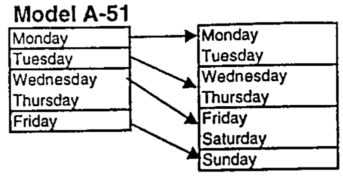

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.06 |
| SSE/Mean | 0.59 |

## Model A-50



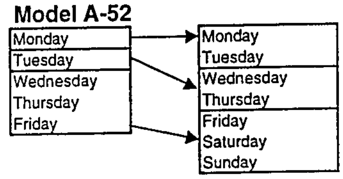

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.05 |
| SSE/Mean | 0.42 |

## Model A-51



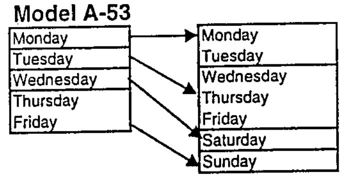

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.07 |
| SSE/Mean | 0.42 |

## Model A-52



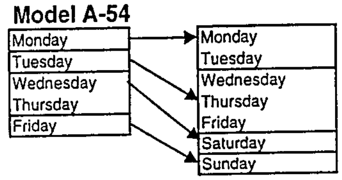

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.58 |
| SSE/Mean | 0.47 |

## Model A-53



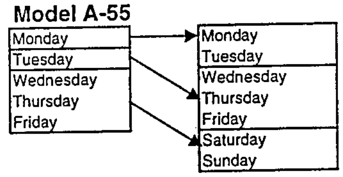

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.05 |
| SSE/Mean | 0.57 |

## Model A-54



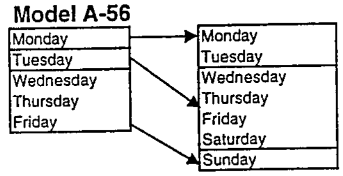

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 20.83 |
| Model sample Size | 38 |
| R square Value | 0.198 |
| SSE/Mean | 0.4 |

## Model A-55



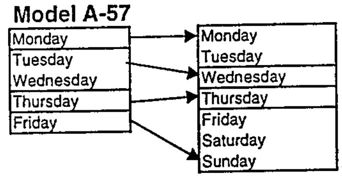

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.002 |
| SSE/Mean | 0.73 |

## Model A-56



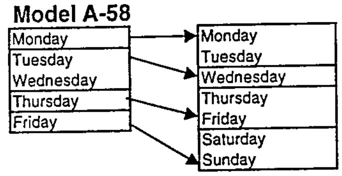

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 22.22 |
| Model sample Size | 28 |
| R square Value | 0.107 |
| SSE/Mean | 0.71 |

## Model A-57



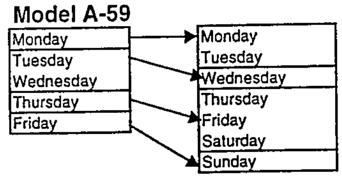

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 18.75 |
| Model sample Size | 39 |
| R square Value | 0.01 |
| SSE/Mean | 0.34 |

## Model A-58



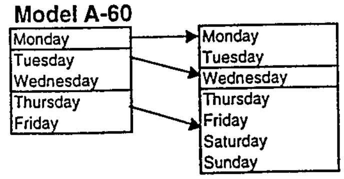

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.01 |
| SSE/Mean | 0.31 |

## Model A-59



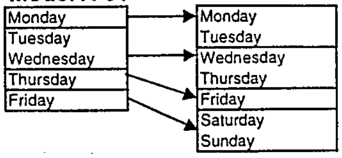

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.03 |
| SSE/Mean | 0.31 |

## Model A-60



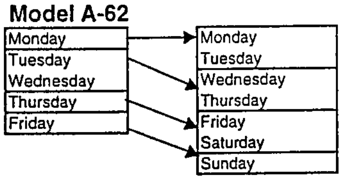

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.38 |
| SSE/Mean | 0.34 |

## Model A-61



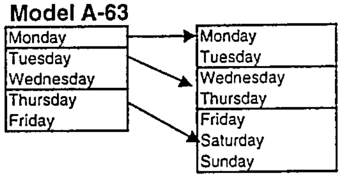

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.13 |
| SSE/Mean | 0.29 |

## Model A-62



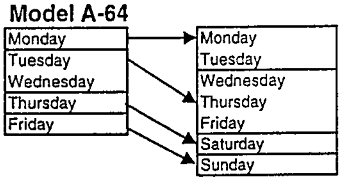

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.02 |
| SSE/Mean | 0.31 |

## Model A-63



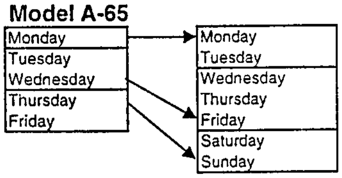

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.52 |
| SSE/Mean | 0.31 |

## Model A-64



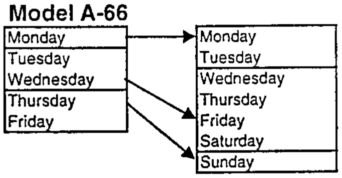

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 35.42 |
| Model sample Size | 31 |
| R square Value | 0.46 |
| SSE/Mean | 0.31 |

## Model A-65



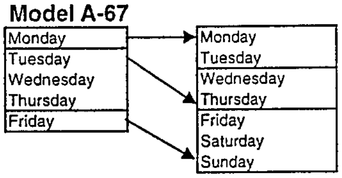

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.198 |
| SSE/Mean | 0.37 |

## Model A-66



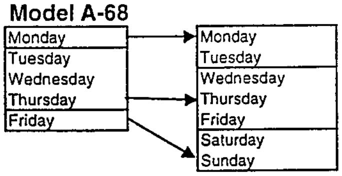

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 33.33 |
| Model sample Size | 24 |
| R square Value | 0.004 |
| SSE/Mean | 0.42 |

## Model A-67



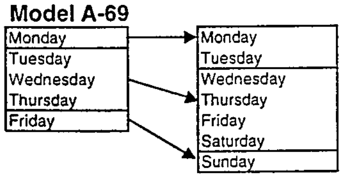

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.16 |
| SSE/Mean | 0.31 |

## Model A-68



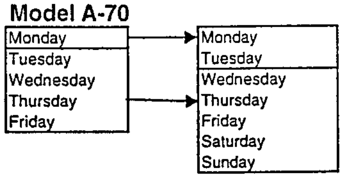

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.43 |
| SSE/Mean | 0.41 |

## Model A-69



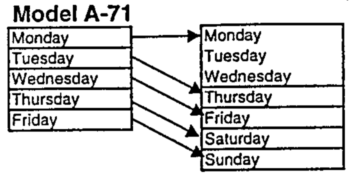

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.63 |
| SSE/Mean | 0.33 |

## Model A-70



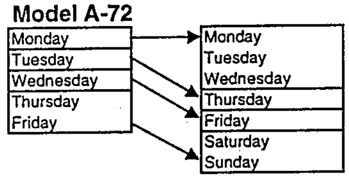

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 20.83 |
| Model sample Size | 19 |
| R square Value | 0.84 |
| SSE/Mean | 0.26 |

## Model A-71



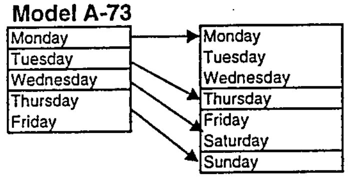

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 10.53 |
| Model sample Size | 51 |
| R square Value | 0.087 |
| SSE/Mean | 0.3 |

## Model A-72



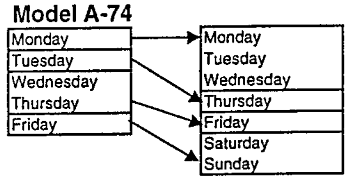

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.124 |
| SSE/Mean | 0.55 |

## Model A-73



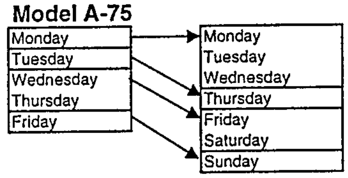

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 18.75 |
| Model sample Size | 39 |
| R square Value | 0.07 |
| SSE/Mean | 0.56 |

## Model A-74



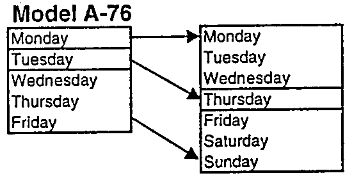

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 18.75 |
| Model sample Size | 39 |
| R square Value | 0.057 |
| SSE/Mean | 0.4 |

## Model A-75



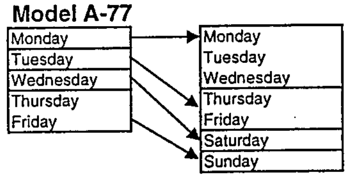

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.036 |
| SSE/Mean | 0.45 |

## Model A-76



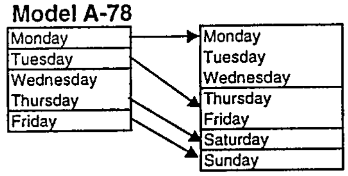

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.48 |
| SSE/Mean | 0.52 |

## Model A-77



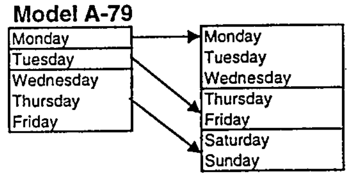

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.048 |
| SSE/Mean | 0.56 |

## Model A-78



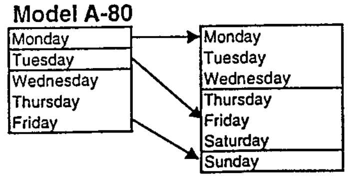

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.225 |
| SSE/Mean | 0.37 |

## Model A-79



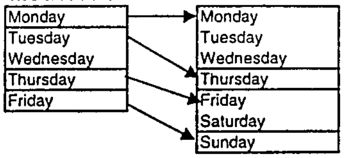

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 8.33 |
| Model sample Size | 33 |
| R square Value | 0.009 |
| SSE/Mean | 0.73 |

## Model A-80



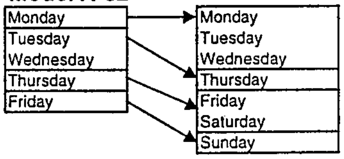

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.737 |
| SSE/Mean | 0.65 |

## Model A-81



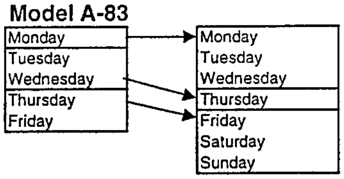

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.144 |
| SSE/Mean | 0.34 |

## Model A-82



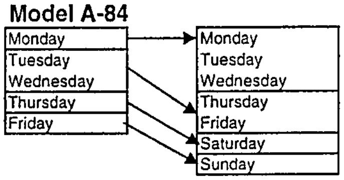

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.221 |
| SSE/Mean | 0.33 |

## Model A-83



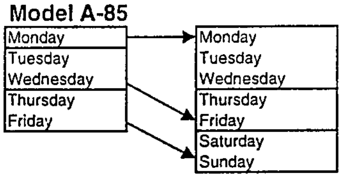

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 19.44 |
| Model sample Size | 29 |
| R square Value | 0.117 |
| SSE/Mean | 0.43 |

## Model A-84



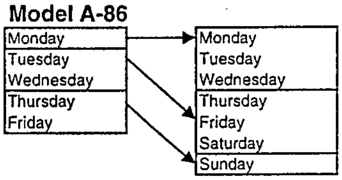

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 10.42 |
| Model sample Size | 43 |
| R square Value | 0.004 |
| SSE/Mean | 0.32 |

## Model A-85



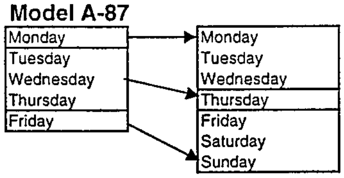

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0 |
| SSE/Mean | 0.44 |

## Model A-86



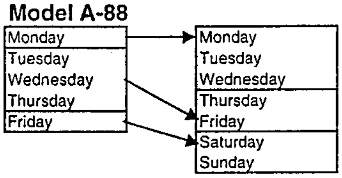

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.04 |
| SSE/Mean | 0.43 |

## Model A-87



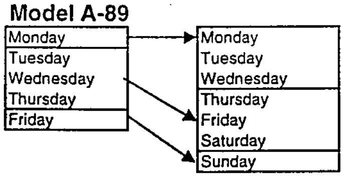

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.04 |
| SSE/Mean | 0.43 |

## Model A-88



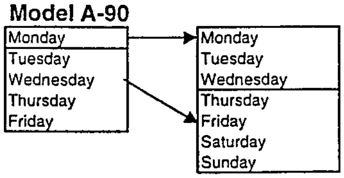

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.03 |
| SSE/Mean | 0.55 |

## Model A-89



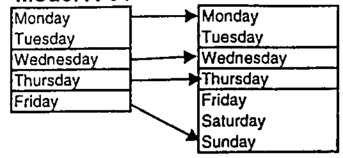

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.02 |
| SSE/Mean | 0.34 |

## Model A-90



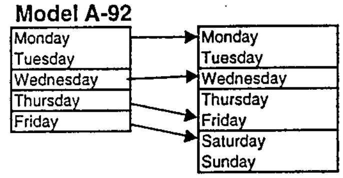

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 12.50 |
| Model sample Size | 21 |
| R square Value | 0.61 |
| SSE/Mean | 0.44 |

## Model A-91



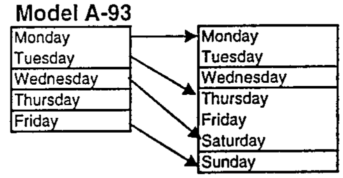

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.06 |
| SSE/Mean | 0.29 |

## Model A-92



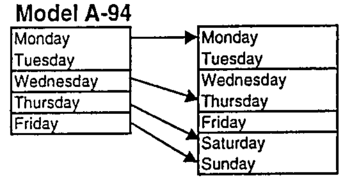

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0 |
| SSE/Mean | 0.29 |

## Model A-93



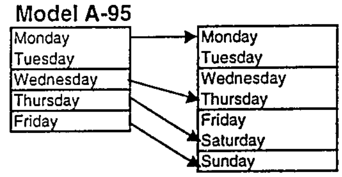

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.017 |
| SSE/Mean | 0.29 |

## Model A-94



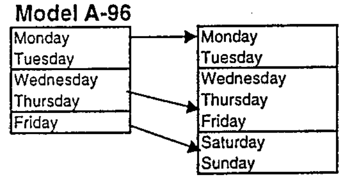

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 6.25 |
| Model sample Size | 45 |
| R square Value | 0.04 |
| SSE/Mean | 0.29 |

## Model A-95



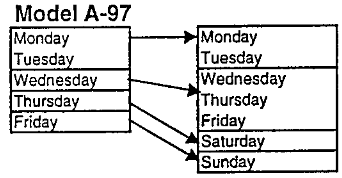

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0.79 |
| SSE/Mean | 0.32 |

## Model A-96



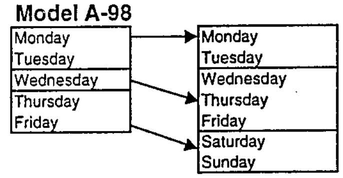

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 8.33 |
| Model sample Size | 33 |
| R square Value | 0.298 |
| SSE/Mean | 0.4 |

## Model A-97



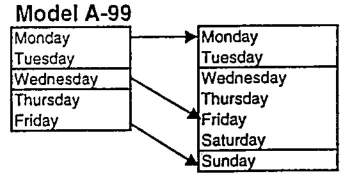

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 10.42 |
| Model sample Size | 43 |
| R square Value | 0.21 |
| SSE/Mean | 0.26 |

## Model A-98



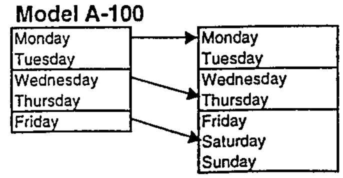

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 8.33 |
| Model sample Size | 33 |
| R square Value | 0.07 |
| SSE/Mean | 0.46 |

## Model A-99



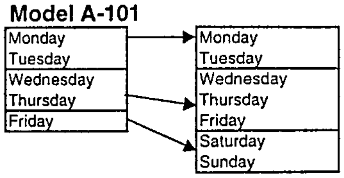

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.418 |
| SSE/Mean | 0.36 |

## Model A-100



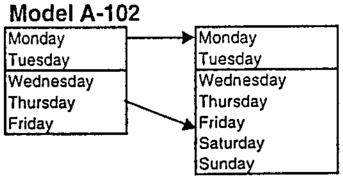

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.06 |
| SSE/Mean | 0.25 |

## Model A-101



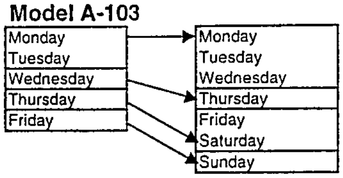

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.13 |
| SSE/Mean | 0.25 |

## Model A-102



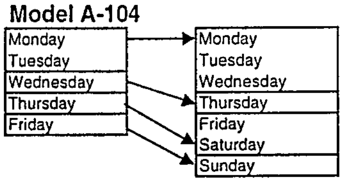

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 12.50 |
| Model sample Size | 21 |
| R square Value | 0.72 |
| SSE/Mean | 0.22 |

## Model A-103



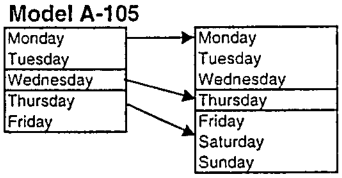

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 10.42 |
| Model sample Size | 43 |
| R square Value | 0.09 |
| SSE/Mean | 0.29 |

## Model A-104



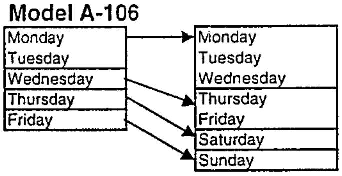

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 10.42 |
| Model sample Size | 43 |
| R square Value | 0.02 |
| SSE/Mean | 0.3 |

## Model A-105



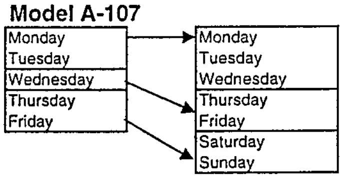

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.42 |
| SSE/Mean | 0.33 |

## Model A-106



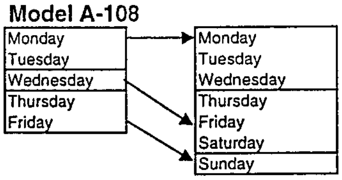

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0.002 |
| SSE/Mean | 0.45 |

## Model A-107



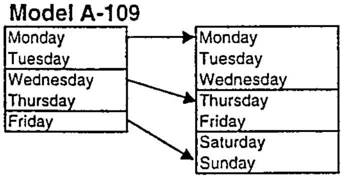

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 5.56 |
| Model sample Size | 34 |
| R square Value | 0 |
| SSE/Mean | 0.3 |

## Model A-108



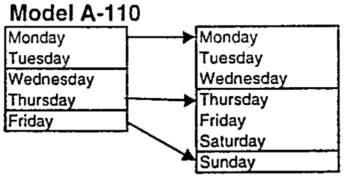

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.4 |
| SSE/Mean | 0.35 |

## Model A-109



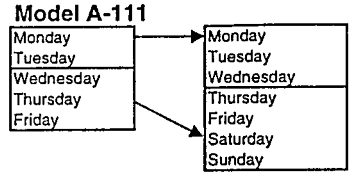

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 5.56 |
| Model sample Size | 34 |
| R square Value | 0.15 |
| SSE/Mean | 0.24 |

## Model A-110



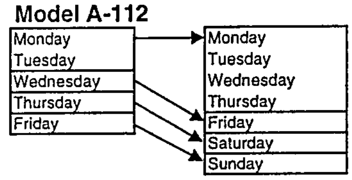

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.06 |
| SSE/Mean | 0.25 |

## Model A-111



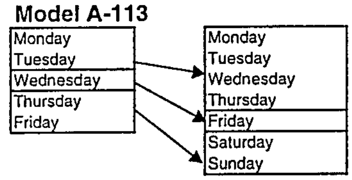

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 4.17 |
| Model sample Size | 23 |
| R square Value | 0.396 |
| SSE/Mean | 0.32 |

## Model A-112



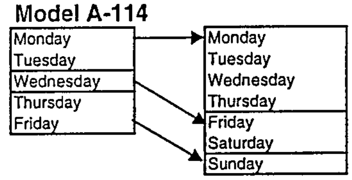

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.133 |
| SSE/Mean | 0.29 |

## Model A-113



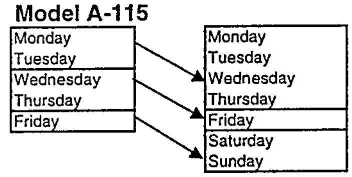

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 5.56 |
| Model sample Size | 34 |
| R square Value | 0.07 |
| SSE/Mean | 0.44 |

## Model A-114



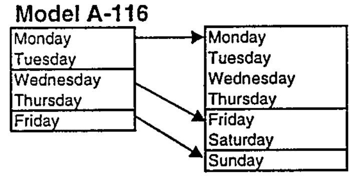

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.172 |
| SSE/Mean | 0.41 |

## Model A-115



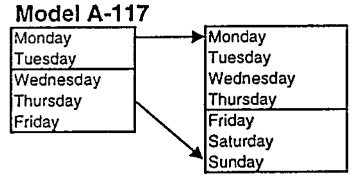

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 5.56 |
| Model sample Size | 34 |
| R square Value | 0.37 |
| SSE/Mean | 0.2 |

## Model A-116



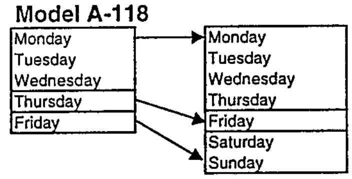

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.006 |
| SSE/Mean | 0.26 |

## Model A-117



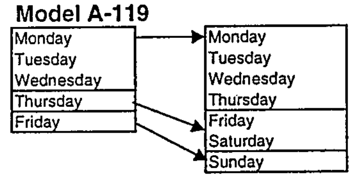

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 4.17 |
| Model sample Size | 23 |
| R square Value | 0.019 |
| SSE/Mean | 0.41 |

## Model A-118



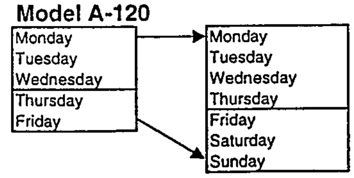

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 8.33 |
| Model sample Size | 33 |
| R square Value | 0.253 |
| SSE/Mean | 0.35 |

## Model A-119



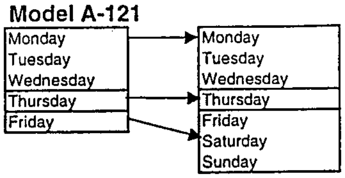

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.119 |
| SSE/Mean | 0.38 |

## Model A-120



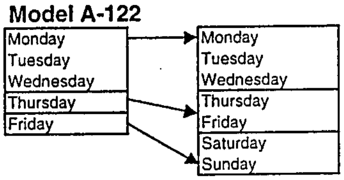

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 4.17 |
| Model sample Size | 23 |
| R square Value | 0.075 |
| SSE/Mean | 0.19 |

## Model A-121



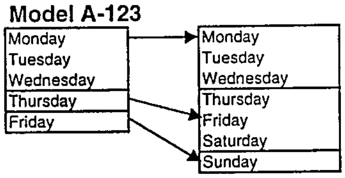

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.005 |
| SSE/Mean | 0.41 |

## Model A-122



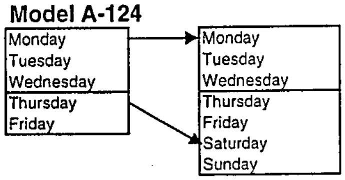

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 5.56 |
| Model sample Size | 34 |
| R square Value | 0.024 |
| SSE/Mean | 0.4 |

## Model A-123



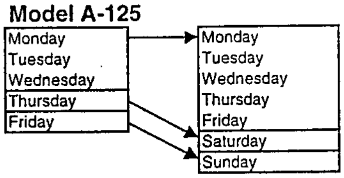

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 8.33 |
| Model sample Size | 33 |
| R square Value | 0.044 |
| SSE/Mean | 0.4 |

## Model A-124



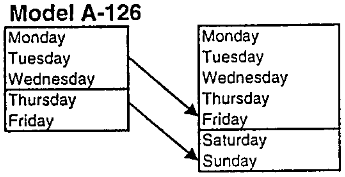

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 8.33 |
| Model sample Size | 22 |
| R square Value | 0.055 |
| SSE/Mean | 0.19 |

## Model A-125



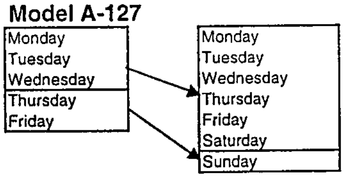

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.524 |
| SSE/Mean | 0.28 |

## Model A-126



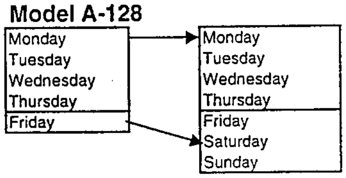

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 8.33 |
| Model sample Size | 22 |
| R square Value | 0.007 |
| SSE/Mean | 0.2 |

## Model A-127



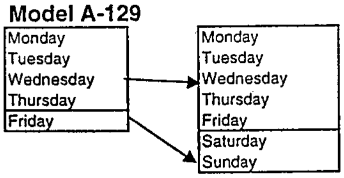

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 12.50 |
| Model sample Size | 21 |
| R square Value | 0.002 |
| SSE/Mean | 0.21 |

## Model A-128



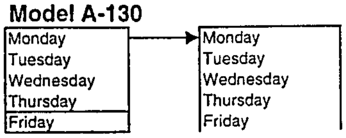

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 4.17 |
| Model sample Size | 23 |
| R square Value | 0.2 |
| SSE/Mean | 0.44 |

## Model A-129



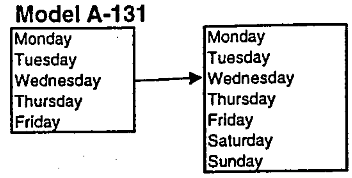

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 4.17 |
| Model sample Size | 23 |
| R square Value | 0.485 |
| SSE/Mean | 0.35 |

## Model A-130




| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 8.33 |
| Model sample Size | 22 |
| R square Value | 0.635 |
| SSE/Mean | 0.29 |

## Model A-131

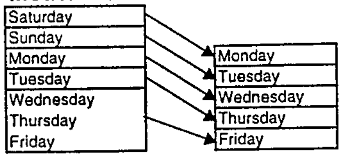



| | |
|---|---|
| Total sample Size | 11 |
| % of outlier | 0.00 |
| Model sample Size | 11 |
| R square Value | 0.07 |
| SSE/Mean | 0.08 |

# APPENDIX I

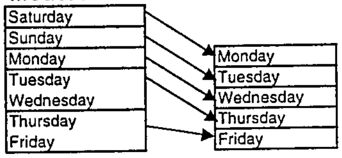
## Outbound Freight Truck Movement Combinations (Production Model)

## Model B-1



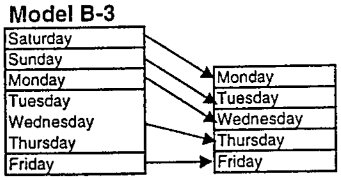

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 15.79 |
| Model sample Size | 48 |
| R square Value | 0.0000479 |
| SSE/Mean | 0.29 |

## Model B-2



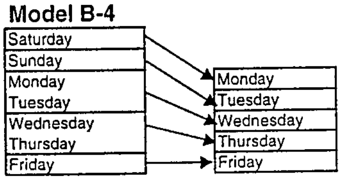

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 5.26 |
| Model sample Size | 54 |
| R square Value | 0.0506 |
| SSE/Mean | 0.37 |

## Model B-3



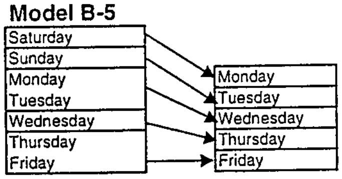

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 3.51 |
| Model sample Size | 55 |
| R square Value | 0.1585 |
| SSE/Mean | 0.35 |

## Model B-4



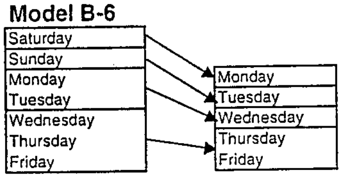

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 0.00 |
| Model sample Size | 57 |
| R square Value | 0.01632 |
| SSE/Mean | 0.46 |

## Model B-5



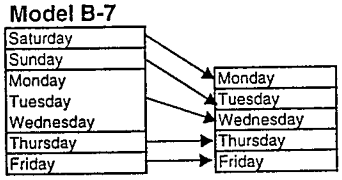

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 0.00 |
| Model sample Size | 57 |
| R square Value | 0.0003787 |
| SSE/Mean | 0.47 |

## Model B-6



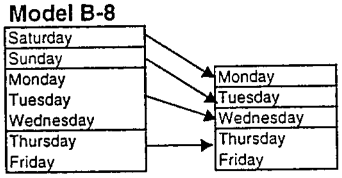

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0.2901 |
| SSE/Mean | 0.39 |

## Model B-7



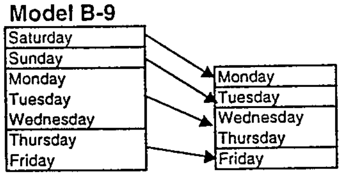

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 1.75 |
| Model sample Size | 56 |
| R square Value | 4.018E-05 |
| SSE/Mean | 0.31 |

## Model B-8



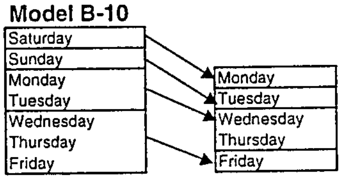

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 6.25 |
| Model sample Size | 45 |
| R square Value | 0.024799 |
| SSE/Mean | 0.46 |

## Model B-9



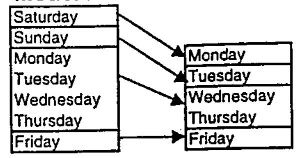

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.0069099 |
| SSE/Mean | 0.45 |

## Model B-10



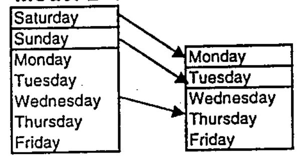

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.119766 |
| SSE/Mean | 0.46 |

## Model B-11



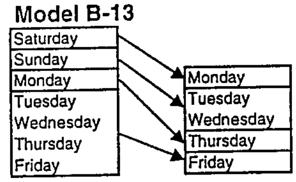

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.58743 |
| SSE/Mean | 0.32 |

## Model B-12



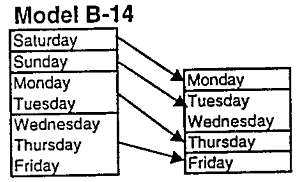

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.73779 |
| SSE/Mean | 0.32 |

## Model B-13



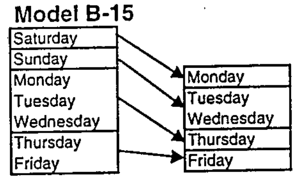

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 18.75 |
| Model sample Size | 39 |
| R square Value | 0.106856 |
| SSE/Mean | 0.38 |

## Model B-14



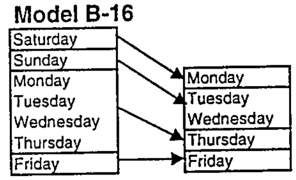

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.0999823 |
| SSE/Mean | 0.40 |

## Model B-15



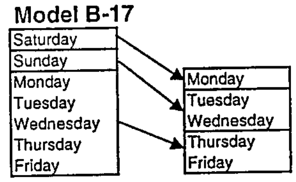

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 29.17 |
| Model sample Size | 34 |
| R square Value | 0.008656 |
| SSE/Mean | 0.35 |

## Model B-16



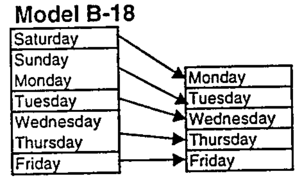

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 22.92 |
| Model sample Size | 37 |
| R square Value | 0.0269291 |
| SSE/Mean | 0.36 |

## Model B-17



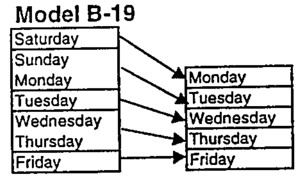

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 27.78 |
| Model sample Size | 26 |
| R square Value | 0.3856615 |
| SSE/Mean | 0.34 |

## Model B-18



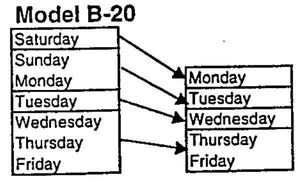

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 12.28 |
| Model sample Size | 50 |
| R square Value | 0.0074754 |
| SSE/Mean | 0.26 |

## Model B-19



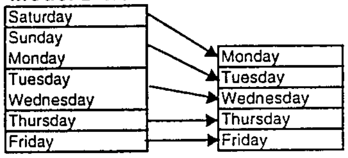

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 7.02 |
| Model sample Size | 53 |
| R square Value | 0.04524 |
| SSE/Mean | 0.26 |

## Model B-20



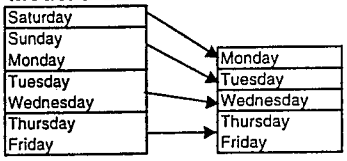

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 22.92 |
| Model sample Size | 37 |
| R square Value | 0.559391 |
| SSE/Mean | 0.34 |

## Model B-21



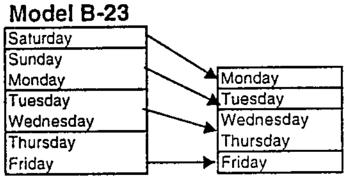

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 8.77 |
| Model sample Size | 52 |
| R square Value | 0.0005049 |
| SSE/Mean | 0.26 |

## Model B-22



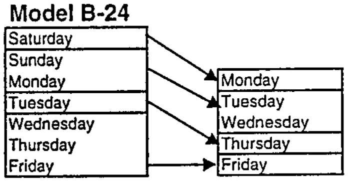

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 10.42 |
| Model sample Size | 43 |
| R square Value | 0.231363 |
| SSE/Mean | 0.41 |

## Model B-23



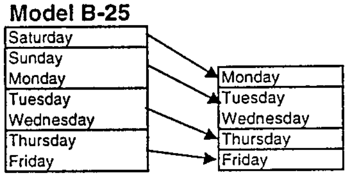

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.0227075 |
| SSE/Mean | 0.49 |

## Model B-24



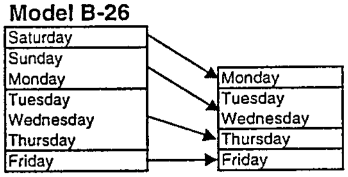

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 18.75 |
| Model sample Size | 39 |
| R square Value | 0.0338976 |
| SSE/Mean | 0.44 |

## Model B-25



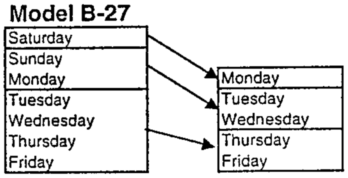

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.010939 |
| SSE/Mean | 0.39 |

## Model B-26



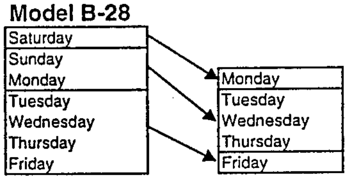

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 6.25 |
| Model sample Size | 45 |
| R square Value | 4.629E-05 |
| SSE/Mean | 0.43 |

## Model B-27



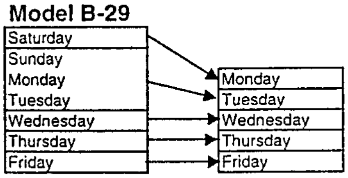

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.5577169 |
| SSE/Mean | 0.32 |

## Model B-28



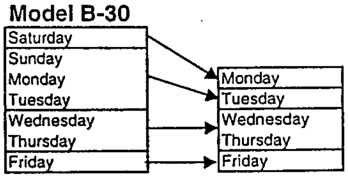

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.1480208 |
| SSE/Mean | 0.63 |

## Model B-29



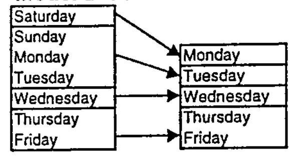

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 7.02 |
| Model sample Size | 53 |
| R square Value | 3.867E-05 |
| SSE/Mean | 0.26 |

## Model B-30



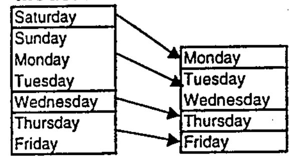

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 10.42 |
| Model sample Size | 43 |
| R square Value | 0.301718 |
| SSE/Mean | 0.40 |

## Model B-31



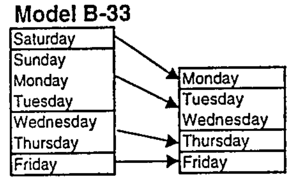

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 20.83 |
| Model sample Size | 38 |
| R square Value | 0.2573309 |
| SSE/Mean | 0.44 |

## Model B-32



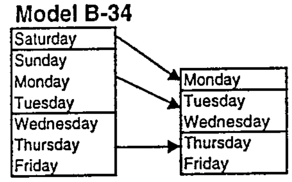

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.0002436 |
| SSE/Mean | 0.41 |

## Model B-33



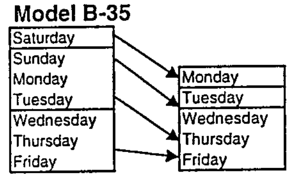

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.018215 |
| SSE/Mean | 0.39 |

## Model B-34



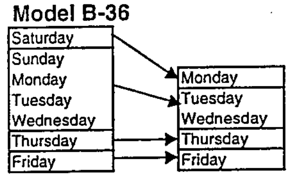

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.28857 |
| SSE/Mean | 0.34 |

## Model B-35



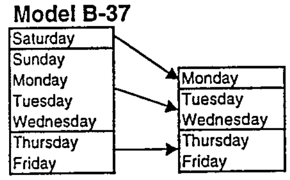

| | |
|---|---|
| Total sample Size | 30 |
| % of outlier | 0.00 |
| Model sample Size | 30 |
| R square Value | 0.56149 |
| SSE/Mean | 0.39 |

## Model B-36



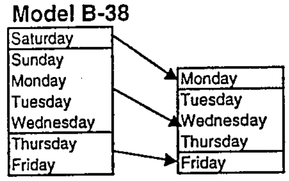

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 25.00 |
| Model sample Size | 36 |
| R square Value | 0.3413386 |
| SSE/Mean | 0.32 |

## Model B-37



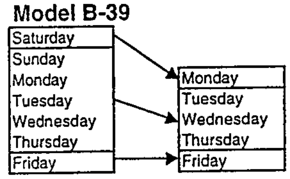

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.2686857 |
| SSE/Mean | 0.32 |

## Model B-38



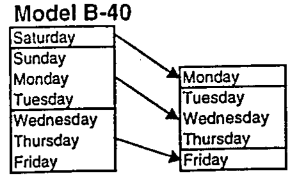

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.1468503 |
| SSE/Mean | 0.63 |

## Model B-39



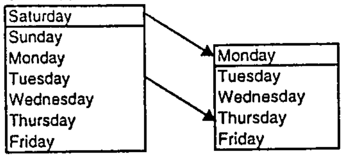

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.7006455 |
| SSE/Mean | 0.36 |

## Model B-40



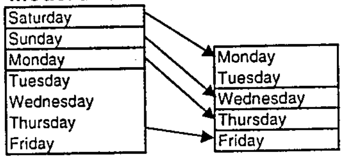

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 19.44 |
| Model sample Size | 29 |
| R square Value | 0.051273 |
| SSE/Mean | 0.63 |

### Model B-41



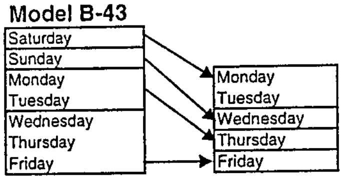

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 12.50 |
| Model sample Size | 21 |
| R square Value | 0.6935 |
| SSE/Mean | 0.35 |

### Model B-42



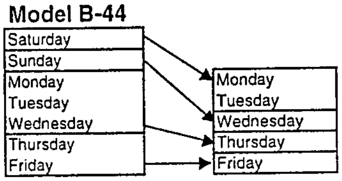

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.02344 |
| SSE/Mean | 0.43 |

### Model B-43



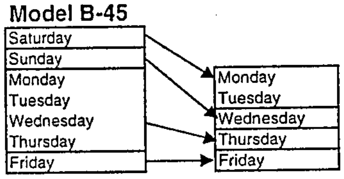

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0.0332 |
| SSE/Mean | 0.45 |

### Model B-44



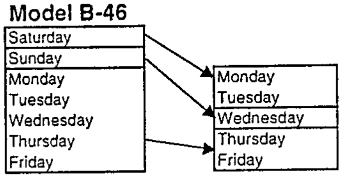

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 10.42 |
| Model sample Size | 43 |
| R square Value | 0.0020838 |
| SSE/Mean | 0.42 |

### Model B-45



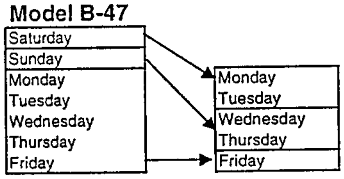

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 6.25 |
| Model sample Size | 45 |
| R square Value | 0.0191148 |
| SSE/Mean | 0.44 |

### Model B-46



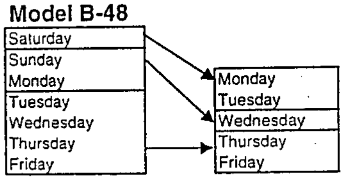

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 5.56 |
| Model sample Size | 34 |
| R square Value | 0.32821 |
| SSE/Mean | 0.37 |

### Model B-47



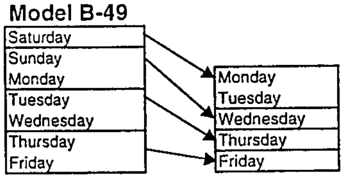

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.347007 |
| SSE/Mean | 0.37 |

### Model B-48



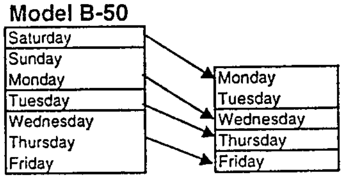

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 2.78 |
| Model sample Size | 35 |
| R square Value | 0.2747 |
| SSE/Mean | 0.38 |

### Model B-49



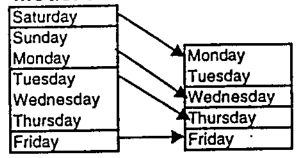

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0.0003274 |
| SSE/Mean | 0.41 |

### Model B-50



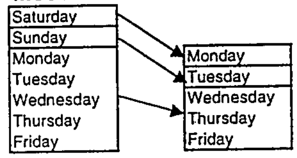

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 10.42 |
| Model sample Size | 43 |
| R square Value | 0.0300351 |
| SSE/Mean | 0.42 |

### Model B-51



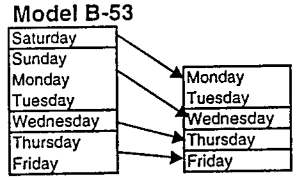

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 6.25 |
| Model sample Size | 45 |
| R square Value | 0.00258 |
| SSE/Mean | 0.41 |

### Model B-52



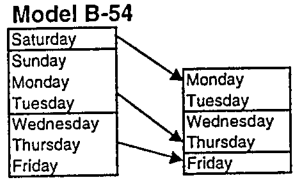

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 5.56 |
| Model sample Size | 34 |
| R square Value | 0.2873 |
| SSE/Mean | 0.34 |

### Model B-53



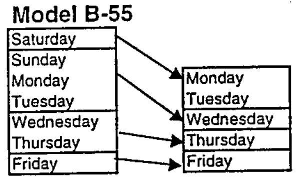

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 6.25 |
| Model sample Size | 45 |
| R square Value | 0.0159466 |
| SSE/Mean | 0.41 |

### Model B-54



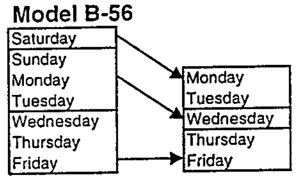

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 8.33 |
| Model sample Size | 33 |
| R square Value | 0.17777 |
| SSE/Mean | 0.37 |

### Model B-55



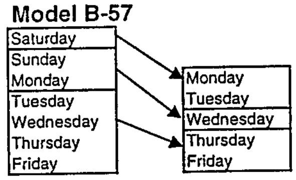

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0.0079251 |
| SSE/Mean | 0.45 |

### Model B-56



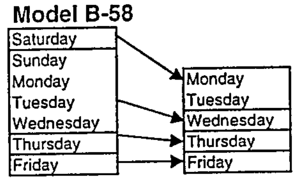

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 5.56 |
| Model sample Size | 34 |
| R square Value | 0.215267 |
| SSE/Mean | 0.40 |

### Model B-57



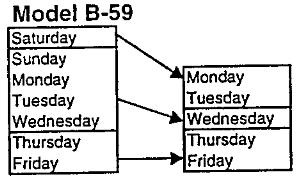

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 8.33 |
| Model sample Size | 33 |
| R square Value | 0.239699 |
| SSE/Mean | 0.39 |

### Model B-58



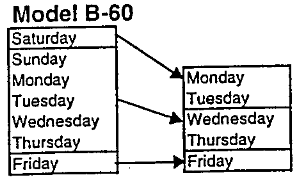

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0.0212809 |
| SSE/Mean | 0.44 |

### Model B-59



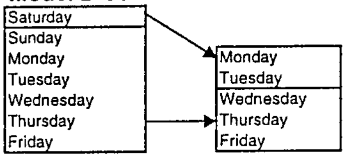

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.0037699 |
| SSE/Mean | 0.45 |

### Model B-60



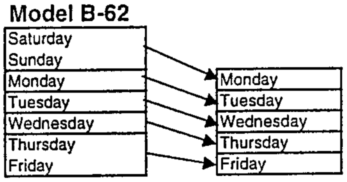

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 8.33 |
| Model sample Size | 33 |
| R square Value | 0.312158 |
| SSE/Mean | 0.35 |

## Model B-61



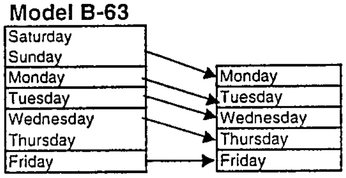

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 8.33 |
| Model sample Size | 22 |
| R square Value | 0.47765 |
| SSE/Mean | 0.27 |

## Model B-62



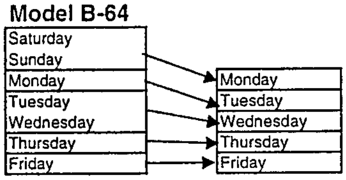

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 12.28 |
| Model sample Size | 50 |
| R square Value | 0.0126697 |
| SSE/Mean | 0.26 |

## Model B-63



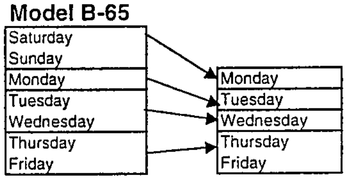

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 12.28 |
| Model sample Size | 50 |
| R square Value | 0.0562256 |
| SSE/Mean | 0.27 |

## Model B-64



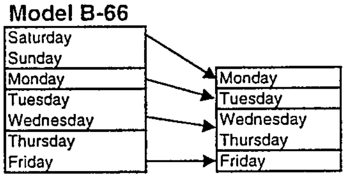

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 12.28 |
| Model sample Size | 50 |
| R square Value | 0.0002965 |
| SSE/Mean | 0.27 |

## Model B-65



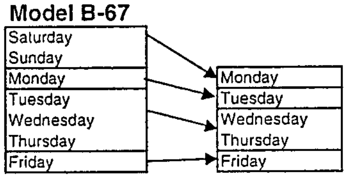

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.1233859 |
| SSE/Mean | 0.47 |

## Model B-66



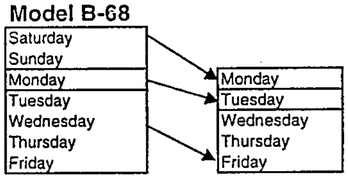

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.0017166 |
| SSE/Mean | 0.53 |

## Model B-67



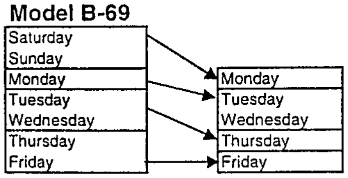

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.4221088 |
| SSE/Mean | 0.38 |

## Model B-68



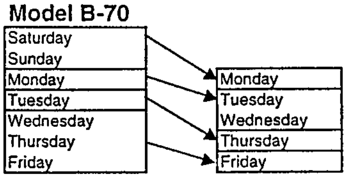

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 27.78 |
| Model sample Size | 26 |
| R square Value | 0.6159816 |
| SSE/Mean | 0.40 |

## Model B-69



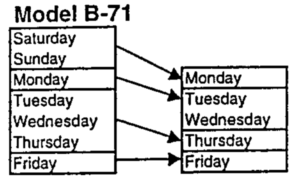

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.0198869 |
| SSE/Mean | 0.33 |

## Model B-70



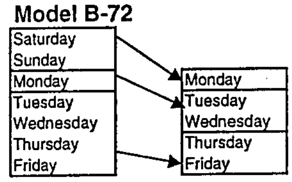

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 22.92 |
| Model sample Size | 37 |
| R square Value | 0.1444 |
| SSE/Mean | 0.38 |

## Model B-71



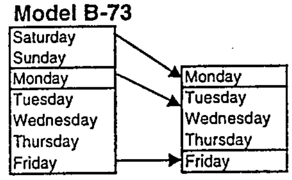

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.000708 |
| SSE/Mean | 0.43 |

## Model B-72



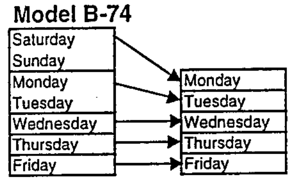

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 22.22 |
| Model sample Size | 28 |
| R square Value | 0.19585 |
| SSE/Mean | 0.37 |

## Model B-73



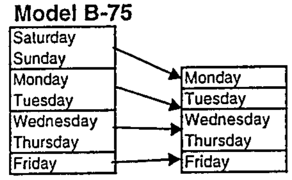

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 25.00 |
| Model sample Size | 27 |
| R square Value | 0.28314 |
| SSE/Mean | 0.56 |

## Model B-74



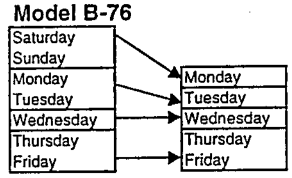

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 7.02 |
| Model sample Size | 53 |
| R square Value | 6.497E-05 |
| SSE/Mean | 0.22 |

## Model B-75



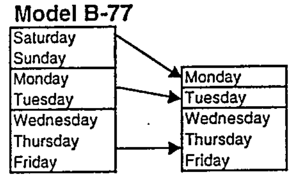

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 6.25 |
| Model sample Size | 45 |
| R square Value | 0.317168 |
| SSE/Mean | 0.45 |

## Model B-76



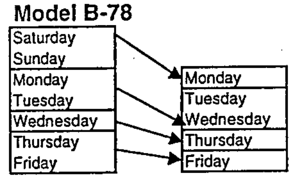

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 10.42 |
| Model sample Size | 43 |
| R square Value | 0.140631 |
| SSE/Mean | 0.46 |

## Model B-77



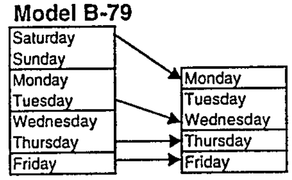

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 25.00 |
| Model sample Size | 27 |
| R square Value | 0.5837988 |
| SSE/Mean | 0.41 |

## Model B-78



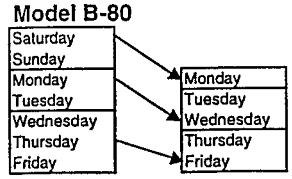

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 18.75 |
| Model sample Size | 39 |
| R square Value | 0.0185405 |
| SSE/Mean | 0.37 |

## Model B-79



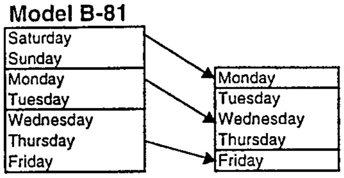

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 20.83 |
| Model sample Size | 38 |
| R square Value | 0.0025102 |
| SSE/Mean | 0.43 |

## Model B-80



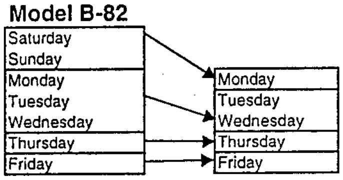

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 19.44 |
| Model sample Size | 29 |
| R square Value | 0.1683506 |
| SSE/Mean | 0.37 |

## Model B-81



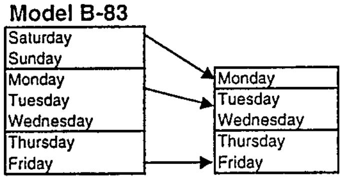

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 27.78 |
| Model sample Size | 26 |
| R square Value | 0.119647 |
| SSE/Mean | 0.62 |

## Model B-82



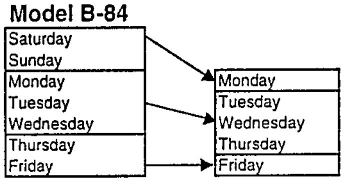

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.060378 |
| SSE/Mean | 0.39 |

## Model B-83



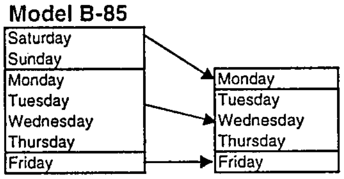

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.811443 |
| SSE/Mean | 0.36 |

## Model B-84



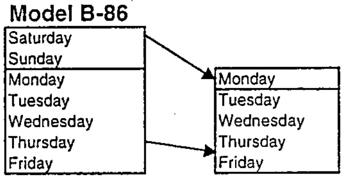

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.03996 |
| SSE/Mean | 0.67 |

## Model B-85



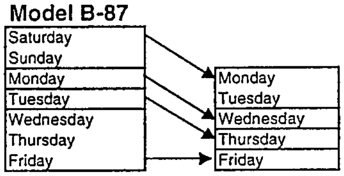

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 19.44 |
| Model sample Size | 29 |
| R square Value | 0.683013 |
| SSE/Mean | 0.36 |

## Model B-86



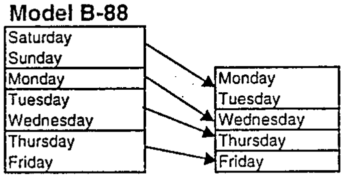

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 12.50 |
| Model sample Size | 21 |
| R square Value | 0.6191242 |
| SSE/Mean | 0.41 |

## Model B-87



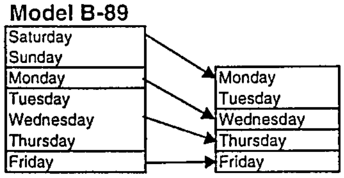

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 20.83 |
| Model sample Size | 38 |
| R square Value | 0.0006754 |
| SSE/Mean | 0.43 |

## Model B-88



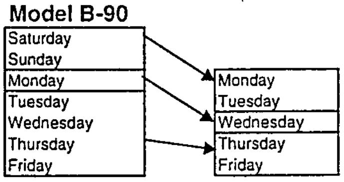

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 21.9 |
| Model sample Size | 25 |
| R square Value | 0.1356078 |
| SSE/Mean | 0.27 |

## Model B-89



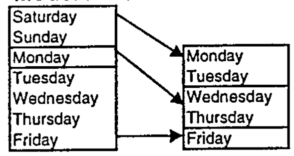

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.081384 |
| SSE/Mean | 0.40 |

## Model B-90



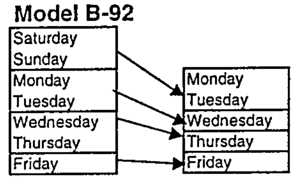

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.385479 |
| SSE/Mean | 0.33 |

## Model B-91



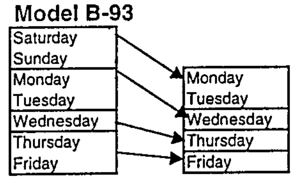

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 30.56 |
| Model sample Size | 25 |
| R square Value | 0.1689567 |
| SSE/Mean | 0.42 |

## Model B-92



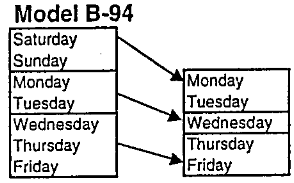

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0.0827 |
| SSE/Mean | 0.40 |

## Model B-93



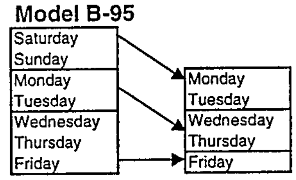

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.03074 |
| SSE/Mean | 0.42 |

## Model B-94



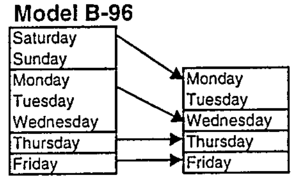

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.366741 |
| SSE/Mean | 0.34 |

## Model B-95



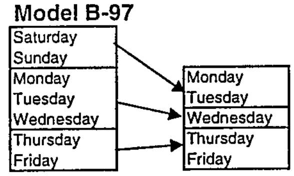

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.20259 |
| SSE/Mean | 0.38 |

## Model B-96



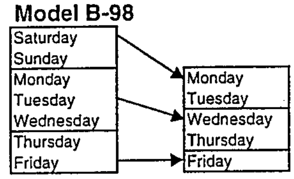

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0.0072387 |
| SSE/Mean | 0.41 |

## Model B-97



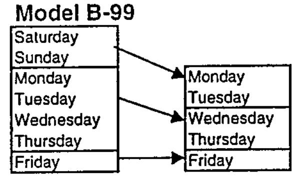

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.1960167 |
| SSE/Mean | 0.38 |

## Model B-98



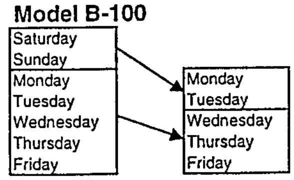

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 5.56 |
| Model sample Size | 34 |
| R square Value | 1.067E-05 |
| SSE/Mean | 0.40 |

## Model B-99



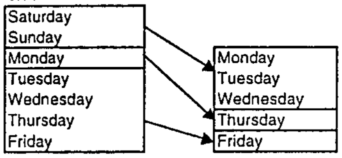

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 2.78 |
| Model sample Size | 35 |
| R square Value | 0.386439 |
| SSE/Mean | 0.32 |

## Model B-100



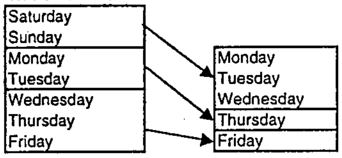

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 8.33 |
| Model sample Size | 22 |
| R square Value | 0.500631 |
| SSE/Mean | 0.26 |

## Model B-101



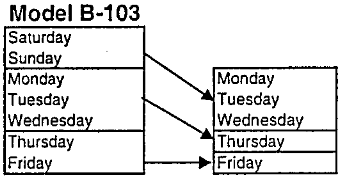

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 22.22 |
| Model sample Size | 28 |
| R square Value | 0.081817 |
| SSE/Mean | 0.56 |

## Model B-102



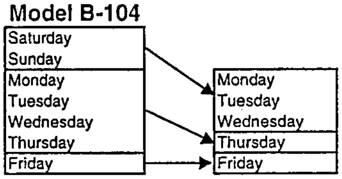

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.0531417 |
| SSE/Mean | 0.55 |

## Model B-103



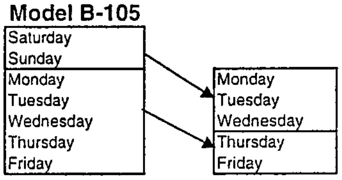

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 5.56 |
| Model sample Size | 34 |
| R square Value | 0.0144498 |
| SSE/Mean | 0.56 |

## Model B-104



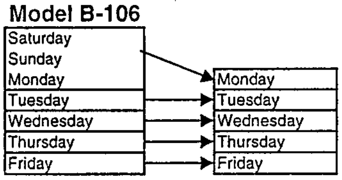

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 2.78 |
| Model sample Size | 35 |
| R square Value | 0.0022514 |
| SSE/Mean | 0.57 |

## Model B-105



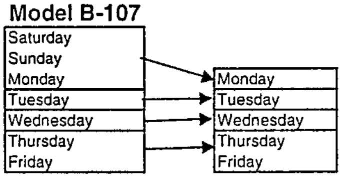

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 4.17 |
| Model sample Size | 23 |
| R square Value | 0.046643 |
| SSE/Mean | 0.30 |

## Model B-106



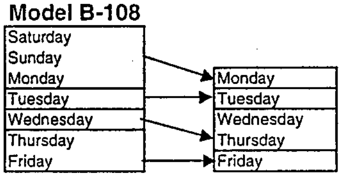

| | |
|---|---|
| Total sample Size | 57 |
| % of outlier | 10.53 |
| Model sample Size | 51 |
| R square Value | 0.0000488 |
| SSE/Mean | 0.26 |

## Model B-107



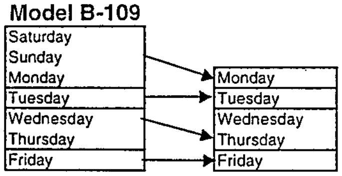

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.1166182 |
| SSE/Mean | 0.46 |

## Model B-108



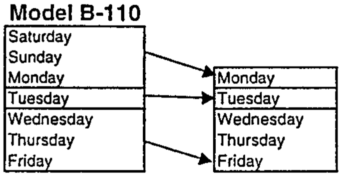

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 18.75 |
| Model sample Size | 39 |
| R square Value | 0.003145 |
| SSE/Mean | 0.46 |

## Model B-109



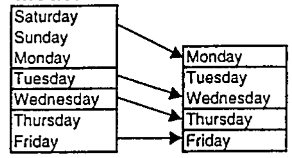

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 12.50 |
| Model sample Size | 42 |
| R square Value | 0.2217749 |
| SSE/Mean | 0.43 |

## Model B-110



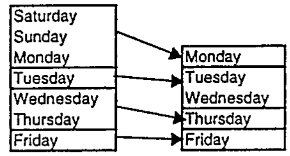

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.4812997 |
| SSE/Mean | 0.47 |

## Model B-111



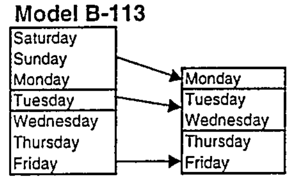

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 20.83 |
| Model sample Size | 38 |
| R square Value | 0.1036326 |
| SSE/Mean | 0.36 |

## Model B-112



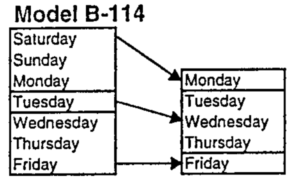

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.066485 |
| SSE/Mean | 0.40 |

## Model B-113



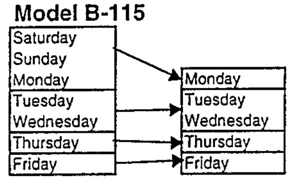

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 19.44 |
| Model sample Size | 29 |
| R square Value | 0.0520004 |
| SSE/Mean | 0.45 |

## Model B-114



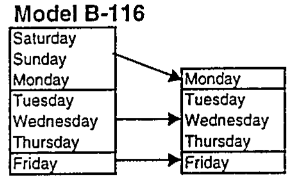

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 30.56 |
| Model sample Size | 25 |
| R square Value | 0.3007607 |
| SSE/Mean | 0.57 |

## Model B-115



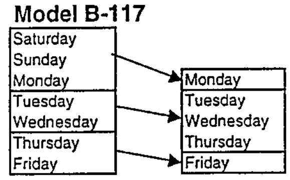

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 14.58 |
| Model sample Size | 41 |
| R square Value | 0.007924 |
| SSE/Mean | 0.39 |

## Model B-116



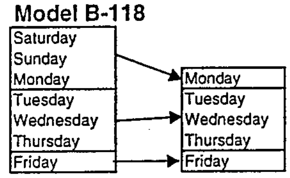

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 8.33 |
| Model sample Size | 33 |
| R square Value | 0.0004785 |
| SSE/Mean | 0.38 |

## Model B-117



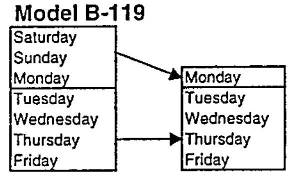

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 13.89 |
| Model sample Size | 31 |
| R square Value | 0.0265371 |
| SSE/Mean | 0.63 |

## Model B-118



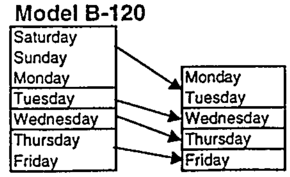

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 8.33 |
| Model sample Size | 33 |
| R square Value | 0.72764 |
| SSE/Mean | 0.34 |

## Model B-119



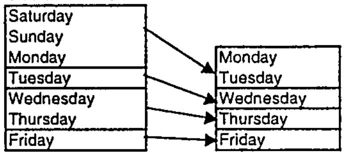

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 12.50 |
| Model sample Size | 21 |
| R square Value | 0.4541 |
| SSE/Mean | 0.49 |

## Model B-120



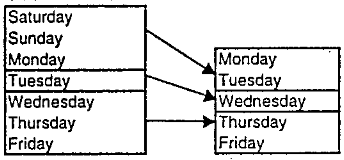

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.307558 |
| SSE/Mean | 0.53 |

### Model B-121



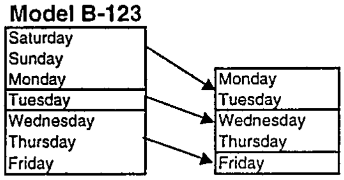

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 16.67 |
| Model sample Size | 40 |
| R square Value | 0.1181376 |
| SSE/Mean | 0.38 |

### Model B-122



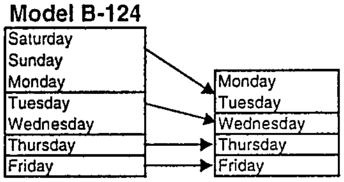

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 22.22 |
| Model sample Size | 28 |
| R square Value | 0.10397 |
| SSE/Mean | 0.29 |

### Model B-123



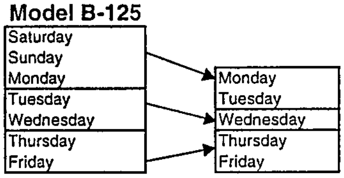

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 25.00 |
| Model sample Size | 27 |
| R square Value | 0.2095 |
| SSE/Mean | 0.39 |

### Model B-124



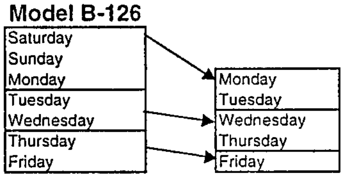

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0.1006407 |
| SSE/Mean | 0.43 |

### Model B-125



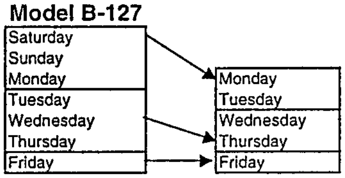

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.121524 |
| SSE/Mean | 0.41 |

### Model B-126



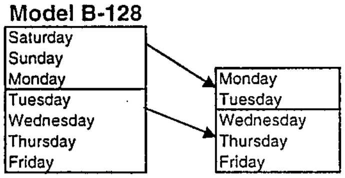

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.001666 |
| SSE/Mean | 0.40 |

### Model B-127



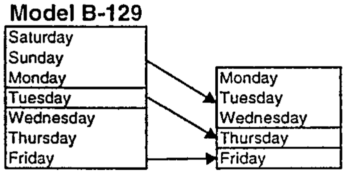

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 19.44 |
| Model sample Size | 29 |
| R square Value | 0.58481 |
| SSE/Mean | 0.23 |

### Model B-128



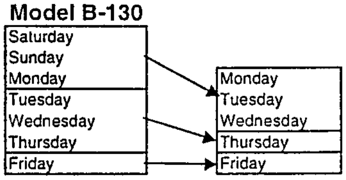

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 4.17 |
| Model sample Size | 23 |
| R square Value | 0.38586 |
| SSE/Mean | 0.29 |

### Model B-129



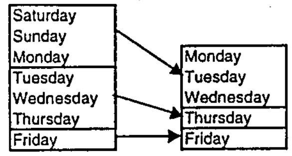

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 19.44 |
| Model sample Size | 29 |
| R square Value | 0.0106895 |
| SSE/Mean | 0.57 |

### Model B-130



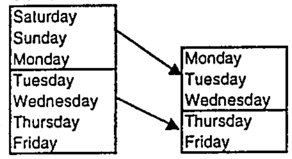

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 16.67 |
| Model sample Size | 30 |
| R square Value | 0.1166968 |
| SSE/Mean | 0.51 |

### Model B-131



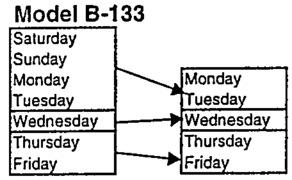

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 2.78 |
| Model sample Size | 35 |
| R square Value | 0.027567 |
| SSE/Mean | 0.57 |

### Model B-132



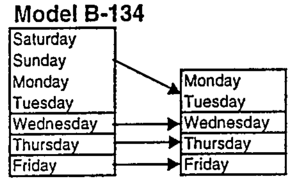

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 4.17 |
| Model sample Size | 23 |
| R square Value | 0.0320819 |
| SSE/Mean | 0.30 |

### Model B-133



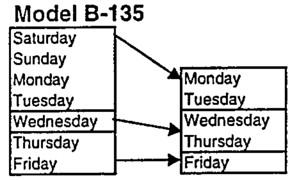

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.178922 |
| SSE/Mean | 0.37 |

### Model B-134



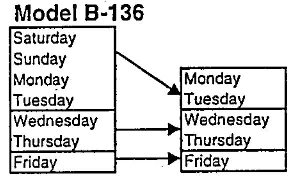

| | |
|---|---|
| Total sample Size | 48 |
| % of outlier | 8.33 |
| Model sample Size | 44 |
| R square Value | 0.2003907 |
| SSE/Mean | 0.37 |

### Model B-135



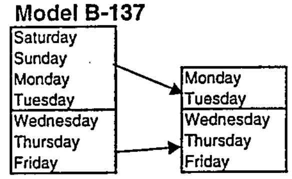

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.010704 |
| SSE/Mean | 0.39 |

### Model B-136



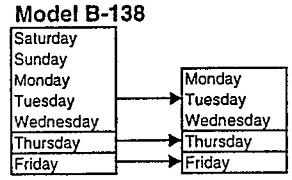

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 22.22 |
| Model sample Size | 28 |
| R square Value | 0.680769 |
| SSE/Mean | 0.20 |

### Model B-137



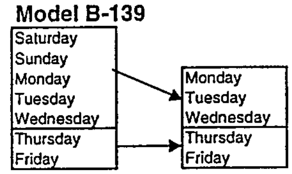

| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 4.17 |
| Model sample Size | 23 |
| R square Value | 0.250683 |
| SSE/Mean | 0.32 |

### Model B-138



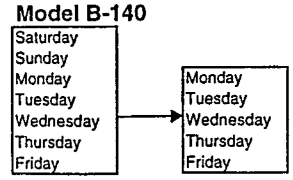

| | |
|---|---|
| Total sample Size | 36 |
| % of outlier | 11.11 |
| Model sample Size | 32 |
| R square Value | 0.480318 |
| SSE/Mean | 0.42 |

### Model B-139




| | |
|---|---|
| Total sample Size | 24 |
| % of outlier | 8.33 |
| Model sample Size | 22 |
| R square Value | 0.1115356 |
| SSE/Mean | 0.29 |

### Model B-140




| | |
|---|---|
| Total sample Size | 11 |
| % of outlier | 0.00 |
| Model sample Size | 11 |
| R square Value | 0.0003 |
| SSE/Mean | 0.19 |

# APPENDIX J

## Time Series Models

## Discussion & Statistical Details

# MONTHLY NUMBER OF FREIGHT UNITS MODEL

# TIME SERIES ANALYSIS DISCUSSION AND RESULTS

## ARIMA MODELS

A single equation ARIMA (Auto Regressive Integrated Moving Average) model states how any value in a single time series is linearly related to its own past values. Our goal is that any ARIMA model we build is a useful approximation of the true but unobservable underlying process. If a model is a good approximation of a process the model tends to mimic the behavior of the process. Thus forecasts from the model may provide useful information about future values of the series.

## General ARIMA(p,d,q)x(P,D,Q)s

Sometimes it is useful to write a general form for combined seasonal and nonseasonal process. The (p,d,q) represents the non seasonal part while the (P,D,Q)s represents the seasonal part with a pattern of length "s". Where "p" represents the nonseasonal Auto-Regressive (AR) part,"d" represents the nonseasonal difference required to perform a constant variance and "q" represents the nonseasonal Moving Average (MA) order. While, Ps is the maximum lag length on seasonal Auto-Regressive (AR) terms, Ds is the maximum seasonal difference and Qs is the maximum lag length on seasonal moving Average Terms (MA).

## Transformation

Standard ARIMA analysis depends on the simplifying assumption that the process that generated a single time series is stationary (mean, variance, auto-correlation function are constant through time).The monthly number of inbound and outbound freight units time series in Figures J.1 and J.2 show that the variances of both series seem to increase as their overall numbers of freight units levels increase.

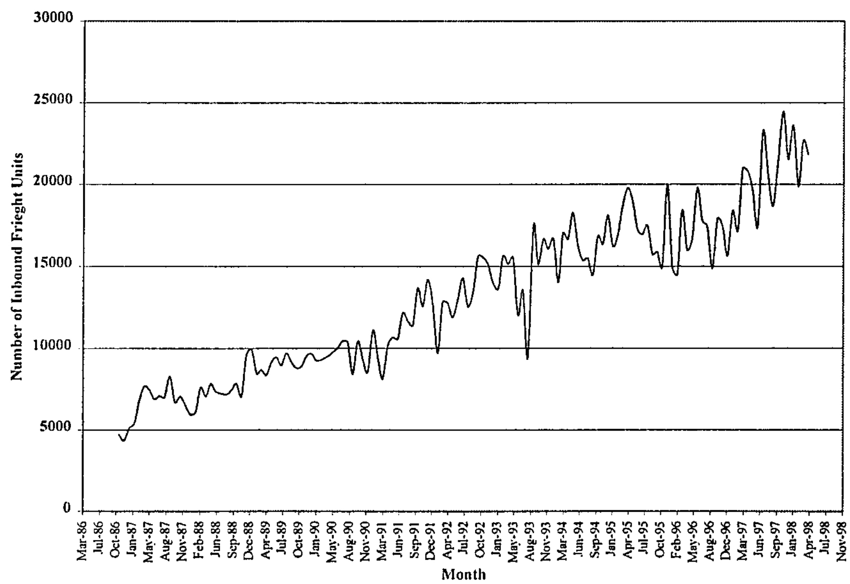



**Figure J.1 Number of Inbound Freight Units Time Series**

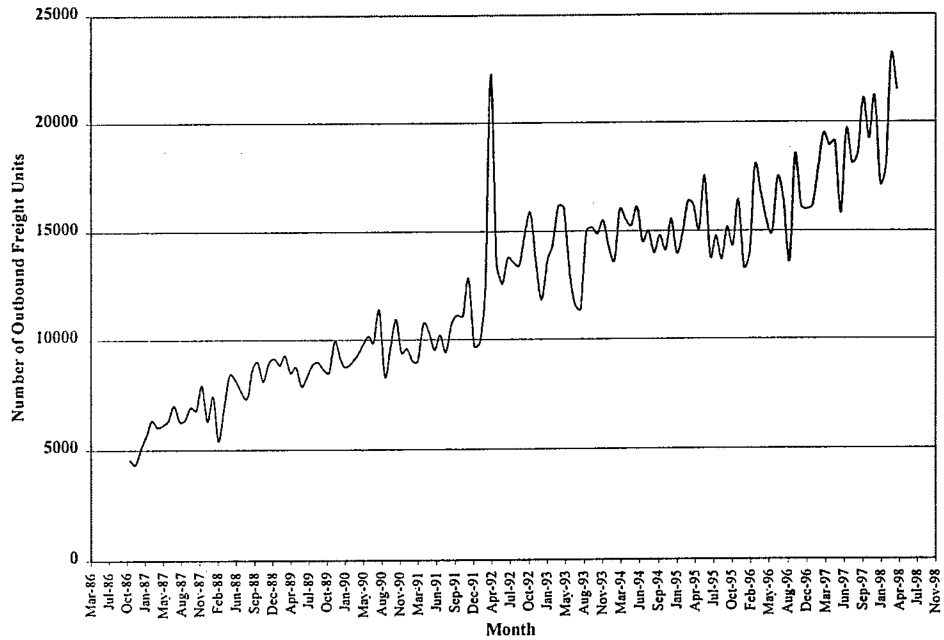



**Figure J.2 Number of Outbound Freight Units Time Series**

Taking the natural logarithms of the monthly numbers of inbound and outbound freight units yields new series with roughly constant variances. The new natural logs series for inbound and outbound directions are plotted in Figures J.3 and J.4. Using these new series result in building ARIMA models as function of the natural logs of the numbers of freight units and these model produce forecasts in the natural logs metric. Therefore, an additional process to transform forecasts back to the original numbers of freight units is needed.

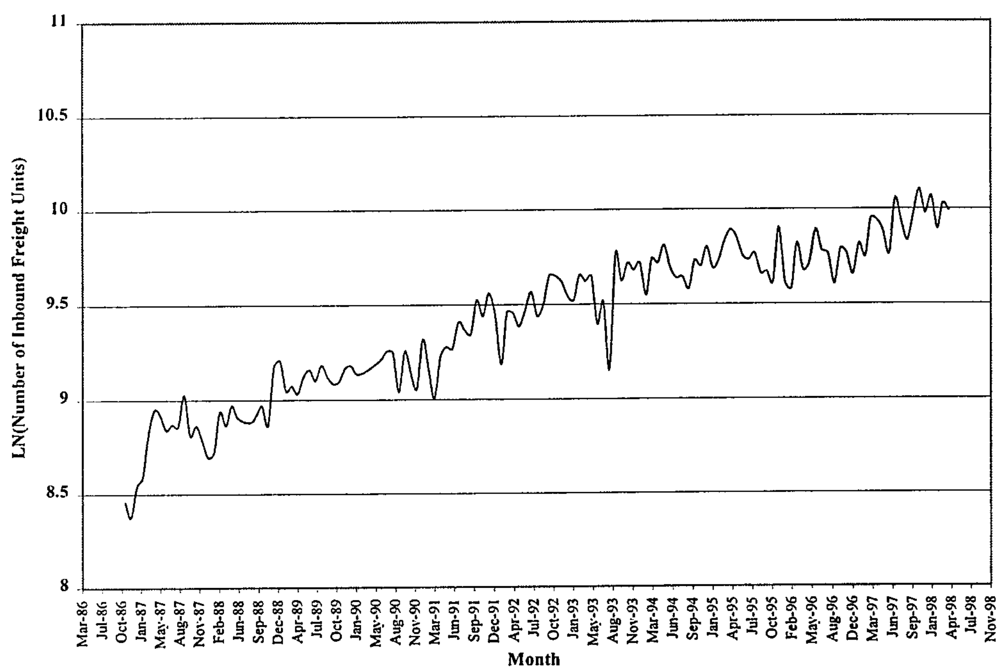



**Figure J.3 Natural Logarithm of the Number of Inbound Freight Units**

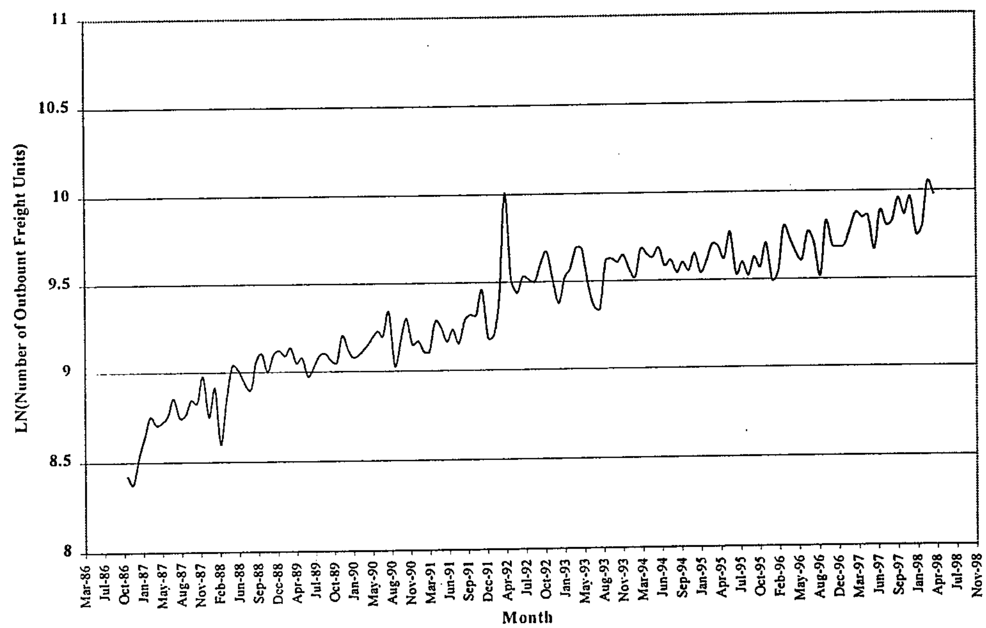



**Figure J.4 Natural Logarithm of the Number of Outbound Freight Units**

## Differencing ("d" value)

Inspection of the monthly numbers of inbound and outbound freight units time series illustrated in Figures J.1 and J.2 indicated that the numbers of freight units for both series do not fluctuate around constant means. These means increase as their overall number of freight units levels increase. In such cases, differencing the data is the recommended approach to convert the original time series to a new time series with a constant mean. Figures J.5 and J.6 plot the first difference time series (difference of two consecutive months) for the natural logarithm of inbound and outbound monthly numbers of freight units. It is clear from these figures that both series performed a constant mean. Therefore, no higher order of differencing is required. As a conclusion, the "d" value in the proposed ARIMA models has to equal to "1".

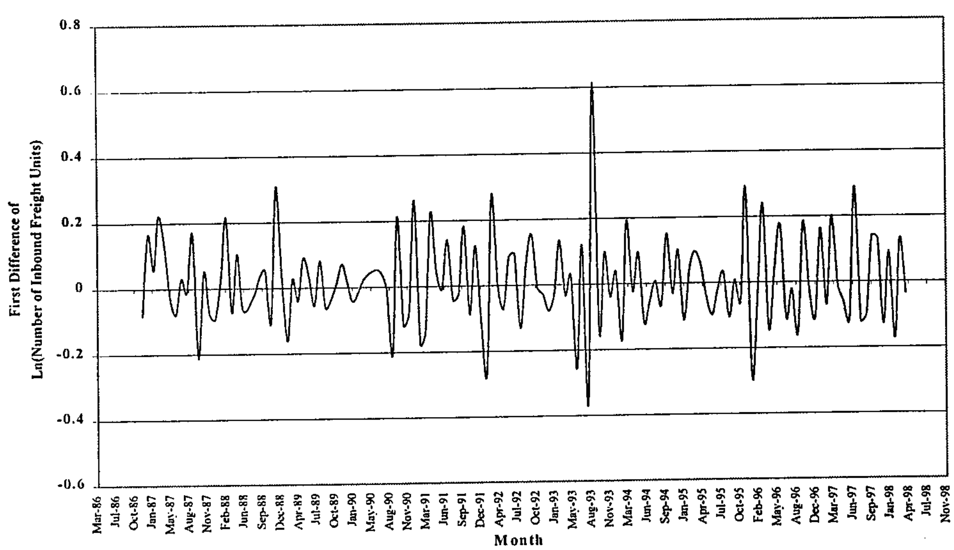



**Figure J.5 First Difference of the Natural Logarithm of the Number of Inbound Freight Units**

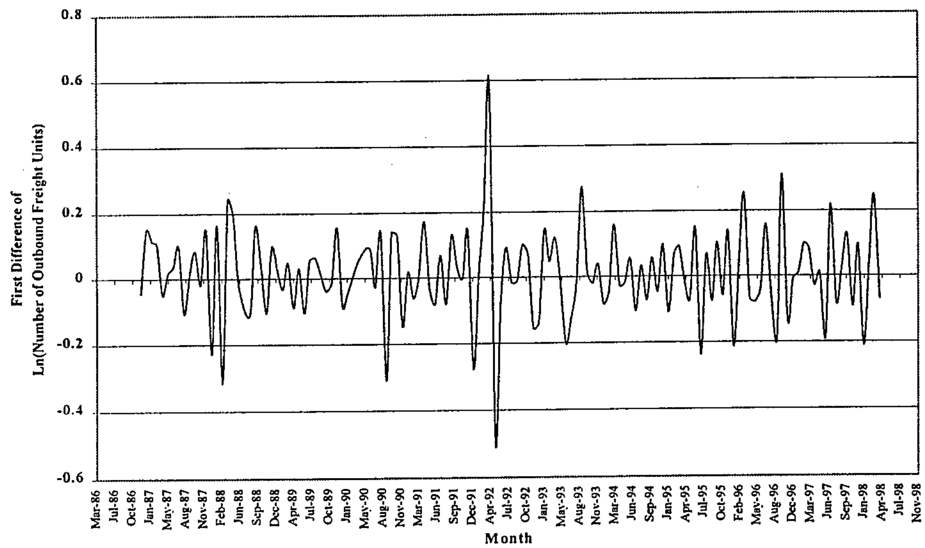



Figure J.6 First Difference of the Natural Logarithm of the Number of Outbound Freight Units

## Moving Average Process ("q" value)

Figures J.7 and J.8 show the autocorrelation pattern for both new inbound and outbound numbers of freight units time series, respectively. It is clear that for both cases, the Auto-Correlation Functions (ACF) spike at lag 1 (significant than zero at 95% confidence) and they cutoff to zero after this lag which indicate that a Moving Average (MA) process of order equal to 1 is needed for both series to construct adequate time series models. Therefore, the "q" value in the proposed ARIMA models should be equal to 1.

In conclusion, the nonseasonal part required for the model is ARIMA(0,1,1). However, seasonal effects must be checked before jumping to the final model.

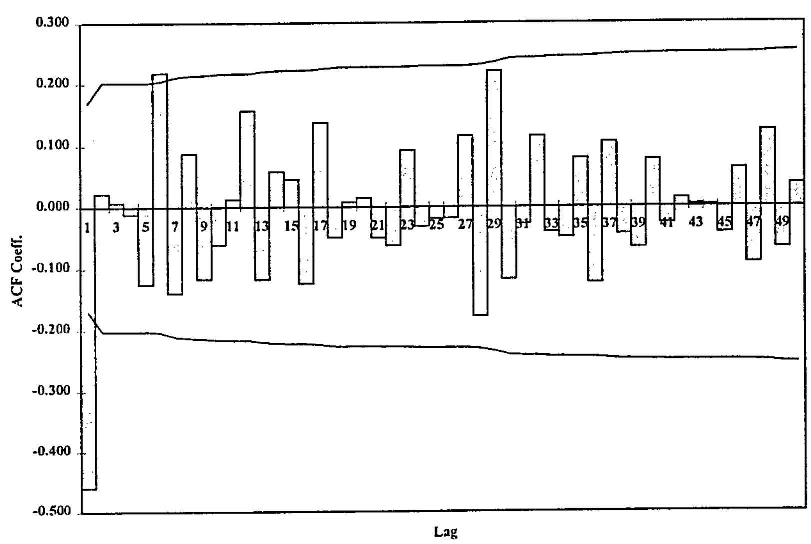



Figure J.7 Auto-Correlation Function for the first difference of natural logarithm of the Inbound Number of Freight Units

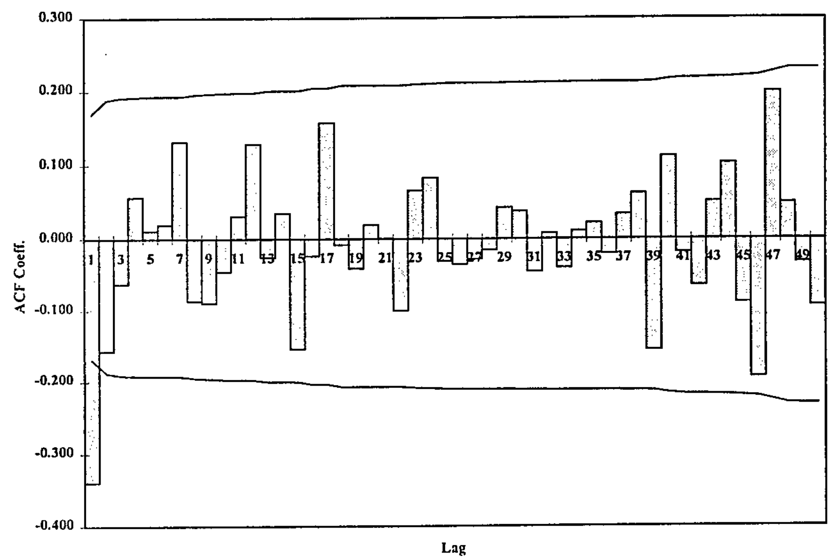



**Figure J.8 Auto-Correlation Function for the first difference of natural logarithm of the Outbound Number of Freight Units**

## Seasonal Pattern

The seasonal and nonseasonal patterns occur together within a time series and in the Auto-Correlation Function (ACF) and the Partial Auto-Correlation Function (PACF). The PACF for both models have spikes at lag 9 then a cutoff to zero, with last nonzero spike at this lag (see Figures J.9 and J.10). This indicates that the Auto-Regressive part in the seasonal term has a maximum of 9. In other words, the "P" value in the seasonal part has to equal to 1 and the s value should be equal to 9.

As a conclusion from this section, the nonseasonal part in the model is $(1,0,0)_9$

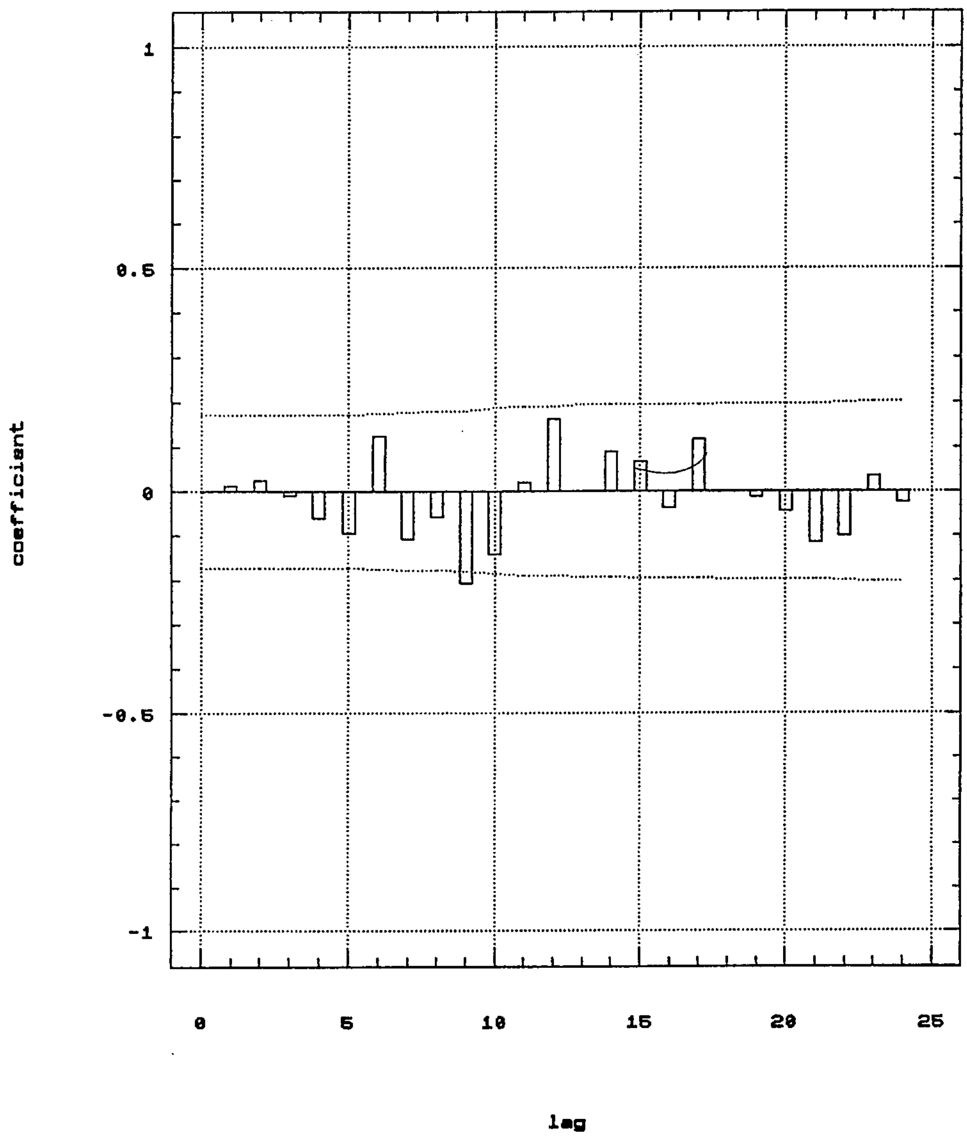



Figure J.9 Partial Auto-Correlation Function for the first difference of natural logarithm of the Inbound Number of Freight Units

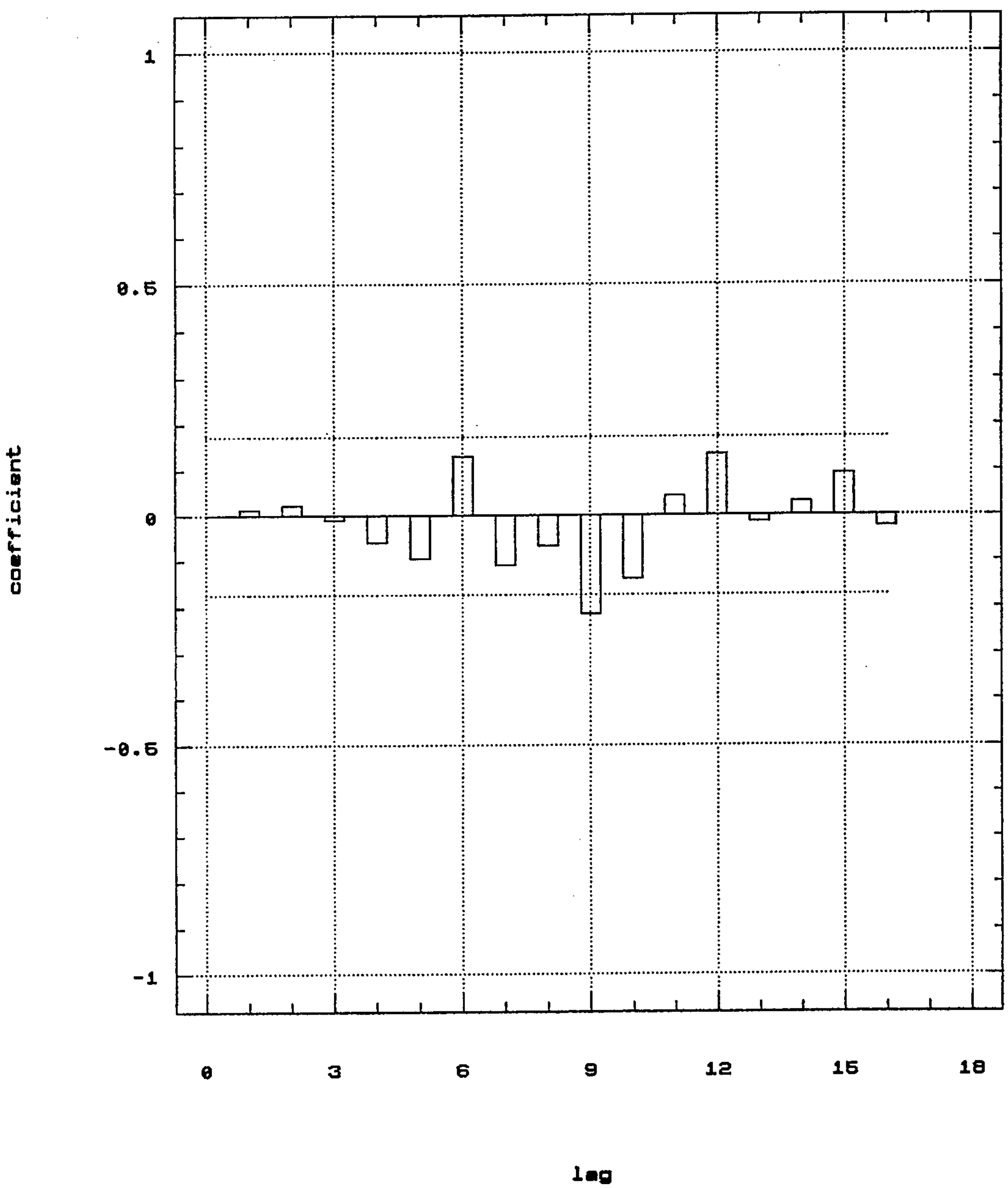



**Figure J.10 Partial Auto-Correlation Function for the first difference of natural logarithm of the Outbound Number of Freight Units**

## Models Statistics

```
Initial:      RSS = 1.94221  b = 0.1 0.459153 0.0114277
Iteration 1: RSS = 1.75272  b = -0.0921418 0.564956 0.0117824
Iteration 2: RSS = 1.70924  b = -0.18583 0.638518 0.0113426
Iteration 3: RSS = 1.70515  b = -0.213463 0.664301 0.0111525
Final:        RSS = 1.70499   ...stopped on criterion 2
------------------------------------------------------------------------------
                     Summary of Fitted Model for:  lncontin
------------------------------------------------------------------------------
          Parameter      Estimate  Stnd.error      T-value      P-value
          SAR( 9)        -.21803      .08710     -2.50310       .01354
          MA ( 1)         .67010      .06509     10.29443       .00000
          MEAN            .01108      .00279      3.97720       .00011
          CONSTANT        .01350
------------------------------------------------------------------------------
Model fitted to differences of order 1
Estimated white noise variance = 0.0130152 with 131 degrees of freedom.
Estimated white noise standard deviation (std err) = 0.114084
Chi-square test statistic on first 20 residual autocorrelations = 19.0881
     with probability of a larger value given white noise = 0.323497
Backforecasting: no                             Number of iterations performed: 4
------------------------------------------------------------------------------
```

**Figure J.11 Inbound Time Series Model Statistics**

```
Estimation begins.....
Initial:      RSS = 2.15724  b = 0.1 0.339362 0.0115904
Iteration 1: RSS = 1.88969  b = -0.074523 0.502438 0.0117256
Iteration 2: RSS = 1.7686  b = -0.161645 0.667535 0.0111272
Iteration 3: RSS = 1.76043  b = -0.179953 0.71484 0.0108877
Final:        RSS = 1.76038   ...stopped on criterion 2
------------------------------------------------------------------------------
                     Summary of Fitted Model for:  lncntout
------------------------------------------------------------------------------
          Parameter      Estimate  Stnd.error      T-value      P-value
          SAR( 9)        -.18032      .08866     -2.03393       .04398
          MA ( 1)         .70997      .06016     11.80195       .00000
          MEAN            .01080      .00248      4.36016       .00003
          CONSTANT        .01275
------------------------------------------------------------------------------
Model fitted to differences of order 1
Estimated white noise variance = 0.013438 with 131 degrees of freedom.
Estimated white noise standard deviation (std err) = 0.115922
Chi-square test statistic on first 20 residual autocorrelations = 18.2744
     with probability of a larger value given white noise = 0.371733
Backforecasting: no                             Number of iterations performed: 4
```

**Figure J.12 Outbound Time Series Model Statistics**

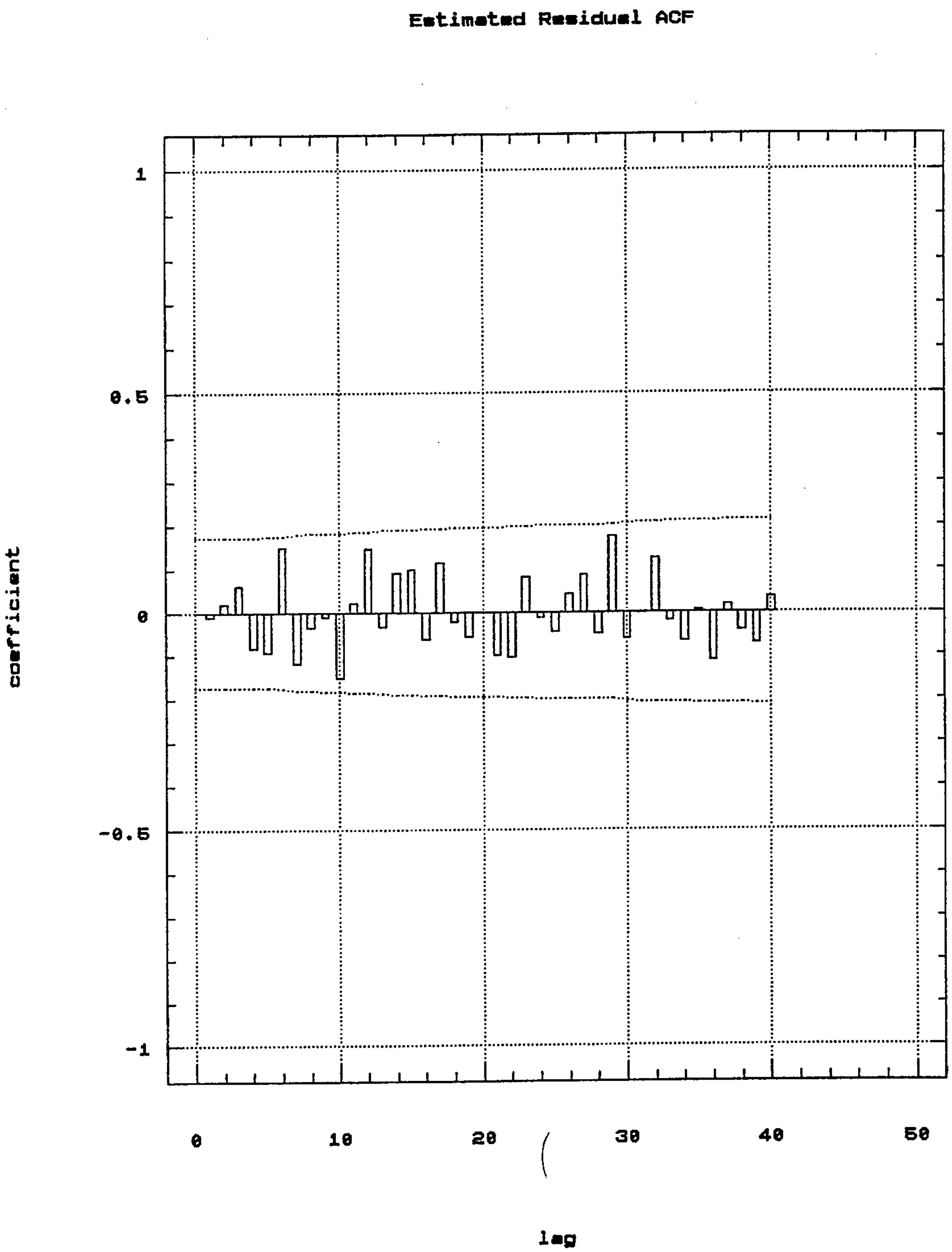



Figure J.13 Auto-Correlation Residuals for the Inbound ARIMA Model

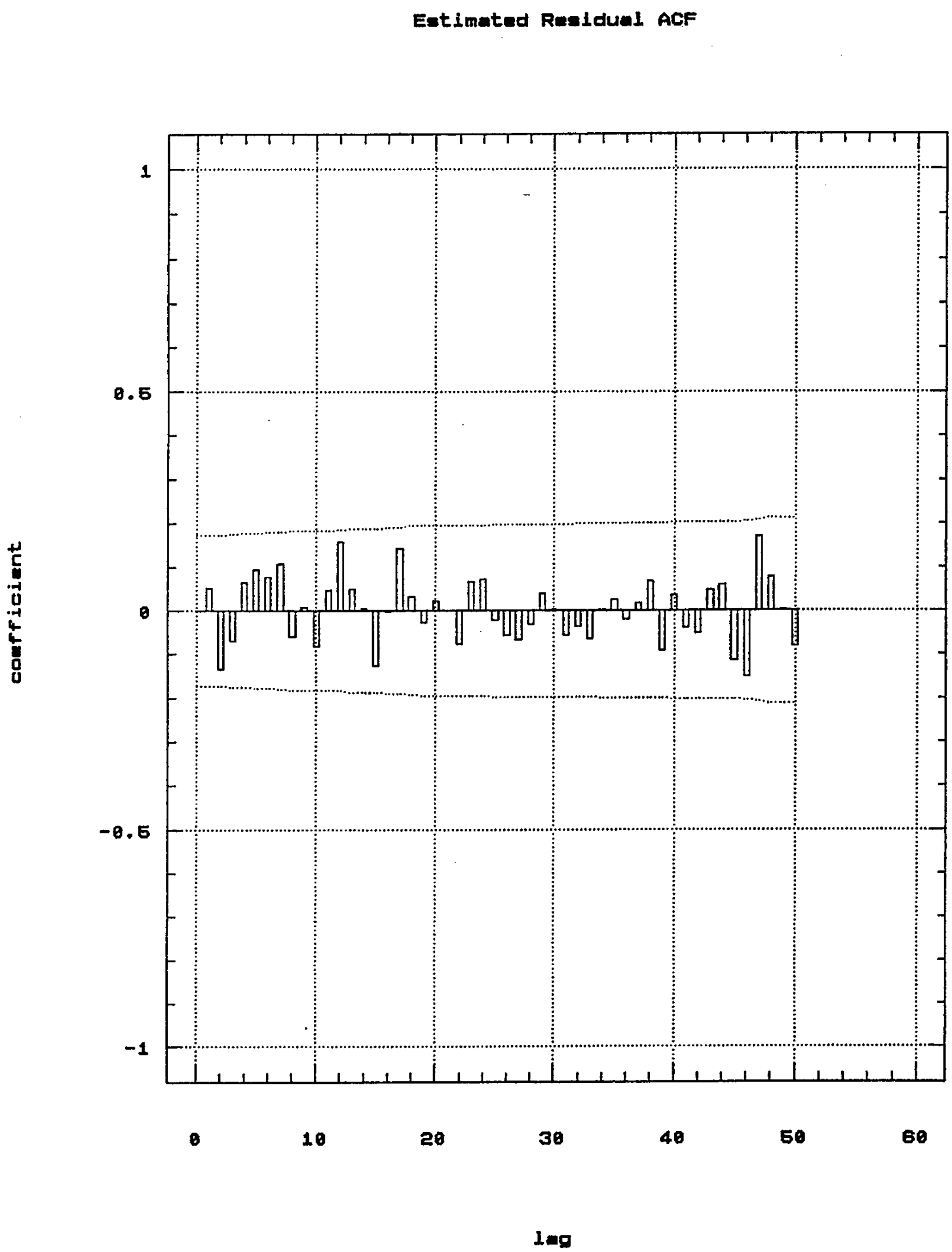



**Figure J.14 Auto-Correlation Residuals for the Outbound ARIMA Model**

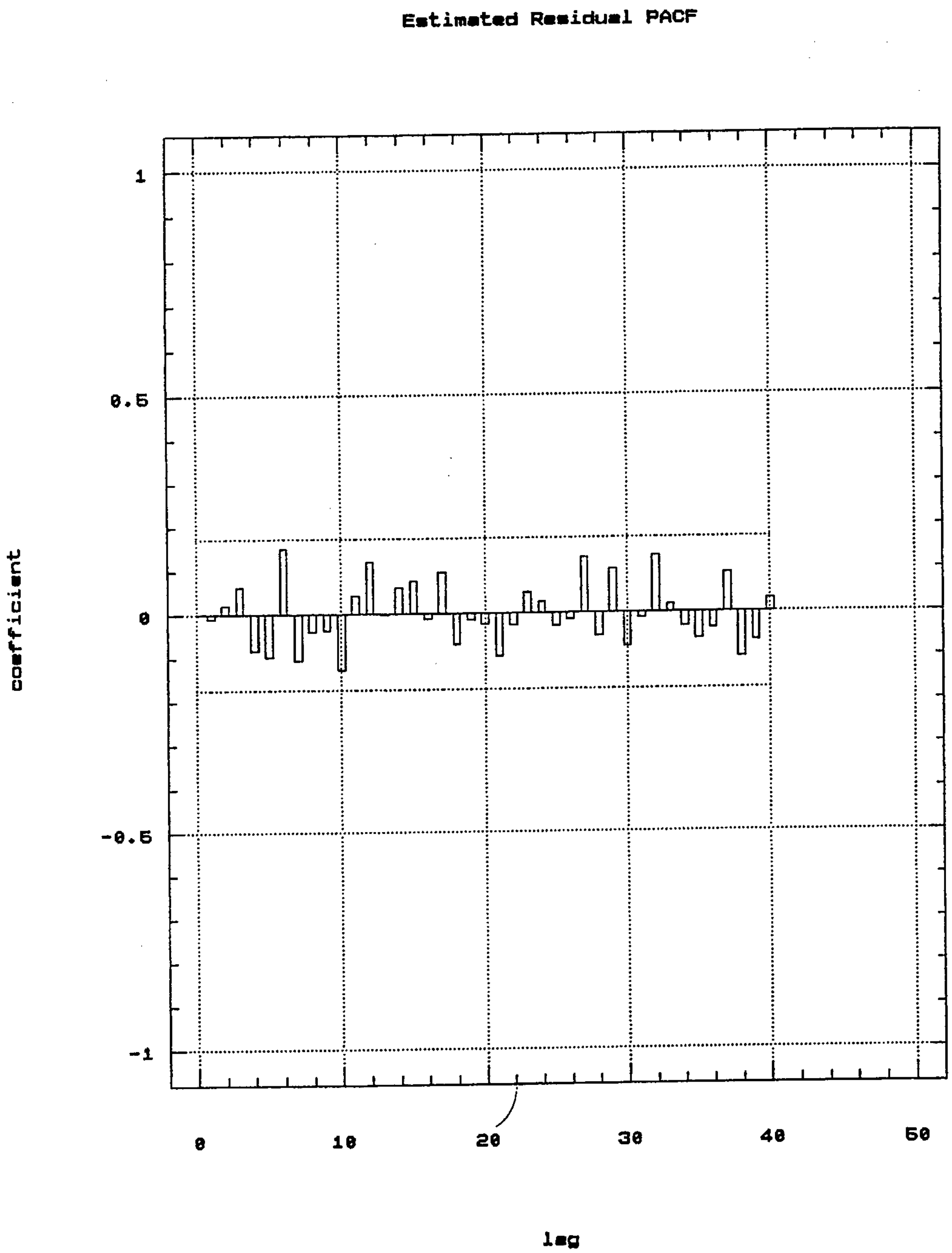



Figure J.15 Partial Auto-Correlation Residuals for the Inbound ARIMA Model

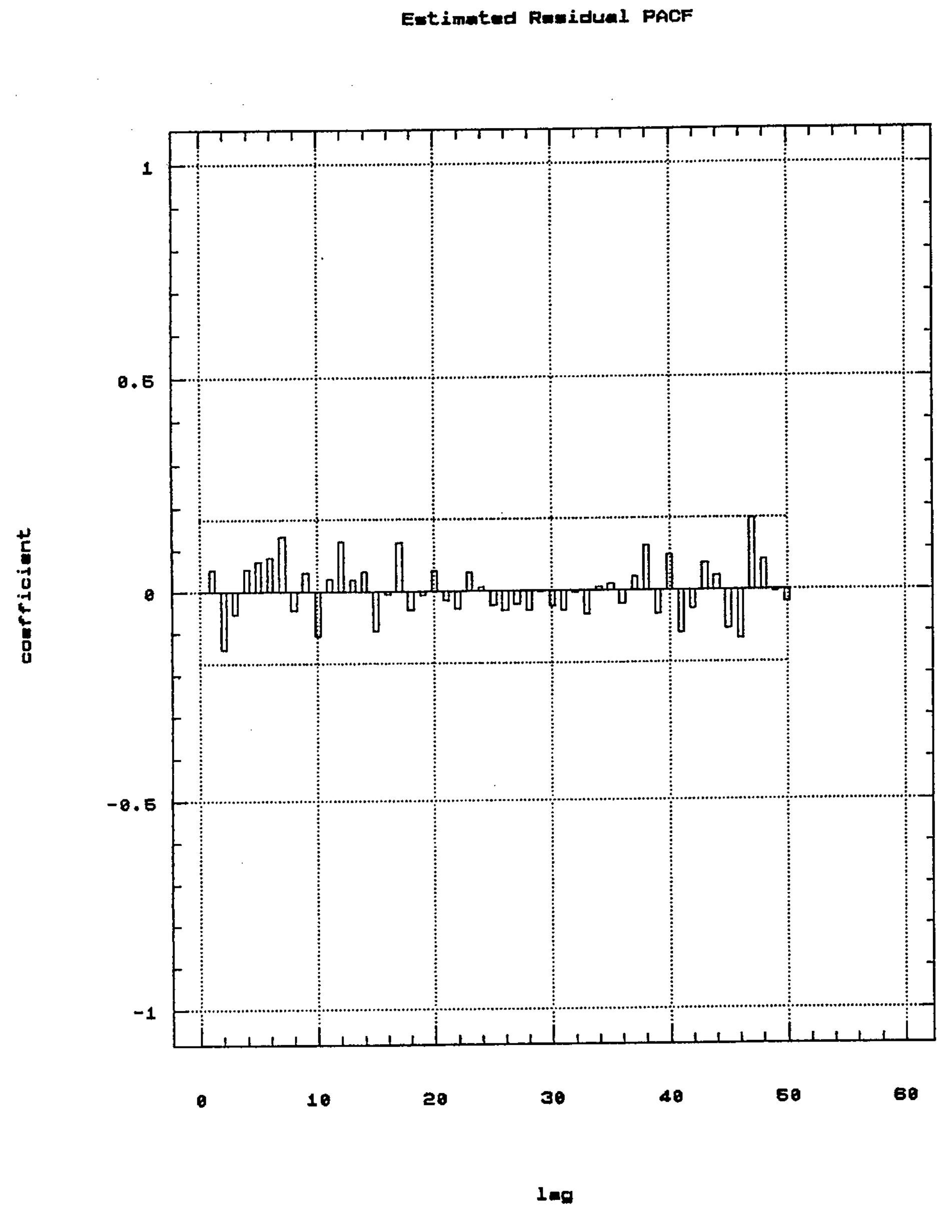



Figure J.26 Partial Auto-Correlation Residuals for the Outbound ARIMA Model

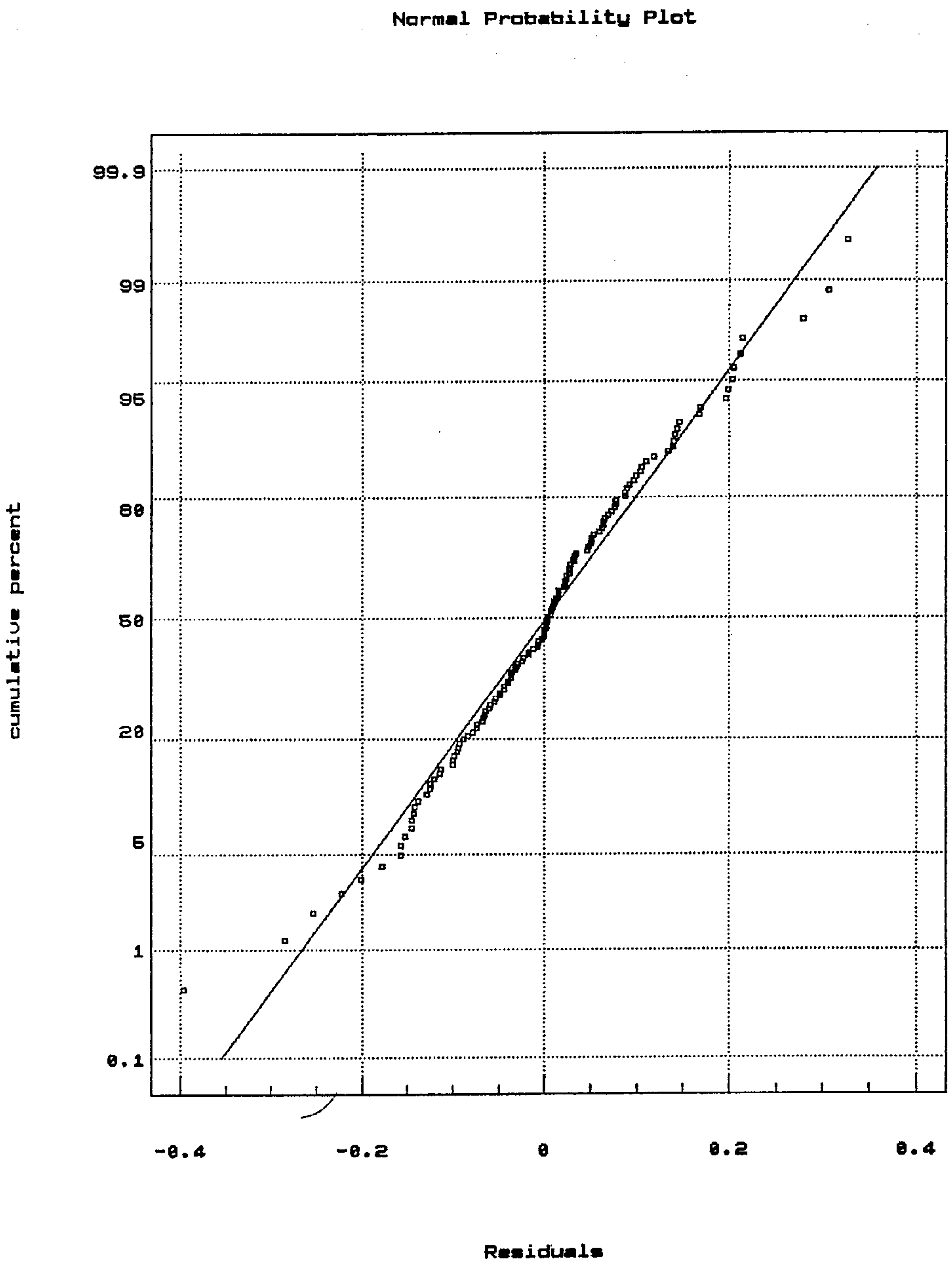



Figure J.37 Normal Probability Plot for the Inbound ARIMA Model

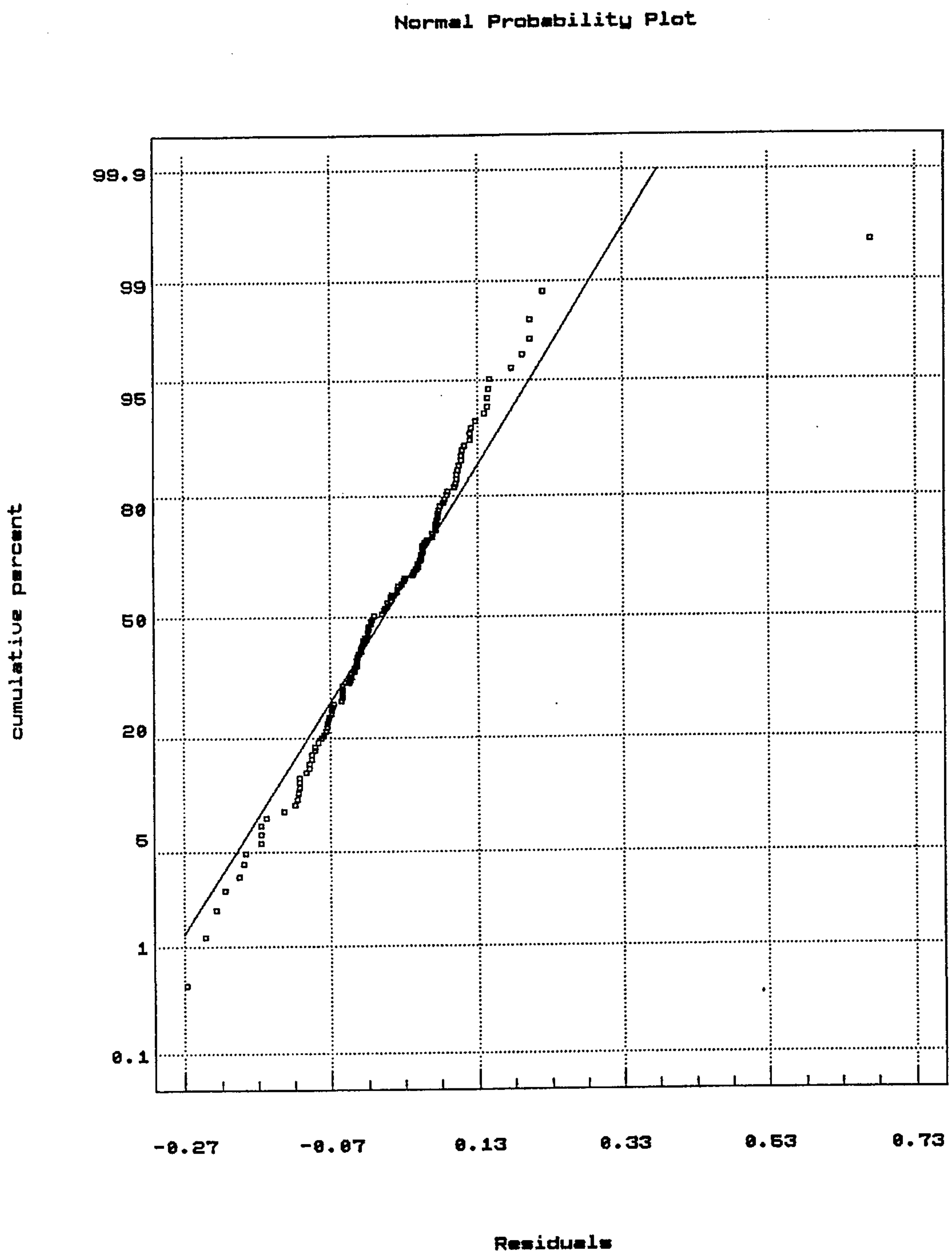



Figure J.48 Normal Probability Plot for the Outbound ARIMA Model

## Forecasting for Number of Freight Units

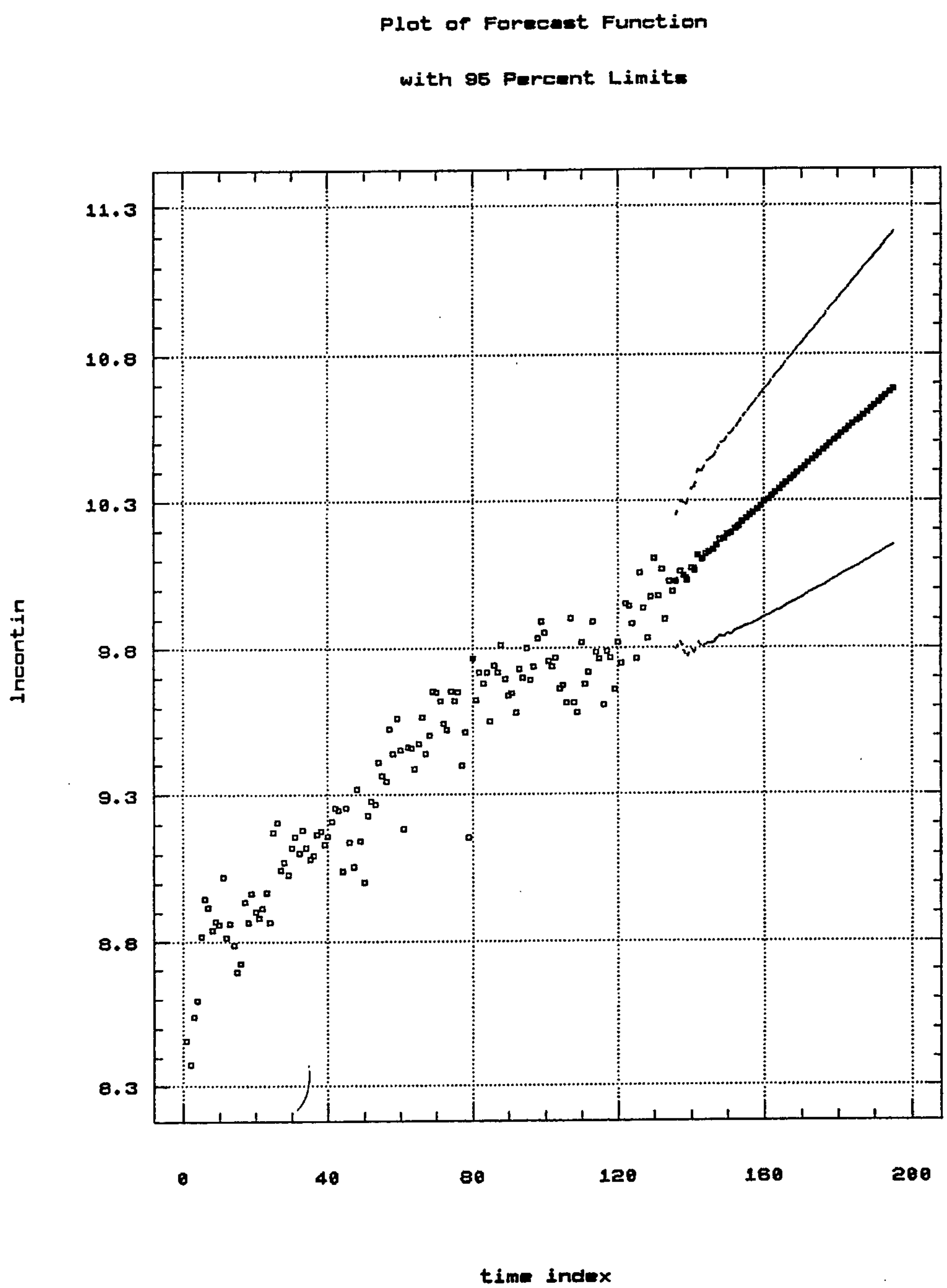



Figure J.19 Forecasts for Inbound number of Freight Units with 95% confidence limits

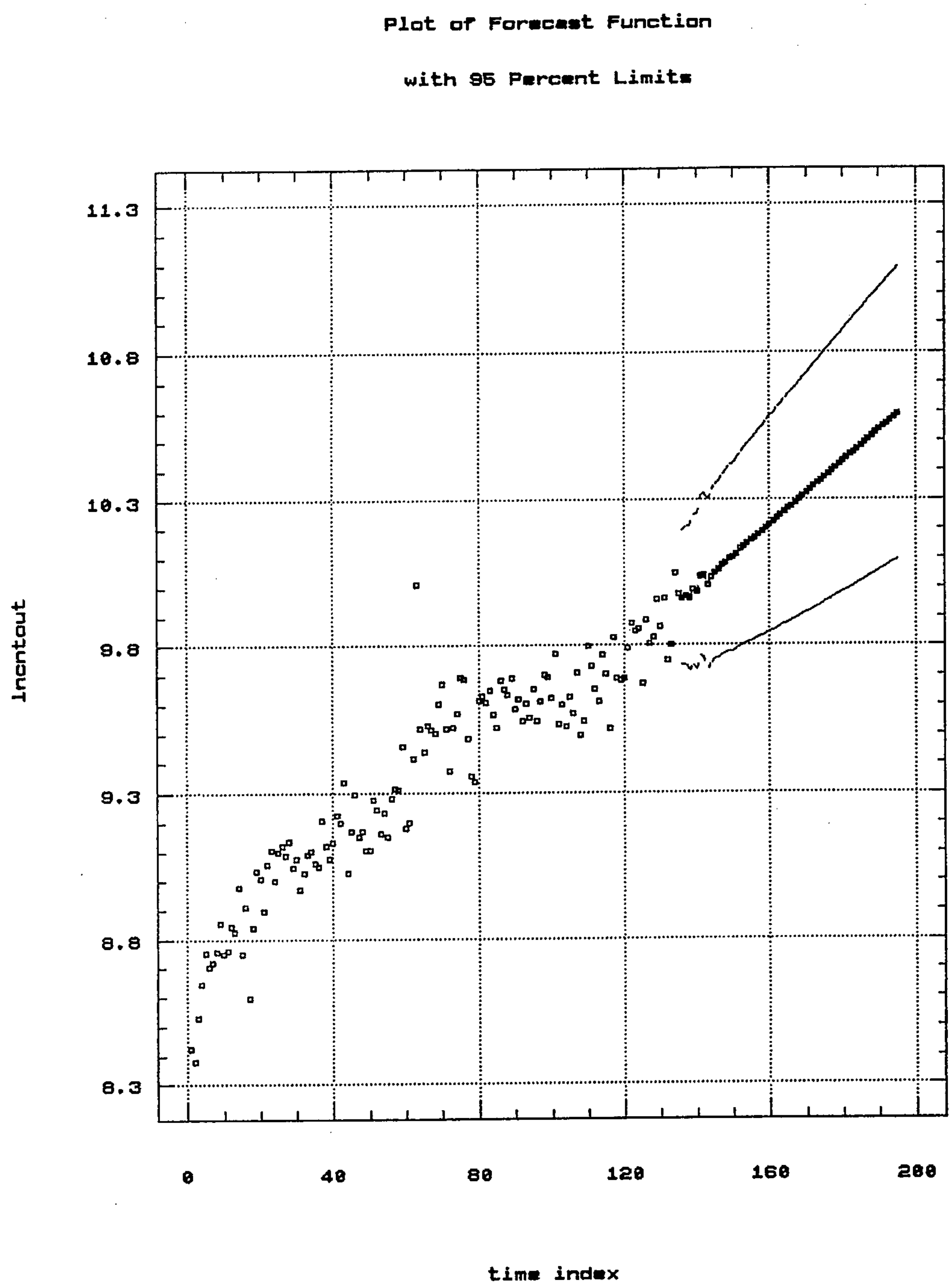



Figure J.20 Forecasts for Outbound number of Freight Units with 95% confidence limits

# APPENDIX K

## Hourly Distributions of Daily Truck Volumes

| Time | Mon 3/17/97 | Mon 3/24/97 | Mon 3/31/97 | Mon 4/7/97 | Mon 4/14/97 | Mon 4/21/97 | Mon 4/28/97 | Average - One Stdev | Average | Average + One Stdev |
|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 1:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 2:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 3:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 4:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 5:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 6:00 | 3% | 1% | 0% | 1% | 2% | 0% | 1% | 0% | 1% | 2% |
| 7:00 | 8% | 2% | 3% | 4% | 6% | 6% | 5% | 3% | 5% | 7% |
| 8:00 | 9% | 8% | 7% | 9% | 8% | 10% | 10% | 8% | 9% | 10% |
| 9:00 | 9% | 11% | 9% | 10% | 9% | 11% | 8% | 8% | 10% | 11% |
| 10:00 | 11% | 11% | 11% | 8% | 11% | 9% | 8% | 8% | 10% | 11% |
| 11:00 | 10% | 10% | 11% | 12% | 11% | 7% | 11% | 9% | 10% | 12% |
| 12:00 | 10% | 9% | 10% | 8% | 13% | 11% | 13% | 9% | 11% | 13% |
| 13:00 | 7% | 11% | 11% | 11% | 9% | 10% | 11% | 8% | 10% | 11% |
| 14:00 | 7% | 11% | 10% | 8% | 10% | 9% | 11% | 8% | 9% | 11% |
| 15:00 | 10% | 13% | 10% | 11% | 9% | 11% | 11% | 10% | 11% | 12% |
| 16:00 | 8% | 10% | 10% | 10% | 9% | 10% | 9% | 8% | 9% | 10% |
| 17:00 | 5% | 2% | 3% | 3% | 2% | 3% | 2% | 2% | 3% | 4% |
| 18:00 | 1% | 1% | 2% | 1% | 0% | 1% | 0% | 0% | 1% | 1% |
| 19:00 | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 1% |
| 20:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 21:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 22:00 | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% |
| 23:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

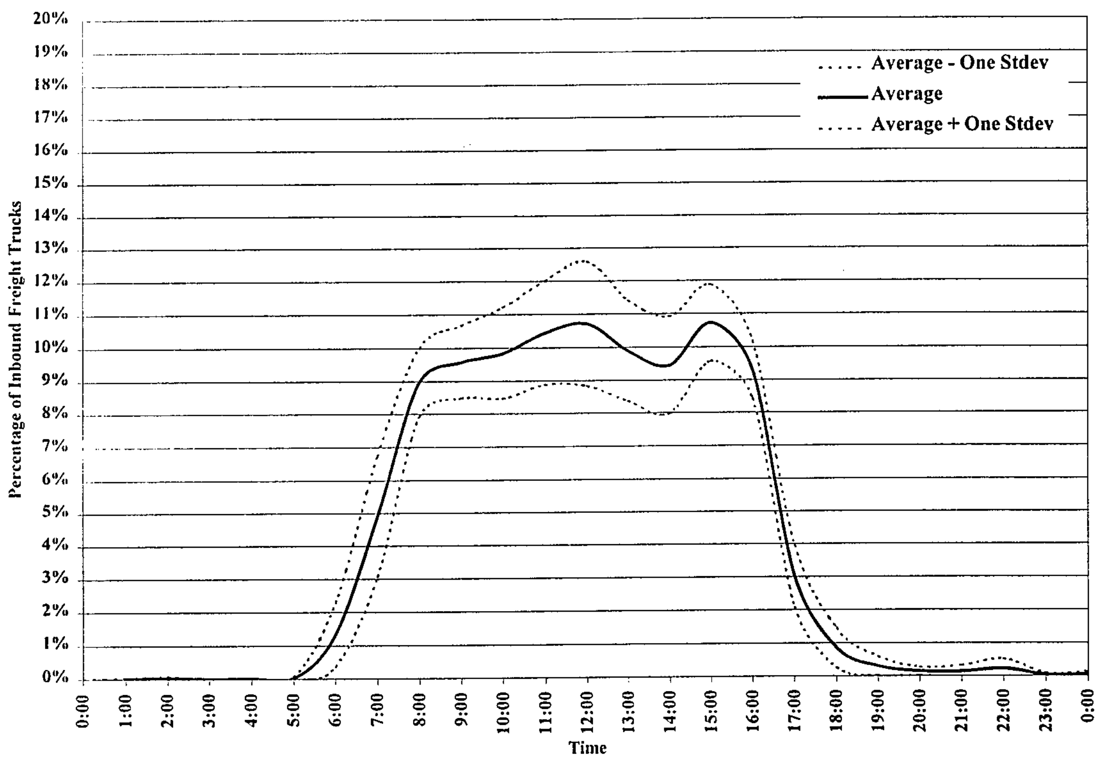
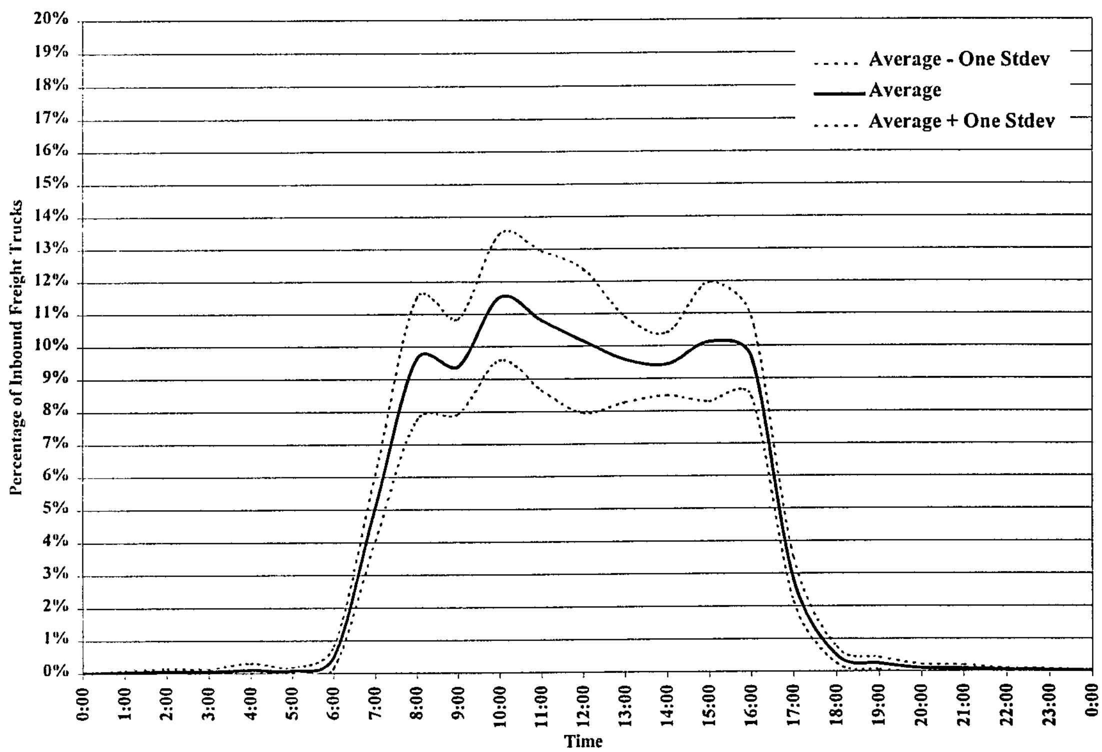


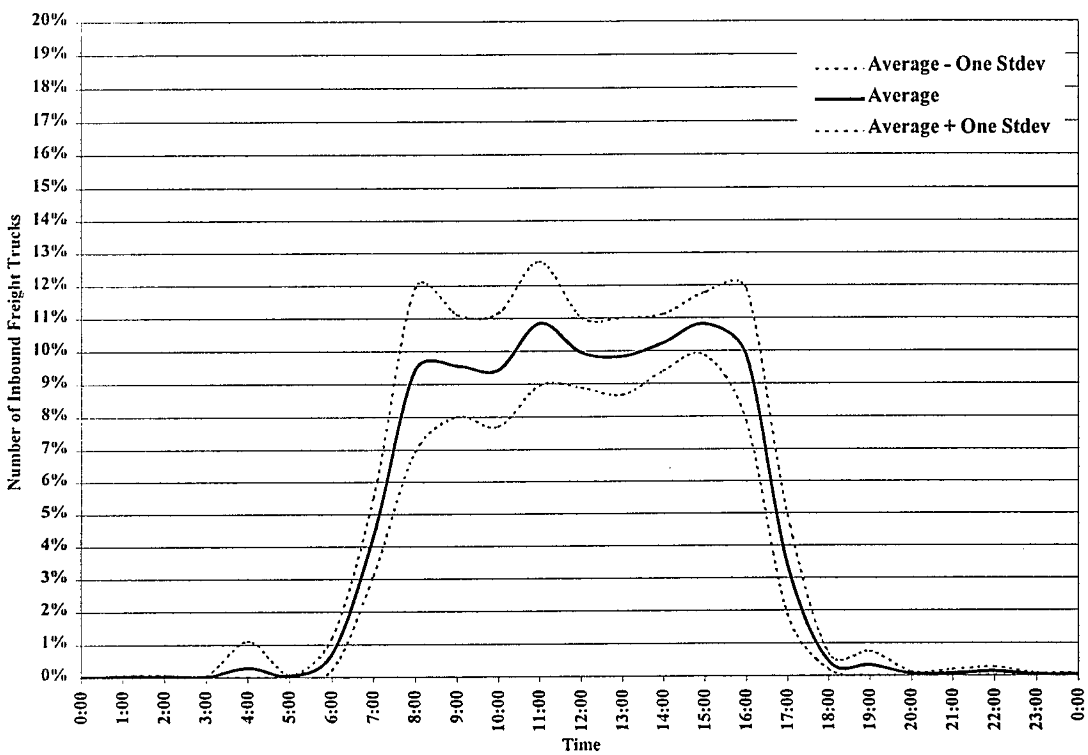

**Figure K.1 Hourly Truck Volume Distributions for Inbound Direction on Mondays (Trip Attraction Model)**

| Time | Tue 1/21/97 | Tue 2/25/97 | Tue 3/18/97 | Tue 3/25/97 | Tue 4/1/97 | Tue 4/8/97 | Tue 4/15/97 | Tue 4/22/97 | Tue 4/29/97 | Average - One Stdev | Average | Average + One Stdev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 1:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 2:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 3:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 4:00 | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 5:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 6:00 | 0% | 1% | 0% | 0% | 0% | 1% | 0% | 0% | 1% | 0% | **0%** | 1% |
| 7:00 | 5% | 6% | 5% | 6% | 5% | 5% | 3% | 6% | 5% | 4% | **5%** | 6% |
| 8:00 | 9% | 11% | 11% | 9% | 10% | 11% | 10% | 11% | 5% | 8% | **10%** | 11% |
| 9:00 | 12% | 8% | 11% | 10% | 10% | 8% | 10% | 9% | 7% | 8% | **9%** | 11% |
| 10:00 | 15% | 11% | 9% | 10% | 11% | 12% | 13% | 9% | 12% | 10% | **12%** | 13% |
| 11:00 | 12% | 10% | 12% | 10% | 9% | 12% | 10% | 7% | 15% | 9% | **11%** | 13% |
| 12:00 | 14% | 10% | 9% | 11% | 8% | 6% | 11% | 12% | 12% | 8% | **10%** | 12% |
| 13:00 | 8% | 8% | 8% | 11% | 10% | 10% | 9% | 12% | 9% | 8% | **10%** | 11% |
| 14:00 | 7% | 10% | 10% | 10% | 9% | 10% | 10% | 10% | 10% | 8% | **9%** | 10% |
| 15:00 | 7% | 11% | 12% | 10% | 13% | 9% | 10% | 9% | 10% | 8% | **10%** | 12% |
| 16:00 | 7% | 11% | 9% | 10% | 9% | 11% | 10% | 10% | 10% | 8% | **10%** | 11% |
| 17:00 | 3% | 2% | 2% | 2% | 2% | 3% | 3% | 4% | 3% | 2% | **3%** | 3% |
| 18:00 | 0% | 0% | 1% | 0% | 1% | 1% | 1% | 0% | 0% | 0% | **0%** | 1% |
| 19:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | **0%** | 0% |
| 20:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 21:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 22:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 23:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |



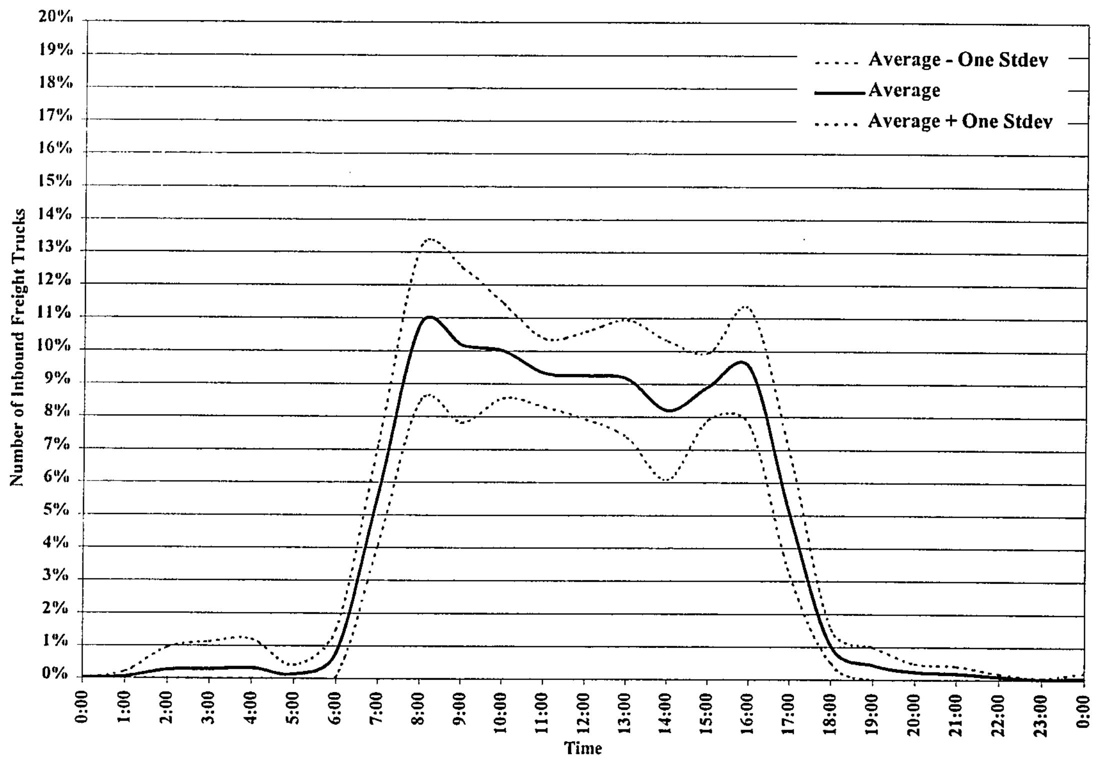

# Figure K.2 Hourly Truck Volume Distributions for Inbound Direction on Tuesdays (Trip Attraction Model)

| Time | Wed 1/22/97 | Wed 2/26/97 | Wed 3/19/97 | Wed 3/26/97 | Wed 4/2/97 | Wed 4/23/97 | Wed 4/9/97 | Wed 4/16/97 | Wed 4/30/97 | Average - One Stdev | Average | Average + One Stdev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 1:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 2:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 3:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 4:00 | 0% | 0% | 0% | 0% | 0% | 2% | 0% | 0% | 0% | 0% | **0%** | 1% |
| 5:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 6:00 | 0% | 0% | 1% | 1% | 1% | 1% | 1% | 0% | 1% | 0% | **1%** | 1% |
| 7:00 | 1% | 6% | 5% | 4% | 5% | 5% | 4% | 5% | 5% | 3% | **4%** | 6% |
| 8:00 | 4% | 10% | 13% | 9% | 11% | 10% | 11% | 11% | 7% | 7% | **9%** | 12% |
| 9:00 | 12% | 8% | 10% | 10% | 9% | 10% | 10% | 7% | 10% | 8% | **10%** | 11% |
| 10:00 | 11% | 10% | 10% | 11% | 10% | 9% | 11% | 7% | 6% | 8% | **9%** | 11% |
| 11:00 | 13% | 11% | 12% | 12% | 11% | 9% | 8% | 13% | 9% | 9% | **11%** | 13% |
| 12:00 | 10% | 10% | 12% | 8% | 10% | 10% | 9% | 10% | 11% | 9% | **10%** | 11% |
| 13:00 | 9% | 10% | 11% | 7% | 10% | 10% | 10% | 10% | 11% | 9% | **10%** | 11% |
| 14:00 | 12% | 10% | 10% | 9% | 10% | 10% | 9% | 12% | 11% | 9% | **10%** | 11% |
| 15:00 | 11% | 11% | 9% | 13% | 10% | 10% | 10% | 12% | 11% | 10% | **11%** | 12% |
| 16:00 | 10% | 10% | 6% | 9% | 10% | 10% | 12% | 9% | 13% | 8% | **10%** | 12% |
| 17:00 | 6% | 2% | 0% | 5% | 4% | 3% | 4% | 3% | 4% | 2% | **3%** | 5% |
| 18:00 | 1% | 1% | 0% | 0% | 1% | 0% | 0% | 1% | 1% | 0% | **0%** | 1% |
| 19:00 | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 1% | 0% | **0%** | 1% |
| 20:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 21:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 22:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 23:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |




# Figure K.3 Hourly Truck Volume Distributions for Inbound Direction on Wednesdays (Trip Attraction Model)

| Time | Thu 1/23/97 | Thu 2/27/97 | Thu 3/20/97 | Thu 3/27/97 | Thu 4/3/97 | Thu 4/10/97 | Thu 4/17/97 | Thu 4/24/97 | Thu 5/1/97 | Average - One Stdev | Average | Average + One Stdev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 1:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 2:00 | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 0% | 0% | 0% | **0%** | 1% |
| 3:00 | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 0% | 0% | 0% | **0%** | 1% |
| 4:00 | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 0% | 0% | 0% | **0%** | 1% |
| 5:00 | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | **0%** | 0% |
| 6:00 | 0% | 1% | 1% | 0% | 0% | 1% | 2% | 0% | 1% | 0% | **1%** | 2% |
| 7:00 | 4% | 4% | 5% | 5% | 5% | 5% | 8% | 6% | 8% | 4% | **6%** | 7% |
| 8:00 | 9% | 10% | 13% | 9% | 12% | 7% | 14% | 10% | 13% | 8% | **11%** | 13% |
| 9:00 | 11% | 9% | 12% | 7% | 7% | 11% | 10% | 11% | 14% | 8% | **10%** | 13% |
| 10:00 | 13% | 10% | 11% | 10% | 9% | 9% | 10% | 8% | 12% | 9% | **10%** | 11% |
| 11:00 | 9% | 9% | 8% | 9% | 8% | 11% | 9% | 10% | 11% | 8% | **9%** | 10% |
| 12:00 | 10% | 11% | 7% | 10% | 11% | 10% | 8% | 8% | 8% | 8% | **9%** | 11% |
| 13:00 | 8% | 11% | 7% | 9% | 9% | 10% | 6% | 12% | 10% | 7% | **9%** | 11% |
| 14:00 | 8% | 8% | 8% | 10% | 10% | 8% | 4% | 10% | 7% | 6% | **8%** | 10% |
| 15:00 | 10% | 10% | 8% | 9% | 11% | 9% | 8% | 9% | 8% | 8% | **9%** | 10% |
| 16:00 | 10% | 8% | 12% | 11% | 10% | 10% | 9% | 10% | 6% | 8% | **10%** | 11% |
| 17:00 | 7% | 6% | 6% | 7% | 5% | 6% | 3% | 5% | 1% | 3% | **5%** | 7% |
| 18:00 | 1% | 1% | 1% | 1% | 1% | 2% | 0% | 1% | 0% | 0% | **1%** | 2% |
| 19:00 | 0% | 1% | 0% | 2% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 1% |
| 20:00 | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 21:00 | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 22:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 23:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |




# Figure K.4 Hourly Truck Volume Distributions for Inbound Direction on Thursdays (Trip Attraction Model)

| Time | Fri 1/17/97 | Fri 1/24/97 | Fri 2/28/97 | Fri 4/4/97 | Fri 4/11/97 | Fri 4/18/97 | Fri 4/25/97 | Average - One Stdev | Average | Average + One Stdev |
|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 1:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 2:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 3:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 4:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 5:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 6:00 | 0% | 1% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 1% |
| 7:00 | 3% | 4% | 7% | 7% | 5% | 2% | 4% | 3% | 5% | 7% |
| 8:00 | 7% | 8% | 7% | 9% | 8% | 3% | 8% | 5% | 7% | 9% |
| 9:00 | 8% | 6% | 7% | 7% | 8% | 9% | 8% | 6% | 7% | 9% |
| 10:00 | 10% | 7% | 8% | 8% | 8% | 10% | 7% | 7% | 8% | 10% |
| 11:00 | 10% | 11% | 10% | 7% | 10% | 10% | 10% | 8% | 10% | 11% |
| 12:00 | 10% | 14% | 12% | 9% | 8% | 12% | 10% | 9% | 11% | 13% |
| 13:00 | 9% | 6% | 8% | 8% | 9% | 10% | 7% | 7% | 8% | 10% |
| 14:00 | 9% | 9% | 8% | 9% | 6% | 14% | 8% | 7% | 9% | 11% |
| 15:00 | 10% | 11% | 7% | 9% | 9% | 7% | 9% | 8% | 9% | 10% |
| 16:00 | 9% | 8% | 8% | 10% | 8% | 6% | 7% | 7% | 8% | 9% |
| 17:00 | 5% | 9% | 7% | 8% | 7% | 5% | 6% | 5% | 7% | 8% |
| 18:00 | 4% | 3% | 3% | 3% | 3% | 4% | 5% | 3% | 4% | 4% |
| 19:00 | 2% | 2% | 2% | 3% | 3% | 3% | 4% | 2% | 3% | 4% |
| 20:00 | 1% | 2% | 2% | 3% | 3% | 3% | 3% | 2% | 2% | 3% |
| 21:00 | 0% | 1% | 2% | 1% | 1% | 1% | 1% | 1% | 1% | 2% |
| 22:00 | 0% | 0% | 0% | 0% | 1% | 1% | 0% | 0% | 0% | 1% |
| 23:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

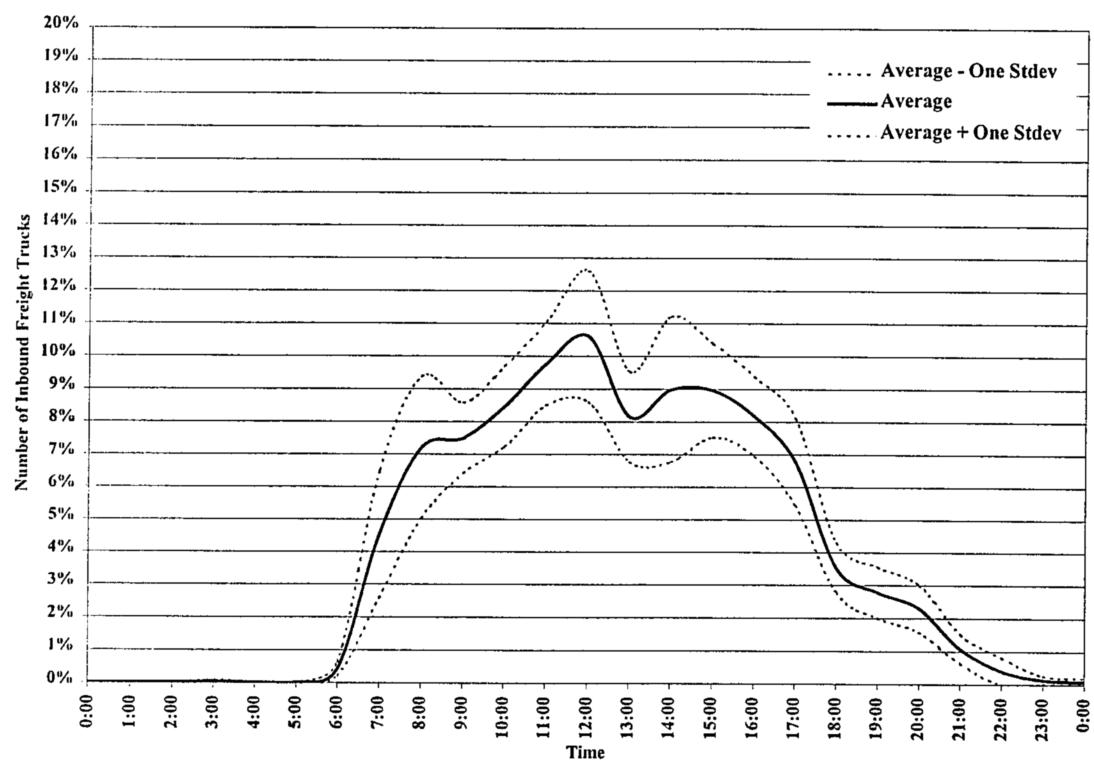



**Figure K.5 Hourly Truck Volume Distributions for Inbound Direction on Fridays (Trip Attraction Model)**

| Time | Mon 3/17/97 | Mon 3/24/97 | Mon 3/31/97 | Mon 4/7/97 | Mon 4/14/97 | Mon 4/21/97 | Mon 4/28/97 | Average - One Stdev | Average | Average + One Stdev |
|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 1:00 | 0% | 0% | 0% | 0% | 1% | 0% | 4% | 0% | 1% | 2% |
| 2:00 | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 0% | 1% | 3% |
| 3:00 | 0% | 0% | 0% | 0% | 0% | 0% | 7% | 0% | 1% | 4% |
| 4:00 | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 0% | 1% | 3% |
| 5:00 | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 0% | 1% | 2% |
| 6:00 | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 1% |
| 7:00 | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| 8:00 | 3% | 3% | 2% | 6% | 3% | 3% | 1% | 1% | 3% | 5% |
| 9:00 | 7% | 7% | 7% | 10% | 8% | 11% | 4% | 6% | 8% | 10% |
| 10:00 | 12% | 9% | 10% | 6% | 7% | 9% | 5% | 6% | 8% | 10% |
| 11:00 | 10% | 12% | 13% | 7% | 10% | 8% | 4% | 6% | 9% | 12% |
| 12:00 | 13% | 9% | 10% | 10% | 15% | 8% | 10% | 8% | 11% | 13% |
| 13:00 | 3% | 10% | 7% | 10% | 10% | 8% | 10% | 5% | 8% | 11% |
| 14:00 | 13% | 11% | 10% | 8% | 11% | 11% | 11% | 10% | 11% | 12% |
| 15:00 | 14% | 12% | 11% | 13% | 12% | 14% | 12% | 12% | 13% | 14% |
| 16:00 | 7% | 11% | 11% | 14% | 10% | 13% | 5% | 7% | 10% | 13% |
| 17:00 | 10% | 11% | 10% | 9% | 9% | 11% | 4% | 7% | 9% | 11% |
| 18:00 | 4% | 2% | 4% | 3% | 2% | 2% | 0% | 1% | 2% | 4% |
| 19:00 | 2% | 1% | 1% | 1% | 0% | 1% | 0% | 0% | 1% | 1% |
| 20:00 | 1% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 1% | 1% |
| 21:00 | 1% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 1% |
| 22:00 | 1% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 1% |
| 23:00 | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% |
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 4% | 0% | 1% | 2% |

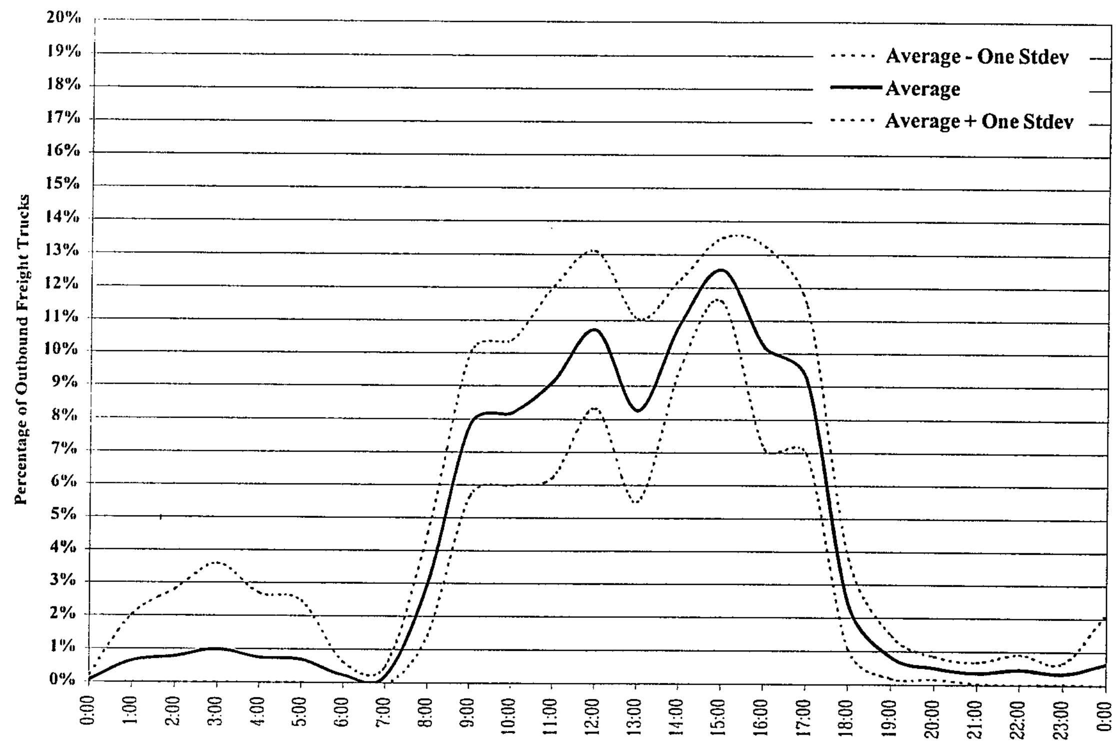



**Figure K.6 Hourly Truck Volume Distributions for Outbound Direction on Mondays (Trip Production Model)**

| Time | Tue 1/21/97 | Tue 2/25/97 | Tue 3/18/97 | Tue 3/25/97 | Tue 4/1/97 | Tue 4/8/97 | Tue 4/15/97 | Tue 4/22/97 | Tue 4/29/97 | Average - One Stdev | Average | Average + One Stdev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 1:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 2:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 0% | 0% | 1% |
| 3:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 0% | 0% | 1% |
| 4:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 0% | 0% | 1% |
| 5:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 0% | 0% | 1% |
| 6:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 7:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 8:00 | 5% | 5% | 2% | 4% | 5% | 4% | 1% | 3% | 2% | 2% | 3% | 5% |
| 9:00 | 10% | 9% | 8% | 8% | 9% | 9% | 10% | 7% | 6% | 7% | 8% | 10% |
| 10:00 | 13% | 10% | 11% | 9% | 9% | 9% | 10% | 10% | 7% | 8% | 10% | 12% |
| 11:00 | 13% | 9% | 11% | 13% | 11% | 10% | 12% | 10% | 11% | 10% | 11% | 12% |
| 12:00 | 11% | 9% | 11% | 13% | 10% | 11% | 11% | 10% | 14% | 10% | 11% | 12% |
| 13:00 | 10% | 11% | 7% | 8% | 7% | 10% | 9% | 9% | 11% | 7% | 9% | 11% |
| 14:00 | 9% | 11% | 10% | 11% | 11% | 10% | 8% | 11% | 10% | 9% | 10% | 11% |
| 15:00 | 10% | 12% | 13% | 11% | 12% | 12% | 12% | 12% | 9% | 10% | 11% | 13% |
| 16:00 | 8% | 9% | 14% | 12% | 12% | 11% | 10% | 11% | 10% | 9% | 11% | 13% |
| 17:00 | 8% | 10% | 9% | 9% | 11% | 11% | 9% | 12% | 8% | 8% | 10% | 11% |
| 18:00 | 2% | 4% | 2% | 3% | 1% | 2% | 5% | 2% | 1% | 1% | 2% | 4% |
| 19:00 | 0% | 0% | 1% | 0% | 1% | 1% | 1% | 1% | 0% | 0% | 1% | 1% |
| 20:00 | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 1% |
| 21:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 1% |
| 22:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 23:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% |

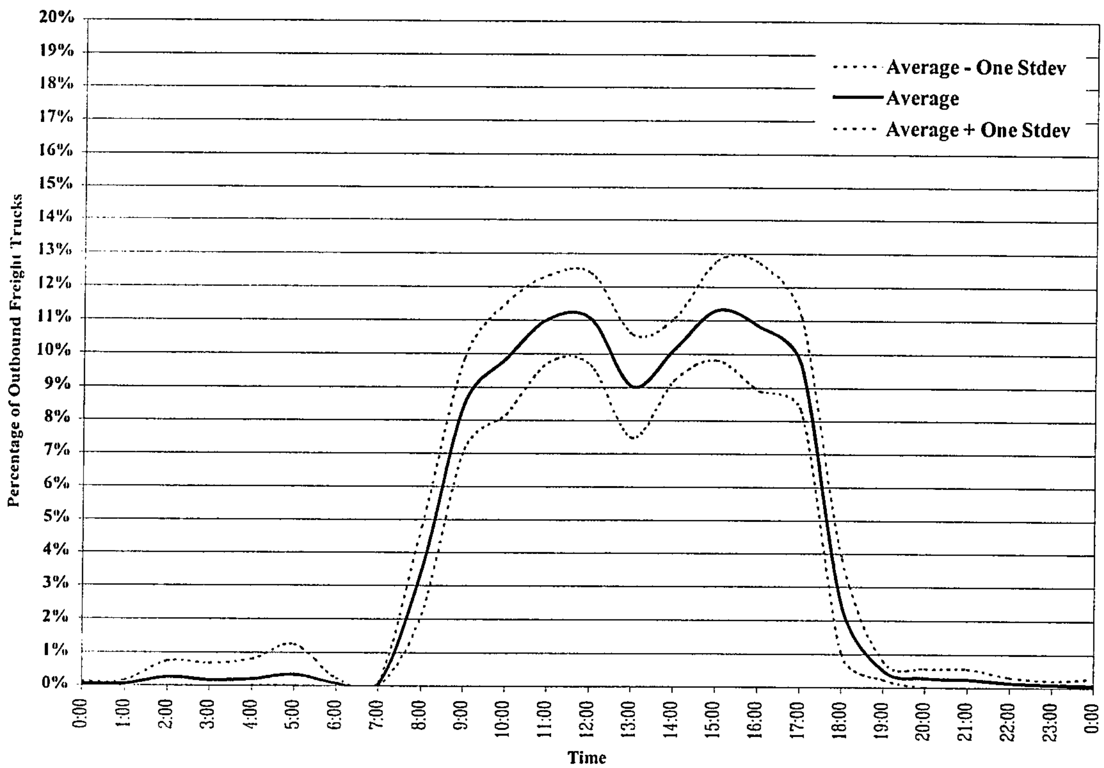
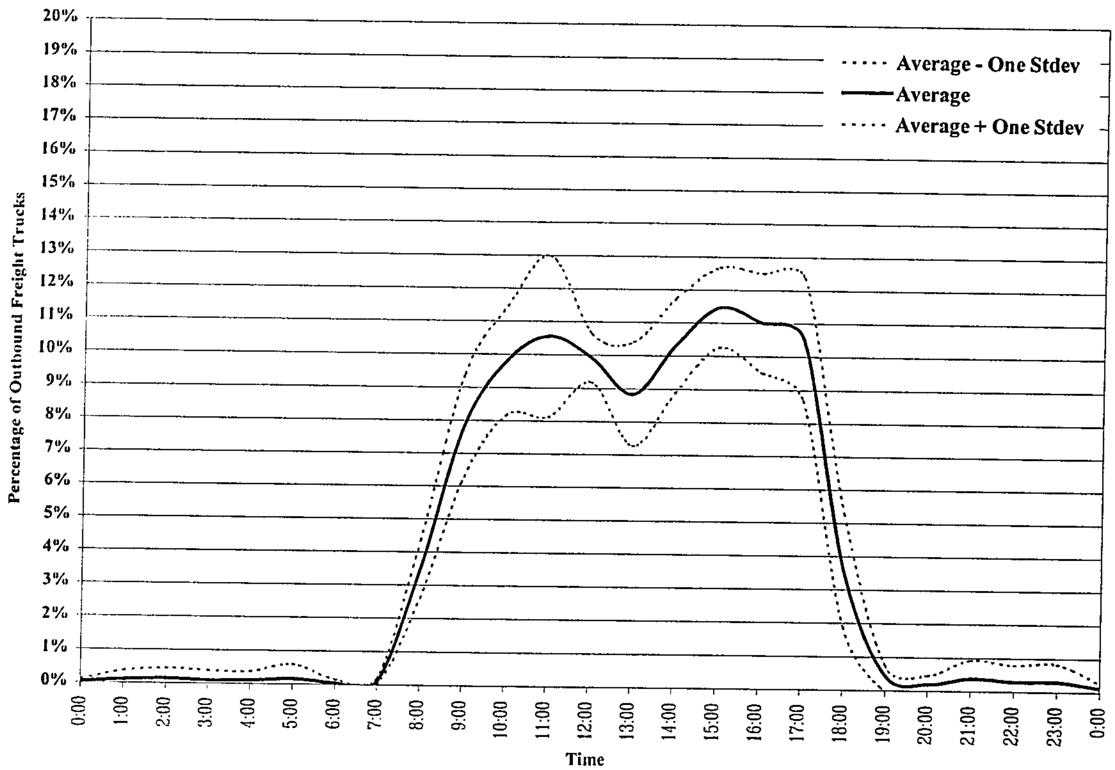



**Figure K.7 Hourly Truck Volume Distributions for Outbound Direction on Tuesdays (Trip Production Model)**

| Time | Wed 1/22/97 | Wed 2/26/97 | Wed 3/19/97 | Wed 3/26/97 | Wed 4/2/97 | Wed 4/23/97 | Wed 4/9/97 | Wed 4/16/97 | Wed 4/30/97 | Average - One Stdev | Average | Average + One Stdev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 1:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | **0%** | 0% |
| 2:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | **0%** | 0% |
| 3:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | **0%** | 0% |
| 4:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | **0%** | 0% |
| 5:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | **0%** | 1% |
| 6:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 7:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 8:00 | 1% | 3% | 4% | 3% | 4% | 4% | 4% | 4% | 3% | 3% | **3%** | 4% |
| 9:00 | 4% | 9% | 8% | 7% | 10% | 8% | 9% | 8% | 8% | 6% | **8%** | 9% |
| 10:00 | 10% | 9% | 12% | 11% | 12% | 9% | 10% | 8% | 8% | 8% | **10%** | 11% |
| 11:00 | 12% | 12% | 13% | 11% | 11% | 10% | 12% | 9% | 5% | 8% | **11%** | 13% |
| 12:00 | 9% | 9% | 11% | 10% | 10% | 11% | 10% | 10% | 9% | 9% | **10%** | 11% |
| 13:00 | 12% | 10% | 8% | 7% | 7% | 9% | 8% | 10% | 8% | 7% | **9%** | 10% |
| 14:00 | 10% | 8% | 12% | 10% | 10% | 10% | 9% | 11% | 13% | 9% | **10%** | 12% |
| 15:00 | 11% | 12% | 14% | 12% | 10% | 13% | 11% | 12% | 10% | 10% | **11%** | 13% |
| 16:00 | 9% | 13% | 8% | 11% | 10% | 12% | 12% | 12% | 12% | 10% | **11%** | 13% |
| 17:00 | 13% | 10% | 7% | 8% | 11% | 12% | 11% | 11% | 11% | 9% | **11%** | 12% |
| 18:00 | 5% | 3% | 1% | 6% | 3% | 4% | 2% | 6% | 3% | 2% | **4%** | 5% |
| 19:00 | 1% | 1% | 0% | 1% | 0% | 0% | 0% | 1% | 1% | 0% | **0%** | 1% |
| 20:00 | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |
| 21:00 | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 0% | **0%** | 1% |
| 22:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 0% | **0%** | 1% |
| 23:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 2% | 0% | **0%** | 1% |
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | **0%** | 0% |




## Figure K.8 Hourly Truck Volume Distributions for Outbound Direction on Wednesdays (Trip Production Model)

| Time | Thu 1/23/97 | Thu 2/27/97 | Thu 3/20/97 | Thu 3/27/97 | Thu 4/3/97 | Thu 4/10/97 | Thu 4/17/97 | Thu 4/24/97 | Thu 5/1/97 | Average - One Stdev | Average | Average + One Stdev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 1:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 5% | 0% | 1% | 2% |
| 2:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 6% | 0% | 1% | 3% |
| 3:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 6% | 0% | 1% | 3% |
| 4:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 4% | 0% | 0% | 2% |
| 5:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 0% | 0% | 1% |
| 6:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 1% |
| 7:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 8:00 | 4% | 5% | 4% | 4% | 3% | 4% | 3% | 4% | 3% | 3% | 4% | 5% |
| 9:00 | 8% | 8% | 9% | 8% | 8% | 10% | 10% | 10% | 5% | 7% | 8% | 10% |
| 10:00 | 10% | 10% | 10% | 9% | 10% | 12% | 10% | 9% | 8% | 9% | 10% | 11% |
| 11:00 | 14% | 10% | 11% | 10% | 10% | 11% | 10% | 10% | 8% | 9% | 10% | 12% |
| 12:00 | 11% | 10% | 9% | 9% | 10% | 8% | 13% | 10% | 5% | 7% | 9% | 12% |
| 13:00 | 7% | 9% | 8% | 7% | 8% | 7% | 8% | 8% | 3% | 6% | 7% | 9% |
| 14:00 | 10% | 10% | 10% | 10% | 12% | 11% | 9% | 11% | 4% | 7% | 10% | 12% |
| 15:00 | 9% | 11% | 9% | 9% | 10% | 10% | 9% | 12% | 5% | 7% | 9% | 11% |
| 16:00 | 10% | 11% | 9% | 11% | 10% | 8% | 9% | 10% | 4% | 7% | 9% | 11% |
| 17:00 | 12% | 10% | 11% | 9% | 11% | 9% | 8% | 8% | 2% | 6% | 9% | 12% |
| 18:00 | 5% | 4% | 7% | 7% | 6% | 7% | 8% | 6% | 1% | 4% | 6% | 8% |
| 19:00 | 0% | 0% | 0% | 1% | 0% | 2% | 1% | 2% | 1% | 0% | 1% | 2% |
| 20:00 | 0% | 0% | 1% | 4% | 1% | 0% | 1% | 0% | 3% | 0% | 1% | 3% |
| 21:00 | 0% | 0% | 0% | 1% | 0% | 1% | 0% | 0% | 5% | 0% | 1% | 2% |
| 22:00 | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 7% | 0% | 1% | 3% |
| 23:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 7% | 0% | 1% | 3% |
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 6% | 0% | 1% | 3% |

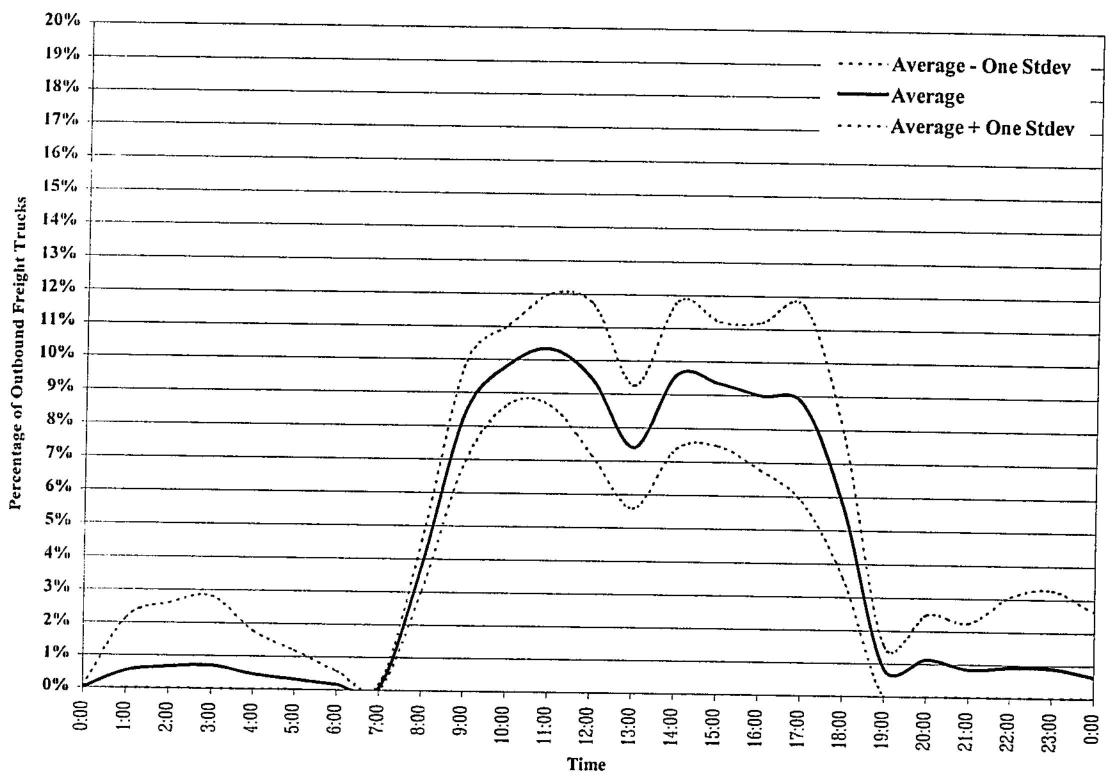
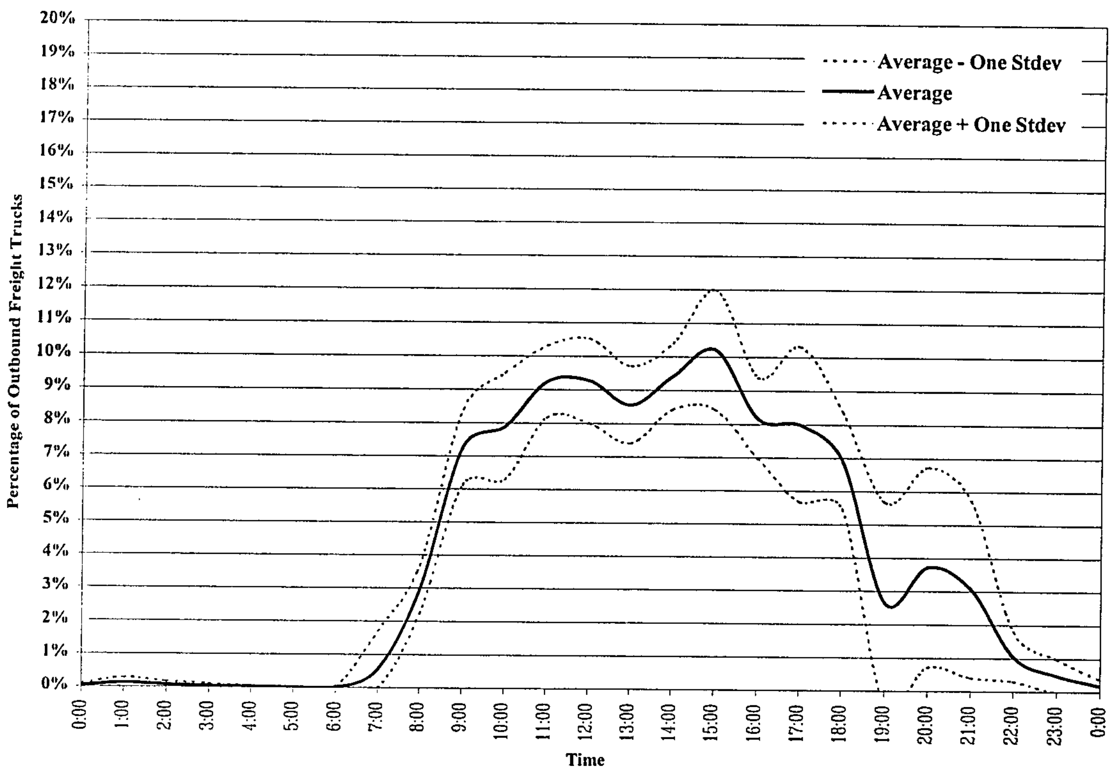



**Figure K.9 Hourly Truck Volume Distributions for Outbound Direction on Thursdays (Trip Production Model)**

| Time | Fri 1/17/97 | Fri 1/24/97 | Fri 2/28/97 | Fri 4/4/97 | Fri 4/11/97 | Fri 4/18/97 | Fri 4/25/97 | Average - One Stdev | Average | Average + One Stdev |
|---|---|---|---|---|---|---|---|---|---|---|
| 0:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 1:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 2:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 3:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 4:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 5:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 6:00 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 7:00 | 0% | 0% | 1% | 0% | 0% | 3% | 0% | 0% | 1% | 2% |
| 8:00 | 3% | 3% | 4% | 3% | 3% | 2% | 3% | 2% | 3% | 4% |
| 9:00 | 8% | 7% | 6% | 6% | 9% | 8% | 7% | 6% | 7% | 8% |
| 10:00 | 9% | 8% | 8% | 9% | 7% | 10% | 5% | 6% | 8% | 9% |
| 11:00 | 9% | 7% | 10% | 9% | 11% | 10% | 8% | 8% | 9% | 10% |
| 12:00 | 9% | 9% | 8% | 9% | 9% | 12% | 10% | 8% | 9% | 11% |
| 13:00 | 9% | 10% | 8% | 7% | 7% | 10% | 9% | 7% | 9% | 10% |
| 14:00 | 11% | 11% | 9% | 9% | 8% | 10% | 9% | 8% | 9% | 10% |
| 15:00 | 11% | 11% | 10% | 10% | 7% | 12% | 10% | 8% | 10% | 12% |
| 16:00 | 9% | 9% | 8% | 9% | 6% | 9% | 7% | 7% | 8% | 9% |
| 17:00 | 9% | 9% | 10% | 9% | 4% | 8% | 5% | 6% | 8% | 10% |
| 18:00 | 7% | 8% | 8% | 8% | 5% | 6% | 6% | 5% | 7% | 8% |
| 19:00 | 1% | 1% | 1% | 2% | 9% | 0% | 5% | 0% | 3% | 6% |
| 20:00 | 2% | 2% | 2% | 5% | 9% | 0% | 5% | 1% | 4% | 7% |
| 21:00 | 3% | 2% | 3% | 2% | 3% | 0% | 9% | 0% | 3% | 6% |
| 22:00 | 1% | 1% | 2% | 1% | 2% | 0% | 2% | 0% | 1% | 2% |
| 23:00 | 0% | 0% | 2% | 0% | 1% | 0% | 0% | 0% | 0% | 1% |
| 0:00 | 0% | 0% | 0% | 0% | 1% | 0% | 0% | 0% | 0% | 0% |




# Figure K.10 Hourly Truck Volume Distributions for Outbound Direction on Fridays (Trip Production Model)