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Traffic Impact of Container Port Operations in the Southwest Region: A Case Study

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16. Abstract

With the evolution of containers and growth in intermodalism, recent years have seen a tremendous growth in international and domestic movement of trade through seaports. Due to increase in port activity, there has been an increase in port traffic. This report involves a case study of two container ports: The Port of Houston's Barbours Cut terminal and the Port of New Orleans Marine Contractors, Inc. (N.O.M.C.); it addresses the impact of container port operations on the urban infrastructure and mobility. The report first presents the methodology used to collect the necessary traffic data using automatic vehicle classification systems. Mathematical models are then developed for the accurate forecasting of the travel demand for use in planning and designing transportation facilities. The results of the analysis provide trip generation rates for both average weekday and peak hour of generator, and they also show the variation in the traffic demand by vehicle types to and from the port. A simulation model is also presented to alleviate traffic congestion at the container terminal gates.

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TRAFFIC IMPACT OF CONTAINER PORT OPERATIONS IN THE SOUTHWEST REGION: A CASE STUDY

by

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EXECUTIVE SUMMARY

Container port operations of two southwest region ports were examined in detail for this report. The terminals studied were Barbours Cut of the Port of Houston and both New Orleans Marine Contractors, Inc., and Puerto Rico Marine Management, Inc. of the Port of New Orleans. Data were collected on traffic volumes, vehicle classification, arrival times of trucks and service times of trucks. Three main types of analysis are presented: (1) trip generation, (2) vehicle classification, and (3) simulation of gate operations. Each assesses the existing traffic impact of the terminals on the surrounding infrastructure. The most significant contributions are in the areas of trip generation and vehicle classification. Information is provided that will assist transportation planners and traffic engineers in assessing and predicting demands for transportation associated with container ports.

ABSTRACT

With the evolution of containers and growth in intermodalism, recent years have seen a tremendous growth in international and domestic movement of trade through seaports. Due to increase in port activity, there has been an increase in port traffic. This report involves a case study of two container ports: the Port of Houston's Barbours Cut terminal and the Port of New Orleans Marine Contractors, Inc. (N.O.M.C.); it addresses the impact of container port operations on the urban infrastructure and mobility. The report first presents the methodology used to collect the necessary traffic data using automatic vehicle classification systems. Mathematical models are then developed for the accurate forecasting of the travel demand for use in planning and designing transportation facilities. The results of the analysis provide trip generation rates for both average weekday and peak hour of generator, and they also show the variation in the traffic demand by vehicle types to and from the port. A simulation model is also presented to alleviate traffic congestion at the container terminal gates.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

FIGURES

TABLES

CHAPTER 1. INTRODUCTION

Intermodal transportation involves the movement of goods using more than one transport mode. The concept of intermodal transportation began to be used widely in the late 1950's. It eased the cargo's transition from one mode of travel to another. An intermodal transfer is a transfer of goods or commodities between two modes. The different types of modes are: (1) by water — ocean vessels, coastal vessels and inland waterway barges; (2) by air — airplanes and helicopters; and (3) by land — rail freight trains, highway trucks, belt conveyers, and pipelines.

One of the most significant forms of intermodal shipping is containerization. The cargo is packed in a container which can be carried by several modes such as ship, railroad, and truck. The use of containers has improved intermodal transfer of general cargo to a great extent. After the 1956 "container revolution," containerization of ocean cargo for intermodal purposes was widely practiced. Well over 60 percent of the world's deep-sea general cargo today moves in containers. Between 1970 and 1984, the increase in container traffic went from 47.3 million metric tons (mt) to 318.2 million mt, increasing at an average rate of 16.2 percent annually. Recent studies indicate that containerized traffic will grow to 430 million mt in 1990 and 607 million mt by the year 2000. Figure 1.1 represents an optimistic forecast of the container growth by world port regions in Twenty Foot Equivalents (TEUs), or 20-feet containers, between 1978 and 1998.

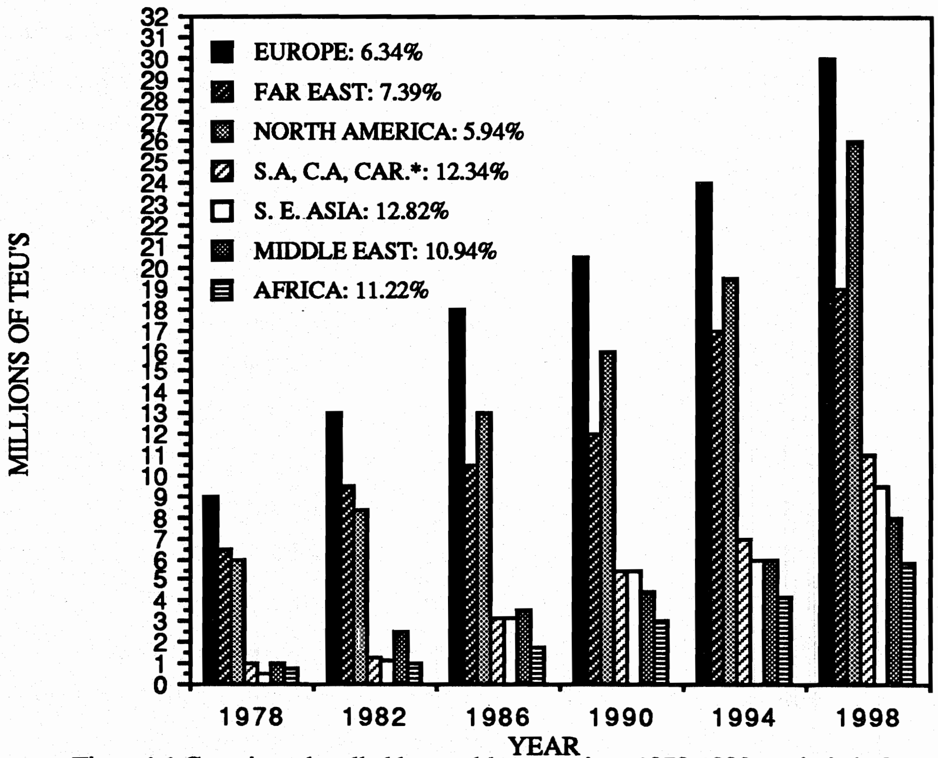

Figure1.1 Containers handled by world port regions 1978-1998, optimistic forecast
* South America, Cen. America, Caribbean

The Containerization or "container revolution" began in 1956 when a ship owned by Pan Atlantic Steamship Corporation departed from Port Newark, New Jersey, destined for Houston, Texas, with 58 freight containers on board. Since then container movements have continued to increase at United States ports and further increases are expected. Between 1974 and 1983, the share of U. S. cargo moving by containers increased from 21 million long tons in 1974 to 39 million long tons in 1983. This increase represents about 83 percent growth during that period as shown in Figure 1.2.

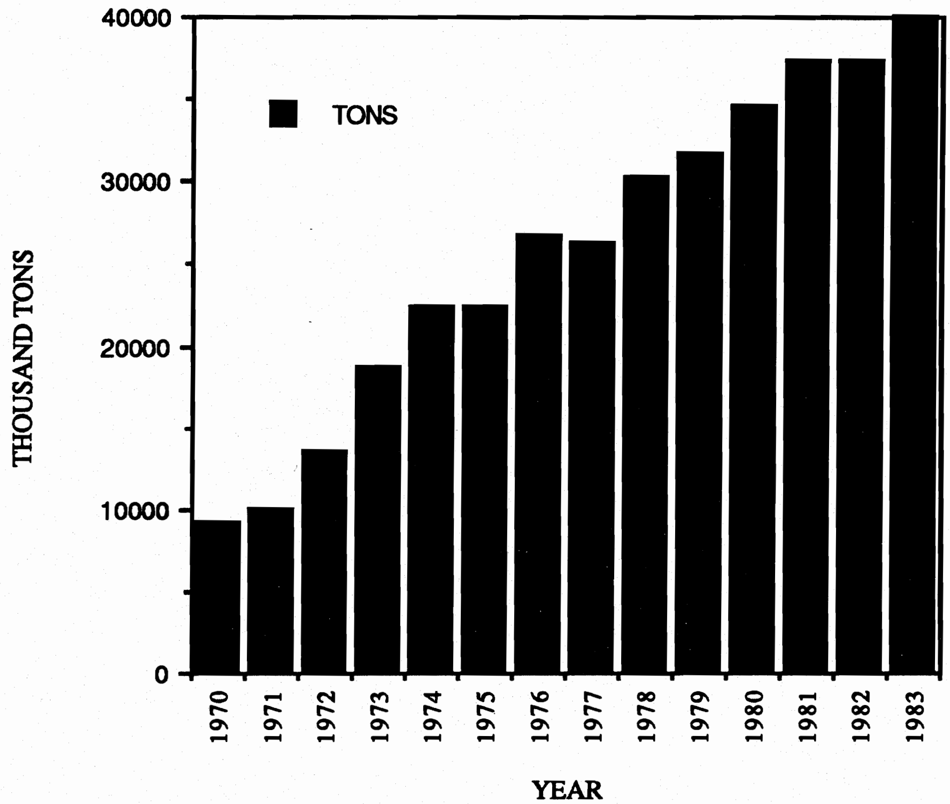

FIGURE 1.2 U. S. COMMERCIAL TONNAGE (all flags)

Figure 1.3 also shows the increase in container throughput for a few selected container ports in the U. S. between 1972 and 1983. In 1986, the ports of Long Beach, Los Angeles, Oakland, and New Orleans handled more than 1.4 million (m), 1.1 m, 0.925 m, and 0.425 m TEUs, respectively.

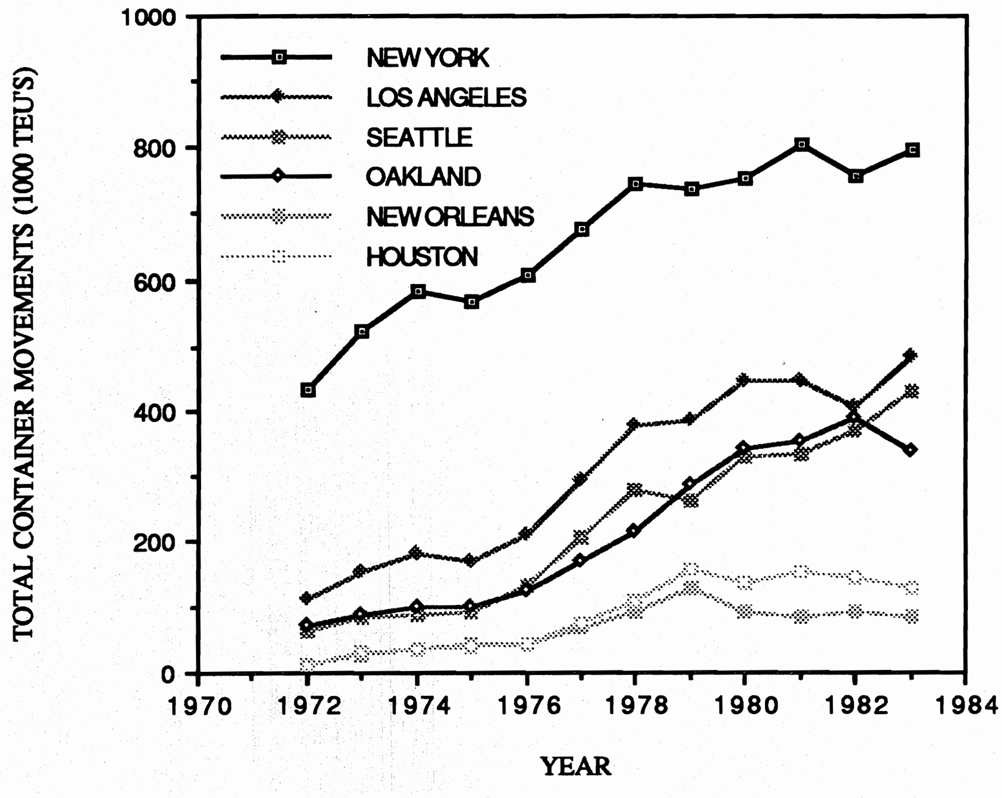

FIGURE 1.3 TOTAL CONTAINER MOVEMENTS BY SELECTED PORTS

In the mid 1970's, with major advancements in intermodal transportation, the concept of "land-bridge," "mini-bridge," and "micro-bridge" emerged. Because of this, there has been an increase in the number of containers and trailers moved by rail. More than 3.1 million double-stacked containers and trailers were carried by train in 1981. By 1985, the number had grown to 4.6 million. By 1987, about 20 percent of all rail car loadings in the U. S. were by piggyback.

As ocean carriers seek to reduce costs and receive higher percentages of open ocean operation from their ships, they confine their operation to fewer ports-of-call, relying on the ground transportation network for more of the cargo's movement. Inland transport to and from the ports may be by coastal waterways, by road, by rail or by a combination of road and rail. Providing access for coordinating the interface of two or more different modes of transportation systems is essential. The inland distribution of the cargo depends upon the local market area of each individual port. Railroads' intermodal service is price-competitive with that of trucks on traffic movements over 500 miles for containers and 700 miles for Trailer on Flat Cars (T.O.F.C).

The split between rail and truck of containerized general cargo of a few ports is further discussed. The modal split at Port Of New York-New Jersey is 96 percent truck and 4 percent others (pipeline, barge, or on-site use). At San Francisco, 71 percent is carried by trucks, 20 percent by rail and the remaining 9 percent by other modes. At Houston's Barbours Cut container facility, 95 percent of containers use trucks and only 5 perecent rail.

Following recent growth in containerized freight movement, both international and domestic movement of trade through seaports have increased significantly. Reasons for poor port productivity include lack of infrastructure (e.g., highway and railroad systems) and port handling facilities. Trucking continues to dominate the movement of containers to and from shipside at U. S. ports. This study focuses only on highway access problems. Good ground-access facilities are needed in order to move the goods quickly and efficiently through the ports. The rise in container traffic has subsequently increased traffic to and from the port terminals. Thus, traffic congestion, owing to these increases in truck and auto volumes near the port, has become an issue that requires addressing. To initiate the planning process for a ground-access system, it is necessary to determine the impact of the port-related traffic on the urban infrastructure to see whether the existing transportation infrastructure can handle the increased movement of containers and other traffic on landside.

The container terminal is the interface between landside and seaside goods movements. Inbound containers arrive by ship at the terminal where they are stored before being loaded onto a truck and dispatched to the final destination. The outbound containers arrive by truck or rail and are stored in a similar manner before they are exported by ship. The container terminal is a point where containers change their mode of travel. The challenge of intermodalism is to move goods efficiently, reducing delay at points of transfer between modes. Achieving smooth onward movement of cargo at the land-water boundary has been the primary goal of intermodal transportation.

All the trucks delivering and removing containers from a port have to pass through the entry gate of the port terminal. The gate operations involve processing the trucks for paperwork before they deliver or pick up the containers. Most terminals are open for collection and delivery by road vehicles from about 0700 to 2300 hours Monday thru Friday. Some terminals are open overnight and on weekends. Usually the trucks start arriving with the export containers a few hours before the gate opens — occassionally two to three hours before the gates opened.

Inefficient processing of these trucks at the gates can cause serious delays to trucks servicing the port. Some ports have enough space within their terminal where the trucks queue up and wait to be processed. But in other cases, trucks wait on a public road to be processed and, hence, cause local congestion to the other traffic using the roadway. The specific type of problem depends on the configuration of each terminal.

In the initial phase of the study regarding port access, traffic volumes of trucks and autos moving to and from the port terminal were examined. Existing port operations were observed and documented. What is the impact of existing port-related traffic on the transportation network? This is the main question addressed in this study. The information presented and the results obtained in this study are intended to provide a framework for transportation planners to proceed with additional research and operational modifications, or to make any development decision.

Two ports were selected in the southwest region, and their container port operations were studied in detail. The terminals chosen for the study were (1) Barbours Cut of the Port of Houston and (2) New Orleans Marine Contractors, Inc., (N.O.M.C) and Puerto Rico Marine Management, Inc. (P.R.M.M.I.) of the Port of New Orleans. Data were collected at these terminals on traffic volumes and vehicle classification. Data were also collected on the arrival times and service times of the trucks at the P.R.M.M.I. terminal gate. This report is a case study of these two ports, and it examines three topics to help identify the port-access problems and the impact of container port traffic on the infrastructure. These are (1) trip generation, (2) vehicle classification, and (3) gate operations.

After the data were collected, an analysis was performed to assess the impact of the port-related traffic on the surrounding infrastructure. Existing trip generation rates were calculated for daily and peak-hour of terminal traffic. One of the uses of trip generation analysis is to assess the impact of a development on the existing, surrounding, transportation infrastructure. Vehicle classification data documented the different types of vehicles that used the terminals in order to provide information for designing pavements and other structures. The vehicles were classified by types and by number of axles. It was necessary to look at different types of vehicles that used the port because truck traffic comprised only a very small portion of the total traffic. A simulation model was used to investigate the gate operations, and bottlenecks were identified. Recommendations to improve gate performance were made using a simulation model in order to reduce truck waiting times and hence public road congestion.

CHAPTER 2. LITERATURE REVIEW

Many mathematical models have been developed by transportation engineers and planners to describe various relationships between land use and travel. The ultimate goal of these modeling procedures is an accurate forecast of travel demand. These models are then used in planning transportation facilities. Land use generates a demand for travel, and these trips indicate the need for transportation facilities in order to serve the trip-making demands. The demand is effected by a number of factors such as land-use character, intensity, and location. The amount of travel and its characteristics are functionally related to the use of land. Trip generation analysis methods fall into one of the three categories: (1) developing relationships between trip ends, land-use and socioeconomic characteristics through regression analysis, (2) classifying trip ends by characteristics of the analysis unit generally referred to as cross-classification analysis, and (3) relating trip ends to land area, floor area, or other measures through trip rates. In this report, the last method is used to develop a relationship between trip ends and site characteristics.

Trip generation analysis is important in a number of phases of transportation planning and traffic engineering activities. One of the uses of trip generation is to assess the impact of a new or existing development. The existing available transportation network affects the location and type of development that occurs. Also, land development has an impact on the existing facilities due to an increase in trip attractions and productions, which cause a need for transportation system improvements. For such purposes, trip generation is most pertinent relative to traffic caused by a specific land-use activity.

By collecting, compiling and quantifying data on rates of trip generation at existing sites, the information can be used, within certain limits, to estimate vehicle trips expected to be generated by proposed land development projects at other sites. The Technical Council of the Institute of Transportation Engineers (ITE) formed the Trip Generation Committee in 1972. Trip generation rate data were collected from many sources and compiled into one common source, and a report was published on trip generation rates. The first edition was published in 1976. It contained data collected between 1965 and 1973 from nearly 80 different sources. The second, third, fourth, and fifth editions were published in 1979, 1983, 1987 and 1991 respectively. The data were collected from ITE members, public agencies and private consultants.

More additional data are needed to update and refine trip generation rates for different land uses. Marine terminals or waterports are special types of generators. In ITE's "Trip

Generation, An informative Report," Fifth Edition, published in 1991, a waterport/marine terminal is described as follows:

Waterport/Marine Terminal: A waterport or marine terminal, is an area for the transfer of materials between land and sea and possibly the storage of some of these materials.

Container terminals have an impact on the roads adjacent to the port area due to the traffic that uses the terminal. It is important and necessary to calculate and document trip rates of these types of land uses in order to forecast traffic flows generated by the land use. There have been a very limited number of trip generation studies done on waterports, especially container ports. The fifth edition of ITE's "Trip Generation Report" presents trip rates based on only seven such studies. The trip rates published were average, weekday vehicle trip rates. The average values reported were 171.5/berth, 11.9/acre, and 0.45/revenue ton. A 1987 study done in San Diego presented average weekday vehicle trip rates: 170/berth and 12/acre. A detailed trip generation study on container ports, prepared for CALTRANS by the Office of Policy Analysis in cooperation with the U. S. DOT and the Federal Highway Administration and called the "San Francisco Bay Ports Access Study," published in May 1985, reported 24 hour, peak hour and 8:00 a.m.-5:00 p.m. trip rates. In this study, trip generation rates for truck trips were also calculated. The trip rates shown below are per revenue ton throughput.

Types	Container terminal (On site container freight station) Trip rates per revenue ton		
	Peak Hour	8:00 a.m. - 5:00 p.m.	24 Hour
Auto	0.019	0.15	0.28
Truck	0.017	0.14	0.17
Total	0.036	0.29	0.45

Table 2.1 Container terminal trip rates per revenue ton

Earlier trip generation studies on waterports have used only land area, number of berths, and revenue tons throughput as the independent variables to calculate the trip rates. This report contributes additional data on trip rates to be used for further development and refinement of container port trip generation rates. New independent variables have been included in the trip rate calculation. They are: number of wharf gantry cranes, storage space of containers, and twenty foot equivalents or 20-feet containers equivalent (TEUs). Though there is a similarity between specific land uses and their trip generation characteristics, there are many factors influencing a particular site. Extreme care should be taken when using the trip rates for a particular site.

Information about type of traffic and traffic loadings are important to transportation engineers and planners. In order to design pavements and other structures, it becomes necessary to count and classify vehicles which use a specific road section. Various organizations use different criteria for classifying vehicles. Detailed classification schemes of a few organizations can be found in the following references: (1) Federal Highway Administration's "Traffic Monitoring Guide," (2) "AASHTO Design Vehicles," and (3) "ASTM Standard for Weigh-in-Motion Systems." When performing trip generation studies, vehicle classification data provides more detailed information about the traffic impact caused by the generator. It is also used to calibrate the mechanical/automatic counters. Containers are usually 20 feet and 40 feet in length and are usually carried by 5-axle tractor-trailers to and from the port but they represent only about 35-40 percent of the total terminal traffic. Therefore it is necessary to consider all the types of vehicles that comprise the port traffic. Manual classification is done for a few hours during the peak period at a site in order to get information about the traffic composition. Pneumatic road tubes, piezoelectric cables, and inductance loop detectors are some of the automatic devices commonly used to count vehicles. Although manual counting and classifying seems to be most accurate, it is too laborious, and limited data are obtained due to time constraints. Automatic counters are now being used to get a larger data base for vehicle counts and are being supplemented by manual classification and vehicle occupancy data. Recently, infrared sensors have been used to count and classify vehicles accurately. These sensors, when properly designed and installed at a location, can be used to get a variety of information about traffic characteristics. In an effort to collect data regarding vehicle volumes and classification for this report, such sensors were used to count and classify vehicles entering and exiting the site at Houston's Barbours Cut Terminal. The classification criteria used for design of photoelectric sensors in this report include: (1) number of axles per vehicle, (2) length of each vehicle, and (3) length of each container. These data were the input to calculate trip generation.

The increase in containerized cargo has created a need for ports to expand or at least alter their facilities and operations to meet the new demand. Until recently, design of marine terminals has been based on experience and modification of existing designs to serve new conditions. Due to increases in cost of new development, efficient use of the existing terminal becomes essential. Computer simulations have been used for many years in planning marine terminals. Programs have been written to evaluate the performance and ability of the terminals to accommodate port activity increases. Port planners have used simulation techniques to estimate the productivity of ports before expanding the facility or prior to building a new facility. Simulation can show whether the proposed facility expansion or modification will have the desired effect.

The container terminal is one point where significant amounts of time can be saved or wasted depending on the terminal operations. One of the keys to efficient terminal operation is the timely access to, and processing of, information at the gates for inland trucks delivering containers. Due to increases in container movements through ports, there has been an increase in gate activities. As a result, trucks waiting to be processed at terminal gates are delayed. To accommodate the increased demand at these gates, planning is necessary.

Robert M. Bennet, Larry Nye and Gene Akridge did a comprehensive study in 1987 of gate operations at Sea-Land's Long Beach Terminal. The paper focused on operating efficiencies and customer services at the gates. Arrival/departure patterns of trucks, waiting time in queue, processing time, total time in terminal, and causes for delays were some of the measures evaluated. Recommendations were made to increase the gate capacity by making changes in the facility, work practices, and staffing assignments.

A 1989 study by Thomas Ward and Richard Woodman discusses the effective use of simulation in the modification or construction of a new terminal. It describes methods used to evaluate system performance using simulation of different terminal components. Values and limitations of simulation studies of marine terminals are also addressed.

Gerald D. Gividen performed a simulation study in 1984 at a multi-user marine container terminal which discussed the interchange process from a truckdriver's standpoint, interchanging equipment with the marine terminal. Bottlenecks, which caused delays in the truck turnaround times, were identified and recommendations were made to improve this activity.

It was observed from the review of previous simulation studies that the models were usually developed for specific terminals. It seems that, although the truck arrival patterns at the terminals are similar in each study, the processing time for trucks varies among terminals. The main objectives of these simulation studies are to improve port accessibility and operations within the port, to increase the container throughput, and hence to stay in competition.

In the remainder of this report, Chapter 3 provides an outline of the methodology used to conduct the research study. Chapter 4 includes a detailed description of the data collection process. Analysis and results of the study are reported in Chapter 5. Chapter 6 provides a summary of the analysis and recommendations.

CHAPTER 3. METHODOLOGY

In this report, analyses were performed to identify port-access problems and to assess the traffic impact of two container ports on the infrastructure surrounding the port. It consists of three parts: (1) trip generation analysis (2) vehicle classification, and (3) simulation of gate operations. As mentioned earlier, the study focused on the Port of Houston's Barbours Cut container facility and the Port of New Orleans's New Orleans Marine Contractors, Inc., (N.O.M.C.) container facility.

TRIP GENERATION ANALYSIS

The first part provides documentation and evaluation of actual trip generation rates and quantifiable independent variables through a case study of two container terminals. Actual trip generation rates at these sites were determined through a field data collection involving automated and manual measurements of vehicular traffic entering and exiting the sites. Mathematical relationships were developed between these measured volumes and independent variables. Trip generation rates were developed for the average weekday and for the peak hour of the generators.

To develop estimates of actual trip rates, traffic volume counts were performed at each site. A detailed trip generation study was conducted at the Barbours Cut container facility. Automatic counters were used to collect data for times varying from one weekday to seven days. These counts were directional and, therefore, separated entering vehicles from exiting. Manual counts were performed for a few hours at each site for the morning peak hour traffic at the sites. At N.O.M.C., only manual counts for the morning peak periods were performed and therefore only AM peak hour trip rates were calculated. For calculation of peak hour trip rates, 15-minute interval counts were made at each site over a 6-hour period. Peak hour trip rates and average weekday vehicle trip rates were calculated for both container truck trips and total vehicle trips, which included trucks, pick-ups, single unit trucks, and passenger cars.

In addition to field-collected traffic volume data, independent variable data were collected through interviews with terminal managers. The independent variables included in the data collection were total land area in acres, storage space for containers in acres, number of ship berths, number of wharf gantry cranes, revenue tons of cargo, and TEU (20-feet containers) throughput. Based on this data, mathematical relationships were developed between traffic volume counts and pertinent independent variables. The obtained trip rates could be different for different times and days, and different from the days on which the data were collected. However, they provide a sample of what can be anticipated to occur at these sites.

VEHICLE CLASSIFICATION

For the second part of analysis, data on the types of vehicles that constituted the port-related traffic were also collected. Data were collected for this purpose on the same days as the traffic volume data. Vehicles were classified into two types: (1) vehicle type similar to container trucks, including pick-up trucks, single-unit trucks and passenger cars; and (2) axle type. The axle classes chosen were 6-axle or more, 5-axle, 4-axle, 3-axle and 2-axle vehicles. An effort was made to collect vehicle classification data for a longer time period by installing automatic equipment (photoelectric sensors) at the Barbours Cut terminal.

GATE OPERATIONS

Seaports are the connections between sea and ground transportation. A container terminal is the interface between landside and seaside. The processing of trucks at the gates is a major concern in terminal operations. If the processing facilities are not properly operated, serious delays to trucks delivering and receiving containers could occur. While collecting data for trip generation and vehicle classification, it was observed that at one of the container facilities (P.R.M.M.I.), trucks were queuing up on the public road while waiting to be processed. Therefore, the third part of this investigation is a detailed study on P.R.M.M.I. gate operations with a concentration upon queuing problems.

Many queuing models have been developed, to date, to analyze such problems. Data were collected on truck arrival times and service times at the gates for a period of about 5 hours. The initial data analysis indicated that the arrival rate was at least as large as service rate. The observed traffic intensity seemed to indicate that the ratio of the arrival rate to service rate, of the queuing system, was greater than one.

Simulation is a very powerful and widely used technique for analysis of complex queuing systems. While analytical models may require many simplifying assumptions, simulation models have few such restrictions, thereby allowing much greater flexibility in representing the real system. A simulation program called SLAM II was used to simulate the system. With the assumptions of arrival and service times as input characteristics, a network model was created to represent the actual gate operations. Validation of the model was very important to test whether the simulated system represented the actual system. The model was validated by comparing the simulation results with the actual observed data. After validation, the following measures were obtained to study the existing gate performance:

(1) terminal gate utilization,

(2) total time to process a truck through the gate,

(3) number of trucks waiting at the gate,

(4) fraction of time that service gate is blocked, and

(5) average waiting times for trucks at the terminal.

Bottlenecks were identified, and recommendations were made for changing the parameters of the model to improve the gate operations in order to reduce truck waiting times and queue lengths on the public road.

CHAPTER 4. DATA COLLECTION

This chapter consists of three main sections: trip generation analysis, vehicle classification, and simulation of gate operations. Each section discusses in detail the data collection effort that was undertaken to accomplish the objectives for this report.

TRIP GENERATION ANALYSIS

To compute actual trip generation rates of the sites, field traffic volume counts were performed at the sites. Data were also collected on most pertinent independent variables of the sites. Mathematical relationships were then developed to describe the trip rates.

Traffic Volume Counts

Basic traffic studies are conducted to gather facts on traffic conditions. These studies may be *administrative*, which is the assembly of already available data, or *field,* which involves measurements or observations of existing conditions. Volume counts are examples of dynamic traffic studies. They include a tabulation, generally by such time intervals as 15 min, 30 min, 1 hr, or 1 day, of the number of pedestrians or vehicles passing a specific point. Counts are performed manually or automatically. Manual counts are the most basic and useful of the volume collection procedures. Manual measurements can also provide information on vehicle classification and auto occupancy. Manual counting also helps obtain directional counts during peak periods when a non-directional count is conducted. Manual traffic counts are markedly superior to mechanical means of counting.

The automatic traffic counters are used when data covering long periods of time are needed. There are many types of such counters available. Junior counters, which utilize road tubes stretched across the road, are used to obtain data in 24-hour period. Also there are the period counters, senior counters and circular graphic chart senior counters, which are used to count volumes at intervals of 5, 10, 15, 20, 30, or 60 min, for up to 7 days duration. Inductive loop and photoelectric detectors are among other types of counters widely used to count vehicles. When performing vehicular traffic volume counts, there are some well established and specific guidelines to follow which are mentioned in The Institute of Transportation Engineers (ITE's) *Transportation and Traffic Engineering Handbook.*

For the purpose of trip generation analysis, procedures for data collection already exist in ITE's "Trip Generation: An Informational Report," Fifth Edition, 1991. A summary of the procedures is described in this paragraph. Automatic counts should be made on driveways of specific generators, without double counting vehicles and without counting through traffic. Directional counts are preferred. Automatic counts for seven days during a typical week of the year are conducted to provide data concerning average weekday, Saturday, Sunday, and peak hour trip rates. Manual counts are made for several hours on a weekday to record hourly inbound and outbound vehicular traffic by classification and vehicle occupancy. These counts are made to adjust raw automatic counts collected over long periods. Manual counts are also made on a typical weekday during the A.M. and P.M. peak two-hour period to record the peak hour entering and exiting volumes. The peak hour of the generator could be different from the peak hour of adjacent traffic which is normally calculated from vehicle counts made during 9 a.m. till 11 a.m. for the morning peak hour and 4 p.m. till 6 p.m. for the evening peak hour.

In an effort to collect data, traffic volume counts were performed at the sites. The two sites that were selected for this purpose were the Barbours Cut Container facility at the port of Houston and the New Orleans Marine Contractors Inc., (N.O.M.C.) facility at the port of New Orleans. Two basic traffic counting methods were employed - manual counting procedures to accurately record directional traffic volume data on the driveway of the site, and automatic recording devices to measure 7-day traffic volumes that entered and exited the site. Manual measurements were conducted at both sites

A detailed trip generation study was conducted at the Barbours Cut facility to estimate the vehicle trips generated or attracted to the site. Automatic counters (photoelectric sensors) were used to collect traffic data for a 7-day period. The equipment was designed and setup at the site in such a way so that vehicles entering and exiting the sites were counted. The equipment was also used to classify vehicles that entered and exited the port. The data collected was for each 15-minute interval for a duration of seven days. These 15-minute interval counts were later tabulated in different, yet successive, combinations to determine a maximum one-hour traffic volume for the site. These traffic volumes were the input into the trip generation calculation procedures.

In the case of N.O.M.C., only manual measurements were made at the site. On a typical weekday, data were collected from 7 - 11:30 a.m. A table was prepared to perform the counting manually. It involved a timepiece, a pencil and an eraser. Directional counts of all vehicles were made. Vehicles were also classified during these counts. From the data collected, trip rates were then calculated for morning peak hour traffic only. To calculate average daily truck trip rates of the site, data about daily truck trips to and from the terminal were available from the historical records maintained by the terminal.

Independent Variables

Another important part in the data collection phase of trip generation calculations, in addition to traffic volume counts, involved compiling data on independent variables for each site. Independent variable is described in the Fifth Edition of ITE's "Trip Generation Report" as:

Independent Variable: A physical, measureable, or predictable unit describing the study site or generator (e.g., gross floor area, employees, seats, dwelling units).

For this report, information was gathered on total acreage of land area of the sites, storage space for containers / chassis in acres, revenue-tons of cargo, number of ship berths, number of wharf gantry cranes and number of TEU's of each site. Land area in acres, revenue-tons, and number of ship berths were chosen for this analysis because these variables are very often used in practice by engineers and planners as input into trip generation calculation. ITE's "Trip Generation, An Informational Report" has also used these variables as independent variables. In actual practice, information about one or the other variable may not be readily available for analysis purposes, therefore it is helpful to have the ability to estimate vehicle trips based on more than one variable. Wharf gantry cranes are used to load and unload containers from the ship. Due to increases in container freight, ports are using a larger number of such cranes to load and unload cargo to keep pace with the container volumes. This variable, number of cranes, therefore has been included as an independent variable to calculate the trip rates. Most of the container terminals have TEU's in lieu of revenue-tons of cargo as their productivity unit . Therefore, this was included in the report to calculate the trip rates. Storage space for containers is the final variable that has been used here as an independent variable. This information about the sites was obtained by telephone interviews from the terminal managers. In the next chapter, this information, along with traffic volumes measured at the sites, is used to compute trip generation rates.

VEHICLE CLASSIFICATION

Whenever performing trip generation studies, information about the types of vehicles that constitute the traffic is valuable. Due to the increases in container traffic, there has been an increase in the number of trucks to and from the terminals. These are usually 5-axle trucks that carry 20-feet and 40-feet import containers to and from the ports. There are also 4-axle, 6-axle, 7-axle, and sometimes 8-axle trucks that carry these containers. Other than these trucks, there are many 2-axle and 3-axle vehicles that use the port for different purposes. These 2-axle vehicles are usually service vehicles, employees' personal vehicles, and other purpose vehicles. They are mainly pick-up's, single-unit trucks, and passenger cars. The 3-axle vehicles are mainly the bob-tails, i.e., truck cabs without the chassis. So, when studying the traffic characteristics of a port and its impact, it is important to consider the total traffic instead of only truck traffic. Thereforec data were collected at each site in order to document the different types of vehicles that entered and exited the sites. Classification was done both manually and by using automatic counters (photoelectric sensors). Manual classification was performed at both N.O.M.C. and Barbours Cut. Automatic counters were used only at Barbours Cut in Houston to collect data for a longer period of time.

Manual Classification

At France Road Terminals' N.O.M.C. Inc., only manual classification were performed. The measurements were made during the same period as the traffic volume counts. A table was prepared as shown to collect the data:

Time	5-axle	4-axle	3-axle	2-axle Single unit trucks	2-axle pick-up trucks	Passenger cars	6-axle or more
7:00-7:15 7:15-7:30 7:30-7:45 7:45-8:00 - - - - - - -							

Table 4.1 Manual Classification at France Road Terminals' N.O.M.C., Inc.

Data was collected from 7 a.m. till 11:30 a.m. on a weekday. When a particular type of vehicle entered or exited the terminal, a check mark was put in the appropriate column. Directional counts were made at the site and data were collected on vehicle types by 15-minute intervals.

Automatic classification

To collect data for a long period of time, manual procedured become cumbersome. Though not as accurate as manual, automatic counters are often used to collect traffic volume data and other types of data. At Barbours Cut terminal an effort was made to collect data on traffic volumes and vehicle classification by using photoelectric sensors. The entire procedure included designing the needed hardware and software, and installing the systems at selected field sites so that data could be collected for the purpose of this report. Among the various sensors that have been used to acquire traffic data, commercially available photoelectric sensors were used to collect data for a week. These sensors, along with microprocessors, were used to collect the required data. Different arrangements of these sensors at the sites were used to count and classify the vehicles. Before designing and installing such sensors, it was very important to determine the type of classification required for the purpose of the experiment. Depending on the type of data required, the sensor arrangements were designed at the sites. The classification criteria selected for this purpose are shown:

(1) Classifying vehicles by number of axles: 6-axles or more, 5-axles, 4-axles, 3-axles and 2-axles vehicles.

(2 Classifying the containers by length: 20-feet and 40-feet containers.

All these data were collected by 15-minute intervals over a period of seven days.

Sensor Arrangements. To collect the data based upon the desired classification scheme mentioned in the previous subsection, sensors were designed and installed on the roadside at the site. These sensors use an infrared light beam to sense the presence of vehicles. The beam is focussed onto a reflector from which it is reflected and sent back to the receiver which is beside the transmitter in the sensor head. The vehicle body is detected when it interrupts the beam, and a signal is generated. The sensors are mounted beside the roadway, and various arrangements of these sensors and reflectors can be used to collect different types of data like counts, classification, speed, spacing between successive axles, weights of vehicles, the approximate size of the tire / pavement contact area and the overall dimension of the vehicle body.

Two pavement-level sensors (S1,S2) were used to count the number of axles per vehicle. They were spaced 2 feet from each other. This also enabled the calculation of speed of the vehicles by dividing the distance between sensors by the time between successive beam interruptions. The speed data were required to find the length of the containers. To determine the overall vehicle length, two sensors (S3,S4) were mounted at about 2.5 and 6 feet high from the road level and placed at such an angle so that almost all vehicle presence was detected. To differentiate trucks from passenger cars and pick-ups, a sensor (S5) was mounted at an even higher level of about 10 feet along the roadside. This also gave information about the length of the containers. Each of the sensors had a corresponding reflector to which the beam was focussed. The sensors and the reflectors were mounted by using steel pipes and other support. There were three such systems for each road that were set up at the site to capture entering and exiting vehicles. The main road which is a public road is two 12- feet lanes in each direction divided by a median. One system was set up to count and classify the entering vehicles and the other for the exiting vehicles. The third system was used for the private road which is two directional and is mainly used for carrying containers that are taken to the rail head from where it is distributed to the final destination. The systems are shown in Figures 4.1 and 4.2.

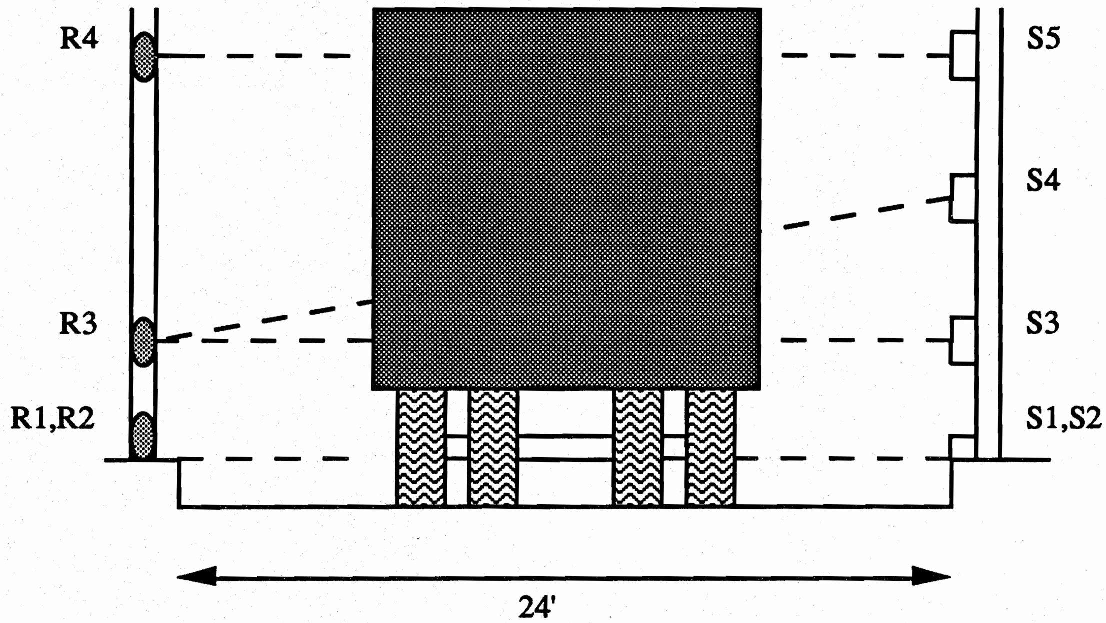

Figure 4.1 Photoelectric Sensor System to Count and Classify Vehicles

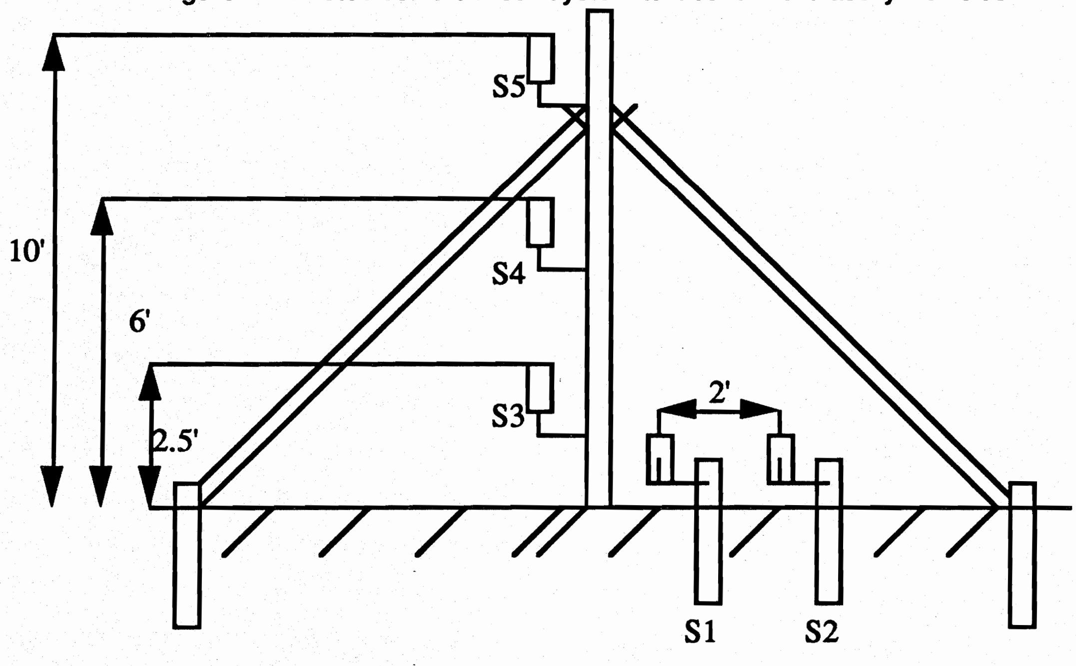

Figure 4.2 Sensor Arrangements: Front Elevation

SIMULATION OF GATE OPERATIONS

Two major types of data were necessary for simulation models of the gate operations: the arrival process and the service time characteristics of the terminal gate operations. Data were also collected on the number of servers, and the actual arrival pattern of the trucks were observed. For this purpose, manual data were collected at France Road Terminals' P.R.M.M.I. Inc., for a duration of about 5 hours at the gate.

Description of the primary gate components

This section discusses the actual operations at the gates which were observed during the data collection period. The trucks arriving at the terminal to deliver the export containers have to go through two gates (hereafter refered to as stage-1 and stage-2 as shown in the Figure 4.3) in order to enter the terminal. The main task performed at the gate is the documentation of receipts and deliveries of loaded and empty containers / chassis. Trucks arrive at the terminal and check in at the gate, stage-1, where the drivers have to complete an interchange form, which contains information like time and date of arrival, booking number, carrier information, container / chassis details, etc. The drivers get off their vehicles with documents and they are checked manually at the gate office by officials. The trucks then move over to another service station, stage-2, where the trucks are inspected for proper placards and signs on the container / chassis, and other details. The trucks then proceed to the storage area where the containers are unloaded. Similar operations are observed for the outbound trucks. The schematic diagram of the terminal entry gate is shown in Figure 4.3.

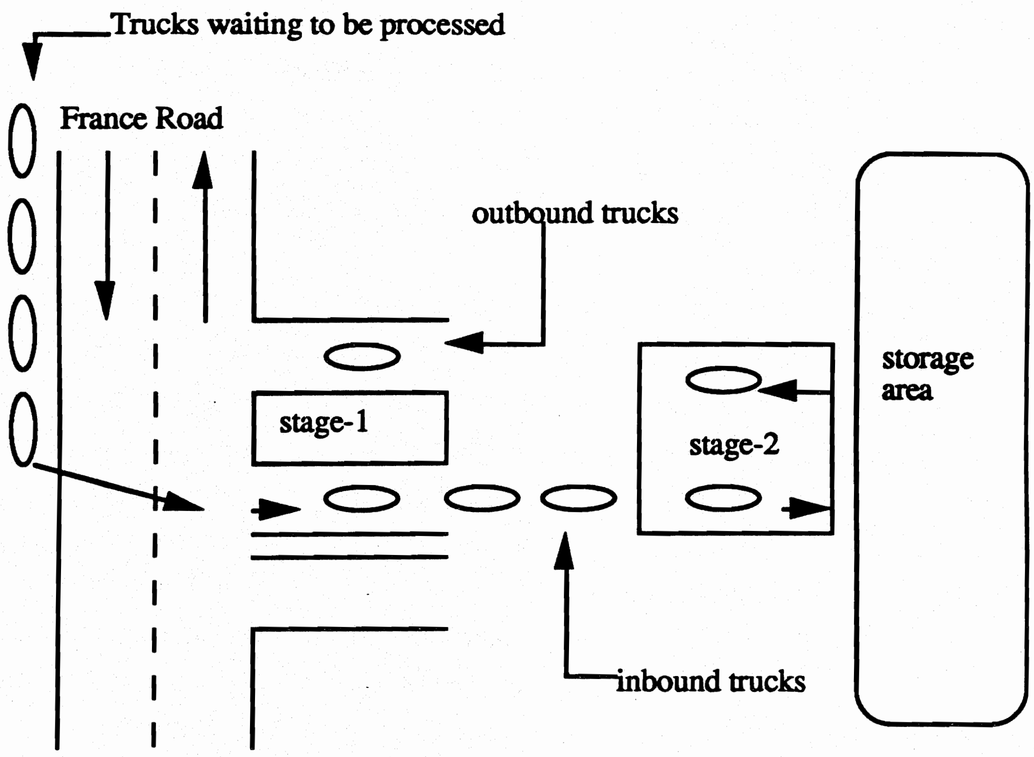

Figure 4.3 P.R.M.M.I. Terminal Entry Gate Layout

The observed traffic pattern was irregular because of peaks and valleys in the arrivals. These peaks in the arrivals caused increased waiting times to the trucks prior to processing by the gate. These trucks wait on the public road in order to be processed and hence sometimes, long delays are incurred by the trucks. The time spent in the system includes the delays, time in service, and the time required for traveling between stages. From the observations, it was found that the service time at stage-1 was longer than that at stage-2 for almost all the trucks.

Data Collection

From the observations at P.R.M.M.I gate, it was found that trucks arrived approximately just when the gate opened. The arrival pattern of the trucks was inconsistent, i.e., trucks arrived at a high rate for a certain period of time, then there were time intervals when trucks did not arrive at all. Trucks arrived one at a time and entered the service at stage-1, then entered stage-2 to complete the service at the facility. There is a space for about two trucks between the two service stations. Data were collected regarding the interarrival and service times.

An arrival time at the gate is defined as the time when a truck joins a queue, if it exists. Interarrival times of trucks were calculated by measuring the clock time between successive arrivals. The service times at each station were collected by measuring the time intervals that each truck took to process. The service time starts at the time when the previous truck leaves the stage, if there are trucks waiting to use the service, until the following truck leaves the stage. This implies that the time gaps between trucks leaving and entering are included in the service time of the following trucks, if a queue exists, and is consistent with the definition of "service" in queueing analysis. These methods provided the distributions of interarrival and service times which were input into the simulation program. There are limitations in the data collection process. One main problem is insufficient data collected for both interarrival times and service times due to time constraints.

CHAPTER 5. DATA EVALUATION

After the data collection procedure was completed, detailed analysis was performed. Trip Generation Analysis, Vehicle Classification and Simulation of Gate Operations are the three sections in this chapter which describe the analysis and the results obtained.

TRIP GENERATION ANALYSIS

Actual trip generation rates of the sites were computed by developing mathematical relationships between measured traffic volumes and the independent variables. Trip rates are expressed in terms of the independent variables selected at the sites. Depending on the duration of the data collected, trip rates are calculated for average weekday trip ends, A.M. peak hour trips, P.M. peak hour trips, peak hour of generator, and peak hour of adjacent street trips. The definitions of some of the terms used in this chapter are summarized below. These terms are defined in the Ffifth Edition of the ITE "Trip Generation" manual.

Trip: A single or one-direction vehicle movement with either the origin or the destination (exiting or entering) inside a study site.

Trip Ends: One trip end is equal to one trip, as defined above. For trip generation purposes, total trip ends for a land use over a given period of time are the total of all trips entering plus all trips exiting a site during that designated time.

Average Trip Rate: A weighted average of the number of vehicle trips or trip ends per unit of independent variable (e.g., trip ends per occupied dwelling unit or employee) using a site's driveway(s). The weighted average is calculated by adding together all trips or trip ends and all independent variable units where paired data are available, and then dividing the sum of the trip ends by the sum of the independent variable units.

Average Trip Rate for Peak Hour of the Generator: A weighted average vehicle trip generation rate during the hour of the highest volume of traffic entering and exiting the site in the morning (A.M.) or the afternoon (P.M.). It may or may not coincide in time or volume with the trip rate for the peak hour of the adjacent street traffic.

Average Weekday Vehicle Trip Ends (AWDVTE): The average 24-hour total of all vehicle trips counted to and from a study site from Monday through Friday.

Average Weekday Trip Rate: The weighted average vehicle trip generation rate during a 24-hour period for a weekday (Monday through Friday). This represents trips using a site's driveways.

Average Saturday Trip Rates: The weighted average vehicle trip generation rate during a 24-hour period for a Saturday. This rate represents trips using a site's driveways.

Average Trip Rate for Saturday Peak Hour of Generator: The weighted average vehicle trip generation rate during the hour of highest volume of traffic entering and exiting a site on a Saturday. It may occur in the A.M. or P.M. This rate represents trips using a site's driveways.

Average Sunday Trip Rate: The weighted average vehicle trip generation rate during a 24-hour period for a Sunday. This rate represents trips using a site's driveways.

Average Trip Rate for Sunday Peak Hour of Generator: The weighted average vehicle trip generation rate during the hour of highest volume of traffic entering and exiting a site on a Sunday. It may occur in the A.M. or P.M. This rate represents trips using a site's driveways.

For the purpose of this report, peak hour of generator trip rates and average weekday trip rates were calculated based upon N.O.M.C. and Barbours Cut data. The trip rates were calculated for both total vehicle and truck trips. Total vehicles included 2 and 3-axle vehicles in addition to the 5-axle and 6 or more axle trucks which commonly used the terminals.

Independent Variables

The values of the independent variables were received from each terminal manager by telephone interviews. The selection of these independent variables is important because they should be related to the dependent variable in trip rate calculations. Regression and correlation analysis are important tools for selecting these variables. Scatter plots of dependent and independent variables and statistical measures of correlation and goodness of fit, such as correlation coefficient and coefficient of determination, are primary analysis tools. The Fifth Edition of ITE's "Trip Generation: An Informational Report," describes guidelines for selecting independent variables in trip rate equations. The guidelines presented in the "Trip Generation" are:

- The R^2 is greater than or equal to 0.25
- The sample size is greater than or equal to 4
- The number of trips increases as the size of the independent variable increases

These were the basic rules followed within this report. The Table 5.01 below is the summary of the total trip and truck trip ends and independent variables for seven days' data collected at the Port of Houston's Barbours Cut Terminal.

DAYS	TOTAL TRIP ENDS	TRUCK TRIP ENDS	TEU's	CRANES	BERTH (# SHIPS)
MONDAY	3229	1139	979	2	1
TUESDAY	3805	1163	816	2	1
WEDNESDAY	4189	1121	800	7	2
THURSDAY	4152	1119	956	2	1
FRIDAY	3825	1142	862	0	0
SATURDAY	1054	85	0	0	0
SUNDAY	1464	124	9	0	0

Table 5.01 Daily trip ends and independent variables at Barbours Cut Terminal

Using these data, regression was performed between trip ends and the appropriate independent variables.

The results are tabulated below in Table 5.02:

INDEPENDENT VARIABLE	TOTAL TRIP ENDS	TRUCK TRIP ENDS
TEU's	$R^2 = 0.878$	$R^2 = 0.973$
Cranes	$R^2 = 0.344$	$R^2 = 0.250$
Berths	$R^2 = 0.470$	$R^2 = 0.404$

Table 5.02 Regression Analysis results of total and truck trip ends vs. independent variables

From the results it is seen that for both total trip ends and truck trip ends, R^2 is the highest for Twenty-feet Equivalent Units (TEU's) implying that the best independent variable to forecast trips is the TEU's throughput of the container terminals. With conditions presented in the "Trip Generation" report, the number of cranes and berths are considered acceptable; however, as seen in Table 5.02 the values are not close to 1. Total land area and storage area in acres are also used in this report to calculate the trip rates because they were used in the previous trip generation studies conducted and presented in the Fifth Edition of the "Trip Generation: An Informational Report." Revenue-tons throughput of a container port is also used to forecast trips and was found to be the best indicator for port facilities. Therefore revenue-tons was selected as an independent variable to calculate the trip rates.

The Table 5.03 below shows the total land areas, storage space, number of cranes, number of berths, total revenue-tons and TEU throughput of each terminal. These are the independent variables characteristics of the terminals. These values were used to calculate the peak hour trip rates at the sites.

Independent Variables	N.O.M.C.	Barbours Cut
Land Area (acres)	69	230
Storage Area (acres)	57	200
Revenue-Tons (per mo)	65020	333,333
TEU's (per yr.)	157,000	500,000
Cranes	3	8
Ship Berths	2	4

Table 5.03 Independent Variables obtained by telephone interviews

After collecting these data and measuring traffic volumes at the sites, trip generation rates were calculated and are presented in the Tables 5.1 through 5.129. Table 5.1 and Table 5.2 are shown in this chapter as examples of the procedures performed to calculate the trip rates. The rest of the Tables are found in Appendix B. Tables 5.1-5.20 are hourly rates and average weekday trip rates for N.O.M.C. Figures 5.1 through Figure 5.14 show the peak hour distribution of truck and total vehicle trip ends at each site. Using these data, the morning and evening peak hour rate was calculated for each day, Tuesday through Sunday, at Barbours Cut. These rates are shown in Tables 5.21 through 5.116 in Appendix B. Monday peak hour rates were not calculated at Barbours Cut because the traffic volume counts were not available.

TABLE 5.1
N.O.M.C. LAND AREA (69 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (FRIDAY)

TOTAL TRIPS:

A.M. PEAK HOUR (7:00 A.M.-8:00 A.M.):

	TOTAL
Vehicles Entering:	89
Vehicles Exiting:	14
	103
Percent of Vehicles Entering:	89/103 =86%
Percent of Vehicles Exiting:	14/103 =14%
Trip Rate:	103/69 = 1.49 Trips per Acre

TABLE 5.2
N.O.M.C. NO. OF CRANES (3)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (FRIDAY)

TOTAL TRIPS:

A.M. PEAK HOUR (7:00 A.M. 8:00 A.M.):

	TOTAL
Vehicles Entering:	89
Vehicles Exiting:	14
	103
Percent of Vehicles Entering	89/103 = 86%
Percent of Vehicles Exiting	14/103 = 14%
Trip Rate:	103/3 = 34.33 Trips per Crane

After data was collected for 7 days, the average weekday trip rate was calculated for the site. The equipment which was used for data collection stopped on the two-directional road on Monday. Therefore a reasonable assumption was made and added to the main enter and exit traffic to calculate total trip ends for Monday's data. Weighted Average Rate was calculated due to the variance within each data set for 7 days. Information regarding the independent variables during the period of traffic counts was gathered from the terminal managers and is listed below in Table 5.04.

DAYS	TOTAL TRIP ENDS	TRUCK TRIP ENDS	TEU's	CRANES	BERTH (# SHIPS)
MONDAY	3229	1139	979	2	1
TUESDAY	3805	1163	816	2	1
WEDNESDAY	4189	1121	800	7	2
THURSDAY	4152	1119	956	2	1
FRIDAY	3825	1142	862	0	0
SATURDAY	1054	85	0	0	0
SUNDAY	1464	124	9	0	0

Table 5.04 Daily total trip ends and number of independent variables

With the above data, average weekday trip rates were calculated. Since data was collected over a period of 7 days and information about the independent variables were also available for this period, weighted average weekday trip rates were calculated by adding together all trip ends and all independent variables, and then dividing the sum of trip ends by the sum of the independent variable units for days Monday through Friday. When calculating trip rate per land area and storage space, the average of trip ends over 5 days was calculated and then divided by the independent variable unit. Regression equations were not used to calculate the trip rates because the minimum number of sample size is 20 observations to plot and calculate the trip rates. The calculations are shown in the two Tables 5.117 and 5.118. The rest of the Tables are of the same procedure and therefore attached in Appendix B.

TABLE 5.117
BARBOURS CUT LAND AREA (230)
TRIP GENERATION RATES PER ACRE
AVERAGE WEEKDAY TRIP RATE (MONDAY-FRIDAY)

TRUCK TRIPS	
Average Weekday Trip Ends:	1136
Total Land Area (Acres):	230
Percent of Vehicles Entering	53%
Percent of Vehicles Exiting	47%
Average Weekday Trip Rate:	1136/230 = 4.93 Trips per Acre

TABLE 5.118
BARBOURS CUT CRANES
TRIP GENERATION RATES PER CRANE
AVERAGE WEEKDAY TRIP RATE (MONDAY-FRIDAY)

TRUCK TRIPS	
Trip Ends:	1136
Total Cranes:	8
Percent of Vehicles Entering	53%
Percent of Vehicles Exiting	47%
Weighted Average Weekday Trip Rate:	1136/8 = 142.12 Trips per Crane

VEHICLE CLASSIFICATION

Data was collected on the different types of vehicle classes that used the terminals. Only manual classification was performed at N.O.M.C., New Orleans, and both automatic and manual classifications were made at Houston's Barbours Cut terminal. The manual counts were performed from 7:00 a.m. until 11:30 a.m. at N.O.M.C. The automatic counts were made for a period of 7 days. In the analysis, the peak periods of different types of vehicles during the day were determined. The vehicle classes that were used are: 2-axle, 3-axle, 4-axle, 5-axle and 6 or more axles. The 2-axle traffic constituted passenger cars, pick-up trucks, and single unit trucks. These are mostly used by the employees, service/repair personnel, and other types of non-freight vehicles. The 3-axle vehicles are mostly bob-tails and very few trucks. The containers are carried by the 4-axle, 5-axle, 6-axle, 8-axle and very rarely even 10-axle trucks, but most of the 20-feet and 40-feet containers are transported by 5-axle trucks. Sometimes three 20-feet containers are carried on the same chassis. The containers, which are taken to the rail yards to be further transported to destinations, are usually carried on 4-axle trucks. After observing the classification count data, questions about accuracy of the counting equipment evolved. Therefore, efforts were taken to minimize errors, and a sample of the data was manually verified. The vehicle classes documented at both N.O.M.C. and Barbours Cut terminals are presented below.

N.O.M.C.

Data were collected manually by observing the entrance gate where all the traffic to and from the terminal had to pass. The duration of the count period was from 7:00 a.m. until 11:30 a.m., to capture the morning peak hour of traffic for that day and to classify the types of vehicles that used the terminals. The Table 5.129 below shows the vehicle classes.

VEHICLE CLASSES	PERCENTAGE
2-AXLE	42
3-AXLE	17
4-AXLE	2
5-AXLE	34
6-AXLE OR MORE	5

Table 5.129 Percent distribution of axle types at N.O.M.C. (7:00 A.M.-11:30 A.M.)

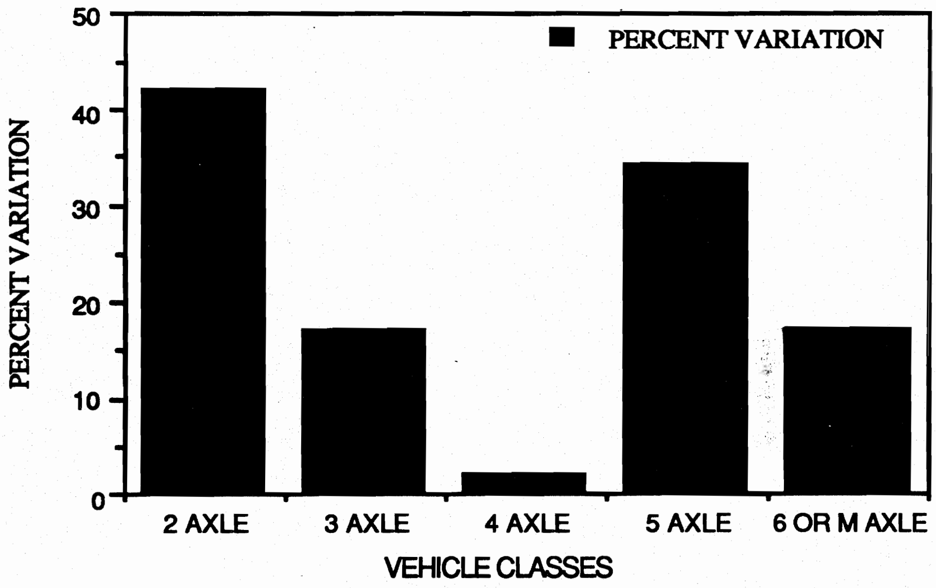

Figure 5.15 Percentage variation of axle types at N.O.M.C. (7 A.M. - 11:30 A.M.)

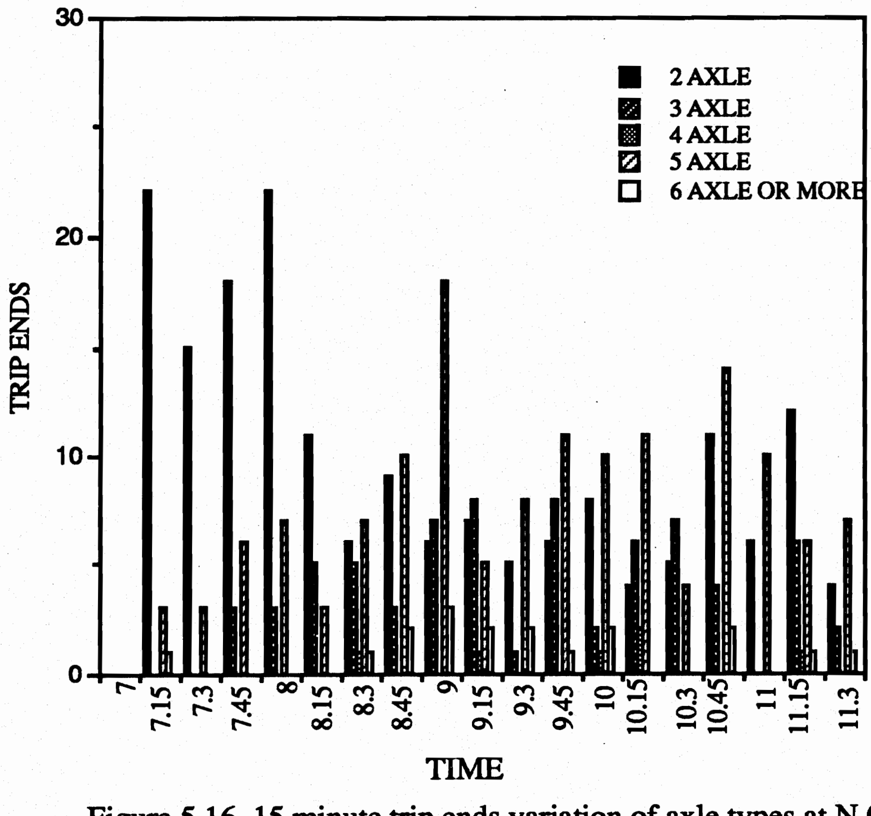

Figure 5.16 15 minute trip ends variation of axle types at N.O.M.C. (7 A.M.-11:30 A.M.)

Barbours Cut Terminal

An elaborate effort was made at the site to record the volumes and types of vehicles. The data were collected over a period of 7 days. The data were checked for accuracy and analysis performed. After the equipment was installed, 15-minute interval manual counts were made to validate the automatic counts. During the counts, the equipment was observed counting more 6 or more axle and less 5-axle vehicle counts, compared to manual counts, though the total number of vehicles was correct. It was found that the trucks had mud flaps behind front and rear wheels which were hanging so low that they were almost touching the road. The sensors were moved as low as possible to the road surface to minimize these errors. Still, it was found that some 5-axle trucks were classified into 6 or more axle trucks. Therefore manual classification was performed to get a percentage distribution of 5-axle vehicles which were put into 6 or more axles. It was found that about 73 percent of the 6-axle or more vehicle class counts can be assumed to be 5-axle type vehicles. Table 5.130 shows the final Barbours Cut results.

DAYS	2 AXLE	3 AXLE	4 AXLE	5 AXLE	6/MORE AXLE
MONDAY	58	11	5	16	10
TUESDAY	58	11	4	19	8
WEDNESDAY	63	10	5	15	7
THURSDAY	63	10	4	16	7
FRIDAY	60	10	5	18	7
SATURDAY	82	10	4	3	1
SUNDAY	80	11	6	2	1

Table 5.130 Percent Variation of Vehicle Classes (Monday-Sunday)

Figure 5.17 shows the daily trip ends of each vehicle class as measured by the equipment. Figure 5.18 represents the total percentage variation each day. As expected, truck volumes are almost negligible on Saturday and Sunday because the terminal is closed during those days.

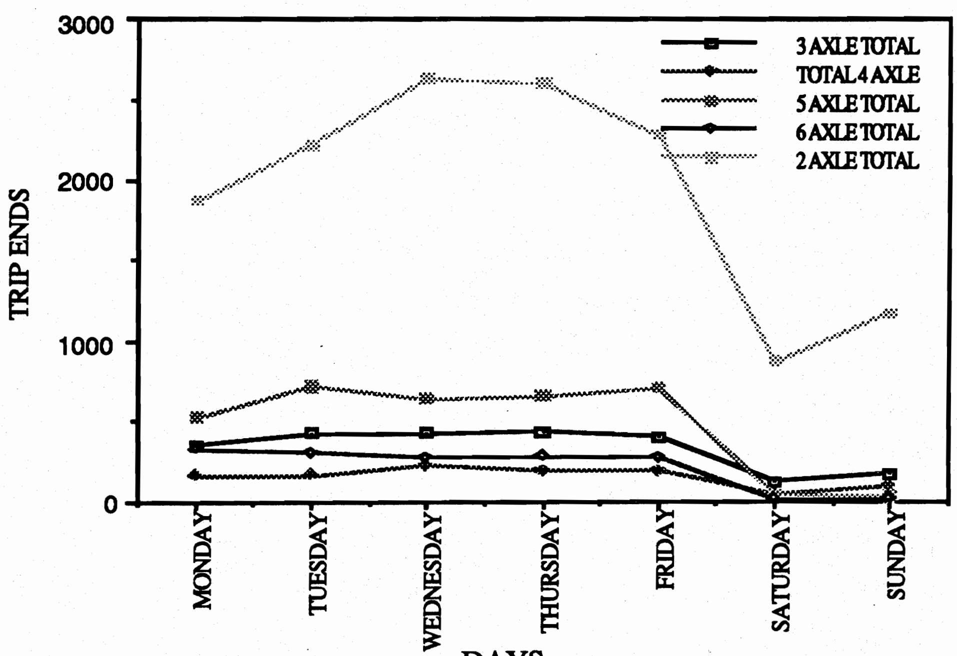

Figure 5.17 Daily variation of axle types at Barbours Cut

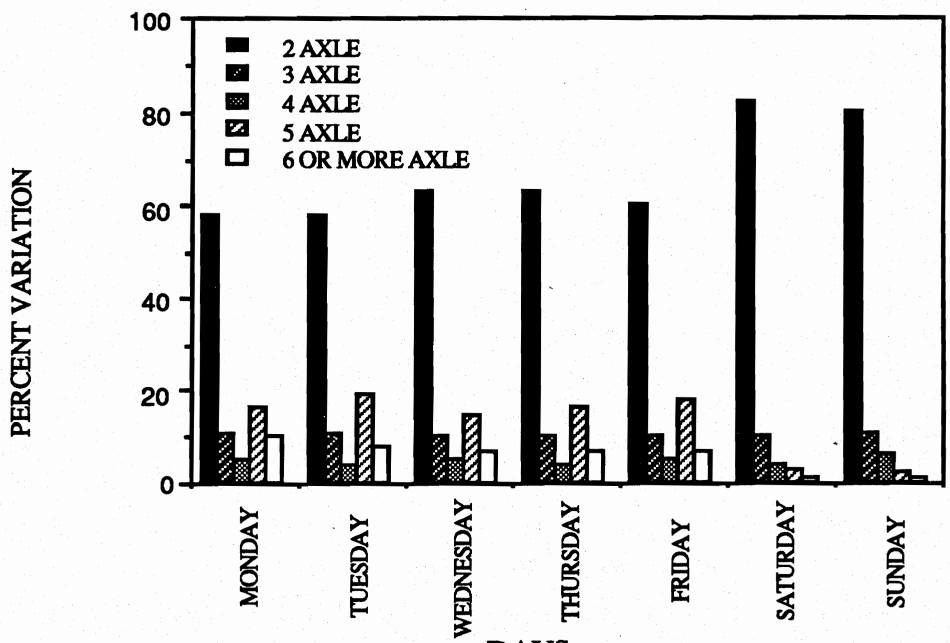

Figure 5.18 Percentage variation of axle types at Barbours Cut

SIMULATION OF GATE OPERATIONS

In the analysis of data, the following steps were performed:

1) construct histograms to characterize the variability of the different processes and compare them to known probability density functions,
2) make assumptions regarding the distributions,
3) estimate the parameters of the assumed distributions,
4) perform statistical tests of the assumptions, and
5) simulate to evaluate the system performance.

In performing statistical tests of the assumptions, the Kolmogorov-Smirnov (K-S) goodness-of-fit test was used. The results are briefly summarized below.

K-S Goodness-of-Fit Test

To test whether a sample is from a specified continuous distribution, the K-S test was performed. The test is exact for any sample size n, because it does not use an approximate distribution to test the null hypothesis.

H_0= data are from a specified distribution with stated parameter values

The cumulative distribution function (cdf) of the observed sample and the hypothesized distribution must be determined to carry out a K-S test. The test statistic d is the *maximum absolute difference* between the two cdf's over all observed values. The range on d is $0 \geq d \leq 1$, and the formula is

$$d = \max | S(x) - F(x) | \text{ for all } x$$

where x= each observed value

S(x) = observed cdf at x

F(x) = hypothesized cdf at x

The following procedure was used:

1. Order the sample data in an ascending order
2. Compute the sample cdf at each x value using S(x) = i/n, where i= 1..,n. n is the sample size. S(x) will increase 1/n at each x value.
3. Use the hypothesized cdf and parameters to determine F(x) at each ordered x value. F(x) is drawn as a smooth, approximating, continuous cdf.

Statistical Analysis of Inter-arrival Time

Histograms were plotted for the observed values to see the distributions of the Inter-arrival, Service-1, and Service-2 in Figures 5.19, 5.20 and 5.21 respectively.

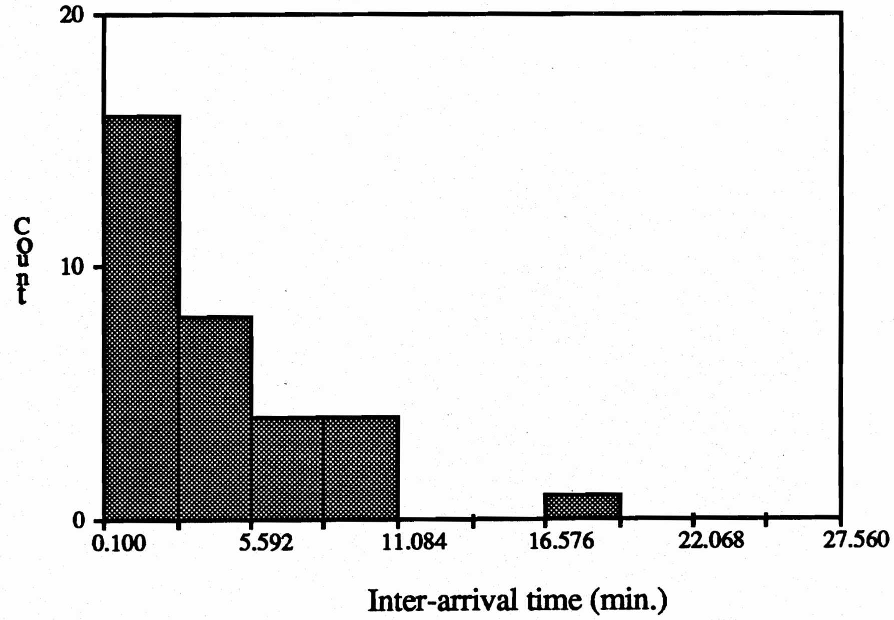

Figure 5.19 Histogram of Inter-arrival time at the gate.

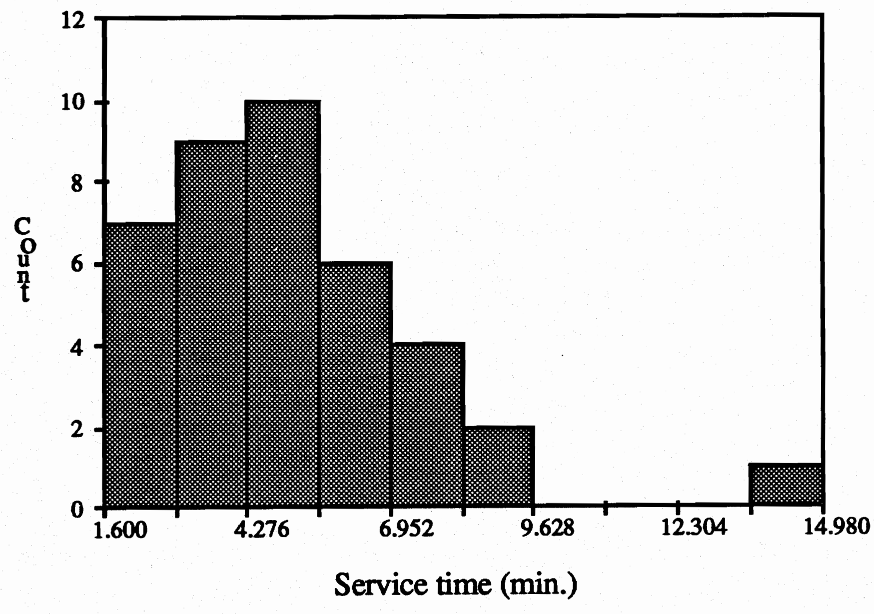

Figure 5.20 Histogram of service time at stage-1

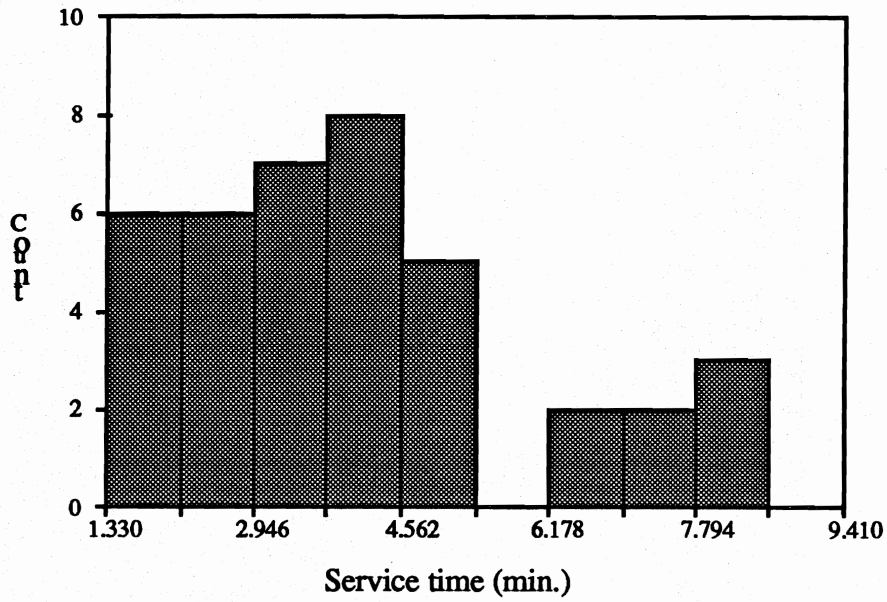

Figure 5 .21 Histogram of service time at stage-2

The statistical description of the observed Inter-arrival times, Service-1 and Service-2 are shown below in Table 5.131:

Variable	Mean (min)	Std. Err.	Var.	Coeff of Var	Std Dev.	Skewness	Kurtosis
Interarrival	4.954	.986	33.06	116.084	5.750	2.132	5.152
Service-1	5.236	.463	8.579	55.943	2.929	1.621	2.928
Service-2	4.203	.333	4.428	50.070	2.104	.737	-.397

Table 5.31 Statistical summary of the observed data

An exponential distribution was selected for comparison with the observed data. An exponential distribution is a continuous distribution, whose density function is f(t), is specified by one parameter l, with mean equal to standard deviation. The complete probability density function is defined as follows:

$$f(t) = le^{-lt} \qquad t > 0; l > 0$$
$$0 \qquad \text{elsewhere}$$

Goodness-of-fit testing with K-S and a 95 percent confidence level indicated the inter-arrival times were approximately exponentially distributed. The service times at both the stages were non-exponential.

The results of the tests are as follows: The specified distribution is exponential.

Summary of hypothesis test results is shown below:

VARIABLE	n	a=0.05	observed	Result	Distribution
SERVICE-1	40	0.21	0.290	Reject H_0	non-exponential
SERVICE-2	40	0.21	0.240	Reject H0	non-exponential
INTERARR	34	0.274	0.110	Accept H0	eponential

The arrival process of the trucks was Poisson and the inter-arrival distribution followed an exponential function as shown in the Figure 5.22.

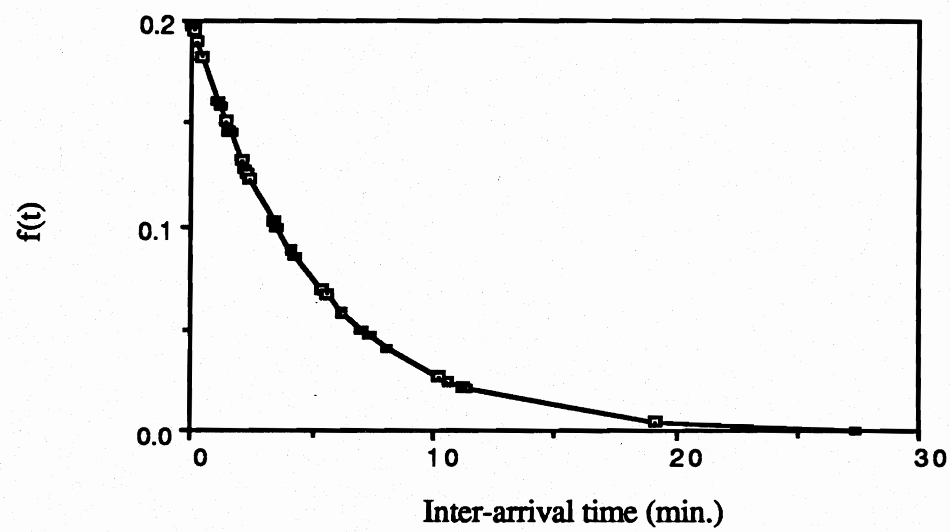

Figure 5.22 Exponential distribution of Inter-arrival times

When a distribution is non-exponential, it is often modeled as an approximate Erlang distribution. It is a continuous random variable whose density function f(t) is specified by two parameters: a rate parameter $R = k\mu$ and shape parameter k. Given values of R and k, the Erlang density has the following probability density function:

$$f(t) = R(Rt)^{k-1}e^{-Rt} / (k-1)! \quad (t \geq 0)$$

The mean of the distribution is $E(T)=1/\mu$, and variance is $Var(T)=1/k\mu^2$.

For an Erlang $Var(T)<E(T)^2$.

Estimating the parameters for an Erlang distribution:

Service-1.

E(T)=5.236 min.

Var(T)=8.579 min.

==> Var(T)<E(T)^2.

μ=1/5.236, Var(T)=(5.236)^2/k===>k=3.19 or 3.

Rate parameter = R = 3/5.236

Shape parameter = k = 3

The Service-1 time distribution which has the shape of an Erlang function with k=3 is shown in Figure 5.23.

Figure 5.23 Erlang distribution (k=3) of service time at stage-1

Erlang distribution with k=3 can be assumed to be the sum of 3 exponential phases, each with mean 1/kμ===>mean of 1.63 min.

Service-2.

E(T)=4.203min; μ=1/4.203;

Var(T)=(4.203)^2/k

===>k=4.

Rate parameter = R =4/4.203

Shape parameter = k =4

Figure 5.24 shows the distribution of Service-2 times which was modeled as an Erlang function with k=4.

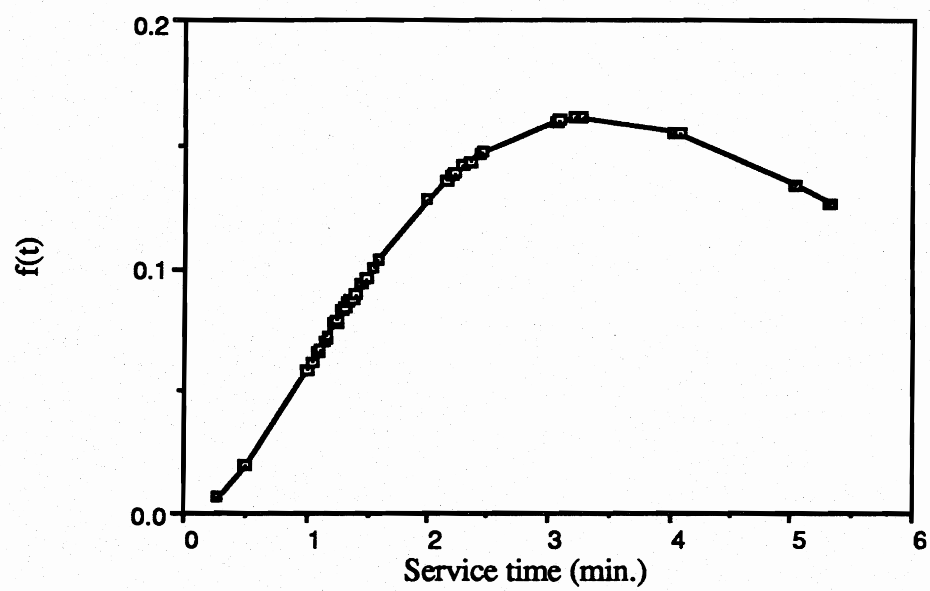

Figure 5.24 Erlang distribution (k=4) of service time at stage-2

Erlang distribution with k=4 can be assumed to be the sum of 4 exponential phases, each with mean of 1.05 min.

The Simulation Model

The Simulation Program:

The simulation model of the truck service times consists of three main parts: 1) the generation of truck arrivals, 2) the stage-1, where paper work is done, and defined as Service-1, and 3) the stage-2, where trucks are inspected for proper placards, and defined as Service-2. It is represented in Figure 5.25. The simulation language used in this study is SLAM II (Pritsker, 1986).

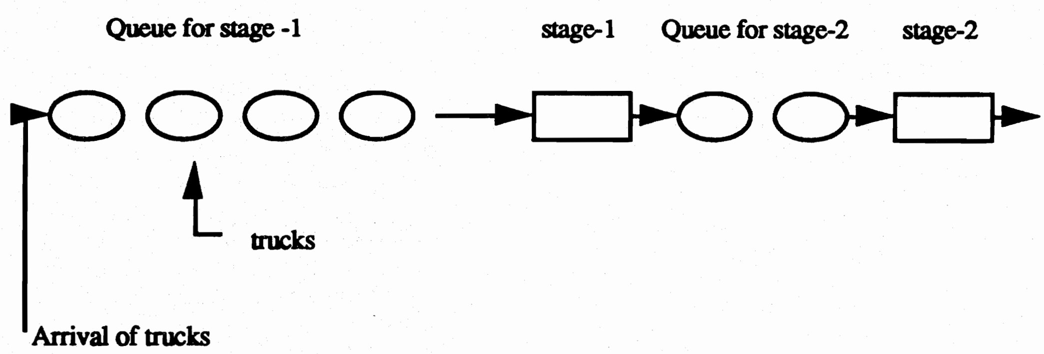

Figure 5.25 Schematic diagram of the terminal entry gates at P.R.M.M.I.

Inputs required for simulating the facility are the probability density functions of the observed inter-arrival times of trucks and the service times for trucks at the two stages. Statistical tests were performed to test whether the data came from a specified distribution as described in previous sections. Kolmogorov-Smirnov test was performed due to the small sample size. To evaluate the performance measures of the gate, a graphical network was drawn to represent the facility which was then transformed directly into the model by the software SLAM II. A network model was built to represent the whole gate activity. It consists of a set of interconnected symbols that depict the operations of the system under study. The symbols can be converted into a form for input to a program that analyzes the model using simulation techniques. The network is shown in Figure 5.26, and the statements are also included. The performance measures were calculated by the QUEUE nodes and the COLCT nodes in the program. The system was started in idle condition and empty state, and the duration of the run was set to 300 minutes for each replication.

Description of SLAM II Network. The SLAM II symbols and their corresponding command statements are described in "Introduction to Simulation and SLAM II" by Pritsker. The flow of the entities will be discussed. The entities correspond to trucks flowing through the network depicting gate operations.

The simulation starts at time 0, indicating the system is in an "idle" or empty state. An entity is generated by the CREATE node. The node CREATE can only generate entities by specifying starting time, generating function, and the number of entities to be generated. Entities representing the trucks are created with time between entities specified to be exponentially distributed, with mean of 4.954 minutes. Each entities' first attribute (ATTRIB(1)) is marked with its time of creation at the CREATE node. Marking is specified to permit interval statistics to be collected on the time in the system for each entity. The entitiy is routed to the first QUEUE node which represents the waiting entities for stage-1. The parameters for this QUEUE node, specify that the queue is initially empty, has a capacity of infinity, and that the entities waiting in the queue are placed in file 1. The stage-1 is represented by activity 1 emanating from the QUEUE node with service time specified as ERLNG (EMN, XK, IS).

It is a sample from an Erlang distribution which is the sum of XK exponential samples each with mean EMN using random number stream IS. Following the completion of service at stage-1, the entities continue to the second QUEUE node. The parameters for this QUEUE node specify that entities waiting in the queue for service are stored in file 2, the queue is initially empty, has a capacity of two, and incoming entities (and service activities) are blocked when the queue is at capacity. Following the QUEUE statement is the ACT statement representing the service activity of stage-2 with a service time specified as ERLNG (EMN, XK, IS). The average service time at stage-2 is shorter than in stage-1. Following the completion of service at stage-2, the entities are routed to a COLCT node which causes interval statistics to be collected. The simulation is initialized by the INIT statement, which sets the beginning time of simulation to 0 and the ending time of the simulation to 300 minutes. The network is completed with a TERMINATE node which terminates the simulation. The FIN statement denotes an end to all SLAM II simulation input and causes execution of the simulation to begin.

The network diagram is shown in Figure 5.26.

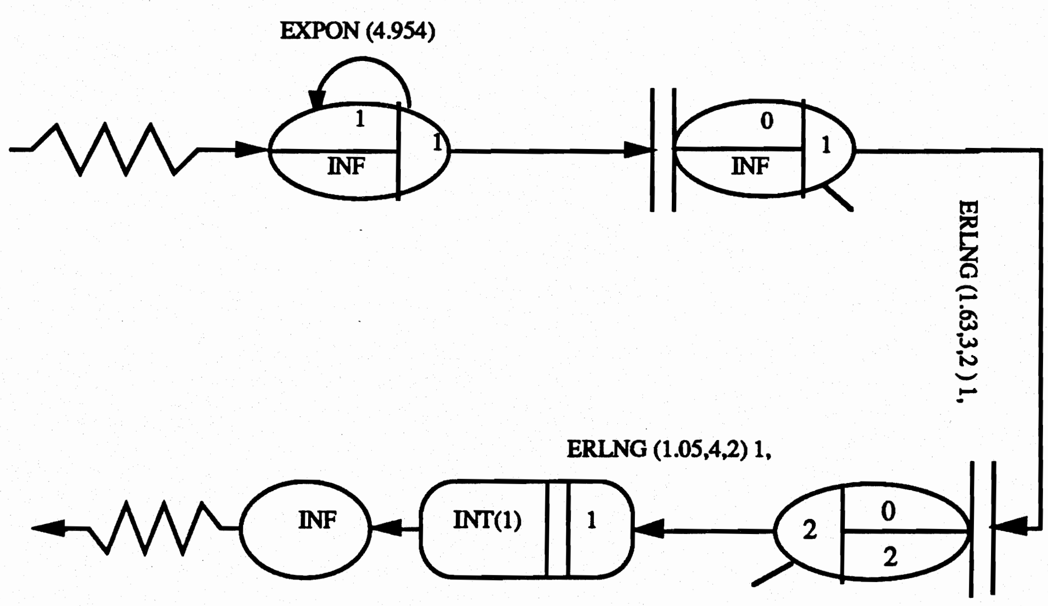

Figure 5.26 SLAM II Network Diagram to represent terminal process

The equivalent SLAM II statement of the graphical representation is shown below:

```
GEN, GUHA, GATE, 5/28/1991, 1, Y, Y, Y/Y, Y, Y/1, 72;
LIMITS, 2, 2, 100;
INITIALIZE, , 300, Y;
NETWORK;
;
        CREATE, EXPON (4.954), , 1, , 1;
        ACTIVITY;
        QUEUE (1), , , ;
        ACTIVITY (1) / 1, ERLNG (1.63, 3, IS);
        QUEUE (2), , 2, BLOCK;
        ACTIVITY (1) / 2, ERLNG (1.05, 4, IS);
        COLCT, INT (1), , , 1;
        ACTIVITY;
        TERMINATE;
        END;
        FIN;
```

Validation of the Model. This process is concerned with evaluating the performance of the simulation model. It is to determine whether the simulation model represents the actual system correctly. To compare the simulation model with the actual system, the following types of statistics were compared.

1) Average waiting time of trucks at stage-1
2) Average queue length of trucks at stage-1
3) Average total time spent in the system by a truck
4) Interdeparture times at stage-2

The Table 5.132 below demonstrates great similarity between observed and simulated performance measures. The measures selected to check the model depended on the types of data that could be collected at the gates. The trucks that arrived with containers waited at the entry gate (stage-1) to be processed. Queue length at stage-1 is the queue corresponding to the waiting trucks. The third measure was the total time that a truck spent in the terminal, ie; from arrival till it left the second stage. The last measure was the departure rate of the trucks from stage-2.

Performance Measures	Observed Data		Simulation	
	Mean (min)	Std. Dev.	Mean (min)	Std. Dev.
Wait time at stage-1	15.680	9.897	15.871	—
Queue length at stage-1	3.867	2.569	3.862	3.367
Total time spent in the system	20.914	10.943	20.66	10.7
interdeparture time at stage-2	5.137	3.023	5.15	3.4

Table 5.132 Comparison of the performance measures between simulation model and observed data

Summary of Results. The results for the simulation are summarized by the SLAM II Summary Report. After doing several replications of the system, an average value was obtained for each performance measure. The actual system was simulated with two stages in series. A space for two trucks was assumed between the two stages (as observed at the terminal). The inter-arrival time distribution was exponential and the service times at both the stages were Erlang with shape parameters 3 and 4 at stage-1 and stage-2, respectively. At each stage there was a single server. The simulation started in "empty" state, and each time the simulation was run for 300 minutes. After the simulation was performed, results were obtained regarding the total time in system, average queue lengths at stage-1 and stage-2, average waiting times for trucks, average utilization of the service stages, maximum idle time per server, and maximum busy time per server.

Simulation Experiments and Methods for Alleviating Current System Performance

As seen from the simulation results, congestion problems could arise from increasing demand. The terminal currently provides one server at both stage-1 and stage-2. From Table 5.3.3, the average queue length of trucks is 4 at stage-1 and about 1 at stage-2. The waiting time of trucks at stage-1 is, on the average, about 15.8 minutes and 4.5 minutes at stage-2. Due to over saturation of the queues observed during data collection, the maximum length of the queue is 15 trucks in the period of 300 minutes, which is quite severe. The service performances are detailed in Table 5.3.4. In the initial condition of one server at both the stages, the service utilization at stage-1 is 90 percent and at stage-2 is 87 percent. The maximum idle time per server and maximum busy time per server are also shown in the table. A very simple measure is suggested to improve the system performance. Assuming that there is no significant change in the service times of servers, and that the space in the terminal remains the same due to physical constraints, a simple solution is to increase the number of servers at the two stages. The changes are made by increasing the number of servers at the gate by one in order to reduce the processing time for the trucks. When the server is increased by one at stage-1, both the queue lengths and the average waiting times for trucks decrease as shown. The average queue length becomes almost one truck at each stage. The wait time at stage-1 reduces at the same time increasing the truck waiting time at the second stage, causing blocking of trucks. Due to the increase in number of servers at stage-1, each server remains busy for only 56 percent of the total time, whereas the server at stage-2 will now remain busy for 90 percent of the time. There is heavy blocking to the trucks at stage-1 due to only one server at stage-2; therefore, the system has still not reached efficiency. The average blocking is 40 percent. When the number of servers at stage-2 is increased by one in order to reduce the blocking caused at stage-1, both the queue statistics and the service statistics show that the system is quite efficient in handling the demand of trucks. All the results are summarized in Tables 5.133 and 5.134. Variations of the performance measures with increasing numbers of servers at each stage are shown. This section described a very simple model to describe the terminal gate operations and study system performance. A more elaborate data collection would be necessary to do a detailed study of the gate operations.

condition	Performance Measures					
	Average length (trucks)		Average wait time(min)		Max. Length(trucks)	
	Stage-1	Stage-2	Stage-1	Stage-2	Stage-1	Stage-2
1 server at stage-1 and stage-2	3.862 (4)	.845 (1)	15.871	4.448	15	0
2 servers at stage-1 and 1 server at stage -2	.843 (1)	1.413 (1)	3.465	6.422	6	2
2 servers at stages 1 and 2	.302 (0)	.083 (0)	1.24	.359	4	2

Table 5.132 Comparison of the performance measures between simulation model and observed data

Condition	Performance Measures							
	Average Utilization		Average Block		Max. Idle Time/ser (min)		Max. Busy Time/ser (min)	
	Stage-1	Stage-2	Stage-1	Stage-2	Stage-1	Stage-2	Stage-1	Stage-2
One server at stage-1 and stage-2	.90	.87	.03	0	11.85	13.93	82.94	136.33
Two servers at stage-1 and one server at stage-2	* 1.12	.904	.4	0	—	13.93	—	170.05
Two servers at stages 1 and 2	* 1.244	.953	0	0	—	—	—	—

* The value shown is sum of the average utilizations of the two servers.

Table 5.134 Service statistics of the simulation results

CHAPTER 6. SUMMARY AND RECOMMENDATIONS

This Chapter presents a summary of the efforts undertaken. It gives a summary of each of the elements which included data collection and data analysis. It also makes recommendations for future types of analyses.

SUMMARY

This report presented three main types of analyses; (1) trip generation, (2) vehicle classification and (3) simulation of gate operations. The data were mainly collected from the Port of New Orlean's N.O.M.C. and P.R.M.M.I. container terminals, and Port of Houston Authority's Barbours Cut container terminal.

Trip Generation Analysis

Actual trip generation rates were calculated for the N.O.M.C. and Barbours Cut sites. Traffic volumes and information about Independent Variables were collected. Data were collected at the sites, both manually and by using automatic counters to record traffic volumes. The duration of the data collection period varied from 6 hours in the case of N.O.M.C., to 7 days at Barbours Cut. Data about the independent variables were collected by conducting telephone interviews with the terminal managers. After collecting the data, peak hour of generator rates and weighted average weekday trip rates with respect to the independent variables were calculated. Trip rates were calculated both for trucks and total vehicles which included even auto trips.

Vehicle Classification

Whenever trip generation studies were performed, vehicle classification data were also collected. The vehicle classes selected for this report were 2-axle, 3-axle, 4-axle, 5-axle and 6 or more axles. Only manual measurements were made at N.O.M.C. An elaborate effort was made at Barbours Cut to record vehicle classes for a period of 7 days using automatic counters (photoelectric sensors). The data collection effort was hindered often due to bad weather, but finally data were collected for a week. Another serious problem was observed while collecting data at the site. Some of the trucks had mud flaps behind their rear wheels to protect the mud from hitting the following vehicles. Whenever such flaps interrupted the infrared beam, the equipment recorded the 5-axle trucks as 6 or more axle trucks. Manual classification was performed to correct this error. It was observed that container carrying trucks constituted about only 30 percent of total traffic.

Simulation of Gate Operations

In the final type of analysis, a very simple simulation model was developed to study the gate performance at P.R.M.M.I. Data were collected on arrival times and service times of the trucks which came to deliver containers. The model was developed based on data collected over a period of 5 hours. From the analysis of the data, it was found that the system was over saturated, i.e., trucks arrived at a peak rate for a certain period of time, and then there were time periods when no trucks would arrive. The truck queues would increase rapidly and then there were instances where the servers would be idle. The inter-arrival distribution corresponded to exponential, but the service times at the two stations were both Erlang distributions. The model was validated and the system performance observed. Very simple recommendations were made to improve the gate operations and system performance. The recommendations involved changing the number of servers.

RECOMMENDATIONS

The two most significant contributions made in this report were detailed studies on trip generation and vehicle classification. It provides additional information to transportation planners and traffic engineers to assess and predict demands for transportation associated with container ports. This information will assist in planning and implementation of transportation networks. Today, with increasing costs to build new transportation facilities, accurate prediction of travel demand has become very critical. Recently, a lot of emphasis has been given to the methods of estimating trip generation precisely, for a variety of land use categories. Marine terminals are one such category.

The Fifth Edition of ITE's "Trip Generation" reports only 7 studies on marine terminals. Only revenue-tons of cargo, ship berths, and enclosed and outdoor storage areas in acres have been included to calculate the trip rates. This report included other types of container port characteristics. After proper analysis, land area in acres, cranes (wharf), and TEU's were included to calculate the trip rates. It was found that TEU was the most significant variable which predicted the trips of a container port. To date, only average weekday trip rates had been calculated. Average weekday trip rates for both trucks and total vehicles (trucks and auto) were calculated at Barbours Cut terminal. Data were collected over five days, Monday through Friday, at the sites. The trip rates for trucks were as follows: 4.93 trips/acre, 437.23 trips/crane, 1136.8 trips/berth, 1.28 trips/TEU and 0.068 trips/ton. The total vehicle trip ends included autos and pickups. The rates were 16.69 trips/acre, 1476 trips/crane, 3840 trips/berth, 4.35 trips/TEU and 0.23trips/ton. This research made an effort to calculate the peak hour of generator trip rates, both morning and evening, at Barbours Cut terminal. Directional distribution of trip ends were assumed to be 50 percent entering and 50 percent exiting in the previous studies. This report measured and presented the actual directional distribution of traffic entering and exiting the sites. Average weekday directional distribution was 53 percent and 47 percent, enter and exit respectively. For total vehicles, the distributions were 48 percent enter and 52 percent exit. The peak hour differed for each day and so did the directional splits. Only approximations of truck trips had been made prior to this work. However this report documented actual percentages of trucks and other types of vehicles by collecting data over a period of 7 days. More data should be collected at each container port on traffic volumes and independent variables for longer durations of time, so that it would give more reasonable values of trip rates.

Additional information collected during trip generation studies is vehicle classification. Most container terminals did not document the percentage of different types of vehicles that used the site. Only manual observation during peak hours have been made to differentiate truck trips from other types of vehicles . From manual classification performed at N.O.M.C. during the peak hour of traffic, it was found that 40 percent comprised of trucks and the rest were 40 percent autos and 20 percent bob-tails. This research contributes information on different classes of vehicles by number of axles, that constituted the port traffic measured at the sites over a period of 7 days at Barbours Cut. Data should be collected on different types of vehicles over longer periods of time to provide more precise information because it was observed from the data collected that only 30 percent were trucks and the rest were other types of vehicles. Sixty percent of traffic were autos (cars, pickups, 2-axle trucks) and of the rest, 10 percent was comprised of 3-axle trucks (bob-tails). The data were collected using photoelectric sensors. The values presented for 5-axle trucks, which carried most of the container traffic, were not exact, due to errors caused by the mud flaps of the trucks. Manual observations were performed to correct the error, and it was found that about 73 percent of 6-axle vehicles recorded were actually 5-axle trucks. Bad weather was also a cause of hindrance in the data collection effort. Further research should be done to identify such types of unanticipated situations in an effort to collect vehicle classification data more precisely and for longer durations of time.

The section on simulation provided information about the performance of the existing terminal gate operations of a particular container terminal. It described the different distributions of inter-arrival and service times in order to model the system operations to get statistics on different performance measures. Only simple solutions were recommended to improve the system performance. With increasing truck traffic at the terminals, scope remains for more detailed study by considering many more complicated variables. From observations of truck arrival patterns at the terminal and from the service utilizations of the stations, it was found that during some periods of the day trucks waited for longer times. The average wait time was 16 minutes, and the average queue length was 4 trucks. With the model that was formulated, the facility can be designed for more efficient operations so that truck waiting times and truck queue lengths are decreased. To cope with the peaks and valleys in truck arrivals, flexibility in operating schedules could be suggested. The simulation models are representative of particular terminals due to different characteristics of the terminals.

Due to steady increases in container tonnage through ports in the U.S., a lot of research is being done to efficiently manage the throughput. In all the above types of analyses that were performed, each part assesses the existing traffic impact of the terminals on the surrounding infrastructure. The results of this report are specifically for N.O.M.C., P.R.M.M.I., and Barbours Cut. Therefore, it is necessary to collect data at different container ports in the U.S., and create a larger data base, to try to create a standard set of values which will best represent container ports in general.

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APPENDIX A

Hourly Variation Graphs

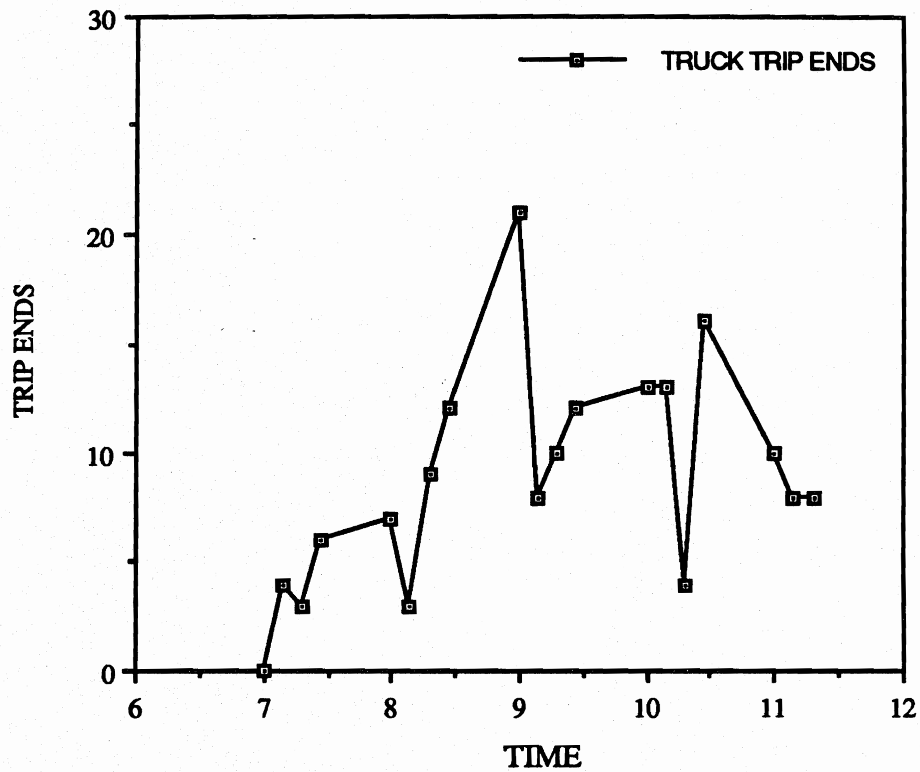

Figure 5.1 Friday peak hour truck volumes
(N.O.M.C.)

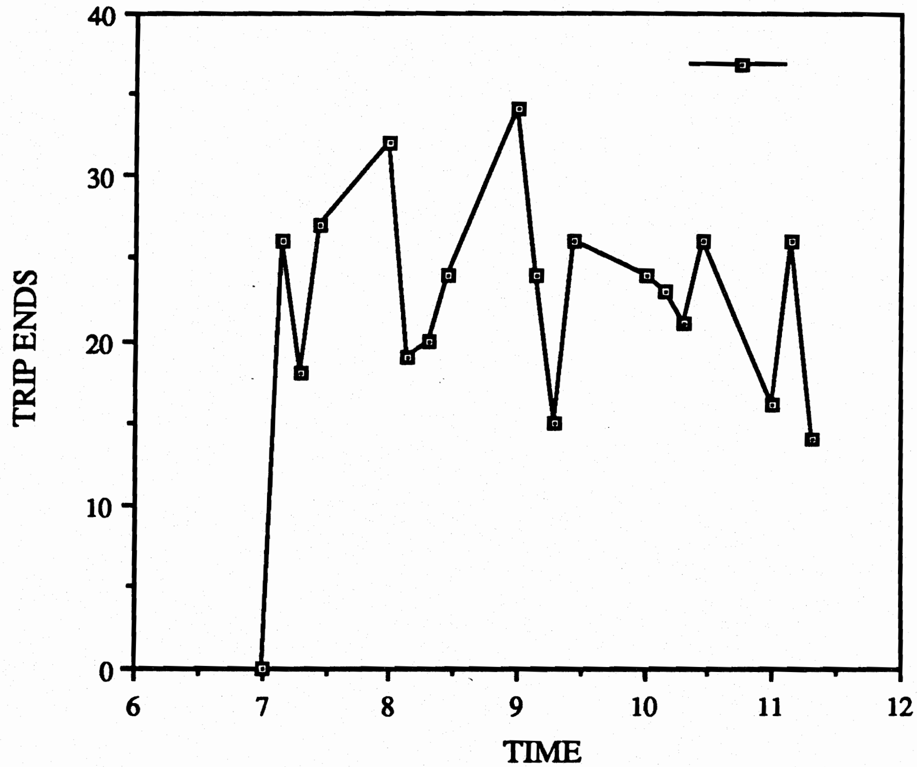

Figure 5.2 Friday peak hour total volumes (N.O.M.C.)

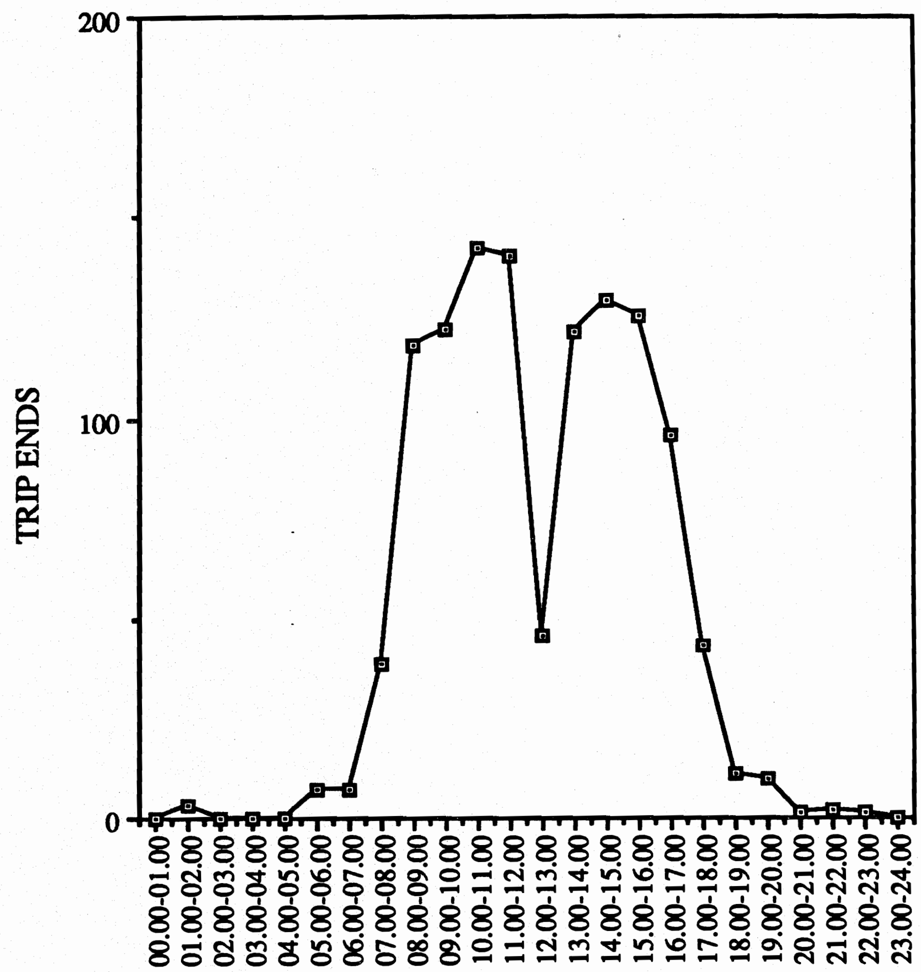

Figure 5.3 Tuesday hourly truck variation
(Barbours Cut)

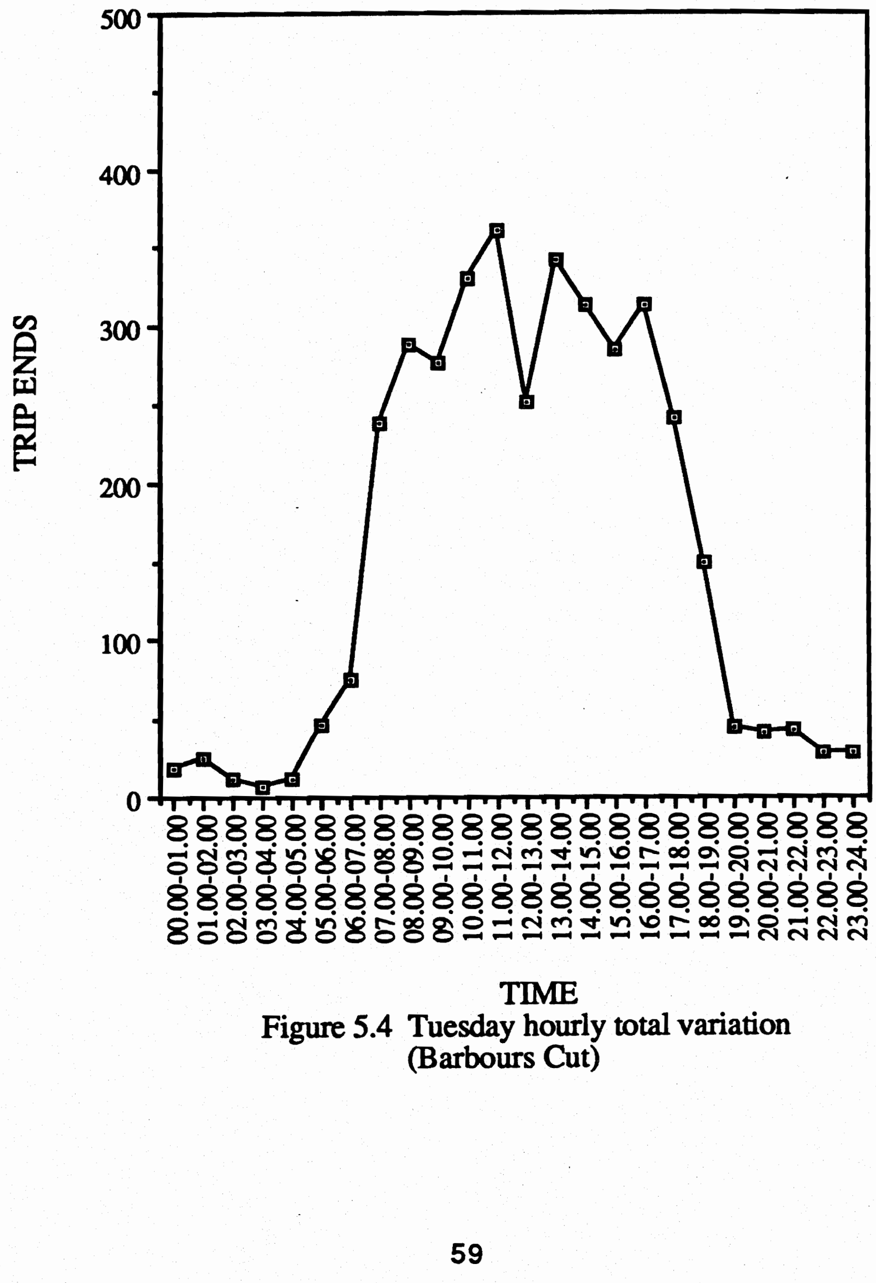

Figure 5.4 Tuesday hourly total variation
(Barbours Cut)

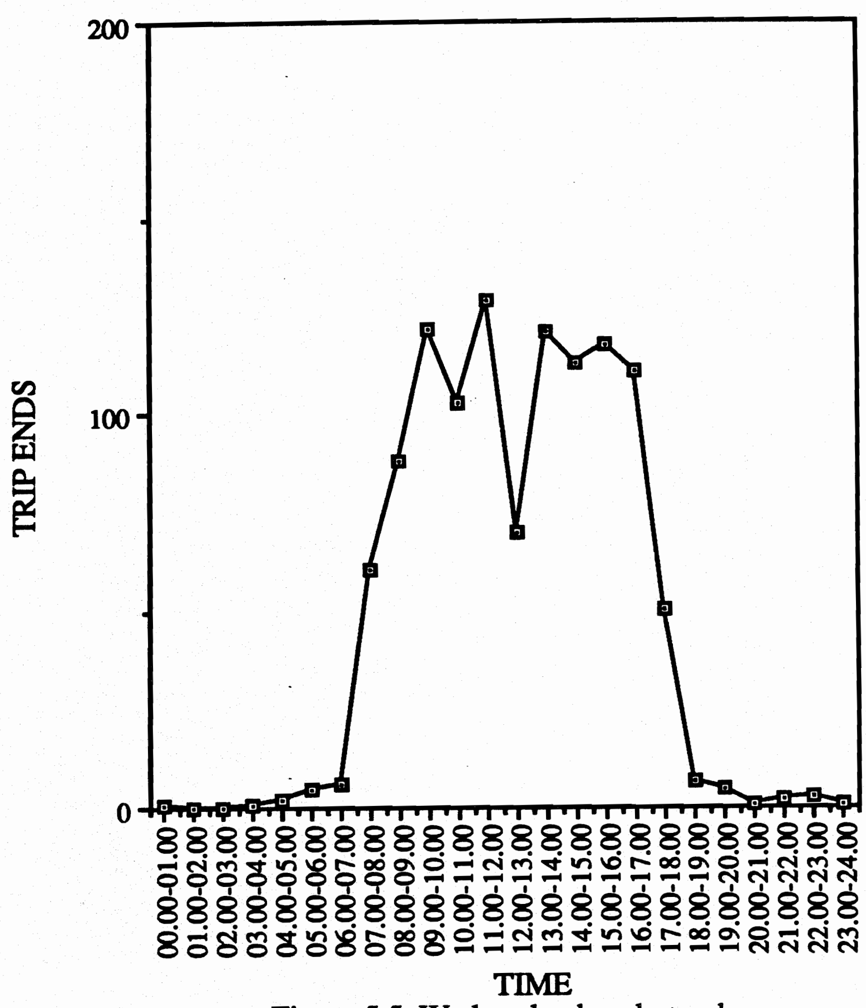

Figure 5.5 Wednesday hourly truck variation (Barbours Cut)

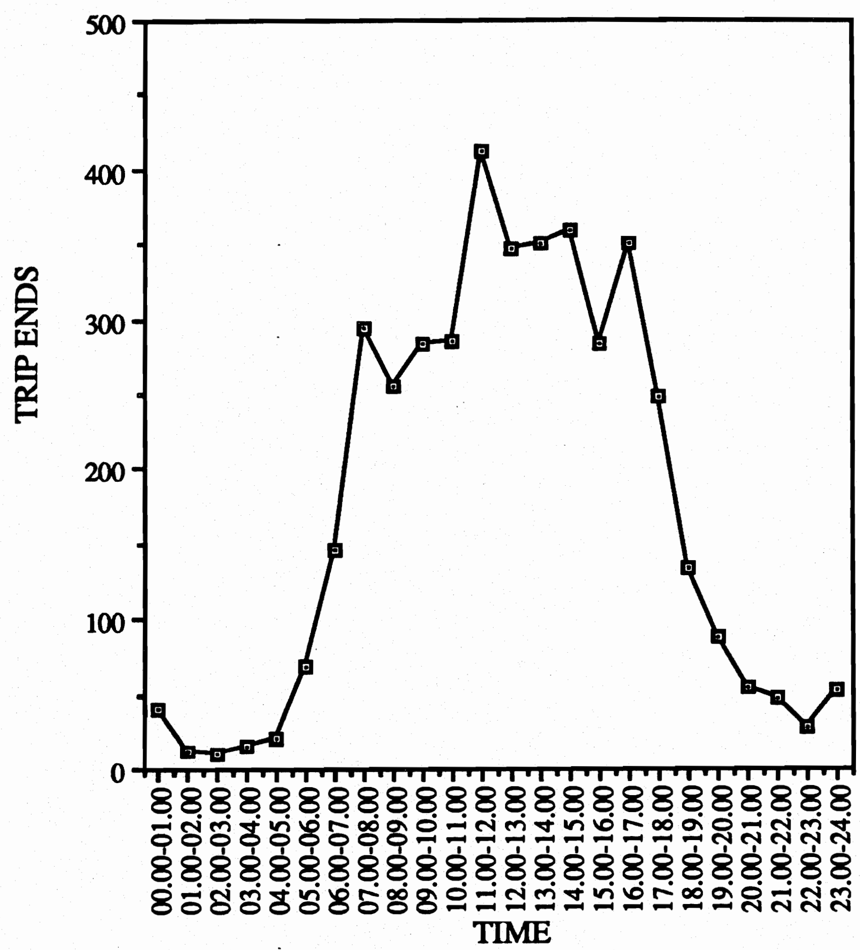

Figure 5.6 Wednesday hourly total variation (Barbours Cut)

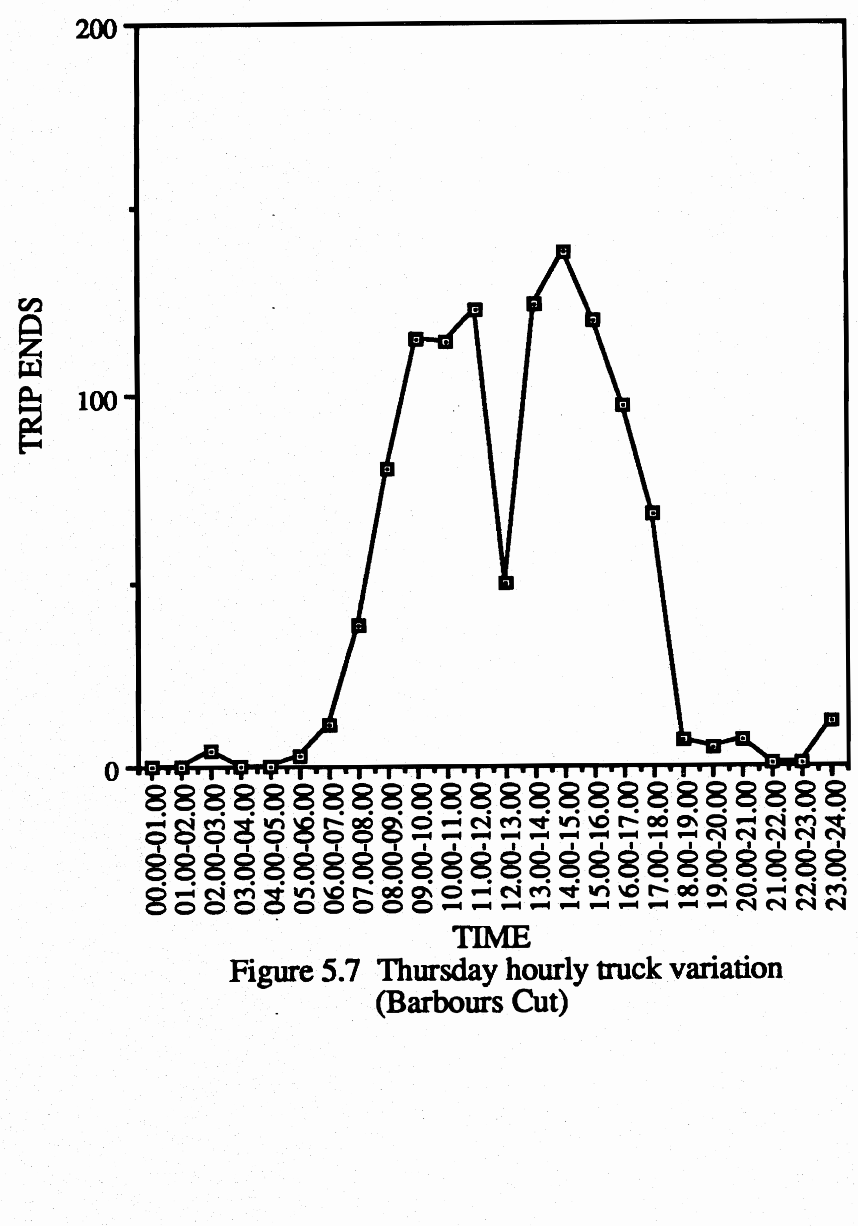

Figure 5.7 Thursday hourly truck variation
(Barbours Cut)

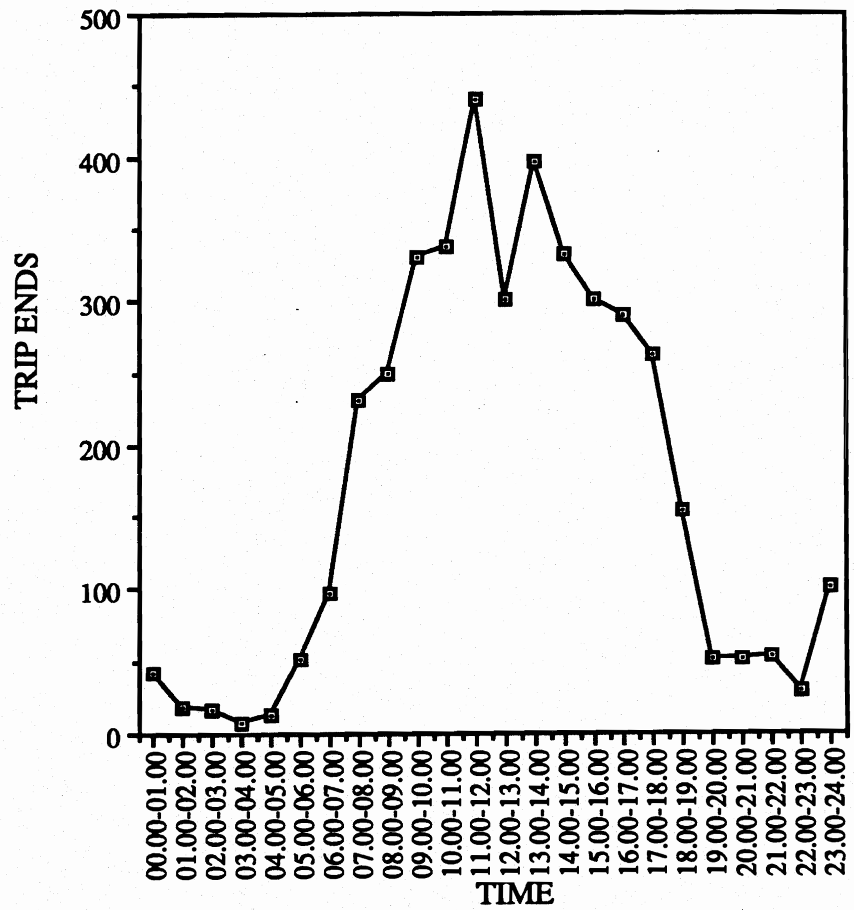

Figure 5.8 Thursday hourly total variation
(Barbours Cut)

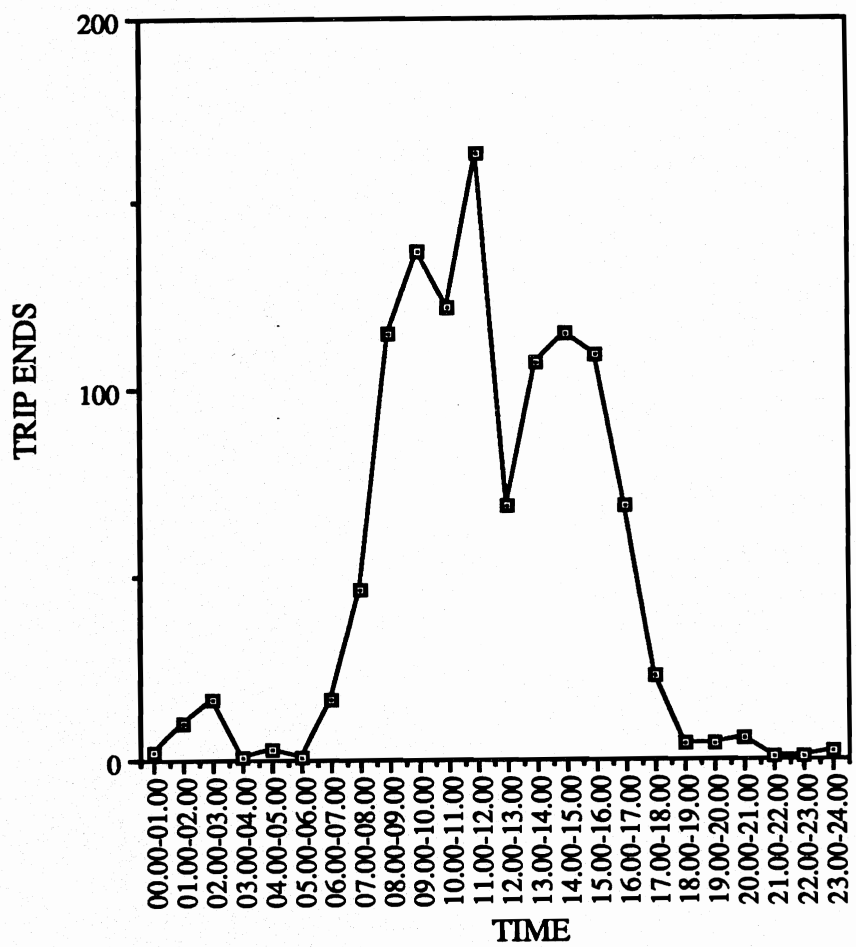

Figure 5.9 Friday hourly truck variation
(Barbours Cut)

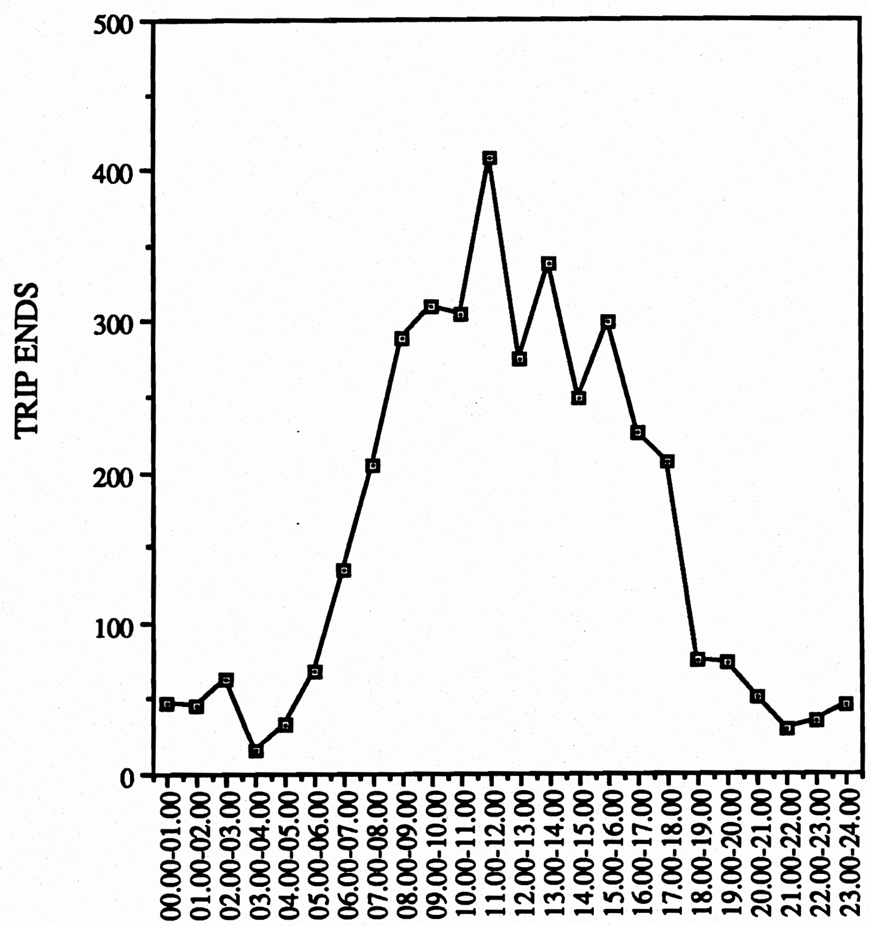

Figure 5.10 Friday hourly total variation
(Barbours Cut)

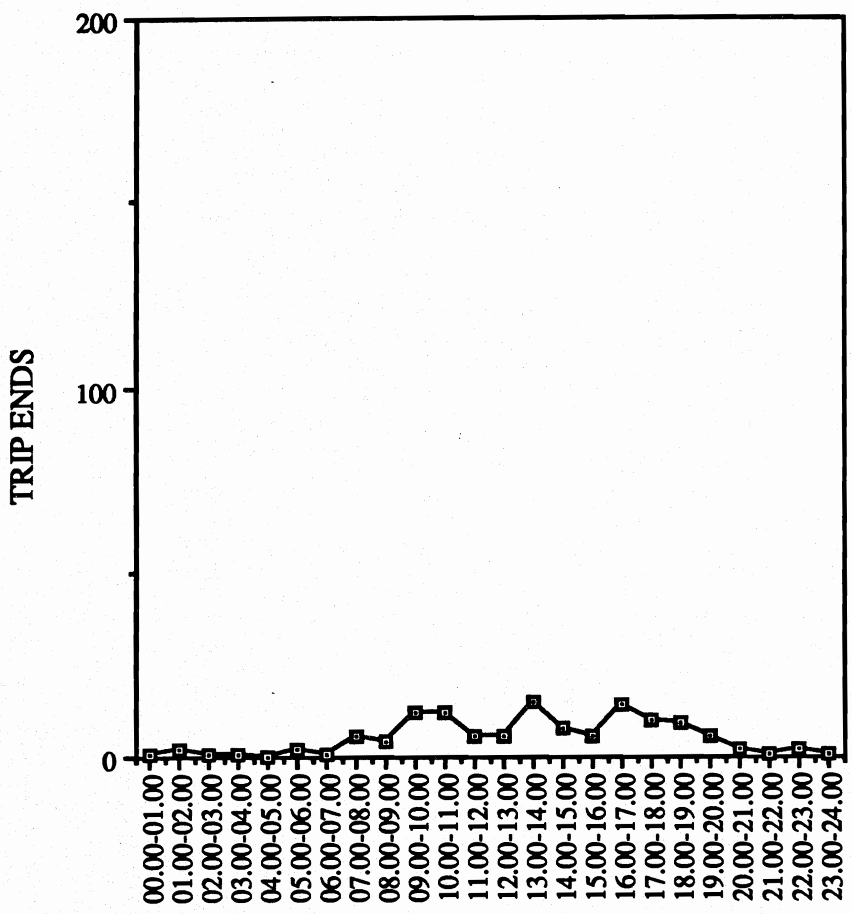

Figure 5.11 Saturday hourly truck variation
(Barbours Cut)

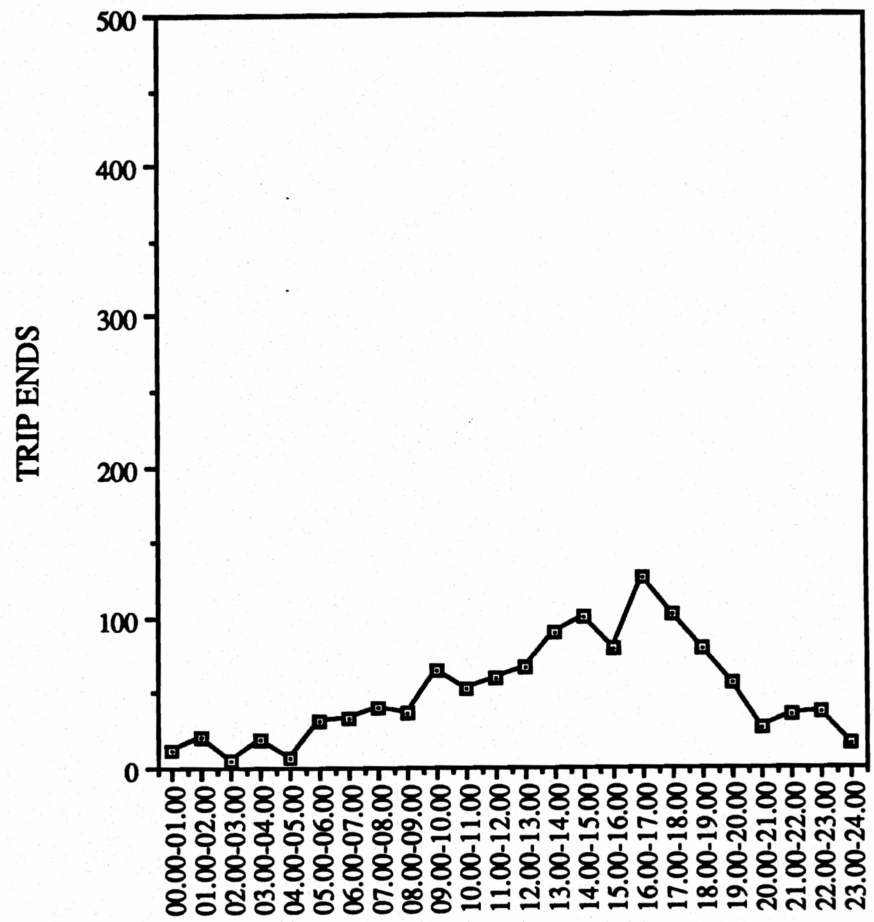

Figure 5.12 Saturday hourly total variation
(Barbours Cut)

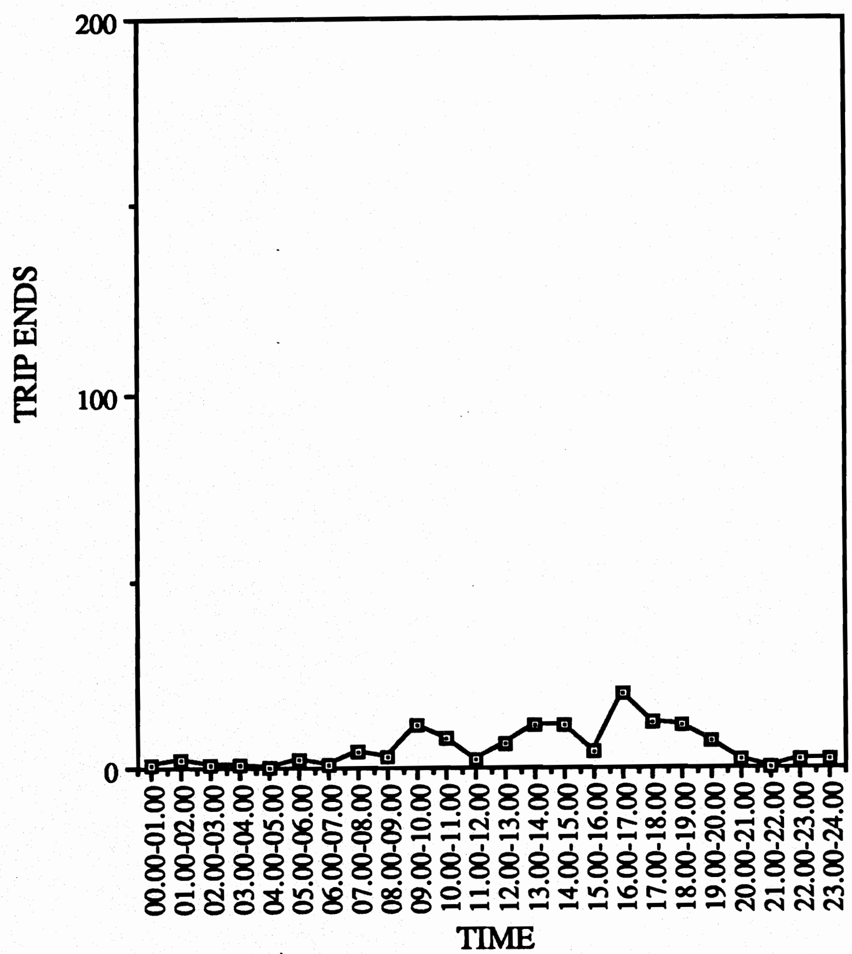

Figure 5.13 Sunday hourly truck variation (Barbours Cut)

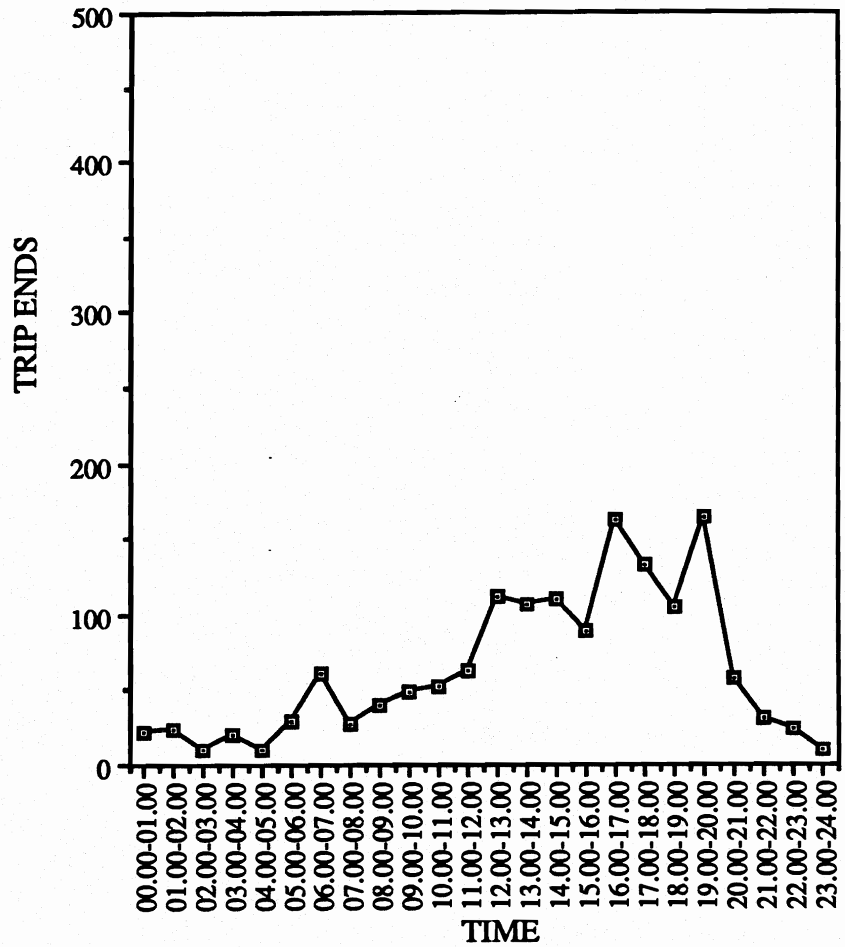

Figure 5.14 Sunday hourly total variation
(Barbours Cut)

APPENDIX B

Trip Generation Tables

TABLE 5.3
N.O.M.C. STORAGE AREA (57 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (FRIDAY)

TOTAL TRIPS:

A.M. PEAK HOUR (7:00 A.M.-8:00 A.M.):

	TOTAL
Vehicles Entering:	89
Vehicles Exiting:	14
	103

Percent of Vehicles Entering	89/103 = 86%
Percent of Vehicles Exiting	14/103 = 14%

Trip Rate: 103/57 = 1.80 Trips per Acre

TABLE 5.4
N.O.M.C. SHIP BERTHS (2)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (FRIDAY)

TOTAL TRIPS:

A.M. PEAK HOUR (7:00 A.M.-8:00 A.M.):

	TOTAL
Vehicles Entering:	89
Vehicles Exiting:	14
	103

Percent of Vehicles Entering:	89/103 = 86%
Percent of Vehicles Exiting:	14/103 = 14%

Trip Rate: 103/2 = 51.5 Trips per Berth

TABLE 5.5
N.O.M.C. LAND AREA (69 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (FRIDAY)

TRUCK TRIPS:

<u>A.M. PEAK HOUR (8:30 A.M.-9:30 A.M.):</u>

	TOTAL
Vehicles Entering:	22
Vehicles Exiting:	29
	51

Percent of Vehicles Entering:	22/51 = 43%
Percent of Vehicles Exiting:	29/51 = 57%

Trip Rate: 51/69 = 0.73 Trips per Acre

TABLE 5.6
N.O.M.C. STORAGE AREA (57 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (FRIDAY)

TRUCK TRIPS:

<u>A.M. PEAK HOUR (8:30 A.M.-9:30 A.M.):</u>

	TOTAL
Vehicles Entering:	22
Vehicles Exiting:	29
	51

Percent of Vehicles Entering	22/51 = 43%
Percent of Vehicles Exiting	29/51 = 57%

Trip Rate: 51/57 = 0.89 Trips per Acre

TABLE 5.7
N.O.M.C. NO. OF CRANES (3)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (FRIDAY)

TRUCK TRIPS:

A.M. PEAK HOUR (8:30 A.M.-9:30 A.M.):

	TOTAL
Vehicles Entering:	22
Vehicles Exiting:	29
	51

Percent of Vehicles Entering	22/51 = 43%
Percent of Vehicles Exiting	29/51 = 57%
Trip Rate:	51/3 = 17 Trips per Crane

TABLE 5.8
N.O.M.C. SHIP BERTHS (2)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (FRIDAY)

TRUCK TRIPS:

A.M. PEAK HOUR (8:30 A.M.-9:30 A.M.):

	TOTAL
Vehicles Entering:	22
Vehicles Exiting:	29
	51

Percent of Vehicles Entering	22/51 = 43%
Percent of Vehicles Exiting	29/51 = 57%
Trip Rate:	51/2 = 25.5 Trips per Berth

TABLE 5.9
N.O.M.C. SHORT TONS (65020 TONS)
TRIP GENERATION RATES PER TON

TRUCK TRIPS:

MONTH OF MARCH:

	TOTAL
Vehicles Entering:	3154
Vehicles Exiting:	2930
	6084

Percent of Vehicles Entering: 3154/6084 = 52%
Percent of Vehicles Exiting: 2930/6084 = 48%

Trip Rate: 6084/65020 = 0.0935 Trips per Ton

TABLE 5.10
N.O.M.C. SHORT TONS (650,20 TONS)
TRIP GENERATION RATES PER TON

TOTAL TRIPS:

MONTH OF MARCH:

	TOTAL
Vehicles Entering:	6065
Vehicles Exiting:	4439
	10504

Percent of Vehicles Entering: 6065/10504 = 58%
Percent of Vehicles Exiting: 4439/10504 = 42%

Trip Rate: 10504/65020 = 0.16 Trips per Ton

TABLE 5.11
N.O.M.C. LAND AREA (69 ACRES)
TRIP GENERATION RATES PER ACRE
AVERAGE WEEKDAY VEHICLE TRIP ENDS

TOTAL TRIPS:

AVERAGE WEEKDAY VEHICLE TRIP ENDS:

	TOTAL
Vehicles Entering:	287
Vehicles Exiting:	223
	510

Percent of Vehicles Entering:	287/510 = 56%
Percent of Vehicles Exiting:	223/510 = 44%
Trip Rate:	510/69 = 7.39 Trips Per Acre

TABLE 5.12
N.O.M.C. STORAGE SPACE (57 ACRES)
TRIP GENERATION RATES PER ACRE
AVERAGE WEEKDAY VEHICLE TRIP ENDS

TOTAL TRIPS:

AVERAGE WEEKDAY VEHICLE TRIP ENDS:

	TOTAL
Vehicles Entering:	287
Vehicles Exiting:	223
	510

Percent of Vehicles Entering	287/510 = 56%
Percent of Vehicles Exiting	223/510 = 44%
Trip Rate:	510/57 = 8.94 Trips per Acre

TABLE 5.13
N.O.M.C. NO. OF CRANES (3)
TRIP GENERATION RATES PER CRANE
AVERAGE WEEKDAY VEHICLE TRIP ENDS

TOTAL TRIPS:

AVERAGE WEEKDAY VEHICLE TRIP ENDS:

	TOTAL
Vehicles Entering:	287
Vehicles Exiting:	223
	510

Percent of Vehicles Entering	287/510 = 56%
Percent of Vehicles Exiting	223/510 = 44%
Trip Rate:	510/3 = 170 Trips per Crane

TABLE 5.14
N.O.M.C. SHIP BERTHS (2)
TRIP GENERATION RATES PER BERTH
AVERAGE WEEKDAY VEHICLE TRIP ENDS

TOTAL TRIPS:

AVERAGE WEEKDAY VEHICLE TRIP ENDS:

	TOTAL
Vehicles Entering:	287
Vehicles Exiting:	223
	510

Percent of Vehicles Entering	287/510 = 56%
Percent of Vehicles Exiting	223/510 = 44%
Trip Rate:	510/2 = 255 Trips per Berth

TABLE 5.15
N.O.M.C. SHORT TONS (3251 TONS)
TRIP GENERATION RATES PER TON
AVERAGE WEEKDAY VEHICLE TRIP ENDS

TOTAL TRIPS:

AVERAGE WEEKDAY VEHICLE TRIP ENDS:

	TOTAL
Vehicles Entering:	287
Vehicles Exiting:	223
	510

Percent of Vehicles Entering	287/510 = 56%
Percent of Vehicles Exiting	223/510 = 44%

Trip Rate: 510/3251 = 0.15 Trips per Ton

TABLE 5.16
N.O.M.C. LAND AREA (69 ACRES)
TRIP GENERATION RATES PER ACRE
AVERAGE WEEKDAY VEHICLE TRIP ENDS

TRUCK TRIPS:

AVERAGE WEEKDAY VEHICLE TRIP ENDS:

	TOTAL
Vehicles Entering:	149
Vehicles Exiting:	147
	296

Percent of Vehicles Entering:	149/296 = 50%
Percent of Vehicles Exiting:	147/296 = 50%

Trip Rate: 296/69 = 4.28 Trips per Acre

TABLE 5.17
N.O.M.C. STORAGE SPACE (57 ACRES)
TRIP GENERATION RATES PER ACRE
AVERAGE WEEKDAY VEHICLE TRIP ENDS

TRUCK TRIPS:

AVERAGE WEEKDAY VEHICLE TRIP ENDS:

	TOTAL
Vehicles Entering:	149
Vehicles Exiting:	147
	296

Percent of Vehicles Entering	149/296 = 50%
Percent of Vehicles Exiting	147/296 = 50%
Trip Rate:	296/57 = 5.19 Trips per Acre

TABLE 5.18
N.O.M.C. NO. OF CRANES (3)
TRIP GENERATION RATES PER CRANE
AVERAGE WEEKDAY VEHICLE TRIP ENDS

TRUCK TRIPS:

AVERAGE WEEKDAY VEHICLE TRIP ENDS:

	TOTAL
Vehicles Entering:	149
Vehicles Exiting:	147
	296

Percent of Vehicles Entering	149/296 = 50%
Percent of Vehicles Exiting	147/296 = 50%
Trip Rate:	296/3 = 98.66 Trips per Crane

TABLE 5.19
N.O.M.C. SHIP BERTHS (2)
TRIP GENERATION RATES PER BERTH
AVERAGE WEEKDAY VEHICLE TRIP ENDS

TRUCK TRIPS:

AVERAGE WEEKDAY VEHICLE TRIP ENDS:

	TOTAL
Vehicles Entering:	149
Vehicles Exiting:	147
	296

Percent of Vehicles Entering	149/296 = 50%
Percent of Vehicles Exiting	147/249 = 50%
Trip Rate:	296/2 = 148 Trips per Berth

TABLE 5.20
N.O.M.C. SHORT TONS (3251 TONS)
TRIP GENERATION RATES PER TON
AVERAGE WEEKDAY VEHICLE TRIP ENDS

TRUCK TRIPS:

AVERAGE WEEKDAY VEHICLE TRIP ENDS:

	TOTAL
Vehicles Entering:	149
Vehicles Exiting:	147
	296

Percent of Vehicles Entering	149/296 = 50%
Percent of VEhicles Exiting	147/296 = 50%
Trip Rate:	296/3251 = .091 Trips per Ton

TABLE 5.21
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (TUESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (10:30 A.M.-11:30 A.M.)

	TOTAL
Vehicles Entering:	92
Vehicles Exiting:	77
	169

Percent of Vehicles Entering:	92/169 = 54%
Percent of Vehicles Exiting:	77/169 = 46%

Trip Rate: 169/230 = 0.73 Trips per Acre

TABLE 5.22
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (TUESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:30 P.M.-14:30 P.M.)

	TOTAL
Vehicles Entering:	79
Vehicles Exiting:	54
	133

Percent of Vehicles Entering:	79/133 = 59%
Percent of Vehicles Exiting:	54/133 = 41%

Trip Rate: 133/230 = 0.57 Trips per Acre

TABLE 5.29
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (TUESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (10:30 A.M.-11:30 A.M.)

	TOTAL
Vehicles Entering:	170
Vehicles Exiting:	192
	362

Percent of Vehicles Entering:	170/362 = 47%
Percent of Vehicles Exiting:	192/362 = 53%

Trip Rate: 362/230 = 1.57 Trips per Acre

TABLE 5.30
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (TUESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (12:45 P.M.-13:45 P.M.)

	TOTAL
Vehicles Entering:	178
Vehicles Exiting:	168
	346

Percent of Vehicles Entering:	178/346 = 51%
Percent of Vehicles Exiting:	168/346 = 49%

Trip Rate: 346/230 = 1.50 Trips per Acre

TABLE 5.23
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (TUESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (10:30 A.M.-11:30 A.M.)

	TOTAL
Vehicles Entering:	92
Vehicles Exiting:	77
	169

Percent of Vehicles Entering: 92/169 = 54%
Percent of Vehicles Exiting: 77/169 = 46%

Trip Rate: 169/200 = 0.845 Trips per Acre

TABLE 5.24
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (TUESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:30 P.M.-14:30 P.M.)

	TOTAL
Vehicles Entering:	79
Vehicles Exiting:	54
	133

Percent of Vehicles Entering: 79/133 = 59%
Percent of Vehicles Exiting: 54/133 = 41%

Trip Rate: 133/200 = 0.665 Trips per Acre

TABLE 5.31
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (TUESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (10:30 A.M.-11:30 A.M.)

	TOTAL
Vehicles Entering:	170
Vehicles Exiting:	192
	362

Percent of Vehicles Entering: 170/362 = 47%
Percent of Vehicles Exiting: 192/362 = 53%

Trip Rate: 362/200 = 1.81 Trips per Acre

TABLE 5.32
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (TUESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (12:45 P.M.-13:45 P.M.)

	TOTAL
Vehicles Entering:	178
Vehicles Exiting:	168
	346

Percent of Vehicles Entering: 178/346 = 51%
Percent of Vehicles Exiting: 168/346 = 49%

Trip Rate: 346/200 = 1.73 Trips per Acre

TABLE 5.25
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (TUESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (10:30 A.M.-11:30 A.M.)

	TOTAL
Vehicles Entering:	92
Vehicles Exiting:	77
	169

Percent of Vehicles Entering:	92/169 = 54%
Percent of Vehicles Exiting:	77/169 = 46%

Trip Rate: 169/8 = 21.12 Trips per Crane

TABLE 5.26
BARBOURS CUT NO OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (TUESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:30 P.M.-14:30 P.M.)

	TOTAL
Vehicles Entering:	79
Vehicles Exiting:	54
	133

Percent of Vehicles Entering:	79/133 = 59%
Percent of Vehicles Exiting:	54/133 = 41%

Trip Rate: 133/8 = 16.62 Trips per Crane

TABLE 5.33
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (TUESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (10:30 A.M.-11:30 A.M.)

	TOTAL
Vehicles Entering:	170
Vehicles Exiting:	192
	362

Percent of Vehicles Entering: 170/362 = 47%
Percent of Vehicles Exiting: 192/362 = 53%

Trip Rate: 362/8 = 45.25 Trips per Crane

TABLE 5.34
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANES
PEAK HOUR OF GENERATOR (TUESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (12:45 P.M.-13:45 P.M.)

	TOTAL
Vehicles Entering:	178
Vehicles Exiting:	168
	346

Percent of Vehicles Entering: 178/346 = 51%
Percent of Vehicles Exiting: 168/346 = 49%

Trip Rate: 346/8 = 43.25 Trips per Crane

TABLE 5.27
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (TUESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (10:30 A.M.-11:30 A.M.)

	TOTAL
Vehicles Entering:	92
Vehicles Exiting:	77
	169

Percent of Vehicles Entering:	92/169 = 54%
Percent of Vehicles Exiting:	77/169 = 46%

Trip Rate: 169/4 = 42.25 Trips per Berth

TABLE 5.28
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (TUESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:30 P.M.-14:30 P.M.)

	TOTAL
Vehicles Entering:	79
Vehicles Exiting:	54
	133

Percent of Vehicles Entering:	79/133 = 59%
Percent of Vehicles Exiting:	54/133 = 41%

Trip Rate: 133/4 = 33.25 Trips per Berth

TABLE 5.35
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (TUESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (10:30 A.M.-11:30 A.M.)

	TOTAL
Vehicles Entering:	170
Vehicles Exiting:	192
	362

Percent of Vehicles Entering:	170/362 = 47%
Percent of Vehicles Exiting:	192/362 = 53%
Trip Rate:	362/4 = 90.5 Trips per Berth

TABLE 5.36
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (TUESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (12:45 P.M.-13:45 P.M.)

	TOTAL
Vehicles Entering:	178
Vehicles Exiting:	168
	346

Percent of Vehicles Entering:	178/346 = 51%
Percent of Vehicles Exiting:	168/346 = 49%
Trip Rate:	346/4 = 86.5 Trips per Berth

TABLE 5.37
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (WEDNESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	68
Vehicles Exiting:	61
	129

Percent of Vehicles Entering: 68/129 = 53%
Percent of Vehicles Exiting: 61/129 = 47%

Trip Rate: 129/230 = 0.56 Trips per Acre

TABLE 5.38
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (WEDNESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:30 P.M.-14:30 P.M)

	TOTAL
Vehicles Entering:	67
Vehicles Exiting:	61
	128

Percent of Vehicles Entering: 67/128 = 52%
Percent of Vehicles Exiting: 61/128 = 48%

Trip Rate: 128/230 = 0.55 Trips per Acre

TABLE 5.45
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (WEDNESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 A.M.)

	TOTAL
Vehicles Entering:	166
Vehicles Exiting:	246
	412

Percent of Vehicles Entering: 166/412 = 40%
Percent of Vehicles Exiting: 246/412 = 60%

Trip Rate: 412/230 = 1.79 Trips per Acre

TABLE 5.46
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (WEDNESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (13:30 P.M.-14:30 P.M.)

	TOTAL
Vehicles Entering:	176
Vehicles Exiting:	215
	391

Percent of Vehicles Entering: 176/391 = 45%
Percent of Vehicles Exiting: 215/391 = 55%

Trip Rate: 391/230 = 1.7 Trips per Acre

TABLE 5.39
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (WEDNESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	68
Vehicles Exiting:	61
	129

Percent of Vehicles Entering: 68/129 = 53%
Percent of Vehicles Exiting: 61/129 = 47%

Trip Rate: 129/200 = 0.64 Trips per Acre

TABLE 5.40
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (WEDNESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:30 P.M.-14:30 P.M)

	TOTAL
Vehicles Entering:	67
Vehicles Exiting:	61
	128

Percent of Vehicles Entering: 67/128 = 52%
Percent of Vehicles Exiting: 61/128 = 48%

Trip Rate: 128/200 = 0.64 Trips per Acre

TABLE 5.47
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (WEDNESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 A.M.)

	TOTAL
Vehicles Entering:	166
Vehicles Exiting:	246
	412

Percent of Vehicles Entering:	166/412 = 40%
Percent of Vehicles Exiting:	246/412 = 60%

Trip Rate: 412/200 = 2.06 Trips per Acre

TABLE 5.48
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (WEDNESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (13:30 P.M.-14:30 P.M.)

	TOTAL
Vehicles Entering:	176
Vehicles Exiting:	215
	391

Percent of Vehicles Entering:	176/391 = 45%
Percent of Vehicles Exiting:	215/391 = 55%

Trip Rate: 391/200 = 1.95 Trips per Acre

TABLE 5.41
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (WEDNESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	68
Vehicles Exiting:	61
	129

Percent of Vehicles Entering:	68/129 = 53%
Percent of Vehicles Exiting:	61/129 = 47%

Trip Rate: 129/8 = 16.12 Trips per Crane

TABLE 5.42
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (WEDNESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:30 P.M.-14:30 P.M)

	TOTAL
Vehicles Entering:	67
Vehicles Exiting:	61
	128

Percent of Vehicles Entering:	67/128 = 52%
Percent of Vehicles Exiting:	61/128 = 48%

Trip Rate: 128/8 = 16 Trips per Crane

TABLE 5.49
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANES
PEAK HOUR OF GENERATOR (WEDNESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 A.M.)

	TOTAL
Vehicles Entering:	166
Vehicles Exiting:	246
	412

Percent of Vehicles Entering: 166/412 = 40%
Percent of Vehicles Exiting: 246/412 = 60%

Trip Rate: 412/8 = 51.5 Trips per Crane

TABLE 5.50
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANES
PEAK HOUR OF GENERATOR (WEDNESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (13:30 P.M.-14:30 P.M.)

	TOTAL
Vehicles Entering:	176
Vehicles Exiting:	215
	391

Percent of Vehicles Entering: 176/391 = 45%
Percent of Vehicles Exiting: 215/391 = 55%

Trip Rate: 391/8 = 65.16 Trips per Crane

TABLE 5.43
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (WEDNESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	68
Vehicles Exiting:	61
	129

Percent of Vehicles Entering: 68/129 = 53%
Percent of Vehicles Exiting: 61/129 = 47%

Trip Rate: 129/4 = 32.25 Trips per Berth

TABLE 5.44
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (WEDNESDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:30 P.M.-14:30 P.M)

	TOTAL
Vehicles Entering:	67
Vehicles Exiting:	61
	128

Percent of Vehicles Entering: 67/128 = 52%
Percent of Vehicles Exiting: 61/128 = 48%

Trip Rate: 128/4 = 32 Trips per Berth

TABLE 5.51
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (WEDNESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 A.M.)

	TOTAL
Vehicles Entering:	166
Vehicles Exiting:	246
	412

Percent of Vehicles Entering: 166/412 = 40%
Percent of Vehicles Exiting: 246/412 = 60%

Trip Rate: 412/4 = 103 Trips per Berth

TABLE 5.52
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (WEDNESDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (13:30 P.M.-14:30 P.M.)

	TOTAL
Vehicles Entering:	176
Vehicles Exiting:	215
	391

Percent of Vehicles Entering: 176/391 = 45%
Percent of Vehicles Exiting: 215/391 = 55%

Trip Rate: 391/4 = 97.75 Trips per Berth

TABLE 5.53
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (THURSDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (09:45 A.M.-10:45 A.M.)

	TOTAL
Vehicles Entering:	75
Vehicles Exiting:	54
	129

Percent of Vehicles Entering: 75/129 = 58%
Percent of Vehicles Exiting: 54/129 = 42%

Trip Rate: 129/230 = 0.56 Trips per Acre

TABLE 5.54
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (THURSDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (14:15 P.M.-15:15 P.M.)

	TOTAL
Vehicles Entering:	66
Vehicles Exiting:	81
	147

Percent of Vehicles Entering: 66/147 = 45%
Percent of Vehicles Exiting: 81/147 = 55%

Trip Rate: 147/230 = 0.63 Trips per Acre

TABLE 5.61
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (THURSDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	166
Vehicles Exiting:	273
	439

Percent of Vehicles Entering: 166/439 = 38%
Percent of Vehicles Exiting: 273/439 = 62%

Trip Rate: 439/230 = 1.90 Trips per Acre

TABLE 5.62
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (THURSDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (12:45 A.M.-13:45 A.M.)

	TOTAL
Vehicles Entering:	180
Vehicles Exiting:	222
	402

Percent of Vehicles Entering: 180/402 = 45%
Percent of Vehicles Exiting: 222/402 = 55%

Trip Rate: 402/230 = 1.74 Trips per Acre

TABLE 5.55
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (THURSDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (09:45 A.M.-10:45 A.M.)

	TOTAL
Vehicles Entering:	75
Vehicles Exiting:	54
	129

Percent of Vehicles Entering: 75/129 = 58%
Percent of Vehicles Exiting: 54/129 = 42%

Trip Rate: 129/200 = 0.56 Trips per Acre

TABLE 5.56
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (THURSDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (14:15 P.M.-15:15 P.M.)

	TOTAL
Vehicles Entering:	66
Vehicles Exiting:	81
	147

Percent of Vehicles Entering: 66/147 = 45%
Percent of Vehicles Exiting: 81/147 = 55%

Trip Rate: 147/200 = 0.73 Trips per Acre

TABLE 5.63
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (THURSDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	166
Vehicles Exiting:	273
	439

Percent of Vehicles Entering: 166/439 = 38%
Percent of Vehicles Exiting: 273/439 = 62%

Trip Rate: 439/200 = 2.19 Trips per Acre

TABLE 5.64
BARBOURS CUT LAND AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (THURSDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (12:45 A.M.-13:45 A.M.)

	TOTAL
Vehicles Entering:	180
Vehicles Exiting:	222
	402

Percent of Vehicles Entering: 180/402 = 45%
Percent of Vehicles Exiting: 222/402 = 55%

Trip Rate: 402/200 = 2.01 Trips per Acre

TABLE 5.57
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANES
PEAK HOUR OF GENERATOR (THURSDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (09:45 A.M.-10:45 A.M.)

	TOTAL
Vehicles Entering:	75
Vehicles Exiting:	54
	129

Percent of Vehicles Entering: 75/129 = 58%
Percent of Vehicles Exiting: 54/129 = 42%

Trip Rate: 129/8 = 16.12 Trips per Crane

TABLE 5.58
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANES
PEAK HOUR OF GENERATOR (THURSDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (14:15 P.M.-15:15 P.M.)

	TOTAL
Vehicles Entering:	66
Vehicles Exiting:	81
	147

Percent of Vehicles Entering: 66/147 = 45%
Percent of Vehicles Exiting: 81/147 = 55%

Trip Rate: 147/8 = 18.37 Trips per Crane

TABLE 5.65
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (THURSDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	166
Vehicles Exiting:	273
	439

Percent of Vehicles Entering:	166/439 = 38%
Percent of Vehicles Exiting:	273/439 = 62%

Trip Rate: 439/8 = 54.87 Trips per Crane

TABLE 5.66
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (THURSDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (12:45 A.M.-13:45 A.M.)

	TOTAL
Vehicles Entering:	180
Vehicles Exiting:	222
	402

Percent of Vehicles Entering:	180/402 = 45%
Percent of Vehicles Exiting:	222/402 = 55%

Trip Rate: 402/8 = 50.25 Trips per Crane

TABLE 5.59
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (THURSDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (09:45 A.M.-10:45 A.M.)

	TOTAL
Vehicles Entering:	75
Vehicles Exiting:	54
	129

Percent of Vehicles Entering:	75/129 = 58%
Percent of Vehicles Exiting:	54/129 = 42%

Trip Rate: 129/4 = 32.25 Trips per Berth

TABLE 5.60
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (THURSDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (14:15 P.M.-15:15 P.M.)

	TOTAL
Vehicles Entering:	66
Vehicles Exiting:	81
	147

Percent of Vehicles Entering:	66/147 = 45%
Percent of Vehicles Exiting:	81/147 = 55%

Trip Rate: 147/4 = 36.75 Trips per Berth

TABLE 5.67
BARBOURS CUT SHIP BERTH
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (THURSDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	166
Vehicles Exiting:	273
	439

Percent of Vehicles Entering: 166/439 = 38%
Percent of Vehicles Exiting: 273/439 = 62%

Trip Rate: 439/4 = 109.75 Trips per Berth

TABLE 5.68
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (THURSDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (12:45 A.M.-13:45 A.M.)

	TOTAL
Vehicles Entering:	180
Vehicles Exiting:	222
	402

Percent of Vehicles Entering: 180/402 = 45%
Percent of Vehicles Exiting: 222/402 = 55%

Trip Rate: 402/4 = 100.5 Trips per Berth

TABLE 5.69
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (FRIDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	70
Vehicles Exiting:	93
	163

Percent of Vehicles Entering:	70/163 = 43%
Percent of Vehicles Exiting:	93/163 = 57%
Trip Rate:	163/230 = 0.70 Trips per Acre

TABLE 5.70
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (FRIDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:45 P.M.-14:45 P.M.)

	TOTAL
Vehicles Entering:	54
Vehicles Exiting:	63
	117

Percent of Vehicles Entering:	54/117 = 46%
Percent of Vehicles Exiting:	63/117 = 54%
Trip Rate:	117/230 = 0.50 Trips per Acre

TABLE 5.77
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (FRIDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	155
Vehicles Exiting:	252
	407

Percent of Vehicles Entering: 155/402 = 38%
Percent of Vehicles Exiting: 252/402 = 62%

Trip Rate: 402/230 = 1.74 Trips per Acre

TABLE 5.78
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (FRIDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (13:00 P.M.-14:00 P.M.)

	TOTAL
Vehicles Entering:	156
Vehicles Exiting:	182
	338

Percent of Vehicles Entering: 156/338 = 46%
Percent of Vehicles Exiting: 182/338 = 54%

Trip Rate: 338/230 = 1.46 Trips per Acre

TABLE 5.71
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (FRIDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	70
Vehicles Exiting:	93
	163

Percent of Vehicles Entering:	70/163 = 43%
Percent of Vehicles Exiting:	93/163 = 57%
Trip Rate:	163/2OO = 81 Trips per Acre

TABLE 5.72
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (FRIDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:45 P.M.-14:45 P.M.)

	TOTAL
Vehicles Entering:	54
Vehicles Exiting:	63
	117

Percent of Vehicles Entering:	54/117 = 46%
Percent of Vehicles Exiting:	63/117 = 54%
Trip Rate:	117/200 = 0.58 Trips per Acre

TABLE 5.79
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (FRIDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	155
Vehicles Exiting:	252
	407

Percent of Vehicles Entering: 155/402 = 38%
Percent of Vehicles Exiting: 252/402 = 62%

Trip Rate: 402/200 = 2.01 Trips per Acre

TABLE 5.80
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (FRIDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (13:00 P.M.-14:00 P.M.)

	TOTAL
Vehicles Entering:	156
Vehicles Exiting:	182
	338

Percent of Vehicles Entering: 156/338 = 46%
Percent of Vehicles Exiting: 182/338 = 54%

Trip Rate: 338/200 = 1.69 Trips per Acre

TABLE 5.73
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (FRIDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	70
Vehicles Exiting:	93
	163

Percent of Vehicles Entering: 70/163 = 43%
Percent of Vehicles Exiting: 93/163 = 57%

Trip Rate: 163/8 = 20.37 Trips per Crane

TABLE 5.74
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (FRIDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:45 P.M.-14:45 P.M.)

	TOTAL
Vehicles Entering:	54
Vehicles Exiting:	63
	117

Percent of Vehicles Entering: 54/117 = 46%
Percent of Vehicles Exiting: 63/117 = 54%

Trip Rate: 117/8 = 14.62 Trips per Crane

TABLE 5.81
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (FRIDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	155
Vehicles Exiting:	252
	407

Percent of Vehicles Entering: 155/402 = 38%
Percent of Vehicles Exiting: 252/402 = 62%

Trip Rate: 407/8 = 50.87 Trips per Crane

TABLE 5.82
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (FRIDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (13:00 P.M.-14:00 P.M.)

	TOTAL
Vehicles Entering:	156
Vehicles Exiting:	182
	338

Percent of Vehicles Entering: 156/338 = 46%
Percent of Vehicles Exiting: 182/338 = 54%

Trip Rate: 338/8 = 42.25 Trips per Crane

TABLE 5.75
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (FRIDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	70
Vehicles Exiting:	93
	163

Percent of Vehicles Entering: 70/163 = 43%
Percent of Vehicles Exiting: 93/163 = 57%

Trip Rate: 163/4 = 40.75 Trips per Berth

TABLE 5.76
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (FRIDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:45 P.M.-14:45 P.M.)

	TOTAL
Vehicles Entering:	54
Vehicles Exiting:	63
	117

Percent of Vehicles Entering: 54/117 = 46%
Percent of Vehicles Exiting: 63/117 = 54%

Trip Rate: 117/4 = 29.25 Trips per Berth

TABLE 5.83
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (FRIDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:00 A.M.-12:00 P.M.)

	TOTAL
Vehicles Entering:	155
Vehicles Exiting:	252
	407

Percent of Vehicles Entering: 155/402 = 38%
Percent of Vehicles Exiting: 252/402 = 62%

Trip Rate: 402/4 = 100.5 Trips per Berth

TABLE 5.84
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (FRIDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (13:00 P.M.-14:00 P.M.)

	TOTAL
Vehicles Entering:	156
Vehicles Exiting:	182
	338

Percent of Vehicles Entering: 156/338 = 46%
Percent of Vehicles Exiting: 182/338 = 54%

Trip Rate: 338/4 = 84.5 Trips per Berth

TABLE 5.85
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SATURDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (9:15 A.M.-10:15 A.M.)

	TOTAL
Vehicles Entering:	10
Vehicles Exiting:	5
	15

Percent of Vehicles Entering:	10/15 = 67%
Percent of Vehicles Exiting:	5/15 = 33%

Trip Rate: 15/230 = 0.06 Trips per Acre

TABLE 5.86
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SATURDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:15 P.M.-14:15 P.M.)

	TOTAL
Vehicles Entering:	10
Vehicles Exiting:	6
	16

Percent of Vehicles Entering:	10/16 = 63%
Percent of Vehicles Exiting:	6/16 = 37%

Trip Rate: 16/230 = 0.06 Trips per Acre

TABLE 5.93
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SATURDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:30 A.M.-12:30 P.M.)

	TOTAL
Vehicles Entering:	31
Vehicles Exiting:	35
	66

Percent of Vehicles Entering:	31/66 = 47%
Percent of Vehicles Exiting:	35/66 = 53%

Trip Rate: 362/230 = 0.28 Trips per Acre

TABLE 5.94
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SATURDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (16:30 P.M.-17:30 P.M.)

	TOTAL
Vehicles Entering:	43
Vehicles Exiting:	53
	96

Percent of Vehicles Entering:	43/96 = 45%
Percent of Vehicles Exiting:	53/96 = 55%

Trip Rate: 362/230 = 0.41 Trips per Acre

TABLE 5.87
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SATURDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (9:15 A.M.-10:15 A.M.)

	TOTAL
Vehicles Entering:	10
Vehicles Exiting:	5
	15

Percent of Vehicles Entering: 10/15 = 67%
Percent of Vehicles Exiting: 5/15 = 33%

Trip Rate: 15/200 = 0.075 Trips per Acre

TABLE 5.88
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SATURDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:15 P.M.-14:15 P.M.)

	TOTAL
Vehicles Entering:	10
Vehicles Exiting:	6
	16

Percent of Vehicles Entering: 10/16 = 63%
Percent of Vehicles Exiting: 6/16 = 37%

Trip Rate 16/200 = 0.08 Trips per Acre

TABLE 5.95
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SATURDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:30 A.M.-12:30 P.M.)

	TOTAL
Vehicles Entering:	31
Vehicles Exiting:	35
	66

Percent of Vehicles Entering: 31/66 = 47%
Percent of Vehicles Exiting: 35/66 = 53%

Trip Rate: 66/200 = 0.33 Trips per Acre

TABLE 5.96
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SATURDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (16:30 P.M.-17:30 P.M.)

	TOTAL
Vehicles Entering:	43
Vehicles Exiting:	53
	96

Percent of Vehicles Entering: 43/96 = 45%
Percent of Vehicles Exiting: 53/96 = 55%

Trip Rate: 96/200 = 0.48 Trips per Acre

TABLE 5.89
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (SATURDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (9:15 A.M.-10:15 A.M.)

	TOTAL
Vehicles Entering:	10
Vehicles Exiting:	5
	15

Percent of Vehicles Entering: 10/15 = 67%
Percent of Vehicles Exiting: 5/15 = 33%

Trip Rate: 15/8.= 1.875 Trips per Crane

TABLE 5.90
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (SATURDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:15 P.M.-14:15 P.M.)

	TOTAL
Vehicles Entering:	10
Vehicles Exiting:	6
	16

Percent of Vehicles Entering: 10/16 = 63%
Percent of Vehicles Exiting: 6/16 = 37%

Trip Rate: 16/8 = 2 Trips per Crane

TABLE 5.97
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (SATURDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:30 A.M.-12:30 P.M.)

	TOTAL
Vehicles Entering:	31
Vehicles Exiting:	35
	66

Percent of Vehicles Entering:	31/66 = 47%
Percent of Vehicles Exiting:	35/66 = 53%

Trip Rate: 66/8 = 8.25 Trips per Crane

TABLE 5.98
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANES
PEAK HOUR OF GENERATOR (SATURDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (16:30 P.M.-17:30 P.M.)

	TOTAL
Vehicles Entering:	43
Vehicles Exiting:	53
	96

Percent of Vehicles Entering:	43/96 = 45%
Percent of Vehicles Exiting:	53/96 = 55%

Trip Rate: 96/8 = 12 Trips per Crane

TABLE 5.91
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (SATURDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (9:15 A.M.-10:15 A.M.)

	TOTAL
Vehicles Entering:	10
Vehicles Exiting:	5
	15

Percent of Vehicles Entering: 10/15 = 67%
Percent of Vehicles Exiting: 5/15 = 33%

Trip Rate: 15/4 = 3.75 Trips per Berth

TABLE 5.92
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (SATURDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (13:15 P.M.-14:15 P.M.)

	TOTAL
Vehicles Entering:	10
Vehicles Exiting:	6
	16

Percent of Vehicles Entering: 10/16 = 63%
Percent of Vehicles Exiting: 6/16 = 37%

Trip Rate: 16/4 = 4 Trips per Berth

TABLE 5.99
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (SATURDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (11:30 A.M.-12:30 P.M.)

	TOTAL
Vehicles Entering:	31
Vehicles Exiting:	35
	66

Percent of Vehicles Entering: 31/66 = 47%
Percent of Vehicles Exiting: 35/66 = 53%

Trip Rate: 66/4 = 16.5 Trips per Berth

TABLE 5.100
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (SATURDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (16:30 P.M.-17:30 P.M.)

	TOTAL
Vehicles Entering:	43
Vehicles Exiting:	53
	96

Percent of Vehicles Entering: 43/96 = 45%
Percent of Vehicles Exiting: 53/96 = 55%

Trip Rate: 96/4 = 24 Trips per Berth

TABLE 5.101
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SUNDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (9:15 A.M.-10:15 A.M.)

	TOTAL
Vehicles Entering:	9
Vehicles Exiting:	3
	12

Percent of Vehicles Entering: 9/12 = 75%
Percent of Vehicles Exiting: 3/12 = 25%

Trip Rate: 12/230 = 0.05 Trips per Acre

TABLE 5.102
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SUNDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (16:00 P.M.-17:00 P.M.)

	TOTAL
Vehicles Entering:	10
Vehicles Exiting:	10
	20

Percent of Vehicles Entering: 10/20 = 50%
Percent of Vehicles Exiting: 10/20 = 50%

Trip Rate: 20/230 = 0.08 Trips per Acre

TABLE 5.109
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SUNDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (10:45 A.M.-11:45 A.M.)

	TOTAL
Vehicles Entering:	33
Vehicles Exiting:	34
	67

Percent of Vehicles Entering: 33/67 = 49%
Percent of Vehicles Exiting: 34/67 = 51%

Trip Rate: 67/230 = 0.29 Trips per Acre

TABLE 5.110
BARBOURS CUT LAND AREA (230 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SUNDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (16:00 A.M.-17:00 A.M.)

	TOTAL
Vehicles Entering:	90
Vehicles Exiting:	72
	162

Percent of Vehicles Entering: 90/162 = 52%
Percent of Vehicles Exiting: 72/162 = 48%

Trip Rate: 162/230 = 0.70 Trips per Acre

TABLE 5.103
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SUNDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (9:15 A.M.-10:15 A.M.)

	TOTAL
Vehicles Entering:	9
Vehicles Exiting:	3
	12

Percent of Vehicles Entering:	9/12 = 75%
Percent of Vehicles Exiting:	3/12 = 25%

Trip Rate: 12/200 = 0.06 Trips per Acre

TABLE 5.104
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SUNDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (16:00 P.M.-17:00 P.M.)

	TOTAL
Vehicles Entering:	10
Vehicles Exiting:	10
	20

Percent of Vehicles Entering:	10/20 = 50%
Percent of Vehicles Exiting:	10/20 = 50%

Trip Rate: 20/200 = 0.1 Trips per Acre

TABLE 5.111
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SUNDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (10:45 A.M.-11:45 A.M.)

	TOTAL
Vehicles Entering:	33
Vehicles Exiting:	34
	67

Percent of Vehicles Entering:	33/67 = 49%
Percent of Vehicles Exiting:	34/67 = 51%

Trip Rate: 67/200 = 0.33 Trips per Acre

TABLE 5.112
BARBOURS CUT STORAGE AREA (200 ACRES)
TRIP GENERATION RATES PER ACRE
PEAK HOUR OF GENERATOR (SUNDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (16:00 A.M.-17:00 A.M.)

	TOTAL
Vehicles Entering:	90
Vehicles Exiting:	72
	162

Percent of Vehicles Entering:	90/162 = 52%
Percent of Vehicles Exiting:	72/162 = 48%

Trip Rate: 162/200 = 0.81 Trips per Acre

TABLE 5.105
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (SUNDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (9:15 A.M.-10:15 A.M.)

	TOTAL
Vehicles Entering:	9
Vehicles Exiting:	3
	12

Percent of Vehicles Entering:	9/12 = 75%
Percent of Vehicles Exiting:	3/12 = 25%

Trip Rate: 12/8 = 1.5 Trips per Crane

TABLE 5.106
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (SUNDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (16:00 P.M.-17:00 P.M.)

	TOTAL
Vehicles Entering:	10
Vehicles Exiting:	10
	20

Percent of Vehicles Entering:	10/20 = 50%
Percent of Vehicles Exiting:	10/20 = 50%

Trip Rate: 20/8 = 2.5 Trips per Crane

TABLE 5.113
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (SUNDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (10:45 A.M.-11:45 A.M.)

	TOTAL
Vehicles Entering:	33
Vehicles Exiting:	34
	67

Percent of Vehicles Entering: 33/67 = 49%
Percent of Vehicles Exiting: 34/67 = 51%

Trip Rate: 67/8 = 8.37 Trips per Crane

TABLE 5.114
BARBOURS CUT NO. OF CRANES (8)
TRIP GENERATION RATES PER CRANE
PEAK HOUR OF GENERATOR (SUNDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (16:00 A.M.-17:00 A.M.)

	TOTAL
Vehicles Entering:	90
Vehicles Exiting:	72
	162

Percent of Vehicles Entering: 90/162 = 52%
Percent of Vehicles Exiting: 72/162 = 48%

Trip Rate: 162/8 = 20.25 Trips per Crane

TABLE 5.107
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (SUNDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (9:15 A.M.-10:15 A.M.)

	TOTAL
Vehicles Entering:	9
Vehicles Exiting:	3
	12

Percent of Vehicles Entering:	9/12 = 75%
Percent of Vehicles Exiting:	3/12 = 25%

Trip Rate: 12/4 = 3 Trips per Berth

TABLE 5.108
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (SUNDAY)

TRUCK TRIPS:

PEAK HOUR OF GENERATOR (16:00 P.M.-17:00 P.M.)

	TOTAL
Vehicles Entering:	10
Vehicles Exiting:	10
	20

Percent of Vehicles Entering:	10/20 = 50%
Percent of Vehicles Exiting:	10/20 = 50%

Trip Rate: 20/4 = 5 Trips per Berth

TABLE 5.115
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (SUNDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (10:45 A.M.-11:45 A.M.)

	TOTAL
Vehicles Entering:	33
Vehicles Exiting:	34
	67

Percent of Vehicles Entering: 33/67 = 49%
Percent of Vehicles Exiting: 34/67 = 51%

Trip Rate: 67/4 = 16.75 Trips per Berth

TABLE 5.116
BARBOURS CUT SHIP BERTHS (4)
TRIP GENERATION RATES PER BERTH
PEAK HOUR OF GENERATOR (SUNDAY)

TOTAL TRIPS:

PEAK HOUR OF GENERATOR (16:00 A.M.-17:00 A.M.)

	TOTAL
Vehicles Entering:	90
Vehicles Exiting:	72
	162

Percent of Vehicles Entering: 90/162 = 52%
Percent of Vehicles Exiting: 72/162 = 48%

Trip Rate: 162/4 = 40.5 Trips per Berth

TABLE 5.118
BARBOURS CUT STORAGE AREA (200)
TRIP GENERATION RATES PER ACRE
AVERAGE WEEKDAY TRIP RATE (MONDAY-FRIDAY)

TRUCK TRIPS

Average Weekday Trip Ends:	1136
Total Land Area (Acres):	200
Percent of Vehicles Entering	53%
Percent of Vehicles Exiting	47%

Average Weekday Trip Rate: 1136/200 = 5.68 Trips per Acre

TABLE 5.120
BARBOURS CUT BERTHS
TRIP GENERATION RATES PER BERTH
AVERAGE WEEKDAY TRIP RATE (MONDAY-FRIDAY)

TRUCK TRIPS

Trip Ends:	1136
Total Berths:	4
Percent of Vehicles Entering	53%
Percent of Vehicles Exiting	47%

Weighted Average Weekday Trip Rate:1136/4 = 284 Trips per Berth

TABLE 5.121
BARBOURS CUT TEU's
TRIP GENERATION RATES PER TEU
AVERAGE WEEKDAY TRIP RATE (MONDAY-FRIDAY)

TRUCK TRIPS	
Trip Ends:	5684
Total TEU's:	4413
Percent of Vehicles Entering	53%
Percent of Vehicles Exiting	47%

Average Weekday Trip Rate: 5684/4413 = 1.28 Trips per TEU

TABLE 5.122
BARBOURS CUT SHORT-TONS
TRIP GENERATION RATES PER TON
AVERAGE WEEKDAY TRIP RATE (MONDAY-FRIDAY)

TRUCK TRIPS	
Trip Ends:	5684
Total Short-Tons:	83333
Percent of Vehicles Entering	53%
Percent of Vehicles Exiting	47%

Average Weekday Trip Rate:5684/83333 = 0.68 Trips per Ton

TABLE 5.123
BARBOURS CUT LAND AREA (230)
TRIP GENERATION RATES PER ACRE
AVERAGE WEEKDAY TRIP RATE (MONDAY-FRIDAY)

TOTAL TRIPS

Average Weekday Trip Ends:	3840
Total Land Area (Acres):	230
Percent of Vehicles Entering	48%
Percent of Vehicles Exiting	52%

Average Weekday Trip Rate:13840/230 = 16.69 Trips per Acre

TABLE 5.124
BARBOURS CUT STORAGE AREA (200)
TRIP GENERATION RATES PER ACRE
AVERAGE WEEKDAY TRIP RATE (MONDAY-FRIDAY)

TOTAL TRIPS

Average Weekday Trip Ends:	3840
Total Storage Area (Acres):	200
Percent of Vehicles Entering	48%
Percent of Vehicles Exiting	52%

Average Weekday Trip Rate: 3840/200 = 19.2 Trip per Acre

TABLE 5.125
BARBOURS CUT CRANES
TRIP GENERATION RATES PER CRANE
AVERAGE WEEKDAY TRIP RATE (MONDAY-FRIDAY)

TOTAL TRIPS	
Trip Ends:	3840
Total Cranes:	8
Percent of Vehicles Entering	48%
Percent of Vehicles Exiting	52%
Average Weekday Trip Rate:	3840/8 = 480 Trips per Crane

TABLE 5.126
BARBOURS CUT BERTHS
TRIP GENERATION RATES PER BERTH
AVERAGE WEEKDAY TRIP RATE (MONDAY-FRIDAY)

TOTAL TRIPS	
Trip Ends:	3840
Total Berths:	4
Percent of Vehicles Entering	48%
Percent of Vehicles Exiting	52%
Average Weekday Trip Rate:	3840/4 = 960 Trips per Berth

TABLE 5.127
BARBOURS CUT TEU's
TRIP GENERATION RATES PER TEU
AVERAGE WEEKDAY TRIP RATE (MONDAY-FRIDAY)

TOTAL TRIPS

Trip Ends:	19200
Total TEU's:	4413
Percent of Vehicles Entering	48%
Percent of Vehicles Exiting	52%

Average Weekday Trip Rate: 19200/4413 = 4.35 Trips per TEU

TABLE 5.128
BARBOURS CUT SHORT-TONS
TRIP GENERATION RATES PER TON
AVERAGE WEEKDAY TRIP RATE (MONDAY-FRIDAY)

TOTAL TRIPS

Trip Ends:	19200
Total Short-Tons:	83333
Percent of Vehicles Entering	48%
Percent of Vehicles Exiting	52%

Average Weekday Trip Rate: 19200/83333 = 0.23 Trips per Ton