Rail Operations Simulation at the Port of Tacoma

By

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TABLE OF CONTENTS

LIST OF FIGURES VI

LIST OF TABLES VIII

GLOSSARY IX

CHAPTER 1 INTRODUCTION AND BACKGROUND 1

Introduction 1

System Background 2

CHAPTER 2: LITERATURE REVIEW 8

Intermodal Yards and Port Operations 8

General Relevance 9

Specific Relevance 12

Simulation/Software Tools 13

General Relevance 13

Specific Relevance 14

CHAPTER 3: PORT OF TACOMA RAIL SYSTEM 16

Overview 16

North Intermodal Yard (NIM). 16

South Intermodal Yard (SIM) 22

Tacoma Rail 27

CHAPTER 4: MODEL DEVELOPMENT 32

Input Sub Model 36

North Intermodal Yard (NIM) Eastbound 39

Bull Frog Junction Branch 40

Fife Branch 40

Tacoma Rail Branch 41

North Intermodal Yard (NIM) Westbound 43

Hyundai Eastbound 44

Bullfrog Junction Branch 44

Tacoma Rail Branch 45

Hyundai Westbound 45

South Intermodal Yard (SIM) Eastbound 47

South Intermodal Yard (SIM) Westbound 48

Commercial Traffic (Non-Intermodal) 49

Interaction of Sub Models 50

CHAPTER 5 MODEL VERIFICATION AND VALIDATION 52

Verification 52

Validation 56

CHAPTER 6 MODEL EXPERIMENTATION 61

Monitored Statistics 61

Simulation Process 62

Yearly Train Volume Determination 63

Simulation Runs 64

System Alternatives 71

CHAPTER 7 CONCLUSION 73

Throughput 73

Bullfrog Junction 74

Tacoma Rail 75

Expansion Timeline 75

Research Conclusions 76

CHAPTER 8 RECOMMENDATIONS 78

Topic Specific Recommendations 78

Port Specific Recommendations 79

General Recommendations 80

BIBLIOGRAPHY 81

APPENDIX A SIMULATION CODE 84

Arena Model Code 84

Input Sub Model 84

NIM East Sub Model 84

SIM EAST 87

Hyundai East 87

NIM West 89

SIM WEST 90

Hyundai West 92

Commercial 93

Arena Experiment Code 95

APPENDIX B RAIL SIMULATOR SCHEDULE BUILDER CODE 101

APPENDIX C REPLICATION OUTPUT 1999-2020 105

APPENDIX D ALTERING EXPERIMENT CODE 129

Resources 129

DSTATS 130

Expressions 131

APPENDIX E PORT RAIL MAP 133

APPENDIX F NIM SCHEDULE 134

APPENDIX G SIM SCHEDULE 140

APPENDIX H CONTAINERIZED CARGO PROJECTIONS 142

LIST OF FIGURES

FIGURE 1.1 RAIL TRAFFIC FLOW THROUGH THE PORT OF TACOMA 4

FIGURE 1.2 PORT OF TACOMA TRACK DIAGRAM 5

FIGURE 3.1 CONTAINER FLOW IN NORTH INTERMODAL YARD (NIM). 16

FIGURE 3.2 RAILCAR FLOW INTO NORTH INTERMODAL YARD (NIM) 18

FIGURE 3.3 FLOW OF TRAINS EASTBOUND FROM NORTH INTERMODAL YARD (NIM) 20

FIGURE 3.4 CONTAINER FLOW IN SOUTH INTERMODAL YARD (SIM) 23

FIGURE 3.5 RAILCAR FLOW INTO THE HYUNDAI INTERMODAL YARD 26

FIGURE 3.6 EASTBOUND TRAFFIC FLOW FROM HYUNDAI YARD 27

FIGURE 3.7 AVERAGE TRACK UTILIZATION TACOMA RAIL 30

FIGURE 3.8 PERCENT TOTAL TRACK UTILIZATION 31

FIGURE 3.9 PERCENT UTILIZATION BANANA TRACKS 31

FIGURE 4.1 CONCEPTUAL MOVEMENT OF TRAINS THROUGH SYSTEM 33

FIGURE 4.2 WESTBOUND AND EASTBOUND TRAFFIC 34

FIGURE 4.3 SCHEDULE BUILDER AND MODEL RELATIONSHIP 37

FIGURE 4.4 NORTH INTERMODAL YARD NIM EASTBOUND TRAFFIC MODEL 42

FIGURE 4.5 HYUNDAI EASTBOUND TRAFFIC MODEL 46

FIGURE 4.6 SOUTH INTERMODAL YARD (SIM) EASTBOUND TRAFFIC MODEL 48

FIGURE 5.1 BF JUNCTION UTILIZATION VERIFICATION 54

FIGURE 5.2 SCHEDULE CHANGE VERIFICATION 54

FIGURE 5.3 CHANGE IN NIM WEST DISTRIBUTION VERIFICATION 55

FIGURE 5.4 COMPARISON CONFIDENCE INTERVALS 1999 SIMULATED AND ACTUAL SCHEDULE 59

FIGURE 6.1 AVERAGE AND MAXIMUM THROUGHPUT TIMES 65

FIGURE 6.2 TACOMA RAIL AVERAGE AND MAX UTILIZATION FOR YARD TRACK (2000-2020) 67

FIGURE 6.3 BULLFROG JUNCTION UTILIZATION 69

FIGURE 6.4 PORT OF TACOMA RD AND ANNIE TRACK UTILIZATION 70

FIGURE 6.5 AVERAGE AND MAXIMUM THROUGHPUT TIMES (3 BF JUNCTION ACCESS POINTS) 71

LIST OF TABLES

TABLE 3.1 WEEKLY PLANNING SHEET TIME GATES 21

TABLE 4.1 SUB MODEL RESOURCE UTILIZATION 50

TABLE 5.1 TALLY VALUES FOR 1999 SIMULATION GENERATED SCHEDULE 57

TABLE 5.2 TALLY VALUES FOR 1999 ACTUAL SCHEDULE 58

TABLE 6.1 TRAIN VOLUME PROJECTIONS 63

Glossary

Annie Tracks: Pair of tracks that provides access to the NIM from Tacoma Rail

ARENA/SIMAN: Simulation language used in this study.

Banana Tracks: Nine tracks contained in the Belt Line yard. The primary purpose of these tracks is the sorting and staging of empty rail cars for movement into the NIM.

Belt Line: Section of track used for servicing the all customers of the Port of Tacoma, used for storage, sorting, and staging of rail cars. The Belt Line is operated by Tacoma Rail and this yard is also known as the Tacoma Rail Yard.

Bullfrog Junction: Two track junctions leading out of the Port of Tacoma to the Burlington Northern and Union Pacific mainlines. Provides the only access into the port from the main lines

Burlington Northern: One of two transcontinental rail carriers who contract with the shipping lines for rail movement of containers throughout the US and Canada.

Commercial Traffic: Non-intermodal train traffic at the port.

Containers: Twenty or forty foot rectangular storage boxes used to transport goods by sea, rail, and truck

Fife: City located to the east of the Port of Tacoma. The location of the Union Pacific main line yard.

Hosters: Vehicles used to transport containers from the ship staging area to the SIM yard.

Hyundai Yard: Container terminal completed in May of 1999. One of the three intermodal yards at the port. Also known as Washington United Terminals (WUT).

Mainline: Union Pacific or Burlington Northern rail road tracks outside of the port used to move trains between destinations in the United States and Canada.

North Intermodal Rail Yard (NIM): Rail yard where the loading and unloading of containers onto train cars occurs for Husky and Evergreen terminals Containers are loaded/unloaded on the trains by means of straddle carriers.

North Intermodal Weekly Planning & Evaluation Sheet: A document written by the port to plan/schedule train arrivals/departures. It also identifies the shipping line, number of containers, train configuration, train destination, and mainline carrier.

Port of Tacoma Road: Major access road into the port from Interstate 5.

Port of Tacoma Road Track: A length of track that crosses Port of Tacoma Road and provides access into the Hyundai yard from the Tacoma Rail yard.

Railcar: The train equipment designed to transport shipping containers. Railcars are connected to form a train.

Rail well: Train equipment designed to transport shipping containers. The shipping containers are stored in individual wells, and three to five wells make up a railcar.

Sea-Land Terminal: Container terminal leased to Sea-Land and adjacent to the Port's South Intermodal Rail Yard.

South Intermodal Yard (SIM) Transfer Yard: Storage and switching and interchange track for the South Intermodal Yard

South Intermodal Yard (SIM) Ramp Track: Set of tracks in the SIM where railcars are loaded and unloaded. Railcars are brought to and from the transfer yard for use on the SIM ramp tracks

South Intermodal Yard (SIM): One of the intermodal yards modeled in this study. This yard consists of a transfer yard and a ramp where railcars are loaded. The SIM performs their own switching and does not use the Tacoma Rail yard

Straddle Carriers: Vehicles used to load containers on railcars in the NIM.

Tacoma Rail: Public utility operating the rail system in the Port of Tacoma.

Tacoma Rail Yard: Rail yard operated by Tacoma Rail for sorting and storage of railcars at the port. Also referred to as the beltline.

Top Picks: Vehicles used to place containers on railcars in the SIM.

Train-Spotting Diagram: Diagram used in the NIM to assist in the placing of rail cars. Document gives the track number, location on the track and type of railcar

Union Pacific: One of two transcontinental rail carriers who contract with the shipping lines for rail movement of containers throughout the US and Canada.

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Chapter 1 Introduction and Background

Introduction

This thesis investigates rail operations at the Port of Tacoma and describes the development of a modeling methodology and a simulation program for simulating rail operations at the port. The simulation examines the projected increase in intermodal rail traffic at the port until the year 2020. An analysis of the port is done and the results are presented and interpreted. Recommendations based on this study are made for future improvements.

This study focuses on developing a model of the rail system at the Port of Tacoma and applying simulation techniques to analyze how various factors can impact the operation of the rail system and the organizations that depend on it. Intermodal traffic into and out of the port are examined at projected levels until the year 2020 for each intermodal yard. Through the simulation, resources at the port are studied to determine which are most sensitive to an increase in intermodal traffic. The final objective of this study is to present a simulation model of the port, which may be used in the future to simulate different scenarios and the consequences on schedules and port operations.

The Port of Tacoma is a vital link for trade between the Pacific Rim and the United States. The Port of Tacoma offers container services to East Coast cities through intermodal rail transportation. The rail system at the Port of Tacoma is a system consisting of various entities moving cargo in and out of the port. Three intermodal yards move containerized cargo to and from the port by rail. In addition, the port has numerous other commercial customers such as Kaiser aluminum and auto warehousing for Japanese and Korean auto manufacturers. The rail system must effectively accommodate the various types of cargoes that move over it and have ample space for expansion due to increased business at the port.

An investigation into this system is beneficial because of the complex nature of the system and the detailed interaction of different facilities on one infrastructure. In an industrial and commercial context, this problem is similar to a distribution problem or a production problem where various processes are competing for the same resources. From the author's military background, this study is beneficial in the military logistics framework. Moving soldiers and equipment quickly and safely is a primary logistics function. Understanding the operations of a port and its rail infrastructure will help for future deployment planning and execution. Military operations commonly involve units or equipment from different services or branches. The knowledge gained from a detailed analysis of this system, translation into simulation code, and interpretation of output are critical lessons that can be applied to complex situations in the military.

System Background

The Port of Tacoma along with the Port of Seattle are vital transportation and trade links for the Northwest as well as important trade links to the Pacific Rim for the United States. The economic well being of the region is linked to the pacific trade established by these ports. Intermodal traffic is dependent primarily on time. It is imperative for the containers to be loaded on the correct train and that train must depart the port in a timely manner. When a ship enters the port, the containers are removed from the ship and staged. From their staging area the containers are sorted and moved to a specific train. Once the train is complete, it is moved from the intermodal yard and pulled out of the port and on to the main line railroads for transport to destinations in the US and Canada. The three intermodal yards at the port all run their operations differently and the flow of trains to and from the intermodal yards do not follow the same route. Movement on the tracks is scheduled independently with each intermodal yard and other commercial traffic. A central controller of the rail assets is not present and competition for the same assets by different intermodal yards is common. The North Intermodal Yard (NIM), South Intermodal Yard (SIM), Hyundai Intermodal Yard (HIY), and commercial traffic all compete for rail assets located in the Port of Tacoma. Each user of the rail system has their own priority and requirements for the rail system.

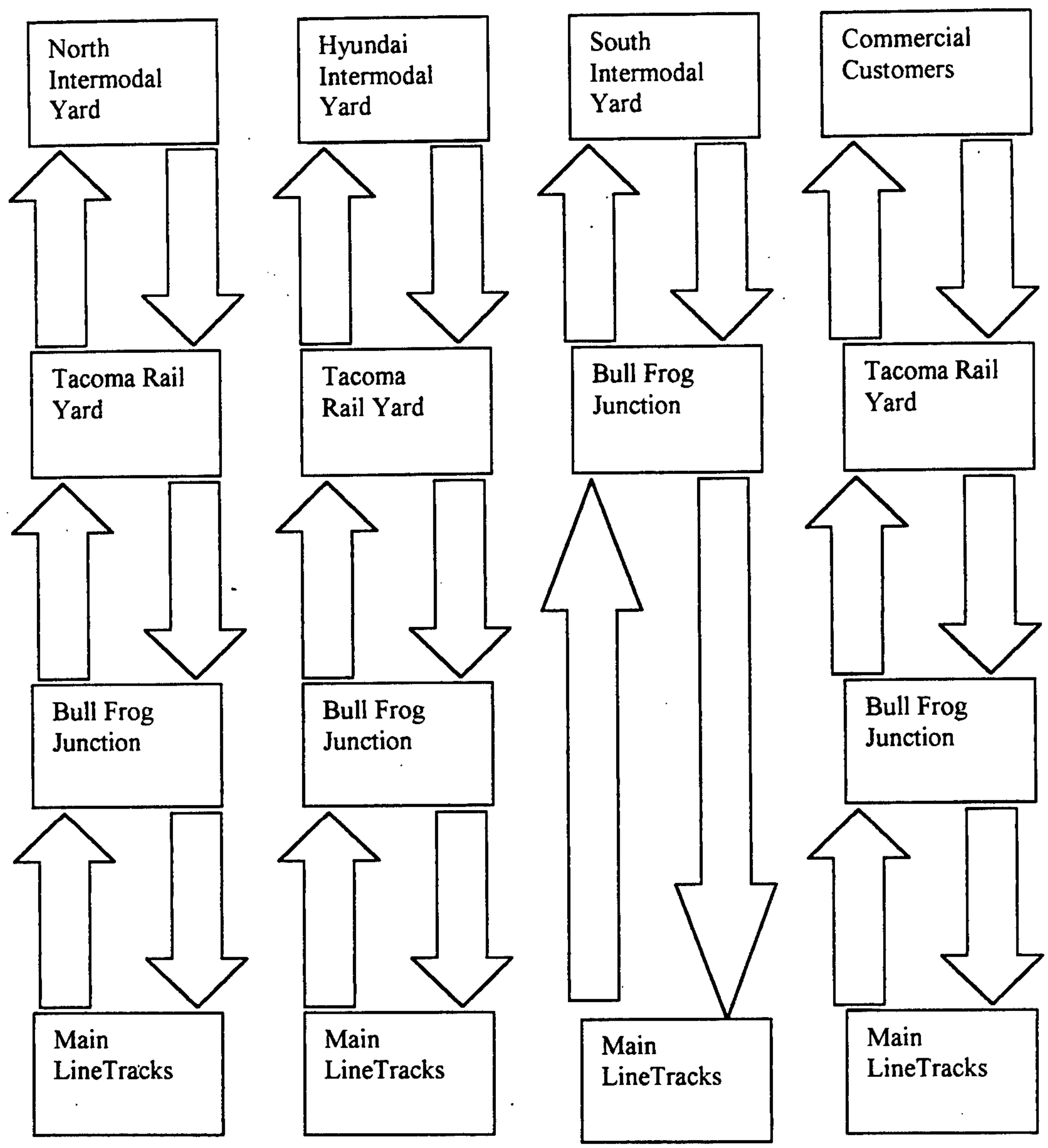


Figure 1.1 Rail Traffic Flow Through the Port of Tacoma

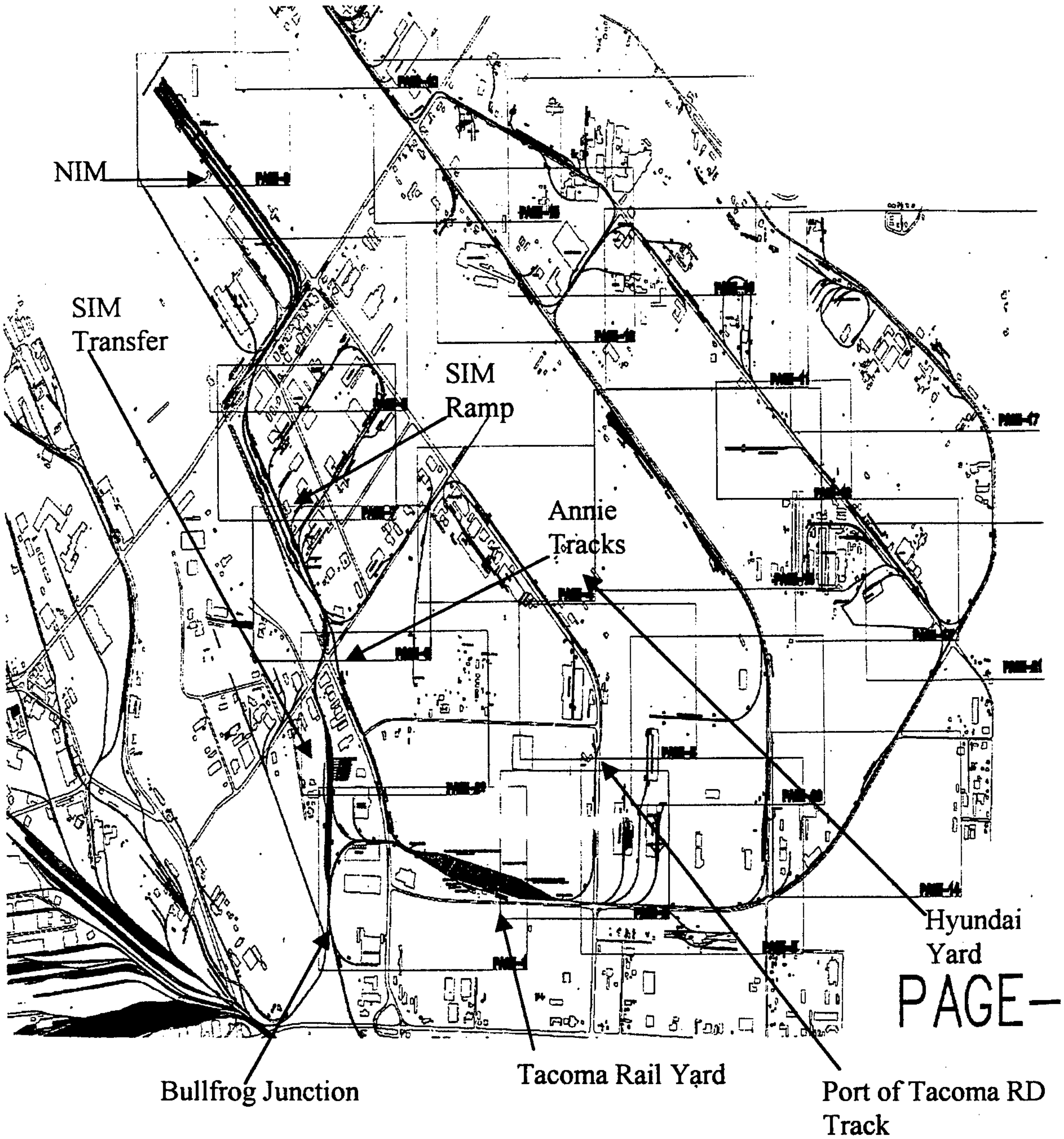


Figure 1.2 Port of Tacoma Track Diagram

In Figure 1.1, the flow of rail traffic to and from the intermodal yards is displayed. All trains must pass through the specified common areas. Figure 1.2 displays the locations of the yards. Bullfrog Junction is a choke point where the tracks within the port converge to form two sets of tracks connecting into the mainline tracks. All traffic in and out of the port must travel over these two tracks Tacoma Rail, a public utility, owns the Tacoma Rail Yard a switching and sorting rail yard for the port. The North Intermodal Yard, Hyundai, and commercial traffic use this yard. Specific objectives for this study include detailed documentation of the rail system and the interactions between the intermodal yards, analysis of the system to identify operational bottlenecks, identification of possible efficiency improvements, and determination of the current system limitations.

A complete description of the rail system is given in Chapter 3. This Chapter describes the use of the rail system by the NIM, SIM, Hyundai, Tacoma Rail, and commercial customers. A description of the process for moving cargo is included as well as a model of the interaction between the users of the rail system. Chapter 4 investigates the development of the model and the constraints and assumptions required to construct the model. Verification and validation of the model is discussed in Chapter 5. The simulation exercises are discussed in Chapter 6. The scenarios simulated are discussed as well as the results and significance of the results. General conclusions drawn from the simulation results are presented in Chapter 7. Recommendations for future study and applications of this study are presented in Chapter 8. The next Chapter is a literature review of research and projects done in simulation, intermodal operations, and rail operations. Included in the appendix are the simulation results, software coding, and schedules used at the port. An explanation of the experiment code in the model is presented in appendix D. Appendix D also demonstrates how the code may be changes to run different scenarios. This appendix enables users to go into the program and adjust expressions and resource allocation for the port so different scenarios can be run and results utilized for planning purposes

Chapter 2: Literature Review

This chapter reviews the body of literature relevant to research conducted for this thesis. The topics include intermodal yards, rail simulation, and the simulation process in general. Numerous simulation studies were found concentrating on the containerization aspects, rail movement, and simulation of port operations. Consultant studies of the Port of Tacoma were also used to acquire an in depth understanding of the rail system at the port of Tacoma. Simulation was chosen in this study as a tool because of the complexity of the model and the desire to present a planning tool to the port that can be used for future scenarios. Analytical tools were not chosen because of the desire to have a model that could be continually updated at the user level. Documentation in the literature supports simulations as a tool (Banks 55-63). The literature review is broken up into two sections. The first section examines research associated with intermodal yards and port operations; the second section reviews literature associated with simulation. Both sections are relevant to this study in that they first provide insight into methodologies for modeling a rail and intermodal system and provide the background for conducting a simulation study

Intermodal Yards and Port Operations

Intermodal traffic has grown significantly over the last thirty-five years (Sarosky, 1233).. Cargo moves from point to point in steel or aluminum containers. These containers add to the security of the cargo and reduce handling costs and damage during transit. The Port of

Tacoma handled 1.16 million containers in 1997, justifying the importance of efficient intermodal handling at the port and a requirement to analyze the effect of increased capacity (Port of Tacoma Annual Report 1997).

General Relevance

The following sources deal mainly with the simulation of rail and port systems.

Hayuth [1994] describes the building of a port simulator that can be used at different ports and follows a modular approach. The methodology of the approach used is widely applicable to other simulation models. The choice of hardware and software is discussed and the organization of the input and output for the simulation model are examined. The author defends their use of C as the language to write the simulation. This simulation played an important role in the investment decisions at Israeli harbors and proved to be comprehensive and adaptable to different port scenarios. The methodology in this paper describes their reasoning and choice of software, input and output formats and deciding on key data required in the simulation to answer operational questions.

Bergman [1996] uses the software tool SIMON to simulate a contiguous railroad net in central Sweden. A capacity analysis of the rail system was done identifying the bottlenecks. In this study the advantages of studying a network instead of single lines are expounded. Though this simulation covers a rail network in Sweden, the concepts presented by Bergmark are transferable to the Port of Tacoma problem. Bergmark uses the simulation to calculate train schedules and then runs these train schedules on the simulation for various years. Similarly the Port of Tacoma is simulated as a network consisting of the various intermodal yards and the commercial traffic. The Port of Tacoma simulation constructs schedules and then runs them for future years

Carr [1997] examines basing logistics decisions based on simulation. Rail operations at the Tropicana facility in Bradenton Florida are simulated. The modeling process is documented and validation and verification procedures discussed. Carr describes the requirement to make assumptions to translate the real model into a simulation software model. The validation of the model was conducted using existing rail schedules by comparing the utilization of certain statistic.

Fuller *et al*,[1983] presents the modeling of an intermodal transfer system for grain terminals. This study focuses on the model designed to analyze the transfer of grain at port grain terminals. The model simulates movements of grain from inland locations to the port by rail, movement of the grain from the trains to the storage and ship loading locations and movement of the ships from the terminal. The model is a stochastic model used to evaluate economic means of improving efficiency and modification of terminal capacity. The port area transfer system is represented as a stochastic transportation queuing network. The process of separating the real system into different models and then translating these sub models into computer code is exercised in this study with good results. Fuller uses five sub models checks them out individually and then combines them to from the model. Development of sub models is presented as a useful methodology for complex problems.

Dessouky *et al,* [1995] present a modeling methodology for modeling complex rail networks. Although this study concentrates on large rail systems, that are unlike the Port of Tacoma, it is still applicable to the port. Specifically it concentrates on the movement of trains over double and single track rail line, determining the track configuration that minimizes the congestion delays to trains. Large rail systems are broken down into track sections and junctions. These are then used as resources in the model to control the movement of trains in the network.

Gibson *et al*, [1992] developed a flexible port traffic planning model which simulated the rail truck and auto traffic at the Port of Long Beach. Their methodology focused on breaking up the port into sections and determines the level of detail required for the output. The modeling utilizes the external data approach allowing for the variations of a network design to be assembled quickly.

Macal *et al.* [1998] documents a discrete event simulation model for seaport operations. The study focus on the military context of minimizing delays at seaport operations ensuring military supplies and equipment are available to deployed forces. The process documents the movement of equipment from the ship to the train or truck. A simulation software designed for use in seaports was used (PORTSIM).

Specific Relevance

Vickman, Zachary, and Miller [1994] conducted a rail infrastructure analysis on the Port of Tacoma. The purpose of the study was to determine the adequacy of current rail facilities and evaluate the adequacy of the intermodal infrastructure. This study presents the results of the simulation study and proposals for the system, but does not examine a model of the system or the logic behind the simulation.

HDR Engineering INC [1996] conducted a circulation study of the Tacoma tideflats region. The purpose of the study was to identify the impact of road changes on the traffic circulation in the tideflats. Specifically the goals were to identify roadway congestion points and rail congestion points that could impede future growth. Like the study conducted in 1994, results and recommendations for improvements were given with little discussion of model development.

Simulation of a railroad intermodal terminal is investigated by Sarosky, *et al,*[1994]. In this study the transfer of containers to and from trucks to rail was simulated using a SLAMSYSTEM model. Model formulation is discussed as well as the operational information for the intermodal terminal. Assumptions and results of the model are discussed and the benefits of simulation to decision making. In this model, the logic is broken up into two networks a loading and an unloading network. The model is contained within an intermodal yard but the flow of trains into and out. of the yard are simulated in the two networks. The structure followed in this simulation study can be utilized for expansion to an entire rail system comprised of more than one intermodal yard

Simulation/Software Tools

Discrete event simulation and its applications and the methodology of conducting a simulation study are critical to the understanding and completion of this study. Computers now provide an efficient means to create and study a simulated environment.

Simulations allow tests of different conditions to be evaluated quickly, and have been widely promoted within the operations arena. The growth of simulation since the 1950's is readily apparent in the amount of literature available. With the proliferation of the personal computer has come the proliferation of simulation.

General Relevance

Banks [1998] presents a handbook of simulation that describes the principles, methodology, applications, and practice of simulation. The fundamental concepts of discrete event simulation are covered and a framework for conducting a simulation study is discussed extensively. The methodology of simulation independent of a specific simulation language, is the focus of this study. Examples of simulation applications are given in various areas such as manufacturing and logistics.

Pegden *et al* [1995] also presents the basics for conducting a simulation exercise. Examples are given using the SIMAN language which is the predecessor to Arena. The methodology of simulation is discussed and then implemented with examples in the SIMAN simulation language.

Rubenstein [1998], presents a guide to simulation, construction system models and the process of verification, validation and the interpretation of output from simulation models.

Graybeal [1980] also presents a guide to basic simulation techniques. This work was written in 1980 and does not focus on a simulation language, but instead on what simulation is and the principles behind it. The modeling principles presented in this work were the most helpful to this study

Specific Relevance

Kelton *et al* [1998] presents simulation in the context of the Arena software. Similar to other simulation sources it discusses the uses of simulation and the formation of a simulation study. Arena software is the software used to illustrate the examples. Modeling concepts are presented and then illustrated using Arena software. Arena is a general simulation software language that may be applied to different simulation models. The history and growth of simulation modeling is documented in this source Arena is the simulation software used in the Port of Tacoma rail simulation study.

Linking together the importance of intermodal traffic and the value of simulation modeling determine the usefulness to this study.

The review of the literature is extremely helpful in forming the model for a simulation of rail operations at the Port of Tacoma. The model is built on modules of each intermodal yard. These modules are designed specifically to the movement of cargo to and from each intermodal yard and linked together in one simulation utilizing shared resources.

Chapter 3: Port of Tacoma Rail System

Overview

The rail system at the Port of Tacoma consists of four different sub systems that control rail cars and trains:

North Intermodal Yard (NIM)

South Intermodal Yard (SIM)

Hyundai Intermodal Yard

Tacoma Rail Yard (Beltline)

This chapter examines each of these major operational divisions in depth and discusses the movement of rail cars through them. A description and analysis is given of the rail system and at the end of this chapter the interaction between the entities is discussed. In addition to intermodal traffic, commercial non-intermodal traffic is discussed with its impact on the rail system. The Port of Tacoma has experienced substantial growth in the last fifteen years. During the 1970s and early 1980s rail traffic in the Puget Sound region was dropping. With the advent of increased trade with Pacific Rim nations rail traffic has increased. From 1985 to 1995 container traffic at the Port of Tacoma has increased by a factor of ten. Seventy percent of all cargo at the port heads east by rail. Thus the importance of the rail system at the Port of Tacoma is apparent. The projection is for container traffic to double by the year 2015 at the port (Vickerman 1.2-1.2).

Understanding the rail system is crucial to the future of the port and the region. The interaction of the different intermodal yards and Tacoma rail determine the effectiveness of the rail system and movement of intermodal cargo into and out of the port.

North Intermodal Yard (NIM).

The North Intermodal Yard (NIM) consists of eight tracks each capable of holding nine 305-foot cars. The NIM services three different terminals at the port. A railcar consists of wells that can hold two stacked forty-foot containers. Containers are unloaded from the steamships at the berths into a holding area where they are stacked and sorted. From this point straddle carriers are used to pick up individual containers and move them to railcars. Train spotting diagrams and container diagrams are used to determine specific types of railcars needed for the train and specific locations for each container (Figure 4.1). The railcars are staged on the eight tracks in the NIM for loading. Railcars are inspected at the NIM and given an air test. Once loading is complete Tacoma rail is called upon to provide power to move the railcars, attaching the segments to form trains

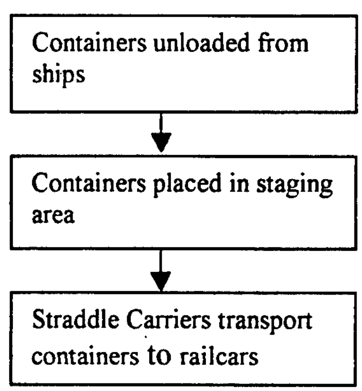


Figure 3.1 Container Flow in North Intermodal Yard (NIM).

The staging of railcars in the NIM in preparation for loading is a critical task. Without properly staged railcars, the NIM can not begin loading operations. The process and responsibility of staging cars in the NIM belongs to Tacoma Rail. For each train Tacoma Rail is given a train-spotting diagram, displaying the location and type of empty cars for an individual train. The pull sequence of the train determines the location of the cars in the spotting diagram. Tacoma Rail is also given a weekly planning sheet from the NIM that specifies the time which the railcars must be staged and the time loading of the railcars is scheduled to start. The supply of empty cars and containers needed to be loaded on ships is provided by the main line railroads (Union Pacific or Burlington Northern). Westbound trains arrive on a schedule from mainline railroads into the Tacoma Rail Yard. These trains are broken up and cars ordered in the NIM are prepared for movement in the NIM. Tacoma Rail power moves the cars from their yard to the NIM and sets them up in the proper order for loading (Figure 3.2).

Cars containing cargo destined for shipment out of the NIM are moved to the NIM in a similar manner as empty railcars. Once containers are pulled off these cars to be loaded on the ship, the railcar will likely have to be moved again because it is not the correct type or in the correct location as specified by the train-spotting diagram. The relative lengthy distance between the Tacoma Rail yard and the NIM makes switching difficult and more time consuming. The arrival times for westbound trains into the Tacoma Rail yard is variable and can not be counted on to provide an ample amount and selection of railcar types to fit the requirements of the NIM. Tacoma Rail overcomes this by keeping a working supply of empty cars on their track. As was noted in Figure 1.1, all rail traffic into the NIM first passes from the mainline carriers through Bullfrog Junction to Tacoma Rail's yard and then is moved by Tacoma rail to the NIM. The path from Tacoma rail to the NIM follows a set of bypass tracks around the South Intermodal Yard (SIM) to two sets of tracks named Annie 1 and Annie 2 which switches into the tracks in the NIM. The average time for movement of Tacoma Rail power from their yard to the NIM is fifeteen minutes.

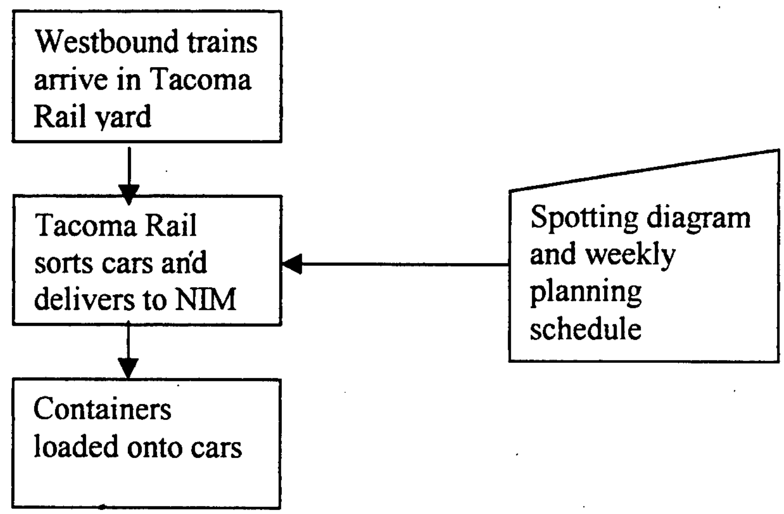


Figure 3.2 Railcar Flow into North Intermodal Yard (NIM)

There are numerous variations of eastbound trains departing the NIM (Figure 3.3). Trains leaving the NIM have three possible intermediate destinations: First a train can be assembled and pulled to Bullfrog Junction by Tacoma Rail power and left at that point awaiting power from Burlington Northern (BN) to pull the train into their yard and to its final destination. The second route is for Tacoma Rail to pull a train from the NIM to the Union Pacific Yard (UP) in Fife. The town of Fife is located just outside the Port of Tacoma. Once the train is in Fife the Tacoma Rail power unhooks and UP power hooks up to the train pulling it to its final destination. The last destination for a train moving from the NIM is to be pulled into the Tacoma Rail yard by Tacoma Rail power. This happens with small trains known as "slop trains". They are pulled into the Tacoma rail yard where they are combined with other slop trains by Tacoma Rail and prepared for pick up by the UP or BN.

The process of connecting trains and transferring them from the NIM has implications beyond the limits of the NIM yard. Between the NIM and Tacoma Rail are two major roads used by cars and trucks to move in and out of the port and the South Intermodal Yard. Bullfrog Junction also becomes busy if a train is moving out of the NIM making it unavailable for use by any other trains. On each of the nine tracks in the NIM there are three breaks in the tracks that act as crossover points for the straddle carriers. Before each segment of railcars can be pulled and combined to form a train, the engine must push each segment together eliminating the gaps. Then the string of cars can be pulled from the yard and then pushed back into the yard combining one track with another to form a train. During this process of pulling and pushing the railcars to complete the train, the two surface streets will be blocked if the train length is sufficient. As the train passes by the SIM, it occupies track the SIM uses for switching. If a train is pulled to Bullfrog Junction and Tacoma Power disconnects for BN power and BN power has not yet arrived the surface roads and Bullfrog Junction may be blocked for an extended period.

The NIM uses a weekly planning and event calendar to coordinate all the eastbound and westbound trains each week. A meeting every Tuesday and Thursday afternoon at the port goes over the entire schedule with all parties involved. The port has taken this course of action to try to alleviate disturbances to the schedule. With the current schedule there is enough slack time built in to accommodate most problems. The simulation will investigate increased traffic in and out of the NIM. Coordination between the NIM and Tacoma Rail is essential as well as coordination between Tacoma Rail and the two mainline railroads.

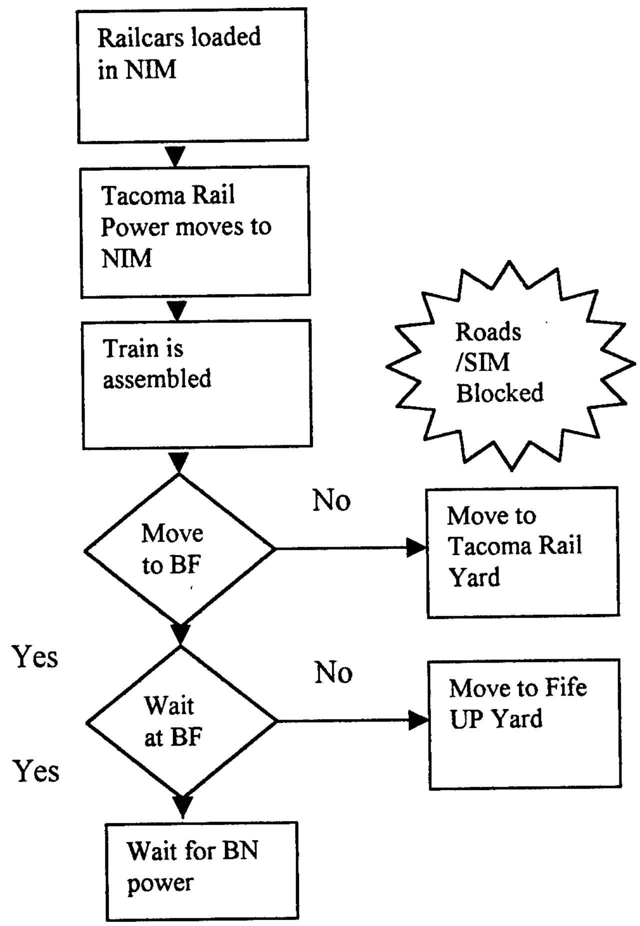


Figure 3.3 Flow of Trains Eastbound from North Intermodal Yard (NIM)

On the NIM weekly planning and evaluation sheet, there are five time gates for every train to process through before it departs. Cars Loaded/Release refers to the time the NIM has planned to complete loading all the containers on the cars and conducted an air test of the railcar break system. At this point the railcars are released to Tacoma Rail. The next gate is the assemble/pull time. This is the time Tacoma Rail has planned to start assembling the train and pulling it. Available at interchange is the next gate. At this time Tacoma Rail must have the train available at a predetermined site for interchange with the UP or the BN. The next two gates are mainline connect and train departure. A delay at any one of these gates can cascade down to the final and most important gate train departure from Tacoma on the mainline. This time is contracted between the mainline carriers and the shipping lines to ensure quick transit of containerized cargo.

Table 3.1 Weekly Planning Sheet Time Gates

Cars Loaded/Released	Assemble	Interchange	ML Connect	Departure
1600	1800	2000	2000	2200
1820	2100	2300	2300	100

Table 3.1 is an example of the time gates and shows some of the slack time in the system. Currently the NIM runs most of their eastbound and westbound trains from Wednesday to Saturday every week. This is determined by ship arrivals on Tuesday and Thursday. From Wednesday to Thursday is the high demand period during the week at the NIM Variability in the arrival times of the ship cause changes in the rail and container loading schedule. Schedules from February until April of 1999 were used to determine the following characteristics of a NIM weekly schedule.

Characteristics of NIM weekly schedule

Eastbound trains

- Four trains meet at Bullfrog Junction per week on Wednesday/Thursday
- One train pulled into Fife yard per week on Friday/Saturday
- Four trains pulled to Tacoma Rail per week on Thursday/Saturday

Westbound trains

- Four trains on Monday/Tuesday
- Three trains on Thursday/Friday

South Intermodal Yard (SIM)

The South Intermodal Yard consists of four tracks with a capacity of 28 (305) foot cars. Sealand shipping lines provides the business for the South Intermodal Yard. Ships arrive at the sealand terminal and are loaded off the ship. Containers are transported by truck to and from the SIM. Top picks and holsters service the yard. Railcars are sorted and combined into trains by Pacific Rail Services. Pacific Rail Services provides the power for switching and sorting in the SIM. The SIM also has a support yard which provides switching and storage space for the SIM. The support yard is located across Lincoln Avenue from the SIM. Switching of rail cars causes traffic delays across the road. Holsters move the containers to and from the marine terminal (Figure 3.4). Not many containers are normally stored in the SIM. Access to the SIM is from the adjacent marine terminal. The holsters move the containes to and from the SIM driving underneath the

Eleventh Street overpass. Containers arriving in the SIM are directed to their proper destination by an intermodal gate.

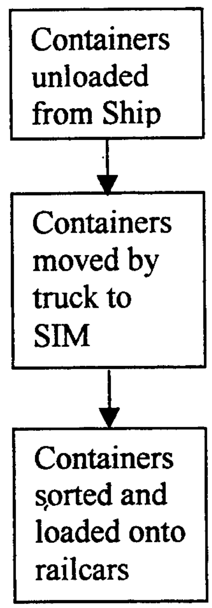


Figure 3.4 Container Flow in South Intermodal Yard (SIM)

The SIM is also serviced by the Union Pacific (UP) and Burlington Northern (BN) railroads. Unlike the NIM, the SIM is able to set up and stage their railcars. Pacific rail power is used by the SIM to position railcars for loading. The mainline railroads bring in railcars for loading to the SIM. If there is space at the SIM yard the cars are brought there, if not they are brought to the SIM transfer yard. From the SIM transfer yard, correct railcar configurations are determined and pacific rail conducts the necessary switching operations to move the railcars.

Railcars are loaded in the SIM and strings of cars are brought to the SIM transfer yard. The next step is to build the train and prepare it for pickup by the mainline carriers. Trains are built by pulling and pushing cars on the network of track including the SIM yard, transfer yard, and the track from the transfer yard past Bullfrog Junction. The internal building of a train from the SIM yard and transfer yard has no effect on rail operations for the rest of the port, but when they are moving to and from the transfer yard they effect traffic on Lincoln Avenue. When the last sections of the train are built, Bullfrog Junction is blocked by the operation in the SIM and has the potential of causing delays for other rail traffic in the port.

Mainline power brings railcars into the NIM and takes trains out. Pacific rail does not enter onto the mainline. Switching and car storage are factors that limit the throughput capacity for the SIM. The SIM has a similar scheduling sheet for their weekly activities. East and westbound trains are scheduled on separate sheets and an inventory of available railcars and required railcars is kept on the scheduling sheet. The layout of railcars is controlled by Pacific Rail. Because they have their own power dedicated to the yard they are able to switch from the transfer yard to the SIM and set up the railcars in any configuration requested by the SIM. The critical times for eastbound trains are depart time from the SIM and depart time from the mainline. Since there is no coordination with Tacoma Rail required in the SIM, there are less time gates on the schedule. For westbound trains the arrival of the train and spot time are recorded on the schedule. Arrival times for eastbound trains are highly variable. An analysis of the train schedules follows:

Eastbound Trains

- Four trains leaving between Thursday and Saturday

Westbound

- Three to four trains arriving between Wednesday and Saturday

Hyundai Yard

The Hyundai yard started operations in May of 1999. The yard is located on the Blair waterway, north of the SIM and NIM. The Hyundai intermodal yard is a 12-acre yard. Hyundai is served by Tacoma Rail for rail and switching operations. The movement of containers from ship to railcars is similar to operations in the NIM yard. Containers are unloaded from the ship, staged, and then placed onto specific railcar configurations with a top loader.

Westbound traffic into the Hyundai yard is similar to the NIM yard. The mainline railroads bring trains through Bullfrog Junction into the Tacoma Rail yard. These trains are broken up and sorted into the proper configuration. Tacoma rail then pushes these cars into the Hyundai yard. Once the railcars are in the intermodal yard they are ready to be loaded (Figure 3.5). Tacoma rail must push cars from their yard north east and cross Port of Tacoma Road. Once past Port of Tacoma Road, the cars are pushed northwest into the Hyundai Intermodal yard. Access to the Hyundai yard is on the north east side of the Tacoma Rail yard. Access to the NIM, SIM and the mainline railroads through Bullfrog Junction are from the southwest end of the Tacoma Rail Yard.

Once the railcars are loaded the train is released to Tacoma Rail. Tacoma Rail builds the train in the Hyundai yard and then pulls it through the Tacoma Rail yard towards

Bullfrog Junction. One of the tracks in the Tacoma Rail Yard must remain clear so the Hyundai yard train can pass. During this process Port of Tacoma road is blocked. Tacoma Rail can pull the train to Bullfrog Junction and wait for the mainline to hook up or pull the train to the UP yard in Fife where it is released to the UP (Figure 3.6). If the train is small

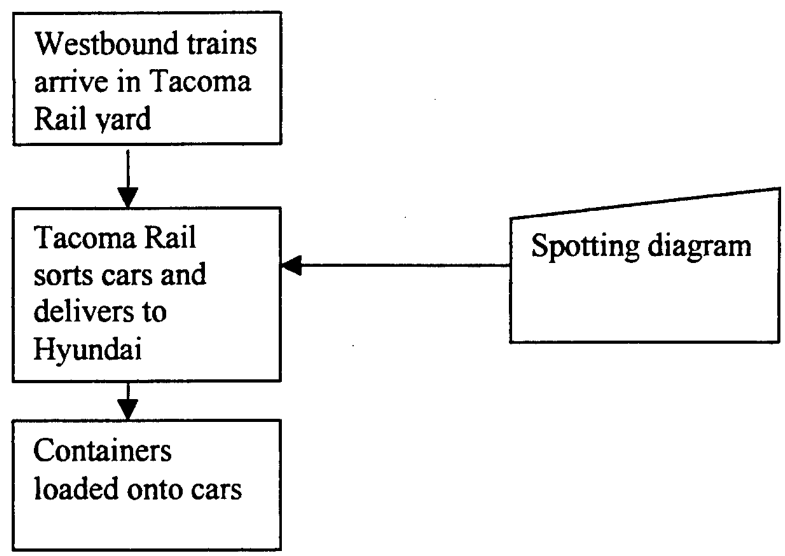


Figure 3.5 Railcar Flow into the Hyundai Intermodal Yard

it can be pulled to the Tacoma Rail yard and remain there until a mainline engine retrieves it. This is a similar flow to the eastbound traffic from the NIM, but it is from the opposite direction for Tacoma Rail.

The movement of eastbound trains causes traffic delays on Port of Tacoma Road, disrupts switching activities in the Tacoma Rail yard, and may conflict with NIM and SIM traffic at Bullfrog Junction. Switching activities in Tacoma Rail are disrupted because of the requirement to clear a track for the Hyundai train and since the train must leave through Bullfrog Junction, SIM and NIM operations may be hindered if they are occurring at the same time. An analysis of train traffic in the Hyundai yard follows.

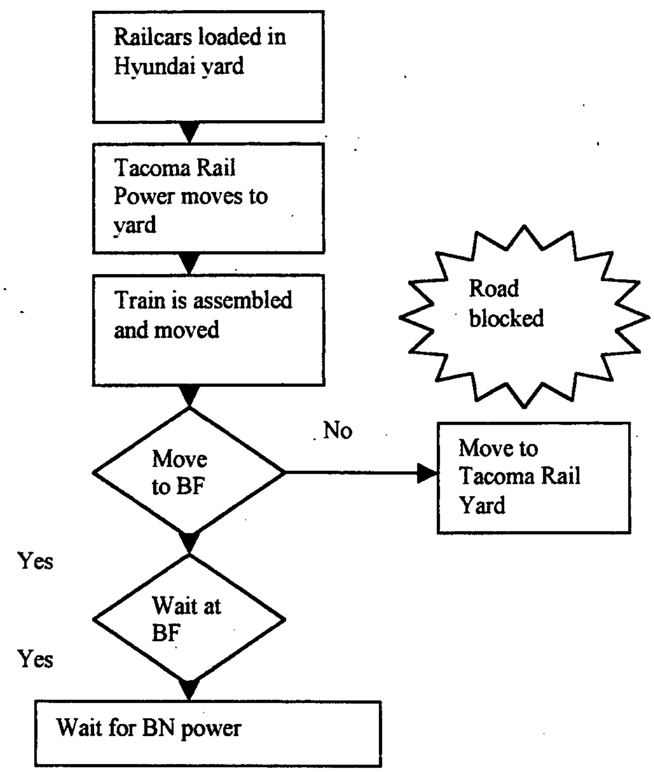


Figure 3.6 Eastbound Traffic Flow from Hyundai Yard

Eastbound Trains

- One unit train departs Wednesday mornings with a Bullfrog meet
- Four to five smaller trains depart from Tuesday to Friday between 1200 and 1800

Westbound

- Four to six trains arriving between Monday and Saturday

Tacoma Rail

Tacoma Rail was formerly known as the Tacoma municipal beltline. Tacoma Rail along with Tacoma power and water form the Tacoma Public Utilities. Tacoma Rail is classified as a shortline railroad serving the Port of Tacoma. This study of the port concentrates mainly on intermodal rail traffic, but there is substantial non-intermodal traffic at the port. In addition to the intermodal yards other industries are located at the port and they are serviced by Tacoma Rail. Tacoma rail provides switching operations for the NIM, Hyundai, and non-intermodal customers such as Kaiser aluminum and auto warehousing for Japanese and Korean auto manufacturers. Unlike the intermodal traffic, the other commercial rail traffic at the port does not follow a specific schedule and the number of cars moved from a specific business at the port is normally less than five. Tacoma Rail is located approximately 1800 meters from the NIM, 900 meters from the SIM and 2000 meters from the Hyundai yard. At this location is a system of tracks used for storage and switching of railcars in the port. These tracks total 54,584 feet. Workers in a control tower overlooking the yard centrally control the location of railcars on the track, switching of railcars, and movement of Tacoma Rail engines. Tacoma Rail Yard is broken into two sections. The first section known as the original beltline yard is composed of seventeen tracks. The tracks range in length from 1297 from to 2334 feet. These tracks are used to support intermodal traffic and commercial traffic at the port This set of tracks offers access to Bullfrog Junction, the NIM, SIM, from the south end and access across Port of Tacoma road to the Hyundai yard. The second set of tracks know as the “slug tracks” or “banana tracks” were recently completed in December 1998. The purpose of these tracks is to ease switching in the NIM and provide for a one to one track ratio for the NIM. There are nine tracks in this section ranging in length from 2745 to 3570 feet. The banana tracks offer access to the NIM and SIM from the south end of the yard. Bullfrog Junction can only be accessed from the banana tracks by pushing the train west toward the NIM and then switching and pulling the train toward Bullfrog Junction. Because of this, the banana tracks are mainly used for the staging of railcars for movement into the NIM and not for any eastbound traffic. The banana yard is also accessible on the north end to the track crossing Port of Tacoma Road. Providing enough space to ensure efficient switching of railcars becomes difficult for Tacoma Rail to manage as rail utilization increases. An analysis of track utilization at Tacoma Rail was done over a one-month period to determine patterns in track usage. Because of the time period this analysis was done before Hyundai Traffic started at the port. Track utilization for Tacoma Rail follows a weekly cycle with Wednesday, Thursday and Friday being the busiest days (Figure 3.7).

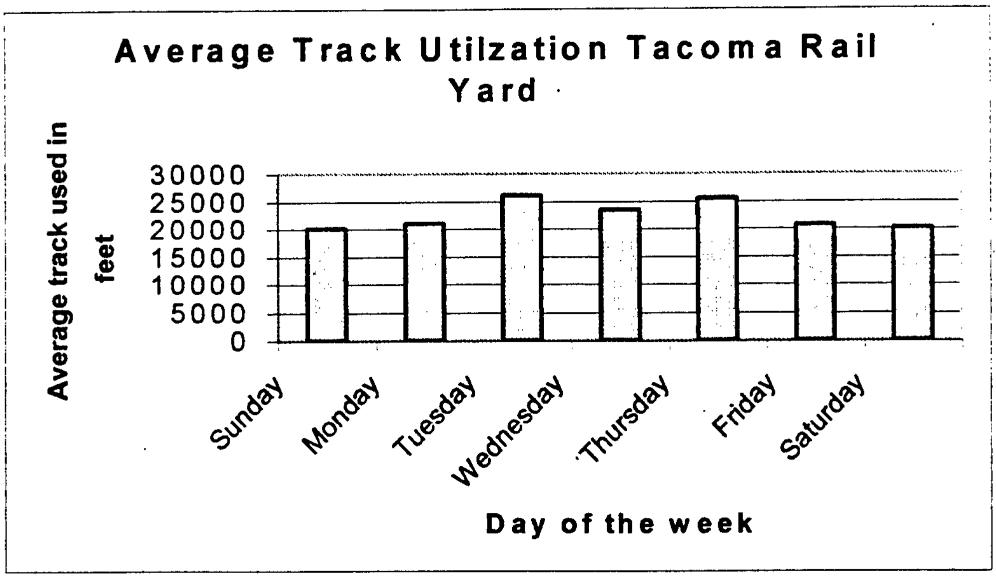


Figure 3.7 Average Track Utilization Tacoma Rail

The high utilization in the middle of the week is due to the ship arrivals for the NIM normally occurring on Tuesday or Wednesday. Figure 3.8 and Figure 3.9 examine the utilization of the Tacoma Rail Tracks and Banana Tracks by percent utilization. Both Figure 3.8 and 3.9 display the same mid week trend.

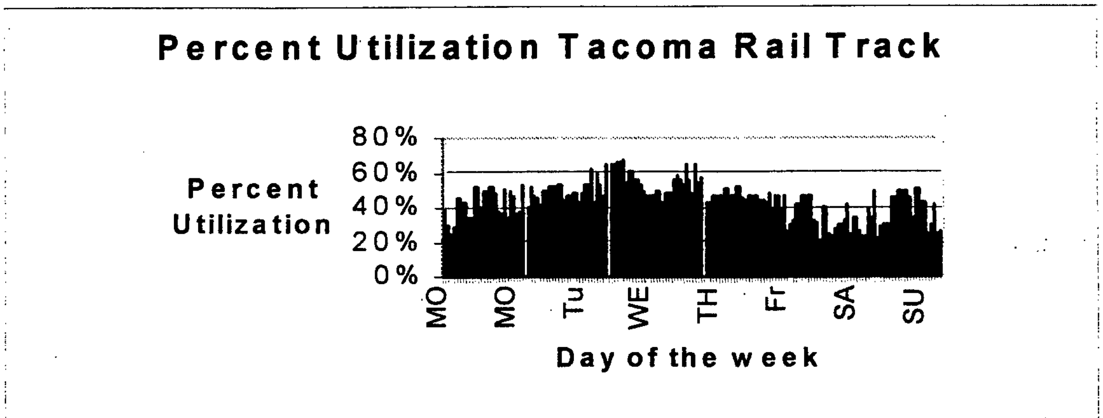


Figure 3.8 Percent Total Track Utilization

The interaction of the NIM, SIM, Hyundai Yard, Tacoma Rail and non-intermodal traffic are complex issues requiring investigation. The next chapters investigate the method of modeling this system and the results obtained

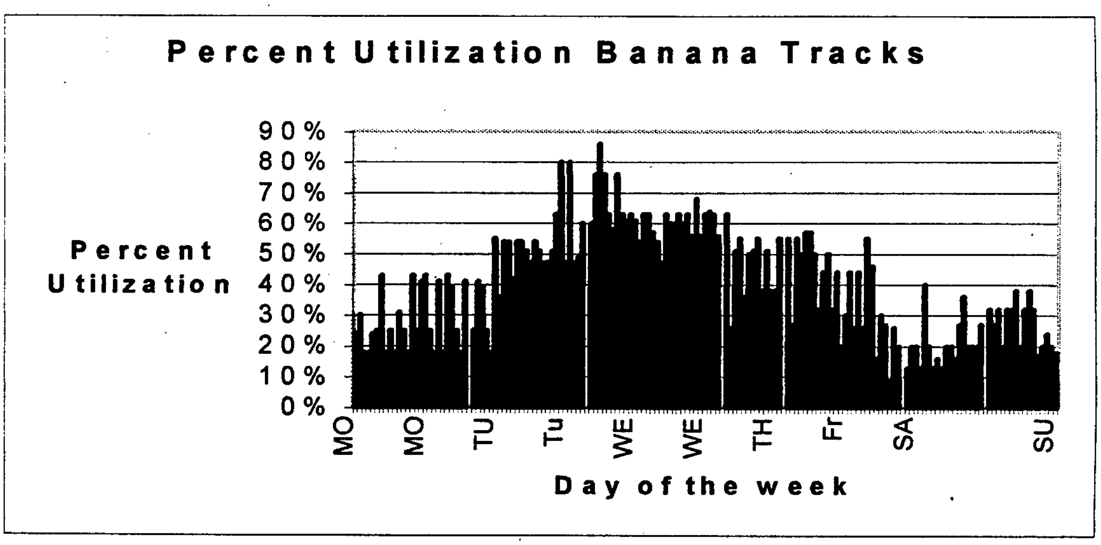


Figure 3.9 Percent Utilization Banana Tracks

Chapter 4: Model Development

A simulation model defines the interactions between components of a system, by describing the facility constraints and resources. The model also describes the logical rules of operations. The rules of operation for the Port of Tacoma model were developed through various field observations from September 1998 to June 1999. Through these field observations the complex relationships between components and the logical rules for the model were obtained. Such rules can be illustrated by describing the flow into and out of any of the intermodal yards.

A conceptual model must first be formed so the simulation software can interpret the model's boundaries and logic. ARENA was chosen as the software to conduct simulation modeling. ARENA is based on the SIMAN/Cinema modeling languages and allows for the programmer to interactively develop the model through graphical flow diagrams. ARENA is a general simulation program that can be used for many applications. Though there are rail and transportation simulation software available, ARENA was chosen because of its availability and the fundamental modeling concepts that are present in ARENA/SIMAN. In this study the SIMAN blocks and elements were used extensively in the programming and proved to be the best way to translate the logic and flow of the system into software. The software allows for the separate development of model logic through the model frame and experiment specifications through the experimental frame. These components control the simulation when linked together. The advantage of this arrangement is that the model logic is separated from the experiment specification.

After a model, which logically depicts the rail system at the Port of Tacoma, is formulated, simulation analysis can be used to investigate the impact of changes that influence the capacity, throughput, or efficiency of the rail system. Simulation is exercising the model to evaluate these changes.

Conceptual Model

The development of a conceptual model of the system is the genesis of the derivation of the simulation model. The real world system is abstracted into a conceptual model. In the case of rail operations at the port, to move trains in and out of the intermodal facilities there is a specific sequence of events that occur and resources utilized. All events occur within the rail facilities and infrastructure of the port (Figure 4.1).

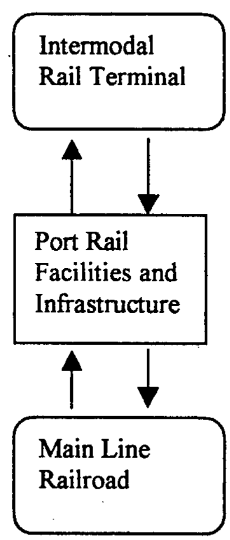


Figure 4.1 Conceptual Movement of Trains Through System

The conceptual model was developed from this basic abstraction. The model concentrates on the rail facilities, infrastructure, and the specific flow through these facilities for different types of trains from the three intermodal yards. All intermodal terminals have

westbound and eastbound train traffic. Eastbound cargo is in the form of imports and westbound in the form of exports or empty container/railcars for intermodal use. From

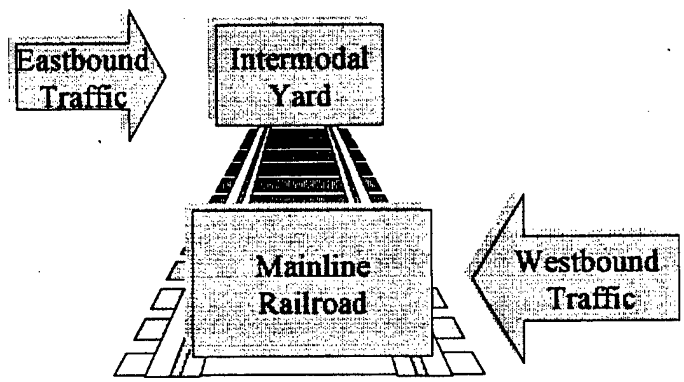


Figure 4.2 Westbound and Eastbound Traffic

this point the rail facilities and infrastructure are utilized in a different sequence for each of the intermodal yards and for eastbound and westbound traffic (Figure 4.2).

A sequential model of the resources used and paths taken for each east and west trains from each intermodal yard is then developed. The simulation methodology consists of trains seizing resources within the system and then being delayed to simulate movement.

Trains move through the simulation in a series of queue, seize, and delay cycles. A train moves into a queue, waits for a required resource to become available and then is delayed for movement. After the train is delayed and once the resource is no longer needed it is released for the next train to use. Resources are seized on a first come first serve basis. In modeling the system, some differences between the real system and the model exists because of complexity of the system or a lack of accessible data. These include commercial traffic only being modeled for utilization in the Tacoma Rail Yard. Ample data was not available to model the movement of commercial non-intermodal traffic through Bullfrog Junction or other track sections. Non-Intermodal traffic also remains at 1999 levels throughout the simulation because of a lack of data on growth of non-intermodal traffic. Other differences include the intermodal yards and the the Tacoma Rail Yard are modeled as an aggregate resource in feet and individual tracks are not modeled in the simulation. The decrease in the efficiency of Tacoma Rail operations is not modeled as rail utilization increases The tracks were modeled in feet to simplfy the simulation and enough data was not available on Tacoma Rail operations to model a degradation in service. From the original conceptual model six models must be developed for each of the following situations.

- NIM Westbound
- NIM Eastbound
- SIM Westbound
- SIM Eastbound

- Hyundai Westbound
- Hyundai Eastbound

The final model is a combination of these six models, a data input model, and a model for non-intermodal traffic. In Chapter 2, the operation of the real world system is described. In the rest of this chapter the translation of that system into eight different sub models is discussed. The term train is used to describe an entity flowing through the model. Movement from point to point is represented by time delays in the model.

Input Sub Model

For the model to run, a train schedule for each of the intermodal yards, a schedule must be input into the simulation model. Schedules vary weekly, but maintain certain characteristics based on the arrival times and dates of the ships. The Input sub model allows for a schedule to be directly input into a text file with the following attributes: train type, direction, train length, and depart yard and then read into the system. Train type refers to direction and intermodal yard. For example train type one is a NIM eastbound train. Direction is only used for NIM Hyundai trains because there are different locations where they may be pulled. Train length is the length of the train in feet and depart yard is the scheduled departure/arrival time for the train in minutes. The input model reads in these trains' schedules determines what type of train it is and sends it to the specific sub model. Before sending the train to a sub model, it checks the depart time and delays the train until the depart time and simulation time are the same.

The file used by the input model to read in the schedule can either be input manually by inputting a specific weekly schedule for all three yards or developed using the schedule simulation program (Figure 3.3). The schedule simulation program (Appendix B) develops a schedule based on the number of trains departing and arriving from each yard. Using the schedules for the intermodal yards (Appendix F and G), a goodness of fit analysis was done and probability distributions were determined for each of the train attributes. Through these distributions, the model creates a schedule. The user can change the distributions or number of trains in the schedule. The schedule is written to a file, which is then read by the input sub model.

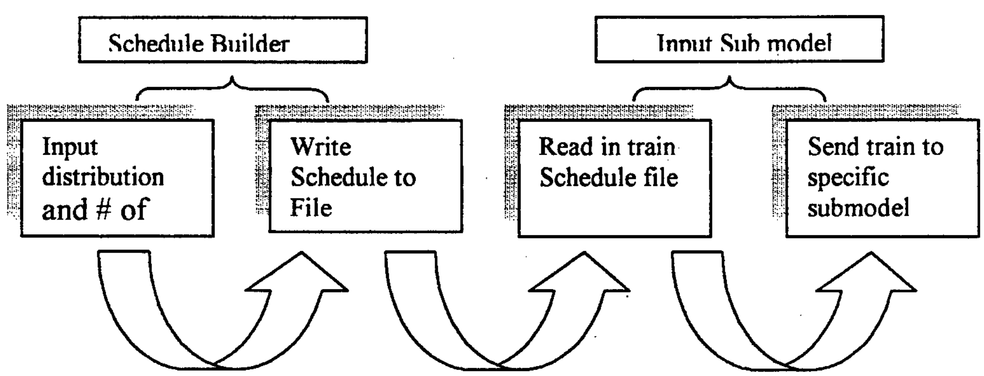


Figure 4.3 Schedule Builder and Model Relationship

The schedule simulation program in Appendix B is built on the schedule trends present in the 1999 schedule. The program assumes that train lengths will be similar to 1999 sizes and the distribution of sizes will be the same as 1999. It also assumes that trains will be scheduled to depart and arrive at the port following a similar distribution to 1999's schedule. The trends for each intrmodal yard presented in Chapter 3 are the building blocks for the simulation and provide the basis for future schedules. The simulation assumes that schedules for future years will follow the same mid week peaks as they presently do, except those peaks will be more pronounced as the number of trains in the system increases. The distribution of types of trains in future schedules is also based on the current distribution of types of trains. For example in the NIM, one out of every five eastbound trains is a Fife meet. Future schedules will retain the same twenty percent for Fife meets as the number of total trains in the NIM increases.

The input to the train schedule simulation is simply the number of trains from each intermodal yard moving east or west on a weekly basis. The simulation then takes this input and applies the current scheduling trends to develop a type of train, train length, and a movement time for the train. These attributes are then written to a file and become a weekly schedule for the particular year being investigated. This file is read into the Port of Tacoma Rail simulation (Figure 4.3). This weekly schedule is then replicated thirty times and statistics are collected on the data, developing averages and confidence intervals used throughout this study.

North Intermodal Yard (NIM) Eastbound

All trains identified in the input sub model as NIM eastbound are sent to this sub model. Once a train arrives in this sub model it is delayed by a probabilistic delay based on a probability distribution. This is representative of the yard delay which can occur if the NIM is late loading containers, there is a maintenance problem with the railcars, or Tacoma Rail is late for the scheduled pickup of the railcars in the NIM. This distribution was determined by times marked on completed schedules and analyzed by a goodness of fit analysis. A counter is then used in the model to count the number of trains that enter the sub model. The train then seizes the resources , annie tracks, E 11th Street and Lincoln Ave as it is processed and put together from the railcar segments in the NIM. Once the resources for movement are seized there is another delay to represent the time it takes to complete the building of the train from railcar segments and moving out of the NIM. The time for this delay is based on observations and interviews with rail personnel. Neither Tacoma Rail nor the NIM collect data on movement times between different points on the tracks. In four different trips to Tacoma Rail, data was recorded while riding/observing train movement. This data was not sufficient to form a distribution. The decision was made to set delay time based on a triangular distribution of hook up time and a function of train length. This was based on interviews with train engineers who have conducted the move numerous times and my own observations. Once the train has been delayed for hook up and movement out of the NIM, a logic decision must be made. The train has three destinations, a meet at Bullfrog Junction, movement to the Tacoma

Rail Yard, or movement to the mainline yard in Fife. The program determines the type of train and the train flows to one of the three branches of logic (Figure 4.4).

Bull Frog Junction Branch

After choosing this branch the train seizes Bullfrog Junction. In the real system, the train is pulled to Bullfrog Junction, and the Tacoma Rail engine and crew depart leaving the train on the track awaiting hook up and movement by a mainline engine. This is represented in the simulation by a delay. This delay is a triangular distribution based on interviews with rail personnel and actual performance captured in schedules. This is followed by another delay for the train to clear Bullfrog Junction. The length of the train and a triangular distribution of the speeds the train is traveling determine the time for this delay. Times and statistics are collected and the train is disposed from the system, because it is now on the mainline moving towards its destination.

Fife Branch

After moving to this branch, Bullfrog Junction is seized. There is a delay to clear Bullfrog Junction based on the length and speed of the train then there is another delay in the mainline yard at Fife following a triangular distribution based on observations and interviews with train personnel. Resources are released in sequence as the train moves east to Fife. Statistics are recorded and written to an output file as the train is disposed of from the simulation.

Tacoma Rail Branch

Trains sent to this branch do not leave directly from the port, but are pulled to Tacoma Rail Yard first .In the rail yard additional cars may be added and the train awaits mainline power to pull it to the mainline. A train pulled from the NIM is brought to the Tacoma rail yard and stored for a period of time in this branch. The delays in this branch include a delay for movement into the rail yard, a delay representing the waiting time in the beltline and a delay representing the pass time of the train through Bullfrog Junction. The delay to clear Bullfrog and the delay for movement into the rail yard are a function of train length and the speed of the train, while the delay in the beltline is determined by the schedules. Again statistics are collected on the movement of the train through this branch and then written to an output file.

From the schedules analyzed, the weekly range of Bullfrog meets is four-to six, rail yard meets is three to four and meets in the Fife yard are between one and two. Modeling with three branches allowed for a more accurate representation of the real world system.

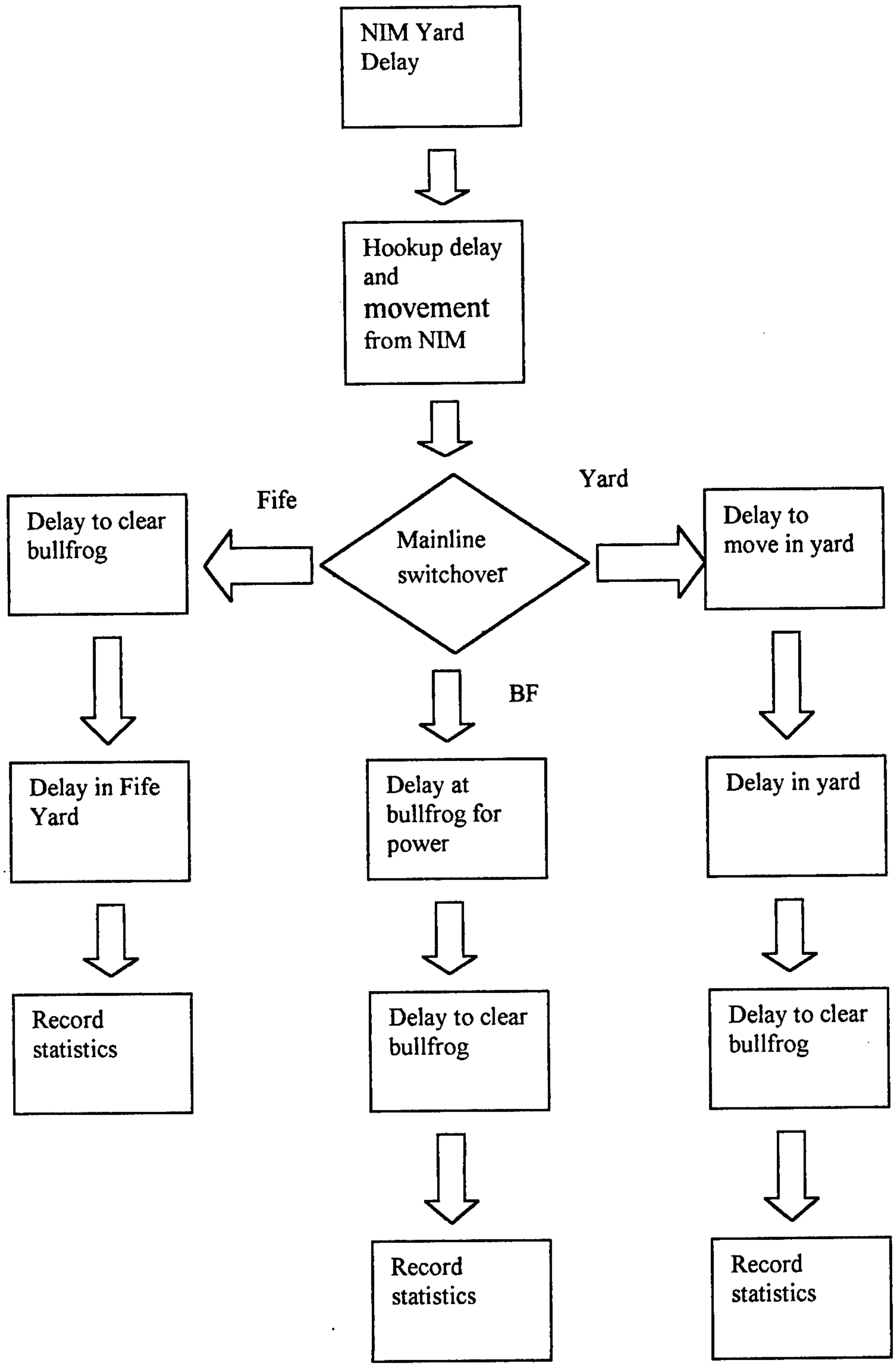


Figure 4.4 North Intermodal Yard NIM Eastbound Traffic Model

North Intermodal Yard (NIM) Westbound

Trains moving into the NIM westbound are composed of exports and empty containers/railcars for loading. The trains are input on the NIM schedule as car requirements and the time they are needed in the NIM. To model westbound movement the railcars were modeled into one train that moves from the main line to the Tacoma Rail Yard and from there is moved into the NIM as track space in the NIM permits. The train enters the NIM westbound sub model according to the input schedule. It seizes Bullfrog Junction, power, and the track into the rail yard. It is delayed to simulate the time to move the train from Bullfrog Junction to the rail yard and stage it in the rail yard. This is based on a triangular distribution derived from interviews of rail personnel. Once in the rail yard resources are released and there is a switching delay based on the length of the train. The simulation then checks to see if there is ample track space in the NIM. If there is, the train is prepared for movement into the NIM. If there is not space available, the train remains in the NIM waiting for track space to become available. In the actual system, a train may be broken up and segments brought into the NIM as track space permits. In the simulation these trains are not broken down, but are brought into the NIM as a singular unit.

Movement from the rail yard to the NIM is modeled by a series of resource requirements and a delay for movement to the NIM. The rail yard to NIM delay is a triangular distribution of delay times plus a function of train length and speed. The train placed in the NIM seizes NIM track as a resource. Statistics are then gathered on the train entity before it is disposed from the system.

Hyundai Eastbound

Similar to the eastbound trains from the NIM, the eastbound trains from Hyundai have different intermediate destinations. Trains from the Hyundai yard may be pulled to the Tacoma Rail or brought to Bullfrog Junction for a link up with the main line. Movement times were determined though interviews with rail personnel and observations of movement to and from the Hyundai Yard. All trains identified in the input sub model as Hyundai eastbound are sent to this sub model. Trains arriving are first delayed for a yard delay based on a probability distribution, representative of any real world delays in the yard. Port of Tacoma Road track, track in Tacoma Rail Yard, and a Tacoma Rail engine are seized as resources. Then it is determined where to send the train. The type of train is either a Bullfrog meet or Tacoma rail is then determined and the train is sent to either one of the branches (Figure 4.5).

Bullfrog Junction Branch

The train is delayed for movement from the Hyundai yard to bull frog Junction, The resource bull frog Junction is seized and then the train is again delayed for the arrival of the main line engine to hook up and pull it past and through bull frog Junction.

Distributions are used based on observations and interviews with rail personnel. Before the train departs the system, statistics are recorded on it and stored.

Tacoma Rail Branch

Arriving in this branch the train is delayed for movement into the yard and staging of rail cars in the yard. Once the train is in the yard non-yard resources are released for use. The train then is delayed in the rail yard. It then is delayed for preparation and movement out of the rail yard as it seizes Bullfrog Junction and moves through it. Statistics are then collected and the train is disposed from the system.

Hyundai Westbound

Westbound trains moving in to the Hyundai yard are composed of exports and empty containers/railcars for loading. The number and type of railcars is determined by the quantity of exports and the requirements for building eastbound trains. In the simulation, westbound trains are modeled from the main line to the Hyundai yard. Trains proceed westbound through Bullfrog Junction and the Tacoma Rail Yard and into the Hyundai yard. Similar to the code for the NIM westbound model, this movement is based on a series of delays and the seizing and releasing of required resources. The train is delayed in the yard and for movement from the Tacoma Rail Yard to the Hyundai yard. Once it arrives in the yard. Hyundai track is seized as a resource and statistics are collected and the train is disposed from the system. Only a month of data was available for the

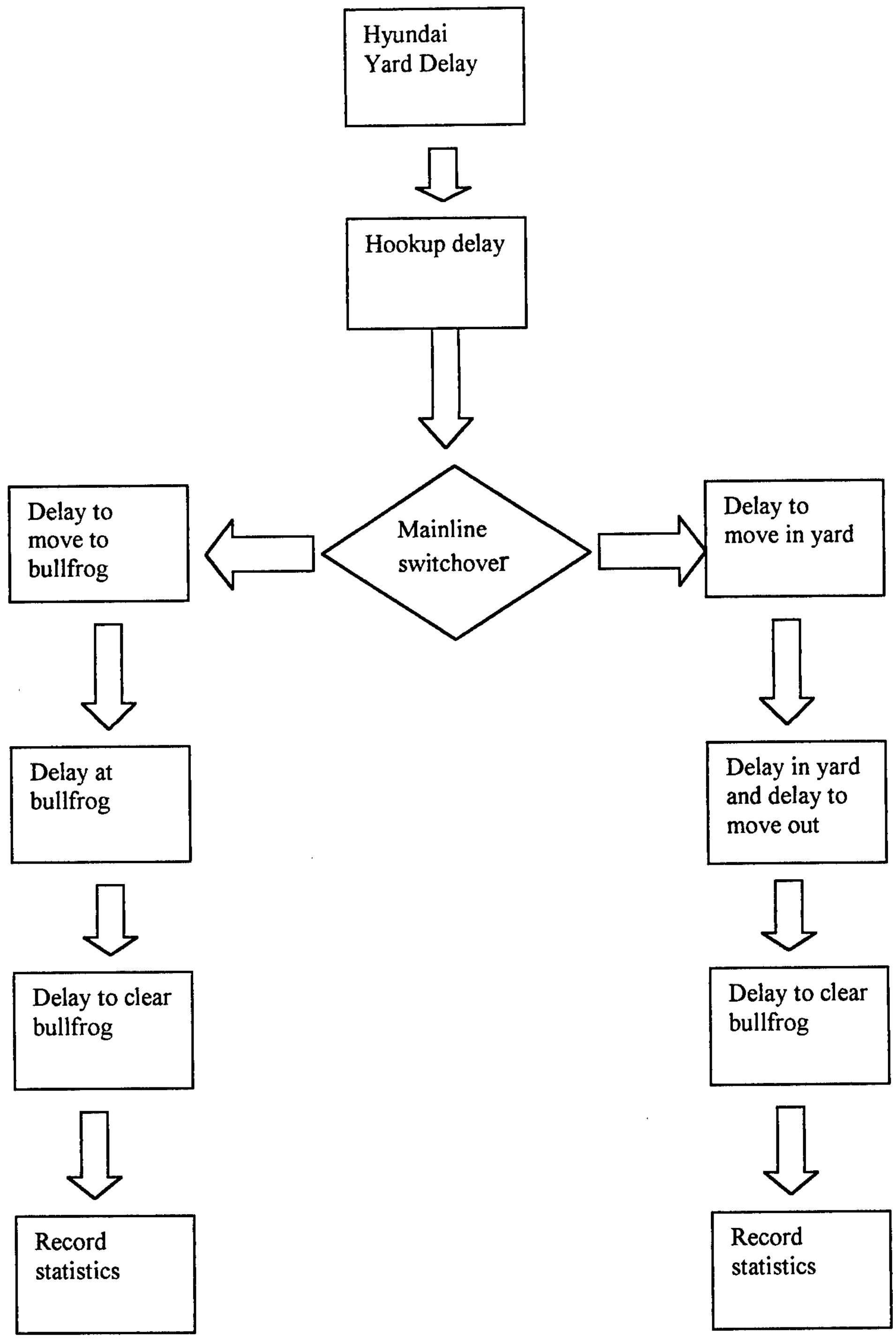


Figure 4.5 Hyundai Eastbound Traffic Model

Hyundai yard, specific details on train arrival time and composition were not as sufficiently developed as the NIM. The Intermodal Equipment Flow report was used to derive the statistics for the westbound traffic into the Hyundai yard.

South Intermodal Yard (SIM) Eastbound

Unlike the NIM or Hyundai, the SIM is not linked with the Tacoma Rail Yard. The SIM operates its own engine for switching of railcars and building trains and has its own transfer yard. Trains once built are picked up from the SIM by the main line carriers and trains are delivered directly to the SIM by the mainline carriers. Though the SIM could be looked as a self-contained system, interaction with Bullfrog Junction and the SIM is an important factor in the performance of the port rail system as a whole.

Once a train arrives in the SIM eastbound sub-model it is delayed by a probabilistic delay. This delay replicates the delay in the yard and the blocking of Bullfrog Junction as a train is prepared to depart the SIM yard. There is another delay in this sub-model for the movement delay through Bullfrog Junction. Once this delay has passed, Bullfrog Junction is released as a resource (Figure 4.6). Delays were based on interviews with SIM personnel and the SIM eastbound and westbound weekly train-operating plan. Statistics are then recorded on the train and it is disposed from the system.

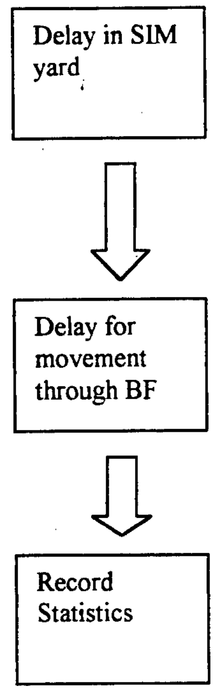


Figure 4.6 South Intermodal Yard (SIM) Eastbound Traffic Model

South Intermodal Yard (SIM) Westbound

Westbound traffic is based on the weekly schedules provided by the SIM. As westbound trains arrive in the SIM, railcars are brought to either the SIM ramp or the SIM transfer yard. The amount of railcars at the SIM ramp is maximized because this is the only location where loading and unloading of railcars can be accomplished. As space becomes available on the ramp railcars are brought forward from the transfer yard to fill the ramp. This is replicated in the simulation. As trains enter the SIM westbound sub model, they are pulled through Bullfrog by main line power into the SIM yard. The model checks for available track in the transfer yard and the SIM ramp. The model then sends an appropriate amount of railcars in feet to both of these locations. There is a delay in the model to simulate the movement from Bullfrog to the appropriate location in the SIM yard. Every five minutes the model checks the amount of SIM ramp track utilized. If there is space available, the appropriate amount of railcars in feet are moved from the transfer yard. If track is not available, the model keeps checking until it is. If at the end of the simulation run an entity is still checking for track it is removed from the loop, counted, and disposed from the system.

Commercial Traffic (Non-Intermodal)

In this model non-intermodal traffic is modeled only with its effect on the Tacoma Rail Yard. The focus of this study was intermodal traffic. The commercial traffic has an influence on intermodal traffic in that it uses the same track resources as intermodal. Data for Tacoma Rail was collected over a six-week period. This data was translated into spreadsheets showing usage of track at specific times during the day. This data was used to develop probability distributions for specific time periods for each day of the week. Each day was broken down into a morning, afternoon/evening, and night period. A goodness of fit test was used to develop probability distributions for the time period. In the model, a branch of code determines the current time and uses the distribution to seize the correct amount of track in the Tacoma Rail Yard. Intermodal traffic from the model then seizes the amount of track required by the specific stages of the model. This process is repeated every fifteen minutes to simulate movement in the yard. The movement of non-intermodal traffic through Bullfrog Junction and other pieces of track were not modeled because of the lack of data available on commercial traffic. Another sub-model can easily be added to the current model, as data on commercial traffic becomes available.

Interaction of Sub Models

To easily examine the extent of interaction between the sub models, resource utilized in each sub model is good guide indicator of interaction. Bullfrog Junction and Tacoma Rail track have the most interactions with the sub models. The experimentation of the model focuses on this interaction and the contribution to the system examining projected volumes from 2000-2020.

Table 4.1 Sub Model Resource Utilization

	NIM W	NIM E	SIM W	SIM E	HYUNDAI W	HYUNDAI E	COMMERCIAL
Bullfrog Junction	X	X	X	X	X	X	
Annie Tracks	X	X					
POT RD Tracks					X	X	
Tacoma Rail Tracks	X	X			X	X	X
Tacom Rail Engine	X	X			X	X	
Main Line Engine	X	X	X	X	X	X	
SIM Ramp Tracks			X	X			
SIM Transfer Tracks			X	X			
Lincoln Ave	X	X					
E 11th St	X	X					
Hyundai Track					X	X	
NIM Track	X	X					

Chapter 5 Model Verification and Validation

Verification, validation and testing are not one phase of the simulation project, but are a continuing task of any simulation exercise. In this study it was necessary to continually conduct verification of the model. Verification is the process of insuring that the model operates as intended and validation is reaching a level of confidence that the inferences made from the results of the model are correct. Successfully performing verification and validation is essential to the credibility of the model results. In this study, the purpose is to examine the interaction of the port rail system and identify resources and traffic levels that present a strain on the system.

Model verification, validation, and testing techniques are categorized into four groupings: informal, static, dynamic, and formal. For this study informal and static techniques were used.

Verification

The verification of this model was performed at three different levels. The first level is individual testing, then sub model testing, and finally integration testing. Individual testing consists of the testing of individual or small groups of code. Conducting simulation runs in an incremental manner enabled the verification of code as it was input into the model. A simple input file of six test trains was used throughout the construction of the model to verify the model logic. One train is targeted for each sub model.

During sub model verification, the six sub models were checked to determine if they operate as intended. The model was checked for errors and the process of tracing entities was conducted. At the sub-model level tracing entities is not a cumbersome process. The trace of entities enables us to examine in detail the movement entities throughout the system. Numerous corrections were made in model logic because of individual testing and sub model testing. Finally the model was verified at the interaction level. All sub models were combined and test runs conducted to determine errors. Test cases that explore boundary conditions are most likely to expose errors that can arise under typical conditions.

The following scenarios were run and the results monitored.

- Available resources increased or decreased in an attempt to induce congestion on the system
- Input schedule was compressed to determine if congestion increases in the model.
- Attributes of trains were changed and reaction to those changes in attributes monitored.
- Probability distributions were changed and the changes to the output monitored.

In running these scenarios, inconsistencies in logic and errors were identified and repaired. Using the Trace function in the software was very beneficial to establishing where the errors were located and the cause of them. The following graphs display the simulations reaction to changing the number of resources, compressing the schedule , altering a probability distribution for delay times, and changing the length of trains.

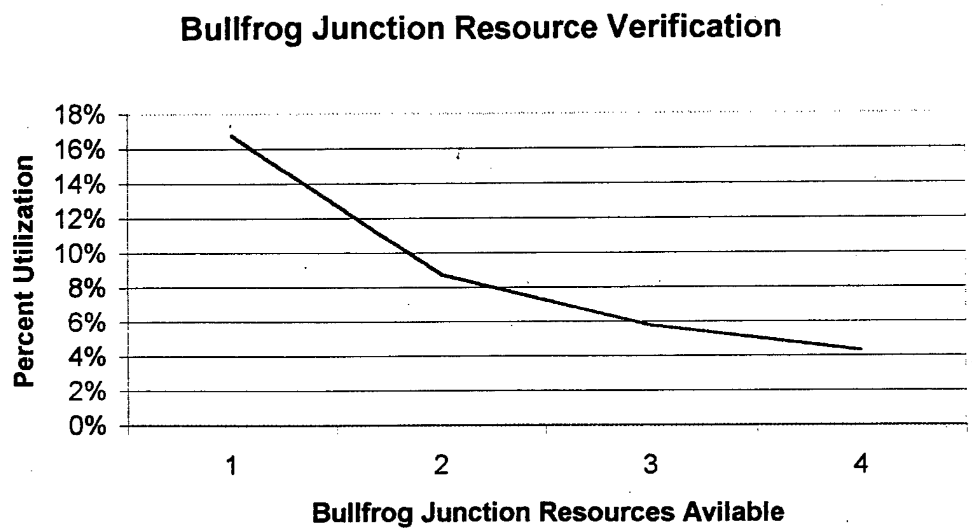


Figure 5.1 BF Junction Utilization Verification

To verify the model is functioning correctly, resources were changed. In the example presented in Figure 5.1, as the numbers of access points for rail through Bullfrog Junction is increased the utilization decreases. Similar analysis was done on other resources.

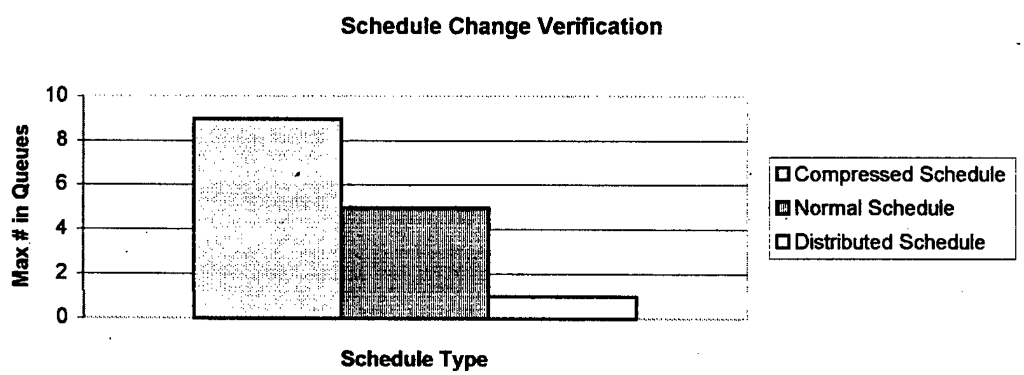


Figure 5.2 Schedule Change Verification

The schedule input into the model was changed by compressing all trains into a three and a half day schedule and then running it and then it was decompressed by allowing the use of all days of the week. Then results of the maximum amount of train in queues is displayed in Figure 5.2.

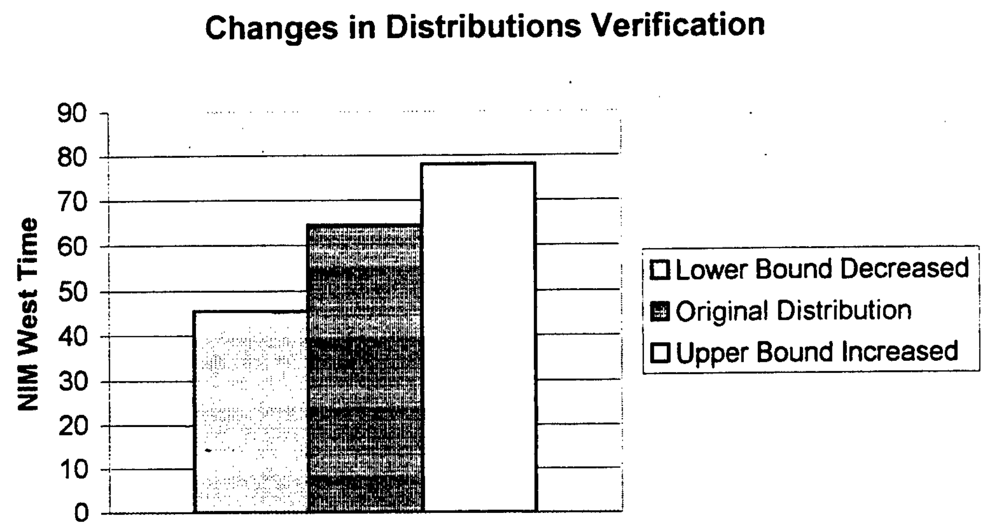


Figure 5.3 Change in NIM West Distribution Verification

Figure 5.3 displays the results of changing a probability distribution in the NIM west sub-model. The lower bound of the triangular distribution was fist lowered and results recorded and then the upper bar was raised and results recorded. As the bound is lowered the average time decreases to 46 minutes and as the bound is raised the average time is increased to 77 minutes. The model behaves as expected. Similar analysis was conducted on the other distributions in the model.

Attributes of the trains were also changed. In one set of runs the length of all the trains was increased by 1000 feet. This caused an increase in the amount of time it took for a train to process through the system as well as an increase in the average utilization of the Tacoma Rail track.

Stepping through this process in a deliberate manner allowed for the discovery and correction of logic and programming errors that were not apparent in the original runs.

Validation

Validation was completed through a series of informal and static testing techniques. Historical schedules from the yards were used to validate the model as well as data recorded in conversations with rail and port personnel and also personal observations while riding Tacoma Rail engines. All three intermodal yards have different scheduling techniques and data required for validation is not consistently recorded.

Validation began by comparing the logic in each of the sub models to the actual system. By comparing the flow of a train entity in the system to the flow of an actual train, The suthor was able to develop confidence in each of the sub models individually. Ensuring the flow of trains is represented correctly in the model is critical to the validity of the model. Since the objective of this model is to monitor current resources with respect to projected future growth at the port, the flow and utilization of resources in the model was considered to be the most important aspect of validation. For westbound traffic into the NIM and Hyundai yard an assumption was required for the time spent in the Tacoma Rail Yard, because of a lack of accessible data. The flow of westbound traffic through the Tacoma Rail Yard to the NIM and Hyundai is depicted correctly through the use of resources and delays.

Individual delay times in the model were then compared to delay and movement times in the real system. Because of the lack of data for movement times, subjective methods were used. Observations and the historical knowledge of operators were utilized. to form and compare delay times.

In the model tallies were used to identify the length of the interval of time between when an entity enters the system and the time in which it departs through Bullfrog Junction. Tallies were recorded for the following intervals: NIM to Fife, NIM to Tacoma Rail Yard, NIM to Bull Frog, SIM eastbound, SIM westbound, Hyundai to Tacoma Rail yard, Hyundai to Bullfrog, and Hyundai Eastbound. To validate time through the system these values were used and compared to the real system planning values for these intervals. To establish confidence intervals the simulation was replicated thirty times first with an actual set of schedules and then with a schedule produced by the schedule builder simulation. The results of each set of replications is presented in the following tables:

Table 5.1 Tally Values for 1999 Simulation Generated Schedule

	Average	95 CI Upper	95 CI Lower
Hyundai to BF	110	117	97.8
Hyundai to TAC Rail	67	83	51
Hyundai West	45	46	44
NIM to BF	108	113	103
NIM to TAC Rail	117	133	101
NIM West	68	70	66
SIM East	75	77	73

In table 5.1 the results of the replications show the confidence intervals in minutes for the different routes a train can travel in the system. These results were generated using the schedule simulation. These results are in general agreement with the times recorded during trips to the port as well as information gained from port personnel and the schedules.

Table 5.2 displays the times when an actual 1999 schedule is input for each of the yards.

Table 5.2 Tally Values for 1999 Actual Schedule

	Average	95 CI Upper	95 CI Lower
Hyundai to BF	103	116	90
Hyundai to TAC Rail	63	70	56
Hyundai West	47	49	45
NIM to BF	106	111	101
NIM to TAC Rail	117	133	101
NIM West	68	70	66
SIM East	75	77	65.5

A comparison of the simulated schedule and the actual schedule is needed to confirm the validity of using the simulated schedule in the model.

The graph in Figure 5.4 displays the close relationship between the results from a 1999 actual schedule and a 1999 schedule produced by simulation. The next task is to validate the results of the simulation with actual times in the real system.

Analysis of the NIM, Hyundai, and SIM schedules produced the following observations. The NIM plans for 120 minutes between when a train is prepared for movement from the yard and when it is expected completed for a bull frog Junction meet. For a Fife destination the planning time is from 90-120 minutes and for a Tacoma Rail Yard meet it is from 90-150. These times are consistent with field observations and the information collected from train operators.

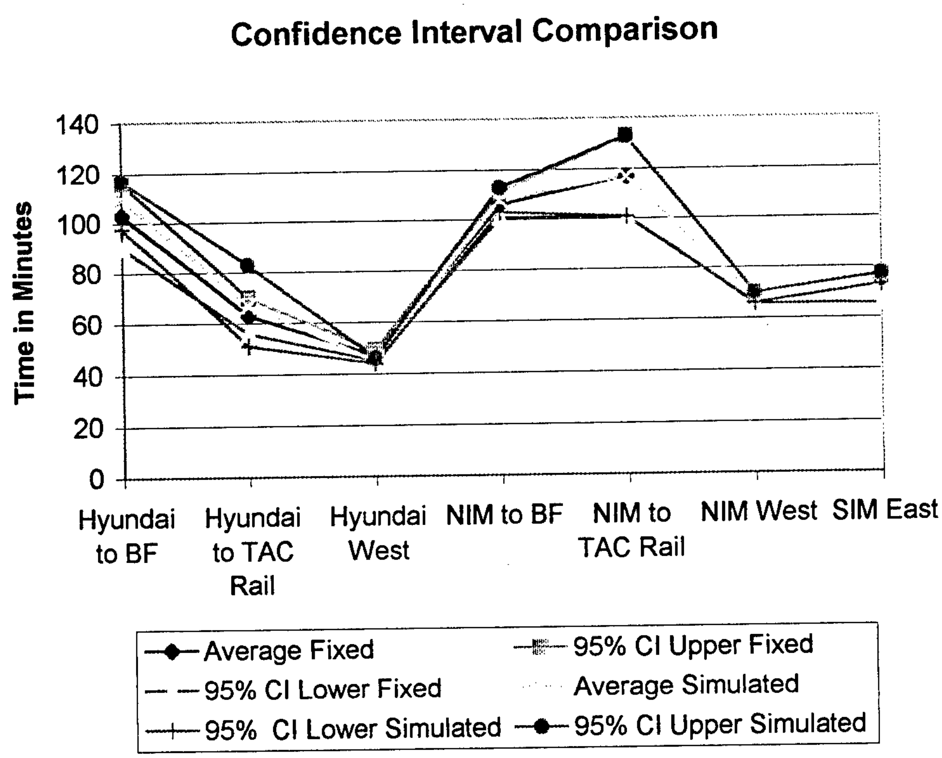


Figure 5.4 Comparison Confidence Intervals 1999 Simulated and Actual Schedule

The Hyundai yard does not have a scheduling system that captures the detail needed to determine interval length. A length of between 70 and 140 minutes was determined through personal observations and observations of rail personnel. Because of the recent start up of the Hyundai terminal this was based on six weeks of operations and only six train pulls from Hyundai to Bullfrog. Hyundai to Tacoma Rail was determined to be between 45 and 90 minutes not counting the time the railcars sit idle in the Tacoma Rail Yard.

The SIM yard prepares a detailed schedule for its weekly runs and allows between 120 and 300 minutes from when it is ready to be pulled and the departure from the main line yard. Since these Figures include time in the mainline yard for reconfiguration of the train, between 60 and 120 minutes is dedicated for movement out of the SIM and past Bullfrog Junction.

The values for the simulation runs in table 5.1 and table 5.2 all fall between the intervals discussed in the preceding paragraphs and perform in accordance with the expectations of the real system. Since the objective of the simulation is not to determine the specific interval times, but to identify how resources are used and problems occurring in the system as volume increases these values are acceptable for this validation.

In addition to analyzing the time intervals and logical routing of trains through the simulation to confirm validity, other statistical output was measured and recorded. Resource utilization, queue length and activity, and counters for different sections of the model assisted in the verification and validation phase. The simulation output for each of the runs is contained in appendix C.

Chapter 6 Model Experimentation

With a verified and validated base model for the current year, the next phase of the simulation project is to exercise the model on projected train volumes for future years and observe trends and stresses on the system. To monitor the system key element of the system are identified. A discussion of each of elements monitored follows.

Monitored Statistics

- Average Throughput Time:

This refers to the average time it takes for a train to process through the different branches in the model. All the time intervals for east and westbound trains are averaged to form this value. As the system becomes congested with trains this time should increase due to the limited resources and the time spent waiting for resources. The average time was chosen instead of monitoring specific times for all the branches so the aggregate system performance could be measured.

- Maximum Throughput Time

This is the average of all maximum times for east and westbound intermodal traffic at the port. Trains waiting for resources become stacked up in queues in the model and their time in the system increases. By monitoring the maximum throughput time for trains in the system, the performance and degradation of the system due to increased congestion and competition for resources is measured.

- Tacoma Rail Average Utilization:

The average amount of track utilized in the Tacoma Rail yard is monitored. This statistic is a good indicator of congestion in the system as well as possible degradation to the system caused by increased switching difficulties in the Tacoma Rail yard.

- Tacoma Rail Average Maximum Utilization

Examining just the average utilization of the Tacoma Rail yard does not take into account added stresses on the system during peak periods. This statistic allows for the monitoring of the Tacoma Rail yard during those peak periods. It is an average of the maximum utilization for all the replications for a specific year

- Annie Track Utilization

This set of tracks provides the only access into and out of the NIM. Currently there are two tracks that present a possible choke point in the system during increased traffic. The utilization of these tracks is measured in the percent of time during the week when these tracks are utilized for intermodal traffic.

- Bullfrog Junction Utilization

Another set of tracks offering only two points to enter and exit the system. Bullfrog Junction is important because all intermodal yards in the system require access to it

- Port of Tacoma Road Track

This section of track crosses Port of Tacoma Road and provides the only access into and out of the Hyundai yard and also blocks the major road into the port.

Simulation Process

The simulation was conducted using projected schedules from the year 2000-2020. The schedules were developed using a simulation to stochastically determine the train size and departure time (Appendix B). The number of trains is determined for each direction and intermodal yard by extrapolating train volumes from projected container volumes for the next twenty years. Once a schedule is built for each of the years a simulation run is completed consisting of thirty replications of a week long schedule. Output is presented in appendix C. Statistics on the key elements are collected using the output analyzer.

Yearly Train Volume Determination

Train volume was determined by using the Port of Tacoma's individual straight-line forecast for container growth for each of the terminals (Appendix H). This is a current forecast by the port updated in May 1999. To translate these container forecasts into train forecasts some assumptions were required. Since containers are moved from the port by truck as well as rail, the first assumption is that the percentage of containers moved by rail remains constant. The second assumption is the eastbound traffic and westbound traffic increase at the same rate.

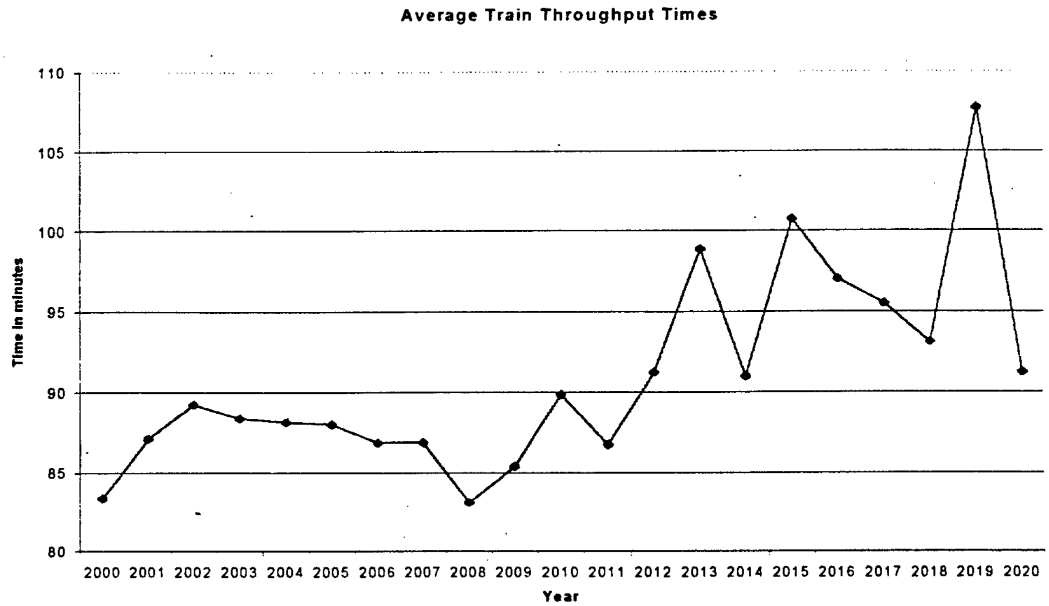
Table 6.1 Train Volume Projections

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NIM W	4	4	4	5	5	5	5	5	6	6	6
NIM E	10	10	11	11	12	12	13	13	14	15	15
SIM W	9	9	10	10	11	11	12	12	13	13	14
SIM E	6	6	6	6	7	7	7	7	7	7	7
HY W	11	15	17	17	18	19	19	20	21	21	22
HY E	5	7	8	8	8	8	9	9	9	10	10
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
NIM W	6	7	7	7	8	8	8	9	9	9	10
NIM E	16	17	17	18	19	20	21	22	23	24	25
SIM W	14	15	16	16	17	18	19	19	20	21	22
SIM E	8	8	8	8	8	9	9	9	9	9	10
HY W	23	24	24	25	26	27	28	29	30	31	32
HY E	10	11	11	11	12	12	13	13	14	14	15

Table 6.1 displays the projected train volumes until the year 2020 and are the input values used in the schedule simulator.

Simulation Runs

The results of the simulation runs are displayed in Figures 6.1-6.5.



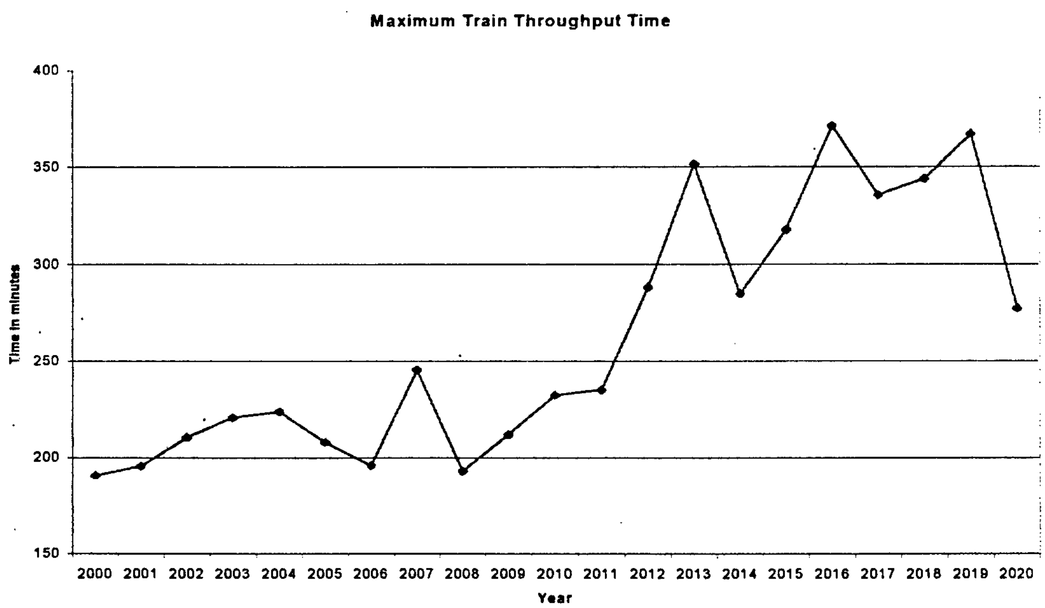


Figure 6.1 Average and Maximum Throughput Times

Figure 6.1 displays the average and maximum throughput times. Average time represents the average throughput times for all eastbound and westbound intermodal traffic at the port for a specific year. After the year 2010 there is an upward trend signaling a problem with congestion in the system. The maximum throughout time is the average of the maximum train throughput times for all east and west bound intermodal traffic throughput times. The maximum throughput times display the same trends as the average throughput times but the range is greater. Trains are sitting in queues waiting for resources for exceedingly long periods of time after 2010.

In Figure 6.2, the maximum and average utilization of Tacoma Rail yard tracks is displayed. The average utilization is for a one-week period of time and the maximum utilization represents the peak period during that one-week. Similar to the throughput times both the average and maximum utilization experience an upward trend after the year 2010. After the year 2014, the maximum utilization approaches within 1500-2000 feet of the current usable track in the yard. As the rail yard becomes more congested, switching becomes more difficult and time consuming. Since switching procedures in the Tacoma Rail Yard were not modeled in this simulation, this model does not show the added time as utilization increases. Delays in the rail yard are likely to be greater than predicted in this model when utilization grows beyond 70% of the 56,000 feet of track available. An aspect of the system, which was not modeled in the simulation, is growth of commercial traffic at the port. Through the simulation non-intermodal traffic remained constant. An increase in non-intermodal traffic will cause an increase in Tacoma Rail Yard utilization. During peak utilization periods, trains departing the Hyundai yard were slowed because of the requirement to seize a full train length to pass through the yard. The requirement to route all Hyundai Yard trains through the Tacoma Rail Yard contributes to the strain on the yard.

Bullfrog Junction utilization follows the same pattern with an upward trend after the year 2010. Figure 6.3 displays the utilization of Bullfrog Junction. The percentages

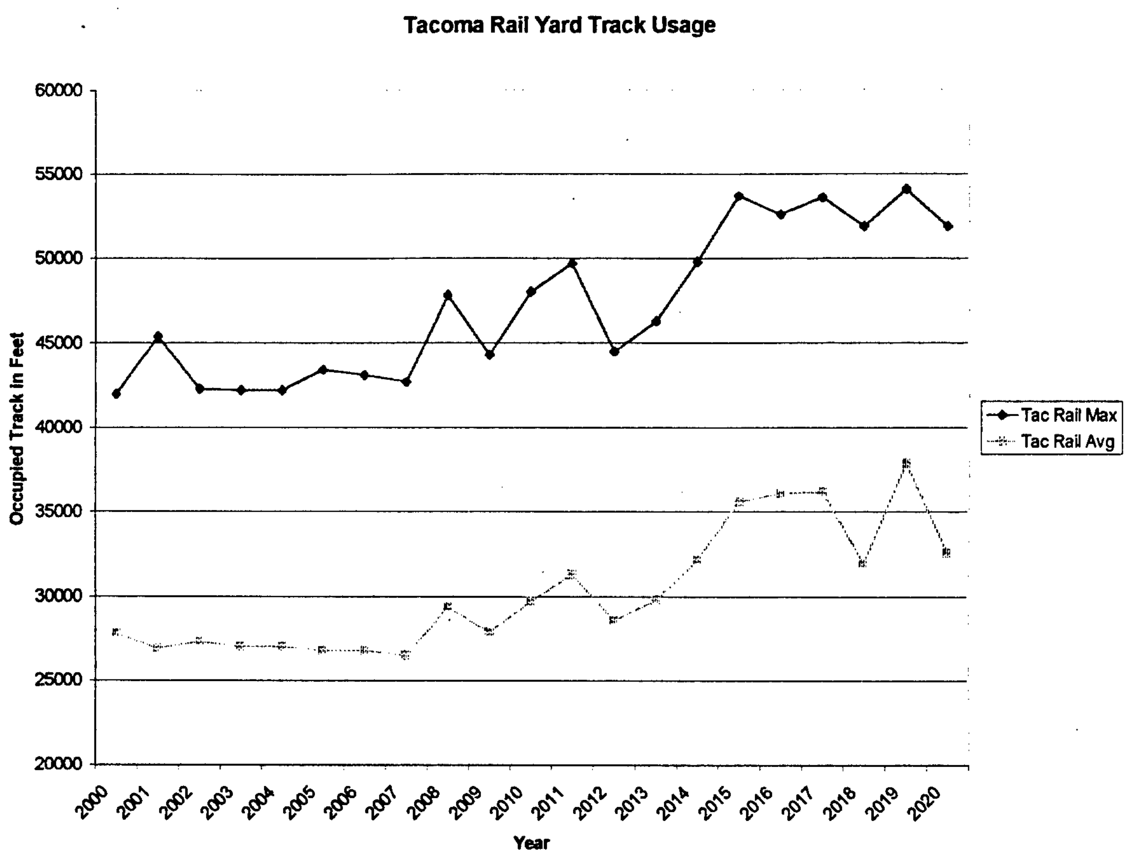


Figure 6.2 Tacoma Rail Average and Max Utilization For Yard Track (2000-2020)

appear to be low but only intermodal traffic is modeled commercial traffic in and out of Bullfrog Junction is not modeled, nor is the effect of blockages at Bullfrog caused by commercial traffic moving into the rail yard. The important result from this simulation to consider is the increase in utilization of Bullfrog Junction from present to 2020.The increase in utilization from 1999 to 2010 is 64%, from 1999 to 2015 is 99%, and from 1999 to 2020 is 134%. Again the greatest rate of increase occurs after the year 2010. Currently Bullfrog Junction is seen as a weak point in the system where a lack of coordination and planning causes blockages and delays. Any increase in utilization without any form of mediation will expand the current problems associated with Bullfrog Junction.

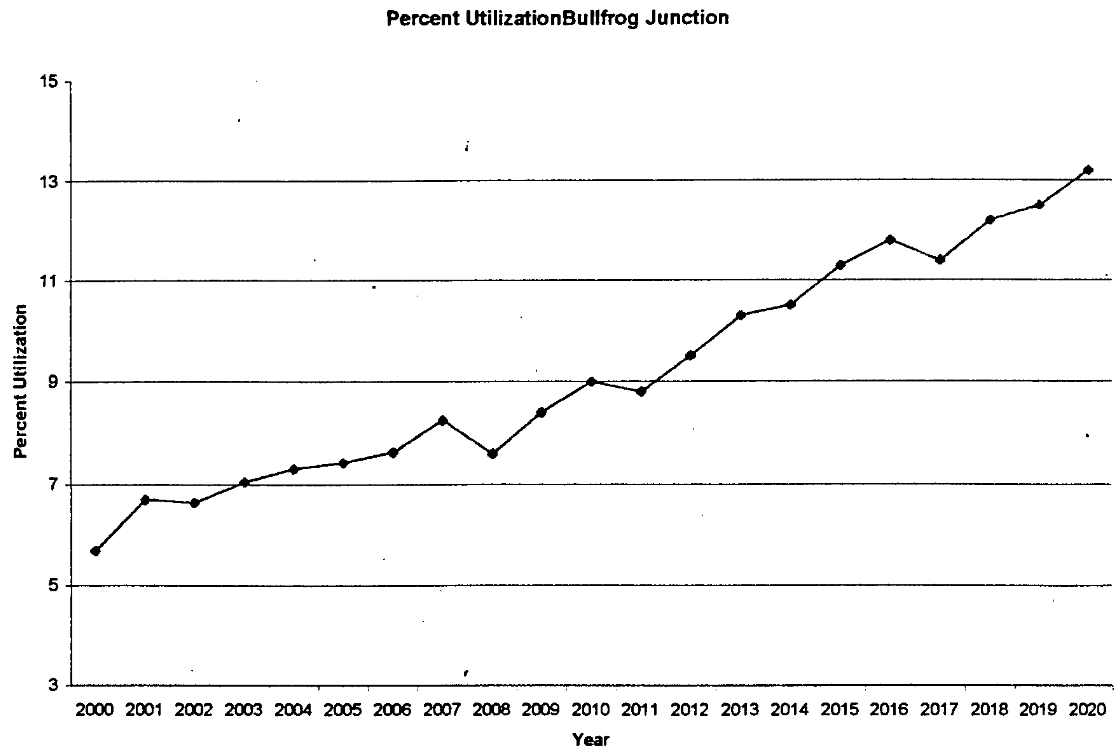


Figure 6.3 Bullfrog Junction Utilization

The last two monitored statistics behaved in a similar manner as the previously discussed statistics (Figure 6.4). The utilization of the annie tracks is an indicator of movement into and out of the NIM yard. Commercial traffic will have an affect on the annie tracks. This is because of a series of sidings off the annie tracks leading to different businesses at the port. An addition of commercial traffic will increase the utilization. Three surface roads are also blocked intermittently when the annie tracks are utilized affecting the flow of truck and car traffic through the port. A track crosses Port of Tacoma Road providing access to the Hyundai yard. Movement across this track blocks Port of Tacoma Road,

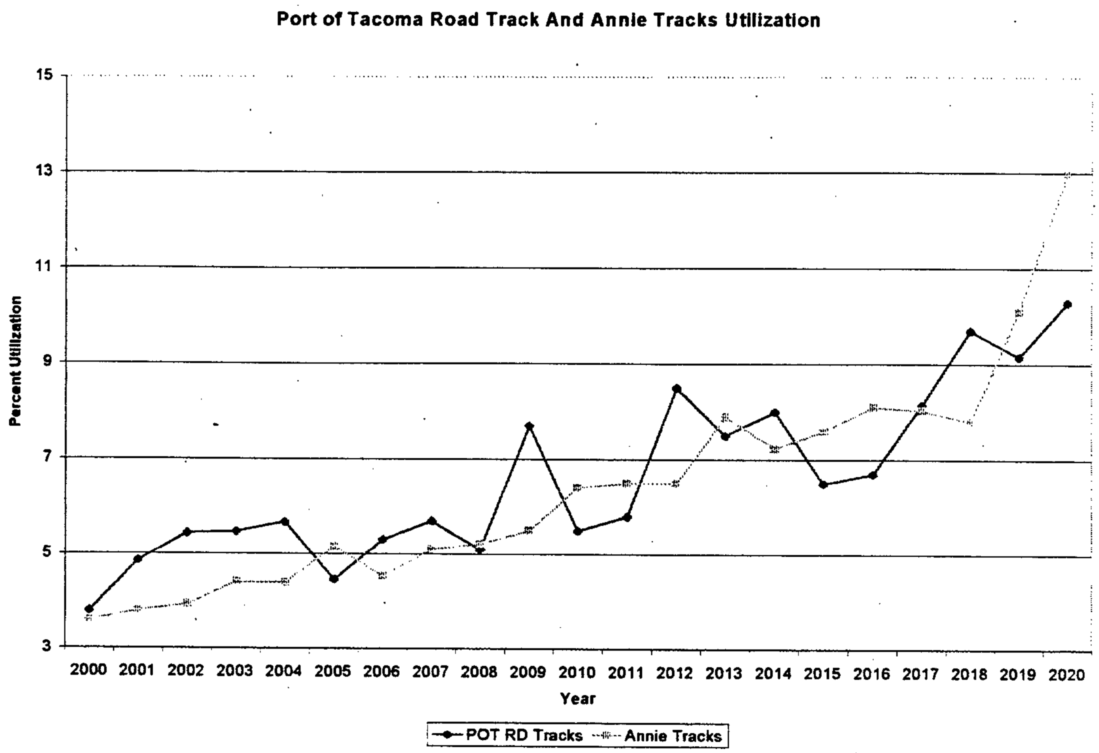
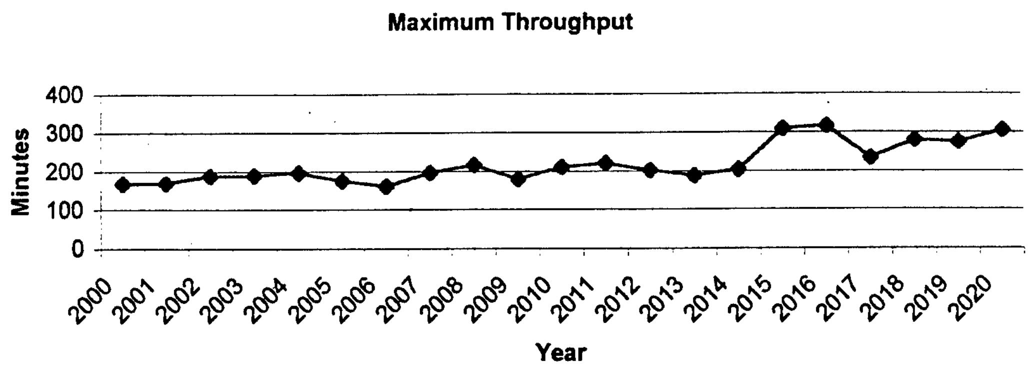


Figure 6.4 Port of Tacoma Rd and Annie Track Utilization

a four-lane road. The major vehicles access road into the port off interstate 5. The simulation results, without blockages for commercial traffic predict this road will be blocked 9.4 hours, 13.5 hours, and 17.3 hours per week in the years 2010, 2015 and 2020 respectively. Figure 6.4 displays the utilization for the annie and POT Road tracks.



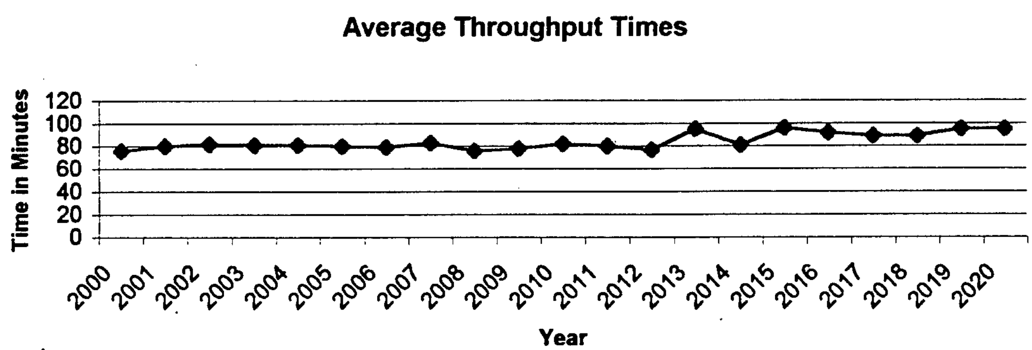


Figure 6.5 Average and Maximum Throughput Times (3 BF Junction Access Points)

System Alternatives

Bullfrog Junction is linked to all intermodal systems. The amount of access points at Bullfrog Junction is increased and statistics monitored through the simulation The simulation was run with the same input files and all resources the same except Bullfrog

Junction. The simulation was run for the years 2000-2020 again. All statistics stayed close to the previous runs with Bullfrog Junction set as two resources, except Bullfrog Junction utilization and maximum and average throughput times. The changes in Bullfrog Junction are to be expected from adding another resource. Figure 6.5 shows the changes associated with the maximum and average throughput.

This output demonstrates that Bullfrog Junction has a direct contribution to relieving congestion in the port rail system. Because of its influence on all aspects of the system Improving the movement through Bullfrog Junction directly influences the throughput times.

Chapter 7 Conclusion

Several general conclusions have been drawn from the completion of this simulation research effort pertaining to throughput, Bullfrog Junction, Tacoma Rail, and expansion timelines for the port. Analyzing the graphs in Chapter 6, peaks are present on all charts. The peaks in the graphs are products of the randomness in the schedule simulator, which can produce trains with close, depart times. This causes competion for resources and an increase in the number of trains in queues. The important aspects of the graphs in the previous chapter are the growth trends and the rate at which growth increases over a time period.

Throughput

From the analysis performed, average throughput expressed in the time it takes a train to process through the Port of Tacoma Rail system, is controlled by the congestion present in the rail system. As intermodal traffic increases, both the average and maximum time spent in the system increases. An increase in available infrastructure resources at the port is the primary tool to alleviate these increases. Changing the access points at Bullfrog from two to three resulted in the maximum average throughput dropping from 370 to 300 minutes and the average dropping from 108 to 99 minutes. In the model future train schedules were based on the present schedules with peaks occurring in the middle of the week. This resulted in high maximum throughput times. Intuitively a better scheduling system spreading out the train arrivals and departures throughout the week will reduce throughput times. But since schedules are based on ship arrival times and coordination between shipping lines arriving at the three intermodal yards is not likely, peaks in throughput times can not be avoided by uniformly distributing the train schedule throughout the week. Access to and from the main lines through Bullfrog Junction is the major limiting factor on throughput times. Increasing access through Bullfrog will give the port the ability to manage increased intermodal loads for the upcoming 20 years. As an interim approach to infrastructure improvements at the port, the research and establishment of a rail traffic control plan is advisable. Coordination for all rail resources is currently based on a first come first serve basis. Establishing priorities and an understanding of the system amongst all intermodal yards should be a priority for the port.

Bullfrog Junction

When running the simulation for upcoming intermodal demands, Bullfrog Junction proved to be the resource causing the most delays. Consistently throughout the simulation the number of trains in the Bullfrog Junction queue was higher than any other queue. From 1999 to 2020, utilization increased by 134%. The average number of trains in the bullfrog queue increased from one to three. When the number of access points at Bullfrog Junction was increased there was a substantial decrease in throughput times and the amount of trains waiting in queues decreased. Increasing access through Bullfrog Junction to the main lines assist with future congestion in the system. Reducing the amount of time the SIM blocks Bullfrog when switching and staging railcars is also a method to reduce Bullfrog utilization and throughput times. Additional track would have to be built to provide the length of track necessary to conduct switching in the SIM.

Tacoma Rail

The simulation demonstrated that the increase intermodal traffic would increase the demands on the Tacoma Rail Yard. Currently the yard operates on average at 50% capacity and at peak periods 67% capacity. The simulation shows an increase to 75% for average utilization and 92.5% for maximum utilization. Switching difficulty increases as track space is filled and Tacoma Rail will not be able to maintain their current level of service. The decrease in performance as utilization increases was not modeled in this simulation, but as utilization increases it can be expected that performance of Tacoma Rail will decrease and this will effect other aspects of the rail system. Since the simulation did not project growth in commercial traffic at the port, utilization of the Tacoma Rail Yard is prone to be higher than projected in this study.

Expansion Timeline

Resource utilization, throughput times, and Tacoma Rail utilization all display an increasing trend over the next twenty years. From the simulation it is apparent that the current infrastructure will be affected at a higher rate after 2009. The steepest increases occur after 2009 for all the statistics monitored in Chapter 6. The rate of growth after 2009 is steeper. There are seventy-four trains in the system in 2009 and seventy-seven in the system in 2010. Though it is only an increase of three trains, it proves to put increased stress on the system due to a combination of other factors. Because the schedule simulation follows 1999 scheduling trends congestion is highest mid week and the 2009 and 2010 levels exacerbate the mid week peak periods. In an analysis of the simulation runs and schedules after 2009, it is seen that more trains are waiting in queues and the schedules have become more compressed. Because of this the level under seventy four trains per week is sustainable under the current infrastructure and scheduling trends but growth increases at a greater rate as the number of trains moves past seventy four. Infrastructure expansion should be concluded before 2009. This allows for the system to be prepared for increasing congestion after 2009 and also allows for construction to occur on the current system while demands on the system are at an acceptable level.

Research Conclusions

This research set out to accomplish the following tasks.

- Understand the interaction of all entities operating at the Port of Tacoma
- Establish a modeling methodology for the port
- Model the port using simulation tools
- Determine weak points in the system relative to increased train traffic
- Present recommendations for improvements at the port

The research accomplished these tasks at different levels of completeness. Not all aspects of the port were researched and modeled. Rail traffic was limited to intermodal rail with in the port. Non-Intermodal traffic was not modeled in the detail present in the actual system nor were the main line yards outside of the port that have an influence on traffic moving into and out of the port. A modeling methodology was presented. This methodology consisted of breaking down the flow of trains from each intermodal yard into westbound and eastbound branches. The individual branches were then modeled and combined to form the final model. Weak points in the system were determined as well as recommendations for improvement. The final analysis of the system and recommendations were more generalized than originally envisioned when starting the research. The next chapter presents recommendations for future research building upon the information gathered in this study.

As a researcher, this study provided me with an exceptional opportunity to investigate a complex system. In future military assignments, the lessons learned in this study will benefit my analysis of other projects. I have gained a better understanding of the process involved in research and have a greater appreciation for the work behind any simulation.

Chapter 8 Recommendations

Topic Specific Recommendations

Several recommendations are made concerning expansion of this research topic. A detailed analysis of commercial traffic in the system should be done. The current model does not fully model commercial traffic and the impact that commercial traffic has on rail operation specifically Bullfrog Junction. An increase in commercial traffic over the next twenty years should also be modeled focusing on the impact on Tacoma Rail as both commercial and intermodal traffic increases at the port.

The interaction of the Union Pacific and Burlington Northern main line yards as they impact on operations of the port should also be studied. As traffic increases at the port, the Burlington Northern and Union Pacific yards will experience increase utilization. How will this impact on the port and what can be done are questions for future research. A similar analysis should be performed based on different schedule trends for departures and arrivals. This study based departure and arrival times for the intermodal yards on current trends and ship arrival times projecting these trends until 2020. An analysis of different types of schedules for the yards would be beneficial and an expansion of this study. It should focus on methods to set up the schedule to evenly distribute train traffic throughout the week, minimizing the number of peak periods. Since schedules are driven by ship arrival times. A distribution of ship arrival times can also be investigated to make the best use out of current resources.

An expansion of the investigation of westbound traffic and switching practices of Tacoma Rail is a beneficial expansion of this topic. Switching was modeled as a time delay in the Tacoma Rail yard, but the actual movement of trains into the yard, breaking down into sections and placed on specific tracks in the yard was not modeled. This analysis is better suited for rail specific simulation software because of the specific constructs built into rail specific software making it easier to model tracks and segments of tracks. An investigation into the switching process at Tacoma Rail to determine at what point the utilization of the Tacoma Rail Yard effects the switching performance of Tacoma Rail crews.

Port Specific Recommendations

It is recommended that the port plan and conduct infrastructure improvements before 2010. The simulation displays a greater trend in resource utilization after 2010. Improvements should be made early to accommodate these changes and further study should be done on the utilization of Bullfrog Junction and the Tacoma Rail Yard. The port should also translate container growth into train volume growth and tracking the volume of trains entering and leaving the port. Accurate projections of the types and composition of future train volume is critical to determining capacity of the system.
A rail traffic control plan with Tacoma Rail incorporating priorities for rail use and a plan to study rail usage at the port should be implemented to track current usage and make projections for future usage. This will help to plan and coordinate the best use of limited rail resources before infrastructure improvements can be made.

General Recommendations

Any simulation study of this scope should be conducted as a team. Much of the current literature on simulations points to a simulation team working on the project consisting of system experts, simulation experts, and managers. The author did not fully achieve this in this study and finds it beneficial for future studies of this type. The analysis of complex systems benefits from input of a team of people looking at the same problem but with different perspectives.

Before choosing generic software for a simulation study, evaluate industry specific simulation software packages. General use software requires considerable time to become familiar with the software's operation and definitions as well as translating the real world system into constructs available in the software. Packages designed with industry-recognized definitions and examples would aid in the translation of and detailed analysis of the system, but in certain situations may not be flexible enough to adapt to specific details of the system being modeled.

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Appendix A Simulation Code

Arena Model Code

Input Sub Model

```
12$      CREATE,      SCHEDULESIZE;
0$       READ,        TRainSChedule,Free:   Reads in train schedule size trainschedule
                 TrainType,                 Train Yard and Direction(E or W)
                 Direction,                 Where Train Meets (BF, Fife, Tac Rail)
                 Departyard,                Scheduled time to leave/enter yard
                 trainlength:MARK(timein);  Train length in feet
28$      BRANCH,      1:
                 If,departyard .eq.tnow,11$,Yes:
                 Else,29$,Yes;                  Check for depart time
11$      COUNT:       INsystem,1:MARK(timein);
47$      BRANCH,      1:                        Branch to send train to sub model
                 If,traintype .eq. 1,NIMeast,Yes:
                 If,traintype .eq. 2,SIMEAST,Yes:
                 If,traintype .eq. 3,Hyundaieast,Yes:
                 If,traintype .eq. 5,NIMwest,Yes:
                 If,traintype .eq. 6,SIMwest,Yes:
                 If,traintype .eq. 7,Hyundaiwest,Yes;
```

NIM East Sub Model

```
nimeast  STATION,     NIMEAST;
126$     DELAY:       NIMYARDDELAY;        Delay in NIM
127$     BRANCH,      1:
                 If,trainlength .le. NR(NIMTRACK),10$,Yes:   Check Available track
                                                             In NIM
                 If,trainlength .gt. NR(NIMTRACK),91$,Yes;
10$      COUNT:       NIM Eastbound,1;                       Count trains entering
1$       QUEUE,       DepartNIM;
2$       SEIZE,       1:                                     Seize resourses to
                 Annietrack,1:                               depart NIM
                 BLEngine,1:
                 E11st,1:
```

```
                LincolnAVE,1;
199$      BRANCH,     1:                                      Check length to
                If,trainlength .le. NR(Nimtrack),204$,Yes:   release
                If,trainlength .gt. NR(nimtrack),200$,Yes;
204$      ASSIGN:    lengthrelease=trainlength;

3$        RELEASE:   NIMTRACK,lengthrelease;                 Release track in NIM
4$        DELAY:     NIMMVT;                                 Delay for movement out
48$       BRANCH,    1:                                      of NIM
                If,direction .eq. 1,49$,Yes:                 Check if FIFE, BF, or
                If,direction .eq. 2,9$,Yes:                  BL
                If,direction .eq. 3,57$,Yes;
49$       QUEUE,     BFJunction;                             Train Sent to Fife
50$       SEIZE,     1:                                      Seize bullfrog
                BFJun,1;
51$       RELEASE:   annietrack,1:                           Release annie track
                e11st,1:
                lincolnave,1;
52$       DELAY:     BFCLEAR;                                Delay to clear BF
157$      DELAY:     fifedelay;                              Delay  in Fife Yard
53$       RELEASE:   bfjun,1:                                Release Bullfrog
                blengine,1;
54$       TALLY:     NIM TO FIFE,int(timein),1;              Tally time in system
146$      WRITE,     scheduleoutput,free:                    Write to output file
                Tnow,
                traintype,
                direction,
                departyard,
                trainlength;
166$      COUNT:     NIM FIFE OUT,1;                         Count trains leaving Fife
195$      COUNT:     OUT SYSTEM,1;                           Branch
83$       DISPOSE;

9$        RELEASE:   BLENgine,1;                             Bullfrog junction hook up
5$        QUEUE,     bfjunction;
6$        SEIZE,     1:
                bfjun,1:
                MLPOWER,1;
7$        DELAY:     WaitBF;                                 delay for arrival and hook up
156$      TALLY:     NIM TO BF MEET,INT(TIMEIN),1;                   NIM to
meet at BF Junction
8$        RELEASE:   Annietrack,1:                           Release resources
                E11st,1:
                Lincolnave,1;
```

```
55$     DELAY:      BFclear;                          Delay to clear BF
56$     RELEASE:     bfjun,1:
            MLPOWER,1;
13$     TALLY:      NIM TO BF,INT(timein),1;          Tally time in system
147$     WRITE,      scheduleoutput,free:              Write to output file
            Tnow,
            traintype,
            direction,
            departyard,
            trainlength;
167$     COUNT:      NIM BF OUT,1:NEXT(195$);          Count trains leaving BF
57$     QUEUE,      BLQUEUE;                           branch
58$     SEIZE,        1:                               NIM E trains in BL
            BLtrack,trainlength;
59$     DELAY:      INBL;                              Movement into Beltline
60$     RELEASE:     annietrack,1:                     Release resources
            blengine,1:
            e11st,1:
            lincolnave,1;
61$     DELAY:      BELTLINE DELAY;                    Delay in Beltline
62$     QUEUE,      BFJunction;
63$     SEIZE,        1:                               Sieze to move from
            bfjun,1:                                   Beltline
            MLPOWER,1;
64$     DELAY:      BFCLEAR;                           Delay to clear BF junction
65$     RELEASE:     MLPOWER,1:
            bfjun,1;
66$     TALLY:      NIM TO BELTLINE,int(timein),1;     Tally time in system
148$     WRITE,      scheduleoutput,free:              Write to output file
            Tnow,
            traintype,
            direction,
            departyard,
            trainlength;
168$     COUNT:      NIM BL OUT,1:NEXT(195$);          Count Trains leaving

200$     ASSIGN:     lengthrelease=NR(nimtrack):NEXT(3$);  Check NIM track

91$     QUEUE,      NIMQueue;
90$     SEIZE,        1:
            NIMTRACK,Nimdifference:NEXT(10$);
```

SIM EAST

```
Simeast      STATION,                                               SIM Eastbound
161$         COUNT:      SIM EASTBOUND1,1;                          Count trains entering
129$         BRANCH,      1:                                        Check track in SIM
                 If,trainlength .ge. NR(simramptrack),95$,Yes:
                 If,trainlength .lt. NR(simramptrack),202$,Yes;
95$          QUEUE,      SIMRAMPTRACKQ;
96$          SEIZE,      1:                                         Sieze track in SIM
                 simramptrack,simrampdiff;
202$         QUEUE,      bfjunction;
201$         SEIZE,      1:
                 bfjun,1;
sim yard delay DELAY:    simyarddelay;
70$          QUEUE,      SIMeastq;
71$          SEIZE,      1:                                    Seize resources
                 MLPOWER,1:
                 SIMtrack,1;
205$         BRANCH,:    If,trainlength .gt. NR(Simramptrack),207$,Yes:   Check SIM
                 If,trainlength .le. NR(simramptrack),97$,Yes;            ramp
207$         QUEUE,      SIMRAMPTRACKQ;
206$         SEIZE,      1:
                 SIMRamptrack,simrampdifference;
97$          RELEASE:    simRampTRACK,trainlength;          Release SIM Ramp Track
72$          DELAY:      SIMOUT;                            Delay movement from SIM
73$          RELEASE:    BFjun,1:
                 SIMtrack,1:
                 MLPOWER,1;
74$          TALLY:      SIM EAST,int(timein),1;            Tally time in system
154$         WRITE,      scheduleoutput,free:               Write to file
                 Tnow,
                 traintype,
                 direction,
                 departyard,
                 trainlength;
162$         COUNT:      SIM EAST OUT,1:NEXT(195$);   Count leaving the system
```

Hyundai East

```
Hyundaieast  STATION,    HYUNDAIEAST;                       Hyundai East
128$         BRANCH,     1:
                 If,trainlength .le. NR(hytrack),68$,Yes:   Check track in yard
```

```
                If,trainlength .gt. NR(hytrack),92$,Yes;
68$     COUNT:      Hyundai eastbound,1;                      Count trains entering
hynudai yard delay DELAY:   hyarddelay;                       Delay in yard
30$     QUEUE,      Hyundaiyard;
31$     SEIZE,      1:                                        Seize resources
                BLENGINE,1:
                POTROAD,1:
                POTRTRACK,1:
                BLTRACK,trainlength;
158$    BRANCH,     1:                                        Check yard track before
                If,trainlength .le. NR(hytrack),94$,Yes:      releasing
                If,trainlength .gt. NR(hytrack),159$,Yes;
94$     RELEASE:    hytrack,trainlength;
172$    BRANCH,     1:                                        Hyundai East to BF or
If,direction .eq. 1,32$,Yes:                                  beltline
                If,direction .eq. 2,173$,Yes;
32$     DELAY:      HYTOBF;                                   Delay time for movement
from Hyundai to BF
33$     QUEUE,      bfjunction;                               Seize resources
34$     SEIZE,      1:
                bfjun,1;
203$    DELAY:      waitbf;
155$    TALLY:      HYUNDAI TO BF MEET,INT(TIMEIN),1; Tally time
35$     DELAY:      BFCLEAR;                                  Delay to Clear BF
36$     RELEASE:    BLENGINE,1:                               Release resources
                POTROAD,1:
                POTRTRACK,1:
                BLTRACK,trainlength:
                bfjun,1;
88$     TALLY:      HYUNDAI BF EAST,int(timein),1;            Tally time in system
150$    WRITE,      scheduleoutput,free:                      Write Output
                Tnow,
                traintype,
                direction,
                departyard,
                trainlength;
164$    COUNT:      HYUNDAI BF OUT,1:NEXT(195$); Count leaving system

173$    DELAY:      INBL;                                     Movement into Beltline
174$    RELEASE:    POTROAD,1:
                POTRTRACK,1:
                blengine,1;
175$    DELAY:      BELTLINE DELAY;                           Delay in beltline
176$    QUEUE,      BFJunction;
```

```
177$      SEIZE,      1:
                bfjun,1:
                MLPOWER,1;
178$      DELAY:      BFCLEAR;                              Delay to clear BF junction
179$      RELEASE:    MLPOWER,1:
                bfjun,1;
180$      TALLY:      HYUNDAI BL EAST,INT(timein),1;  Tally time in system
181$      WRITE,      scheduleoutput,free:                  Write to file
                Tnow,
                traintype,
                direction,
                departyard,
                trainlength;
182$      COUNT:      HYUNDAI BL OUT,1:NEXT(195$);  Count depart system

159$      QUEUE,      Hyundaitrack,3;
160$      SEIZE,      1:
                Hytrack,Hydifference:NEXT(94$);   Seize available track

92$       QUEUE,      Hyundaitrack,3;
93$       SEIZE,      1:
                Hytrack,Hydifference:NEXT(68$);
```

NIM West

```
NIMWEST     STATION,     NIMWEST;                    NIM westbound
67$       COUNT:      NIM westbound,1;               Count entering
14$       QUEUE,      MLQUEUE,5;
15$       SEIZE,      1:
                MLPower,1:
                bfjun,1;
16$       DELAY:      BFTOBL;                        Movement delay to beltline from bf
17$       QUEUE,      BLQueue,3;
18$       SEIZE,      1                              Move into beltline:
                blengine,1:
                BLTRACK,trainlength;
19$       RELEASE:    MLPOWER,1:
                bfjun,1;
20$       DELAY:      10;                            Switching delay in beltlin
Check NIM Space BRANCH,   1:                         Check NIM Space
                If,(MR(nimtrack)-NR(nimtrack)).gt.trainlength,198$,Yes:
                Else,20$,Yes;
```

```
198$    RELEASE:    blengine,1;
21$     QUEUE,      NIMINCOMING,3;
22$     SEIZE,      1:                              Seize to move to NIM
                e11st,1:
                lincolnave,1:
                BLENGINE,1:
                ANNIETRACK,1;
23$     RELEASE:    BLTRACK,trainlength;
24$     DELAY:      BLTONIM;                        Movement to NIM from Beltline
25$     QUEUE,      NIMQUEUE,3;
26$     SEIZE,      1:
                NIMTRACK,trainlength;               Occupy track in NIM
27$     RELEASE:    e11st,1:
                lincolnave,1:
                BLENGINE,1:
                ANNIETRACK,1;
87$     TALLY:      NIM WEST,int(timein),1;  Tally time in system
149$    WRITE,      scheduleoutput,free:         Write output
                Tnow,
                traintype,
                direction,
                departyard,
                trainlength;
165$    COUNT:      NIM WEST OUT,1:NEXT(195$);    Count trains leaving
```

SIM WEST

```
Simwest   STATION,    Simwest;                      SIM West
98$     COUNT:      SIM WESTBOUND,1;                Count # in
75$     QUEUE,      MLQUEUE;
76$     SEIZE,      1:
                MLPOWER,1;
77$     QUEUE,      BFJunction;
78$     SEIZE,      1:
                bfjun,1:
                SIMtrack,1;
79$     DELAY:      BFCLEAR;                        Movement through Bull frog
134$    RELEASE:    MLPOWER,1;
130$    BRANCH,     1:
                If,(MR(SIMramptrack)-NR(simramptrack)) .ge. trainlength,84$,Yes:
                If,(MR(SIMRAMPTRACK)-NR(simramptrack))
.lt.trainlength,131$,Yes;          Check lenth of train and available SIM ramp track
```

```
84$       QUEUE,      SIMramp;
85$       SEIZE,       1:
               SIMramptrack,trainlength;                Sieze SIM ramp Tracks
86$       DELAY:      SIMRAMP1;                         Movement to ramp tracks
208$      RELEASE:    SIMtrack,1:
               bfjun,1;
80$       TALLY:      SimRamptally,int(timein),1;       Tally time in System
153$      WRITE,      scheduleoutput,free:              Write to output file
               Tnow,
               traintype,
               direction,
               departyard,
               trainlength;
169$      COUNT:      SIM WEST OUT,1:NEXT(195$);        Count number leaving

131$      ASSIGN:     ramplength=ramplen:               Send to ramp and
               transferlength=transferlen;              transfer track
170$      BRANCH,     1:
               If,transferlength .le. (MR(simtransfertrack)-
NR(simtransfertrack)),209$,Yes:                         Check transfer length
               If,TRANSFERLENGTH .GT. (MR(SIMTRANSFERTRACK)-
NR(sIMTRANSFERTRACK)),171$,Yes;
209$      DELAY:      SIMRAMP1;                         Movement to ramp tracks
81$       QUEUE,      SIMTransfer;                      from transfer tracks
82$       SEIZE,      1:
               SIMtransfertrack,transferlen;
132$      QUEUE,      SImramp;
133$      SEIZE,      1:
               SIMRamptrack,ramplength;
210$      RELEASE:    bfjun,1:
               SIMtrack,1;
135$      BRANCH,     1:
               If,NR(SIMRAmptrack) .lt. MR(simramptrack) .and.
NR(Simtransfertrack) .gt. 0,137$,Yes:                   Check for ramp space
               Else,136$,Yes;
137$      BRANCH,:    If,(MR(Simramptrack)-NR(simramptrack)) .lt.
NR(simtransfertrack),144$,Yes:                          Check for ramp space
               If,NR(simtransfertrack) .le. (MR(simramptrack)-
NR(simramptrack)),145$,Yes;
144$      ASSIGN:     rampavailable=MR(simramptrack)-NR(simramptrack);
138$      QUEUE,      simramp;
139$      SEIZE,      1:
               simramptrack,rampavailable;              Seize available ramp space
142$      RELEASE:    Simtransfertrack,rampavailable;   Release transfer track
```

```
152$    WRITE,       scheduleoutput,free:
              Tnow,
              traintype,
              direction,
              departyard,
              trainlength:NEXT(169$);

145$    ASSIGN:      cleartransfer=NR(simtransfertrack);
140$    QUEUE,       simramp;
141$    SEIZE,       1:
              simramptrack,cleartransfer;             Send all transfer track to ramp
143$    RELEASE:     Simtransfertrack,cleartransfer:NEXT(152$);

136$    DELAY:       5;             Check track level every five minutes
211$    BRANCH,:     If,tnow .gt.10081,152$,Yes:
              If,tnow .le. 10081,135$,Yes;            End of week count for SIM
171$    RELEASE:     Simtransfertrack,TRANSFERLEN:NEXT(209$);
```

Hyundai West

```
Hyundaiwest  STATION,     HYUNDAIW;
69$     COUNT:       Hyundai westbound,1;      Count trains entering
37$     QUEUE,       MLQUEUE;
38$     SEIZE,       1:                        Seize resources
              BFJUN,1:
              MLPOWER,1;
39$     DELAY:       BFCLEAR;                  Delay to clear BF
41$     QUEUE,       BLQUEUE;
42$     SEIZE,       1:                        Move to beltline
              bltrack,trainlength:
              BLengine,1;
40$     RELEASE:     BFJUN,1:
              MLPOWER,1;
212$    SEIZE,       1:                        Move to Hyundai yard
              POTROAD,1:
              POTRTRACK,1;
43$     DELAY:       BLTOHY;                   Delay Time from BL to Hyundai
196$    BRANCH,:     If,TRAINLENGTH .GT. (mr(HYTRACK)-
NR(HYTRACK)),197$,Yes:                         Check yard track
              If,TRAINLENGTH .LE. (mR(HYTRACK)-
NR(HYTRACK)),44$,Yes;
197$    RELEASE:     hytRACK,HYDIFF;
44$     QUEUE,       HYUNDAIINQ,2;
```

```
45$     SEIZE,      1:                              Seize yard track
                HYtrack,trainlength;
46$     RELEASE:    bltrack,trainlength:
                POTROAD,1:
                POTRTRACK,1;
189$    DELAY:      spotting time;                  Delay time for spotting in yard
190$    RELEASE:    blengine,1;
89$     TALLY:      HYUNDAI WEST,int(timein),1;  Tally time in system
151$    WRITE,      scheduleoutput,free:
                Tnow,
                traintype,
                direction,
                departyard,
                trainlength;
163$    COUNT:      HYUNDAI WEST OUT,1:NEXT(195$);  Count trains leaving

29$     DELAY:      departyard-tnow:NEXT(28$);      Wait for scheduled time
```

Commercial

```
99$     CREATE,     1,0:15,100000;          Create every 15 minutes
187$    BRANCH,     1:
                If,TRACKRELEASE .GT. nr(BLTRACk),188$,Yes:  Check track to
                If,TRACKRELEASE .LE. nr(BLTRACK),105$,Yes;  release
188$    RELEASE:    BLTRACK,nr(bltrack);
102$    BRANCH,     1:      Check day and time of day
                If,tnow .ge. 9661,125$,Yes:
                If,tnow .ge. 9181 .and. tnow .le. 9660,124$,Yes:
                If,tnow .ge. 8641 .and. tnow .le. 9180,123$,Yes:
                If,Tnow .ge. 8281 .and. tnow .le. 8640,122$,Yes:
                If,tnow .ge. 7621 .and. tnow .le. 8280,121$,Yes:
                If,tnow  .ge. 7201 .and. tnow .le. 7620,120$,Yes:
                If,tnow .ge. 6721 .and. tnow .le.7200,119$,Yes:
                If,tnow .ge. 6241 .and.tnow .le. 6720,118$,Yes:
                If,tnow .ge. 5761 .and.  tnow .le. 6240,117$,Yes:
                If,tnow .ge. 5341 .and. tnow .le. 5760,116$,Yes:
                If,tnow .ge. 4801 .and. tnow .le. 5340,115$,Yes:
                If,tnow .ge. 4321 .and. tnow .le. 4800,114$,Yes:
                If,tnow .ge. 3841 .and. tnow .le. 4320,113$,Yes:
                If,tnow .ge. 3361 .and. tnow .le.3840,112$,Yes:
                If,tnow .ge. 2881 .and. tnow .le. 3360,111$,Yes:
                If,tnow .ge.2461 .and. tnow .le. 2880,110$,Yes:
                If,tnow .ge. 1981 .and.  tnow .le. 2460,109$,Yes:
```

```
              If,tnow .ge.1441 .and. tnow .le. 1980,108$,No:
              If,tnow  .Ge. 961 .and. tnow .le .1440,107$,No:
              If,tnow  .Ge. 541 .and. tnow.Le. 960,106$,Yes:
              If,tnow .Ge.0 .and.tnow  .Le.540,103$,Yes;
125$     ASSIGN:     track#=SA24;
183$     ASSIGN:     TRACK#=TRACK#+INCREASE;
184$     BRANCH,      1:
              If,TRACK# .GT. 0,100$,Yes:
              If,TRACK# .LE. 0,185$,Yes;
100$     QUEUE,      COMMERCIALQUEUE;
101$     SEIZE,      1:
              BLTRACK,track#;
186$     ASSIGN:     TRACKRELEASE=TRACK#;
104$     DISPOSE;

185$     ASSIGN:     TRACK#=8000:NEXT(100$);

124$     ASSIGN:     track#=SA17:NEXT(183$);

123$     ASSIGN:     track#=SA09:NEXT(183$);

122$     ASSIGN:     track#=FR24:NEXT(183$);

121$     ASSIGN:     track#=FR18:NEXT(183$);

120$     ASSIGN:     track#=FR07:NEXT(183$);

119$     ASSIGN:     track#=th24:NEXT(183$);

118$     ASSIGN:     track#=th16:NEXT(183$);

117$     ASSIGN:     track#=Th08:NEXT(183$);

116$     ASSIGN:     track#=we24:NEXT(183$);

115$     ASSIGN:     track#=we17:NEXT(183$);

114$     ASSIGN:     track#=we08:NEXT(183$);

113$     ASSIGN:     track#=tu24:NEXT(183$);

112$     ASSIGN:     track#=tu16:NEXT(183$);

111$     ASSIGN:     track#=tu08:NEXT(183$);
```

Assign BL track to seize in accordance day and time

```
110$    ASSIGN:    track#=mon24:NEXT(183$);

109$    ASSIGN:    track#=mon15:NEXT(183$);

108$    ASSIGN:    track#=Mon09:NEXT(183$);

107$    ASSIGN:    track#=SUN24:NEXT(183$);

106$    ASSIGN:    track#=SUN16:NEXT(183$);

103$    ASSIGN:    track#=SUN09:NEXT(183$);

105$    RELEASE:   BLTRACK,TRACKRELEASE:NEXT(102$);


191$    CREATE,    1,0.0;          Initial tracks utilized in SIM
192$    QUEUE,     SIMramp;
193$    SEIZE,     1:
                Simtransfertrack,5000:
                SIMRamptrack,2000;
194$    DISPOSE;
```

Arena Experiment Code

```
ATTRIBUTES:  1,Traintype:        Type of Train NIM, SIM Hyundai
        2,direction:             Fife, Beltline, BF
        3,trainlength:           Length in feet
        4,Departyard:            Scheduled time to depart
        5,priority:
        6,timein:
        7,ramplength:            SIM track length on ramp
        8,transferlength;        SIM transfer length

FILES:      2,scheduleoutput,"output1",Sequential(),WKS File,Ignore,No,Hold:
        TrainSchedule,"2020.wks",Sequential(),WKS File,Rewind,No,Hold;

VARIABLES:  2,track#,0:          Commercial track in beltline
        3,track:
        4,rampavailable,0:       Amount of track available on SIM ramp
        5,cleartransfer:         Amount of track to clear transfer yard
        6,SCHEDULESIZE,114:      Total number of trains in system for a replication
```

7,TRACKRELEASE: Total amount of commercial track to releas

QUEUES: DepartNIM,FirstInFirstOut: Trains departing from the NIM
SIMEastq,FirstInFirstOut: Eastbound trains from the SIM
BLQUEUE,FirstInFirstOut(),shared: Trains moving into beltline
NIMQUEUE,FirstInFirstOut(),shared: Trains moving into NIM
COMMERCIALQUEUE,FirstInFirstOut: Entity waiting to seize beltline track
HYUNDAIYARD,FirstInFirstOut: Trains waiting to depart yard
SIMRAMPTRACKQ,FirstInFirstOut(),shared: Trains waiting to seize SIM ramp
HYUNDAIINQ,FirstInFirstOut: Trains waiting to move in yard
MLQUEUE,FirstInFirstOut(),shared: Trains waiting on main line

bfjunction,FirstInFirstOut(),shared: Trains waiting for bullfrog

SIMramp,FirstInFirstOut(),shared: Trains waiting to release SIM track
simtransfer,FirstInFirstOut; Trains waiting to seize transfer track

RESOURCES: 1,annietrack,Capacity(2,),-,Stationary: # of Annie tracks
3,Simtransfertrack,Capacity(10600,),-,Stationary: SIM transfer track capacity
4,SIMRamptrack,Capacity(8634,),-,Stationary: Ramp track capacity i
5,SIMtrack,Capacity(1,),-,Stationary: # of SIM access tracks
6,bfjun,Capacity(2,),-,Stationary: # of access points at BF
7,POTROAD,Capacity(1,),-,Stationary: # of POT road
8,POTRTRACK,Capacity(1,),-,Stationary: # of track across POT RD
9,BLTRACK,Capacity(54584,),-,Stationary: Capacity of beltline
10,MLPOWER,Capacity(12,),-,Stationary: Main line power capacity
11,NIMTRACK,Capacity(26700,),-,Stationary: Capacity of NIM track
12,blengine,Capacity(5,),-,Stationary: Beltline engine capacity
13,e11st,Capacity(2,),-,Stationary: # of tracks across 11th St
14,lincolnave,Capacity(2,),-,Stationary: # of tracks across Lincoln Ave

hytrack,Capacity(8624,),-,Stationary; Capacity of Hyundai yard

STATIONS: 1,NIMEAST: Different sub models
2,simeast:
3,HYUNDAIEAST:
4,Commercial:
5,NIMWEST:
6,HYUNDAIW:
7,SIMWEST;

COUNTERS: 1,HYUNDAI EASTBOUND,,Replicate: Counters for all sub models
2,HYUNDAI WESTBOUND,,Replicate: (entering and departing)

3,INSYSTEM,,Replicate:
4,NIM WESTBOUND,,Replicate:
5,SIM EASTBOUND1,,Replicate:
6,SIM WESTBOUND,,Replicate:
7,NIM EASTBOUND,,Replicate:
8,NIM BF OUT,,Replicate:
9,NIM BL OUT,,Replicate:
10,NIM FIFE OUT,,Replicate:
11,NIM WEST OUT,,Replicate:
12,SIM EAST OUT,,Replicate:
13,HYUNDAI BF OUT,,Replicate:
14,HYUNDAI WEST OUT,,Replicate:
15,SIM WEST OUT,,Replicate:
16,HYUNDAI BL OUT,,Replicate:
19,OUT SYSTEM,,Replicate;

TALLIES: 1,NIM TO BF MEET,"NIMBF.dat": Tallies for all routes in the program
2,hYUNDAI TO BF MEET,"hybf.dat":
3,HYUNDAI WEST,"HYWEST.dat":
4,HYUNDAI BF EAST,"HYdBFeast.dat":
5,NIM WEST,"Nimwest.dat":
7,simramptally:
8,SIM EAST,"simeast.dat":
9,NIM TO BELTLINE,"nimtobl.dat":
10,NIM TO FIFE,"nimtofife.dat":
11,NIM TO BF,"nimtobf.dat":
12,HYUNDAI BL EAST,"HYBLEAST.DAT";

DSTATS collect statistics on all queues and resource utilization

DSTATS: 1,NR(BLTRACK),Tacoma Rail Track Resource,"NRBLTRACK.dat":
2,NR(NIMTRACK),NIM Track Resource,"NRNIMTRACK.dat":
5,NR(POTROAD)*100,Port of Tacoma RD Yrack Utilization,"NRPOTRD.dat":
6,NR(LincolnAVE),Lincoln Ave Resource,"NRLINave.dat":
7,NR(e11st),East 11th Street Resource,"NRE11ST.dat":
8,NR(Hytrack),Hyundai Yard Track Resource,"NRHYTRACK.dat":
9,NR(SIMtransfertrack),SIM Transfer track Resource,"NRsimtranfertrack.dat":
10,NR(SIMTRACK),SIM Track Resource,"NRSIMTRACK.dat":
11,NQ(SIMRAMPTRACK),Sim Ramp Track Q,"nqSimramptrack":
12,NQ(Hyundaitrack),Hyundai Track Q,"NQHYUNdaitrack.dat":
13,NQ(simtransfer),SIM Transfer Q,"NQsimtransfer":
14,NQ(Simramp),SIM Ramp Q,"NQSIMRAMPTRACK":
15,NQ(Simeastq),SIM East Q,"NQSIMEASTQ":
16,NQ(Hyundaiinq),Hyundai Inbound Q,"NQHyundaiINBOUNDQ.dat":

17,NQ(Hyundaiyard),Hyundai Yard Q,"NQHYUDAIYARD.dat":
18,NQ(NIMqueue),NIM Q,"NQNIMQ.dat":
19,NQ(NIMINCOMING),NIM Incoming Q,"NQNIMINCOMING.dat":
20,NQ(BLQUEUE),Beltline Q,"NQBELTLINEQ.dat":
21,NQ(MLQUEUE),Main Line Q,"NQMAINLINEQ.dat":
22,nq(bfjunction),Bull Frog Junction Q,"NQBullfrogJUNCTIONQ.dat":
23,NQ(DepartNIM),Departing NIM Q,"NQDepartnimQ.dat":
24,NR(BFJUN)*(100/2),Bull frog Junction Utilization,"nrbfjun.DAT":
25,NR(simramptrack),SIMRAMP TRACK UTILIZATION,"nrsimramp":
26,NR(annietrack)*(100/2),Annie Tracks Utilization:
27,nr(BLENGINE),TACOMA RAIL ENGINE
UTILIZATION,"NRBLENGINE":
28,NR(MLPOWER),MAIN LINE ENGINE uTILIZATION,"NRMLENGINE";

OUTPUTS: 1,dmax(22),"22",Bullfrog Junction Q Max: Outputs for key statistics
2,davg(24),"24",Bullfrog Junction Average Utilization:
3,DMAX(23),"23",Depart NIM Q Max:
4,DMAX(20),"20",Tacoma Rail Q Max:
5,DMAX(16),"16",Hyundai Inbound Max:
6,DMAX(21),"21",Mainline Q Max:
7,dmax(19),"19",Nim Westbound QMax:
8,DMAX(18),"18",NIM Eastbound Q Max:
9,DMAX(17),"17",Hyundai Yard Q Max:
11,DMAX(14),"14",SIM Ramp Q Max:
12,DMAX(13),"13",SIM Transfer Q Max:
13,DMAX(12),"12",Hyundai Track Q Max:
14,DAVG(5),"5",POT Road AVG UTIL:
15,DAVG(1),"1A",Tacoma Rail AVG Util:
16,DMAX(1),"1",Tacoma Rail Max Track Usage:
17,DAVG(26),"26",Annie Track Avg Util:
18,DMAX(11),"11",SIM Ramp Q Max;

REPLICATE, 30,0.0,11080,Yes,Yes,0.0; Replicate for 30 times, one week in length

EXPRESSIONS: 2,BFCLEAR,(1/TRIA(352,440,616))*trainlength: Time to clear BF
3,NIMMVT,tria(20,30,50)+(1/TRIA(352,440,616))*TRAINLENGTH: Time to move from the NIM
4,BFTOBL,tria(10,15,20): Time from beltline to bullfrog
5,INBL,tria(5,10,20)+(1/tria(352,440,616))*trainlength: Time spent in beltline
6,BLTONIM,tria(30,40,50): Time from beltline to NIM
7,HYTOBF,Tria(30,45,60): Hyundai to BF
8,simout,tria(30,45,60)+(1/tria(352,440,616))*trainlength: Time to

move from the SIM

10,waitbf,Tria(0,15,45): Time waiting at BF

The following expressions describe beltline utilization during different time periods during the week
13,SUN09,15800+10800*Beta(0.229,0.204):
14,SUN16,Uniform(13200,27200):
15,sun24,13600+EXponential(2880):
16,MON09,13100+exponential(3310):
17,mon15,uniform(10900,28000):
18,MON24,uniform(18400,28800):
19,tu08,uniform(21900,28900):
20,tu16,normal (25400,3660):
21,tu24,uniform(23200,35600):
22,we08,uniform(28500,36500):
23,we17,Triangular(23100,25400,30800):
24,we24,Triangular(26200,30600,35000):
25,th08,triangular(15400,31300,37000):
26,th16,Normal(23200,4230):
27,th24,24000+erla(1250,1):
28,fr07,TRiangular(20800,25500,25900):
29,fr18,uniform(14100,25200):
30,FR24,Normal(16400,5610):
31,SA09,triangular(12500,13500,22500):
32,sa17,12300+exponential(568):
33,SA24,Triangular(11800,15600,16000):

34,NIMYARDDELAY,-.0001+190*bETA(0.477,2.46): Delay in NIM
36,simyarddelay,tria(5, 15, 30)+ (1/tria(352,440,616))*trainlength: Delay in SIM
37,NImdifference,trainlength-NR(nimtrack): Difference in train length and track utilized in NIM
38,hydifference,trainlength-NR(hytrack): Difference in Hyundai track and train length
39,simrampdiff,trainlength-NR(simramptrack):Difference in SIM ramp track utilized and train length
40,transferlen,trainlength-(MR(simramptrack)-NR(simramptrack)): Difference in train length and available track on ramp
41,ramplen,MR(simramptrack)-NR(simramptrack): Available ramp length
42,BLTOHY,TRIA(5,10,30)+(1/TRIA(352,440,616)*TRAINLENGTH): Beltline to Hyundai yard
43,hyarddelay,-.0001+190*bETA(0.477,2.46): Hyundai yard delay

44,BELTLINE DELAY,UNIFORM(5,10):	Beltline delay
45,fifedelay,tria(5,10,30):	Delay in Fife
47,spotting time,triangular(15,25,30):	Time to spot in Hyund

Appendix B Rail Simulator Schedule Builder Code

```
0$      CREATE,.    NIMEAST;                              NIM Eastbound Trains
1$      ASSIGN:     direction=dir:                        Assign direction
            traintype=1;                                  and train type
24$     BRANCH,     1:
            If,DIRECTION.EQ.3,27$,Yes:                    Send to branch for
            If,DIRECTION.EQ. 2,25$,Yes:                   each direction
            If,DIRECTION .EQ. 1,26$,Yes;
27$     ASSIGN:     TRAINLENGTH=NIMEBLLENGTH:             NIM east beltline
                                                          length
            DEPARTYARD=NIMEBLTIME;                        and time assigned
2$      WRITE,      TRAINSCHEDULE,FREE:                   Write to file
            TRAINTYPE,
            DIRECTION,
            DEPARTYARD,
            TRAINLENGTH;
18$     DISPOSE;

25$     ASSIGN:     TRAINLENGTH=NIMEBFLENGTH:             NIM east to bullfrog
            DEPARTYARD=NIMEBFTIME:NEXT(2$);               Assign depart time

26$     ASSIGN:     TRAINLENGTH=NIMEFLENGTH:              Assign train length
            DEPARTYARD=NIMEFTIME:NEXT(2$);


3$      CREATE,     NIMWEST;                              NIM Westbound Trains
4$      ASSIGN:     TRAINTYPE=5:
            TRAINLENGTH=NIMWLENGTH:                       Assign length and time
            DEPARTYARD=NIMWTIME;
13$     WRITE,      TRAINSCHEDULE,FREE:                   Write to  file
            TRAINTYPE,
            DIRECTION,
            DEPARTYARD,
            TRAINLENGTH;
19$     DISPOSE;

5$      CREATE,     SIMEAST;                              SIM Eastbound Trains
6$      ASSIGN:     TRAINTYPE=2:
            TRAINLENGTH=SIMELENGTH:                       Assign length and time
            DEPARTYARD=SIMETIME;
```

```
14$     WRITE,      TRAINSCHEDULE,FREE:               Write to file
              TRAINTYPE,
              DIRECTION,
              DEPARTYARD,
              TRAINLENGTH;
20$     DISPOSE;


7$      CREATE,     SIMWEST;                          SIM Westbound Trains
8$      ASSIGN:     TRAINTYPE=6:
              TRAINLENGTH=SIMWLENGTH:                 Assign length and time
              DEPARTYARD=SIMWTIME;
15$     WRITE,      TRAINSCHEDULE,FREE:               Write to file
              TRAINTYPE,
              DIRECTION,
              DEPARTYARD,
              trainlength;
21$     DISPOSE;


9$      CREATE,     HYEAST;                           Hyundai Eastbound
Trains
10$     ASSIGN:     TRAINTYPE=3:                      Determine direction
              direction=hyeastdir;
28$     BRANCH,     1:                                Send to branch
              If,direction .eq. 1,29$,Yes:            for direction
              If,direction .eq. 2,30$,Yes;
29$     ASSIGN:     departyard=hyeast contract time:  Assign time and length
              trainlength=hyeast contract length;     for BF meet
16$     WRITE,      TRAINSCHEDULE,FREE:               Write to file
              TRAINTYPE,
              DIRECTION,
              DEPARTYARD,
              TRAINLENGTH;
22$     DISPOSE;

30$     ASSIGN:     trainlength=hyeastlength:         Assign time and length for
              departyard=hyeasttime:NEXT(16$);        beltline meet


11$     CREATE,     HYWEST;                           Hyundai Westbound Trains
12$     ASSIGN:     TRAINTYPE=7:
              TRAINLENGTH=HYWLENGTH:                  Assign time and length
              DEPARTYARD=HYWTIME;
```

```
17$      WRITE,      TRAINSCHEDULE,FREE:          Erite to file
                TRAINTYPE,
                DIRECTION,
                DEPARTYARD,
                TRAINLENGTH;
23$      DISPOSE;
```

ATTRIBUTES: 1,TRAINTYPE: Type of train NIM, SIM Hyundai East/West

□ 2,DIRECTION,0: Fife, BF, BL

□ 3,TRAINLENGTH: Length in feet.

□ 4,DEPARTYARD; Scheduled time

FILES: 1,TRAINSCHEDULE,"1999",Sequential(),WKS File,Dispose,No,Hold;

REPLICATE, 1,0.0,1000,Yes,Yes,10;

```
EXPRESSIONS: 1,HYWEST,11:      # Hyundai Westbound
        3,SIMEAST,6:           # SIM Eastbound
        4,SIMWEST,9:           # Sim Westbound
        5,NIMEAST,10:          # NIM Eastbound
        7,DIR,DISCRETE(.15,1,.62,2,1,3): Direction for NIM Eastbound
        8,HYEAST,5:            # Hyundai eastbound
        9,SIMETIME,360+9600*BETA(0.485,.334): SIM East Depart time
        10,SIMWLENGTH,TRIANGULAR(58,1120,3000): SIM West Length
        11,SIMWTIME,NORMAL(6970,2390): SIM West Depart time
        12,HYWLENGTH,tria(58,1120,2100): Hyundai West Length
        13,HYWTIME,uniform(200,10079): Hyundai West TIme
        14,HYELENGTH,58+6890*beta(.576,.583): Hyundai East Length
        15,HYETIME,uniform(4320, 7200)     Hyundai East Time:
        16,NIMWLENGTH,289+ERLA(1780,1): NIM west length
        17,NIMWTIME,4200+5700*BETA(1.14,1.54): NIM West time
        18,NIMEBFLENGTH,TRIA(432,6310,7000): NIM BF length
        19,NIMEBFTIME,TRIA(4350,4800,9720): NIM BF Time
        20,NIMEFLENGTH,NORMAL(4080,1970): NIM Fife length
        21,NIMEFTIME,UNIFORM(7350,10000): NIM Fife Time
        22,hyeastdir,Discrete(.2,1,1,2):   Hyundai east direction
        23,NIMEBLTIME,NORMAL(7510,1730): NIM BL Time
        24,hyeast contract length,uniform(4000,6000): Nyundai east contract length
        25,NIMWEST,4:                      # NIM West
        26,hyeasttime,discrete(.25, Mo,.50, T,.75,t1,1,f): Hyundai east time
```

```
27,MO,triangular(1900,2340,2800):            MO time
28,t1,triangular(3700,4500,5000):            t1 time
29,t,triangular(6100,6660,7200):             t time
30,f,triangular(7600,8100,8600):             f time
31,hyeast contract time,triangular(4000,4800,5600):
33,NIMEBLLENGTH,TRIA(116,688,5840):
35,SIMELENGTH,58+6890*bETA(.576,.583):
44,hyeastlength,uniform(500,2500);
```

Appendix C Replication Output 1999-2020

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **1999** Run execution date : 7/11/1999
Analyst: Model revision date: 7/11/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	74.277	(Insuf)	53.715	109.46	8
hYUNDAI TO BF MEET	104.61	(Insuf)	104.61	104.61	1
HYUNDAI WEST	50.129	(Insuf)	27.186	136.74	11
HYUNDAI BF EAST	115.23	(Insuf)	115.23	115.23	1
NIM WEST	61.082	(Insuf)	58.274	63.766	4
simramptally	70.213	(Insuf)	17.228	131.58	8
SIM EAST	74.493	(Insuf)	59.872	97.669	6
NIM TO BELTLINE	94.387	(Insuf)	94.387	94.387	1
NIM TO FIFE	134.14	(Insuf)	134.14	134.14	1
NIM TO BF	85.172	(Insuf)	61.618	124.74	8
HYUNDAI BL EAST	72.279	(Insuf)	30.956	171.01	4

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	1.0000
Bullfrog Junction Aver	6.3400
Depart NIM Q Max	.00000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	.00000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	3.0541
Tacoma Rail AVG Util	27122.
Tacoma Rail Max Track	39137.

Annie Track Avg Util	3.2928
SIM Ramp Q Max	.00000

1999a ARENA Simulation Results

Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: Run execution date : 7/11/1999
Analyst: Model revision date: 7/11/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	90.450	(Insuf)	53.715	191.95	8
hYUNDAI TO BF MEET	69.762	(Insuf)	69.762	69.762	1
HYUNDAI WEST	44.358	(Insuf)	34.385	54.351	11
HYUNDAI BF EAST	80.008	(Insuf)	80.008	80.008	1
NIM WEST	60.756	(Insuf)	58.274	63.196	4
simramptally	86.682	(Insuf)	17.228	172.25	8
SIM EAST	74.493	(Insuf)	59.872	97.669	6
NIM TO BELTLINE	94.387	(Insuf)	94.387	94.387	1
NIM TO FIFE	134.14	(Insuf)	134.14	134.14	1
NIM TO BF	101.13	(Insuf)	61.618	201.97	8
HYUNDAI BL EAST	73.188	(Insuf)	32.652	126.89	4

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	1.0000
Bullfrog Junction Aver	7.0152
Depart NIM Q Max	.00000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	1.0000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	.00000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	2.9119
Tacoma Rail AVG Util	27018.
Tacoma Rail Max Track	42900.

Annie Track Avg Util	3.3496
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2000** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	108.27	(Insuf)	61.139	153.54	9
hYUNDAI TO BF MEET	147.93	(Insuf)	147.93	147.93	1
HYUNDAI WEST	45.101	(Insuf)	29.148	74.189	15
HYUNDAI BF EAST	158.04	(Insuf)	158.04	158.04	1
NIM WEST	69.106	(Insuf)	56.305	96.306	4
simramptally	122.94	(Insuf)	36.785	272.80	8
SIM EAST	74.606	(Insuf)	63.557	82.785	6
NIM TO BELTLINE	106.81	(Insuf)	106.81	106.81	1
NIM TO FIFE	136.31	(Insuf)	136.31	136.31	1
NIM TO BF	119.40	(Insuf)	70.437	164.13	9
HYUNDAI BL EAST	77.159	(Insuf)	33.519	151.78	6

.00000

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	1.0000
Bullfrog Junction Aver	8.7025
Depart NIM Q Max	.00000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000
Nim Westbound QMax	1.0000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	.00000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	4.0358
Tacoma Rail AVG Util	27705.

Tacoma Rail Max Track	42110.
Annie Track Avg Util	3.9684
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2001** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	107.89	(Insuf)	65.047	162.95	9
hYUNDAI TO BF MEET	135.87	(Insuf)	118.60	153.14	2
HYUNDAI WEST	41.083	(Insuf)	28.055	49.946	17
HYUNDAI BF EAST	146.05	(Insuf)	129.34	162.75	2
NIM WEST	62.303	(Insuf)	59.245	64.728	4
simramptally	99.536	(Insuf)	33.109	192.46	8
SIM EAST	85.887	(Insuf)	75.441	100.88	6
NIM TO BELTLINE	93.444	(Insuf)	93.444	93.444	1
NIM TO FIFE	128.29	(Insuf)	128.29	128.29	1
NIM TO BF	118.45	(Insuf)	78.138	171.14	9
HYUNDAI BL EAST	49.942	(Insuf)	26.586	105.16	6

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	1.0000
Bullfrog Junction Aver	8.9223
Depart NIM Q Max	.00000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	4.5882
Tacoma Rail AVG Util	26919.
Tacoma Rail Max Track	45005.

Annie Track Avg Util	3.5149
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2002** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	104.91	(Insuf)	56.420	220.09	9
hYUNDAI TO BF MEET	97.432	(Insuf)	83.173	123.88	3
HYUNDAI WEST	43.101	(Insuf)	31.749	61.335	17
HYUNDAI BF EAST	107.77	(Insuf)	93.217	132.67	3
NIM WEST	65.306	(Insuf)	59.245	72.073	5
simramptally	111.74	(Insuf)	38.761	234.81	8
SIM EAST	101.93	(Insuf)	62.415	145.83	6
NIM TO BELTLINE	105.28	(Insuf)	105.28	105.28	1
NIM TO FIFE	75.121	(Insuf)	75.121	75.121	1
NIM TO BF	115.27	(Insuf)	66.197	233.95	9
HYUNDAI BL EAST	49.599	(Insuf)	24.949	87.371	5

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	1.0000
Bullfrog Junction Aver	10.071
Depart NIM Q Max	.00000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	5.3635
Tacoma Rail AVG Util	27290.
Tacoma Rail Max Track	43902.

Annie Track Avg Util 3.9066
SIM Ramp Q Max .00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2003** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	126.62	(Insuf)	61.908	235.92	11
hYUNDAI TO BF MEET	103.61	(Insuf)	85.312	126.16	3
HYUNDAI WEST	44.599	(Insuf)	33.811	55.481	18
HYUNDAI BF EAST	113.29	(Insuf)	92.718	135.17	3
NIM WEST	58.525	77.849	5		
simramptally	82.555	(Insuf)	20.935	206.97	6
SIM EAST	91.144	(Insuf)	68.817	129.65	7
NIM TO BELTLINE	93.632	(Insuf)	93.632	93.632	1
NIM TO FIFE	87.841	(Insuf)	87.841	87.841	1
NIM TO BF	136.92	(Insuf)	67.557	243.56	11
HYUNDAI BL EAST	88.291	(Insuf)	33.771	145.80	5

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	2.0000
Bullfrog Junction Aver	10.389
Depart NIM Q Max	1.0000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000
Nim Westbound QMax	1.0000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	5.7837
Tacoma Rail AVG Util	26987.

Tacoma Rail Max Track	41440.
Annie Track Avg Util	4.6441
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: 2004 Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	130.03	(Insuf)	56.649	235.92	11
hYUNDAI TO BF MEET	103.61	(Insuf)	85.312	126.16	3
HYUNDAI WEST	43.685	(Insuf)	33.811	53.995	19
HYUNDAI BF EAST	113.29	(Insuf)	92.718	135.17	3
NIM WEST	68.144	(Insuf)	60.580	81.466	5
simramptally	83.206	(Insuf)	24.841	206.97	6
SIM EAST	91.675	(Insuf)	69.932	132.24	7
NIM TO BELTLINE	93.632	(Insuf)	93.632	93.632	1
NIM TO FIFE	101.06	(Insuf)	101.06	101.06	1
NIM TO BF	140.75	(Insuf)	61.583	243.56	11
HYUNDAI BL EAST	99.784	(Insuf)	47.451	145.80	5

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	2.0000
Bullfrog Junction Aver	10.243
Depart NIM Q Max	1.0000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000
Nim Westbound QMax	1.0000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	5.8627
Tacoma Rail AVG Util	26920.
Tacoma Rail Max Track	41440.

Annie Track Avg Util	4.7037
SIM Ramp Q Max	. 00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2005** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	113.29	(Insuf)	57.463	206.69	10
hYUNDAI TO BF MEET	97.145	(Insuf)	80.686	113.60	2
HYUNDAI WEST	39.115	(Insuf)	28.066	52.609	19
HYUNDAI BF EAST	110.06	(Insuf)	94.707	125.41	2
NIM WEST	66.763	(Insuf)	61.982	71.012	5
simramptally	74.544	(Insuf)	37.201	97.073	5
SIM EAST	91.353	(Insuf)	61.299	147.34	7
NIM TO BELTLINE	101.78	(Insuf)	90.887	112.67	2
NIM TO FIFE	68.793	(Insuf)	68.793	68.793	1
NIM TO BF	123.87	(Insuf)	68.285	221.81	10
HYUNDAI BL EAST	67.135	(Insuf)	27.733	109.94	7

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	4.0000
Bullfrog Junction Aver	10.548
Depart NIM Q Max	.00000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	4.9247

Tacoma Rail AVG Util	26860.
Tacoma Rail Max Track	42723.
Annie Track Avg Util	4.5508
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2006** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	90.176	(Insuf)	59.841	130.01	10
hYUNDAI TO BF MEET	80.686	113.60	2		
HYUNDAI WEST	41.410	(Insuf)	28.066	55.433	20
HYUNDAI BF EAST	110.06	(Insuf)	94.707	125.41	2
NIM WEST	67.062	(Insuf)	58.877	70.997	5
simramptally	74.544	(Insuf)	37.201	97.073	5
SIM EAST	89.934	(Insuf)	52.599	136.92	7
NIM TO BELTLINE	94.643	(Insuf)	90.237	99.049	2
NIM TO FIFE	151.63	(Insuf)	151.63	151.63	1
NIM TO BF	101.04	(Insuf)	71.425	142.92	10
HYUNDAI BL EAST	66.816	(Insuf)	27.733	159.60	7

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	1.0000
Bullfrog Junction Aver	10.387
Depart NIM Q Max	.00000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	00000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000

Hyundai Track Q Max	.00000
POT Road AVG UTIL	5.4083
Tacoma Rail AVG Util	26832.
Tacoma Rail Max Track	42723.
Annie Track Avg Util	4.6385
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2007** Run execution date : 7/10/1999
Analyst: . Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	125.97	(Insuf)	42.795	246.49	11
hYUNDAI TO BF MEET	132.30	(Insuf)	96.685	167.92	2
HYUNDAI WEST	48.295	(Insuf)	37.012	138.94	21
HYUNDAI BF EAST	141.92	(Insuf)	106.49	177.36	2
NIM WEST	63.562	(Insuf)	59.633	68.312	6
simramptally	146.21	(Insuf)	39.458	255.06	10
SIM EAST	86.442	(Insuf)	60.846	129.59	7
NIM TO BELTLINE	124.34	(Insuf)	111.27	137.41	2
NIM TO FIFE	113.12	(Insuf)	113.12	113.12	1
NIM TO BF	135.82	(Insuf)	50.443	255.20	11
HYUNDAI BL EAST	62.739	(Insuf)	16.488	133.57	7

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	3.0000
Bullfrog Junction Aver	12.731
Depart NIM Q Max	.00000
Tacoma Rail Q Max	. 00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	.00000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000

Hyundai Track Q Max	00000
POT Road AVG UTIL	6.6193
Tacoma Rail AVG Util	26608.
Tacoma Rail Max Track	43424.
Annie Track Avg Util	5.3322
SIM Ramp Q Max	.00000

ARENA Simulation Results
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Summary for Replication 1 of 30

Project: **2008** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	85.059	(Insuf)	55.492	143.57	11
hYUNDAI TO BF MEET	88.242	(Insuf)	88.242	88.242	1
HYUNDAI WEST	42.005	(Insuf)	36.558	49.122	21
HYUNDAI BF EAST	97.966	(Insuf)	97.966	97.966	1
NIM WEST	64.104	(Insuf)	56.069	68.237	6
simramptally	140.13	(Insuf)	48.547	245.63	12
SIM EAST	84.086	(Insuf)	67.844	104.61	7
NIM TO BELTLINE	98.806	(Insuf)	82.100	130.54	3
NIM TO FIFE	165.35	(Insuf)	165.35	165.35	1
NIM TO BF	95.284	(Insuf)	64.502	159.80	11
HYUNDAI BL EAST	47.702	(Insuf)	19.902	126.56	9

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	.00000
Bullfrog Junction Aver	12.844
Depart NIM Q Max	1.0000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000

Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	5.2714
Tacoma Rail AVG Util	29419.
Tacoma Rail Max Track	48325.
Annie Track Avg Util	5.3938
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: Run execution date : 7/10/1999
Analyst: **2009** Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	91.754	(Insuf)	45.223	163.48	12
hYUNDAI TO BF MEET	114.57	(Insuf)	53.020	178.57	5
HYUNDAI WEST	47.366	(Insuf)	35.467	87.375	22
HYUNDAI BF EAST	125.69	(Insuf)	66.542	188.41	5
NIM WEST	65.895	(Insuf)	62.014	71.294	6
simramptally	84.271	(Insuf)	21.725	237.06	13
SIM EAST	82.620	(Insuf)	70.382	93.977	7
NIM TO BELTLINE	89.524	(Insuf)	52.999	127.35	3
NIM TO FIFE	68.734	(Insuf)	68.734	68.734	1
NIM TO BF	101.95	(Insuf)	57.187	175.91	12
HYUNDAI BL EAST	52.739	(Insuf)	30.288	79.887	5

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	2.0000
Bullfrog Junction Aver	10.800
Depart NIM Q Max	.00000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000
Nim Westbound QMax	.00000

NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	8.2573
Tacoma Rail AVG Util	27804.
Tacoma Rail Max Track	44702.
Annie Track Avg Util	5.3064
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2010** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	141.10	(Insuf)	77.485	271.17	11
hYUNDAI TO BF MEET	67.622	(Insuf)	67.622	67.622	1
HYUNDAI WEST	43.762	(Insuf)	35.130	55.068	23
HYUNDAI BF EAST	78.326	(Insuf)	78.326	78.326	1
NIM WEST	64.214	(Insuf)	59.701	71.418	6
simramptally	144.17	(Insuf)	31.064	399.47	14
SIM EAST	102.45	(Insuf)	72.628	207.42	8
NIM TO BELTLINE	93.776	(Insuf)	46.005	169.56	4
NIM TO FIFE	114.79	(Insuf)	114.79	114.79	1
NIM TO BF	150.41	(Insuf)	88.110	276.03	11
HYUNDAI BL EAST	50.736	(Insuf)	22.915	105.28	9

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	3.0000
Bullfrog Junction Aver	13.7938
Depart NIM Q Max	1.0000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	. 00000
Mainline Q Max	1.0000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	.00000

SIM Ramp Q Max	.00000
SIM Transfer Q Max	..00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	5.3912
Tacoma Rail AVG Util	29610.
Tacoma Rail Max Track	48224.
Annie Track Avg Util	6.7117
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2011** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	126.62	(Insuf)	52.518	286.33	13
hYUNDAI TO BF MEET	73.783	(Insuf)	73.783	73.783	1
HYUNDAI WEST	49.706	(Insuf)	33.277	98.546	24
HYUNDAI BF EAST	83.797	(Insuf)	83.797	83.797	1
NIM WEST	61.930	(Insuf)	58.547	66.592	7
simramptally	152.14	(Insuf)	39.035	222.16	7
SIM EAST	79.224	(Insuf)	51.961	105.25	8
NIM TO BELTLINE	143.17	(Insuf)	74.353	308.68	4
NIM TO FIFE	126.52	(Insuf)	126.52	126.52	1
NIM TO BF	137.43	(Insuf)	62.981	301.46	13
HYUNDAI BL EAST	53.873	(Insuf)	28.712	145.41	10

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	3.0000
Bullfrog Junction Aver	13.6606
Depart NIM Q Max	1.0000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	1.0000

Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	.00000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	6.2033
Tacoma Rail AVG Util	31478.
Tacoma Rail Max Track	48911.
Annie Track Avg Util	6.6005
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2012** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	146.54	(Insuf)	65.949	436.82	12
hYUNDAI TO BF MEET	102.13	(Insuf)	75.074	135.81	5
HYUNDAI WEST	46.651	(Insuf)	31.780	70.902	24
HYUNDAI BF EAST	113.23	(Insuf)	83.961	150.52	5
NIM WEST	65.210	(Insuf)	56.967	70.099	7
simramptally	205.72	(Insuf)	39.597	387.96	7
SIM EAST	92.813	(Insuf)	60.577	150.52	8
NIM TO BELTLINE	154.73	(Insuf)	57.086	343.19	4
NIM TO FIFE	64.832	(Insuf)	64.832	64.832	1
NIM TO BF	157.54	(Insuf)	76.494	452.39	12
HYUNDAI BL EAST	32.405	(Insuf)	23.700	50.406	6

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	5.0000
Bullfrog Junction Aver	16.383
Depart NIM Q Max	.00000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000

Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	8.2639
Tacoma Rail AVG Util	28542.
Tacoma Rail Max Track	43424.
Annie Track Avg Util	7.9802
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2013** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	112.21	(Insuf)	47.397	235.88	12
hYUNDAI TO BF MEET	79.392	(Insuf)	52.890	134.72	4
HYUNDAI WEST	45.122	(Insuf)	31.869	67.835	25
HYUNDAI BF EAST	89.526	(Insuf)	61.035	143.16	4
NIM WEST	64.624	(Insuf)	61.652	68.518	7
simramptally	81.768	(Insuf)	24.556	210.57	11
SIM EAST	104.59	(Insuf)	74.766	160.23	8
NIM TO BELTLINE	84.464	(Insuf)	54.876	133.26	4
NIM TO FIFE	106.41	(Insuf)	92.351	120.48	2
NIM TO BF	122.35	(Insuf)	59.050	247.73	12
HYUNDAI BL EAST	44.763	(Insuf)	20.462	124.24	7

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	4.0000
Bullfrog Junction Aver	13.011
Depart NIM Q Max	2.0000
Tacoma Rail Q Max	.00000

Hyundai Inbound Max	.00000
Mainline Q Max	1.0000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	7.4668
Tacoma Rail AVG Util	29817.
Tacoma Rail Max Track	44373.
Annie Track Avg Util	6.8354
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2014** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	86.924	(Insuf)	43.819	172.92	13
hYUNDAI TO BF MEET	94.636	(Insuf)	65.957	164.78	4
HYUNDAI WEST	41.648	(Insuf)	28.144	55.495	26
HYUNDAI BF EAST	105.26	(Insuf)	77.630	174.78	4
NIM WEST	67.144	(Insuf)	59.262	82.761	8
simramptally	142.35	(Insuf)	24.249	266.44	10
SIM EAST	108.92	(Insuf)	61.856	271.50	8
NIM TO BELTLINE	117.74	(Insuf)	63.653	202.21	5
NIM TO FIFE	84.652	(Insuf)	78.822	90.482	2
NIM TO BF	97.702	(Insuf)	53.310	185.36	13
HYUNDAI BL EAST	63.650	(Insuf)	27.448	103.09	8

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	3.0000
Bullfrog Junction Aver	14.614

Depart NIM Q Max	1.0000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000
Nim Westbound QMax	1.0000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	7.9668
Tacoma Rail AVG Util	31969.
Tacoma Rail Max Track	49119.
Annie Track Avg Util	6.9736
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2015** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	88.362	(Insuf)	53.030	158.49	14
hYUNDAI TO BF MEET	146.84	(Insuf)	146.84	146.84	1
HYUNDAI WEST	44.926	(Insuf)	27.145	132.86	27
HYUNDAI BF EAST	157.05	(Insuf)	157.05	157.05	1
NIM WEST	101.04	(Insuf)	56.952	227.23	8
simramptally	159.33	(Insuf)	21.270	373.98	17
SIM EAST	135.97	(Insuf)	66.773	266.93	9
NIM TO BELTLINE	67.054	(Insuf)	52.921	79.307	5
NIM TO FIFE	156.94	(Insuf)	114.53	199.34	2
NIM TO BF	98.280	(Insuf)	64.514	164.95	14
HYUNDAI BL EAST	73.188	(Insuf)	22.324	268.36	11

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	2.0000
Bullfrog Junction Aver	19.472
Depart NIM Q Max	2.0000

Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	4.0000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	6.5758
Tacoma Rail AVG Util	35230.
Tacoma Rail Max Track	53404.
Annie Track Avg Util	7.0408
SIM Ramp Q Max	.00000

ARENA Simulation Results
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Summary for Replication 1 of 30

Project: **2016** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	100.33	(Insuf)	43.916	194.87	13
hYUNDAI TO BF MEET	71.624	(Insuf)	71.624	71.624	1
HYUNDAI WEST	42.598	(Insuf)	31.157	73.271	28
HYUNDAI BF EAST	82.923	(Insuf)	82.923	82.923	1
NIM WEST	78.666	(Insuf)	61.882	149.81	8
simramptally	133.59	(Insuf)	66.339	299.59	6
SIM EAST	122.60	(Insuf)	58.148	339.05	9
NIM TO BELTLINE	129.68	(Insuf)	87.976	212.46	6
NIM TO FIFE	101.55	(Insuf)	87.545	115.55	2
NIM TO BF	110.16	(Insuf)	49.504	208.04	13
HYUNDAI BL EAST	113.37	(Insuf)	25.997	224.46	12

OUTPUTS

Identifier	Value

Bullfrog Junction Q Ma	3.0000
Bullfrog Junction Aver	18.883
Depart NIM Q Max	1.0000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	1.0000
Nim Westbound QMax	1.0000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	.00000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	6.3388
Tacoma Rail AVG Util	35680.
Tacoma Rail Max Track	52143.
Annie Track Avg Util	7.6008
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2017** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	107.33	(Insuf)	54.696	168.63	15
hYUNDAI TO BF MEET	88.149	(Insuf)	59.809	125.24	3
HYUNDAI WEST	45.602	(Insuf)	35.216	73.386	29
HYUNDAI BF EAST	98.999	(Insuf)	72.804	134.95	3
NIM WEST	68.812	(Insuf)	58.016	94.652	9
simramptally	113.64	(Insuf)	17.879	272.07	9
SIM EAST	118.35	(Insuf)	68.724	328.10	9
NIM TO BELTLINE	89.734	(Insuf)	47.691	171.15	7
NIM TO FIFE	124.53	(Insuf)	121.84	127.22	2
NIM TO BF	117.36	(Insuf)	59.798	175.99	15
HYUNDAI BL EAST	44.255	(Insuf)	27.258	91.184	10

OUTPUTS

Identifier	Value

Bullfrog Junction Q Ma	1.0000
Bullfrog Junction Aver	16.833
Depart NIM Q Max	2.0000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	1.0000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	7.8493
Tacoma Rail AVG Util	35824.
Tacoma Rail Max Track	53106.
Annie Track Avg Util	8.2784
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2018** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	101.22	(Insuf)	61.658	175.53	13
hYUNDAI TO BF MEET	114.77	(Insuf)	82.445	145.77	5
HYUNDAI WEST	50.157	(Insuf)	31.600	127.23	30
HYUNDAI BF EAST	124.76	(Insuf)	94.288	155.24	5
NIM WEST	66.702	(Insuf)	59.205	74.281	9
simramptally	128.35	(Insuf)	36.955	232.87	5
SIM EAST	.82.480	(Insuf)	53.711	99.475	9
NIM TO BELTLINE	88.245	(Insuf)	59.215	133.97	7
NIM TO FIFE	79.422	(Insuf)	65.631	87.585	3
NIM TO BF	111.04	(Insuf)	72.198	185.34	13
HYUNDAI BL EAST	75.012	(Insuf)	44.269	106.24	9

OUTPUTS

Identifier	Value

Bullfrog Junction Q Ma	2.0000
Bullfrog Junction Aver	17.754
Depart NIM Q Max	2.0000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	.00000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	. 00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	9.5085
Tacoma Rail AVG Util	32087.
Tacoma Rail Max Track	49421.
Annie Track Avg Util	7.7585
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2019** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	115.18	(Insuf)	52.437	210.18	17
hYUNDAI TO BF MEET	83.948	(Insuf)	78.667	92.491	3
HYUNDAI WEST	48.147	(Insuf)	31.157	122.98	31
HYUNDAI BF EAST	94.310	(Insuf)	87.638	101.94	3
NIM WEST	84.868	(Insuf)	58.991	165.50	9
simramptally	122.35	(Insuf)	49.218	211.37	10
SIM EAST	101.15	(Insuf)	67.435	179.39	9
NIM TO BELTLINE	112.68	(Insuf)	64.051	249.53	7
NIM TO FIFE	173.93	(Insuf)	100.90	251.20	3
NIM TO BF	125.59	(Insuf)	60.819	222.88	17
HYUNDAI BL EAST	68.351	(Insuf)	23.088	159.04	11

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	2.0000
Bullfrog Junction Aver	17.111
Depart NIM Q Max	2.0000
Tacoma Rail Q Max	1.0000
Hyundai Inbound Max	.00000
Mainline Q Max	2.0000
Nim Westbound QMax	1.0000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	2.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	8.6319
Tacoma Rail AVG Util	38352.
Tacoma Rail Max Track	54508.
Annie Track Avg Util	10.403
SIM Ramp Q Max	.00000

ARENA Simulation Results
Martin A. Zybura - License #9310661

Summary for Replication 1 of 30

Project: **2020** Run execution date : 7/10/1999
Analyst: Model revision date: 7/10/1999

Replication ended at time : 11080.0

TALLY VARIABLES

Identifier	Average	Half Width	Minimum	Maximum	Observations
NIM TO BF MEET	113.13	(Insuf)	69.931	259.70	14
hYUNDAI TO BF MEET	114.63	(Insuf)	77.725	143.71	6
HYUNDAI WEST	45.740	(Insuf)	31.157	104.98	32
HYUNDAI BF EAST	124.81	(Insuf)	88.740	152.99	6
NIM WEST	71.070	(Insuf)	58.627	101.58	10
simramptally	145.35	(Insuf)	20.467	316.86	15
SIM EAST	79.547	(Insuf)	53.711	119.35	10
NIM TO BELTLINE	130.13	(Insuf)	64.218	340.31	8
NIM TO FIFE	93.349	(Insuf)	75.242	105.79	3
NIM TO BF	123.17	(Insuf)	76.229	272.73	14
HYUNDAI BL EAST	88.195	(Insuf)	34.399	176.70	9

OUTPUTS

Identifier	Value
Bullfrog Junction Q Ma	3.0000
Bullfrog Junction Aver	18.520
Depart NIM Q Max	2.0000
Tacoma Rail Q Max	.00000
Hyundai Inbound Max	.00000
Mainline Q Max	1.0000
Nim Westbound QMax	.00000
NIM Eastbound Q Max	.00000
Hyundai Yard Q Max	1.0000
SIM Ramp Q Max	.00000
SIM Transfer Q Max	.00000
Hyundai Track Q Max	.00000
POT Road AVG UTIL	10.184
Tacoma Rail AVG Util	32437.
Tacoma Rail Max Track	49342.
Annie Track Avg Util	8.2291
SIM Ramp Q Max	.00000

Appendix D Altering Experiment Code

This appendix describes how changes may be made in the experiment code and the functions of the code represents in the real system.

Resources

Resources may be changed by simply adjusting the quantity for each resource. In the simulation bullfrog junction has a capacity of two because the current system has only two access points at bullfrog junction. By changing the quantity in the simulation the number of access points can be increased or decreased. This is the same for all the resources. The following resource values may be altered to investigate different scenarios.

Annietrack Quantity 2. The Port of Tacoma rail system currently has two sets of tracks that connect the NIM with bullfrog Junction and Tacoma Rail.

Simtransfertrack Quantity 10600. The quantity of track in feet available at the SIM transfer yard.

Simramptrack Quantity 8634. The quantity of track in feet available at the SIM ramp.

Bfjun Quantity 2. The number of rail access points at bullfrog Junction.

Potroad Quantity 1. The number of blockage points on Port of Tacoma Road caused by train crossings

Potrtrack Quantity 1. The numbers of tracks that cross Port of Tacoma Road and provide access to the Hyundai Yard from Tacoma Rail and bullfrog.

Bltrack Quantity 54584. The number in feet of track available at the Tacoma Rail Yard for storage and sorting.

NIMtrack Quantity 26700. The number in feet of track available in the NIM for loading and unloading of railcars.

Blengine Quantity 5. The number of engines available in the Tacoma Rail Yard to conduct operations.

Hytrack Quantity 8624, The number in feet of tracks available in the Hyundai Yard to conduct loading and unloading of railcars.

DSTATS

The DSTATS element causes automatic recording of statistics of one or more time-dependent variables. The DSTATS currently in the program record statistics utilizing two basic operations.

NR(Resource name). This gives the average utilization for a resource, the maximum number used at any one time and the minimum number used at any time. To determine the percent utilization NR must be multiplied by 100/(resource quantity). Percent utilization of bullfrog Junction is NR(bfjun)*100/2 because there are two access points to bullfrog.

NQ(Queue name) Using this operation the average number of entities in a queue, the maximum number and the minimum number is given.

In the model a NQ is done for each queue and a NR is done for each resource.

Expressions

Expressions define a specific expression or distribution assigned for an operand in a block in the model. In this model, expressions are used extensively to in the delay blocks and representing the utilization of Tacoma rail for different times and days. Any expression in the model may be changed to observe the effects of changing a delay time or changing the amount of Tacoma Rail Tracks utilized.

Delay Times

BF CLEAR This is the expression representing the delay time for a train to clear bullfrog Junction

NIMMVT This expression represents the delay in time associated with hooking up and moving a train from the NIM to bullfrog.

BFTOBL This represents the movement time from Tacoma Rail to bullfrog junction.

INBL this expression represents the time a train spends in the Tacoma Rail yard.

BLTONIM This Expression represents the amount of time it takes to move a train from the Tacoma Rail Yard to the NIM.

HYTOBF. This expression represents the amount of time it takes to move from the Hyundai yard to bullfrog junction.

SIMOUT. This expression represents the amount of time it takes to move a train out of the SIM and to bullfrog.

Waitbf. This expression represents the amount of time a train is delayed at bullfrog waiting for power from the main line to hook up.

Nimyarddelay Expression represents the delay in the NIM yard.

Simyarddelay. Expression represents the delay in the SIM

Bltohy. Expression represents the time delay for movement from Tacoma Rail to the Hyundai Yard.

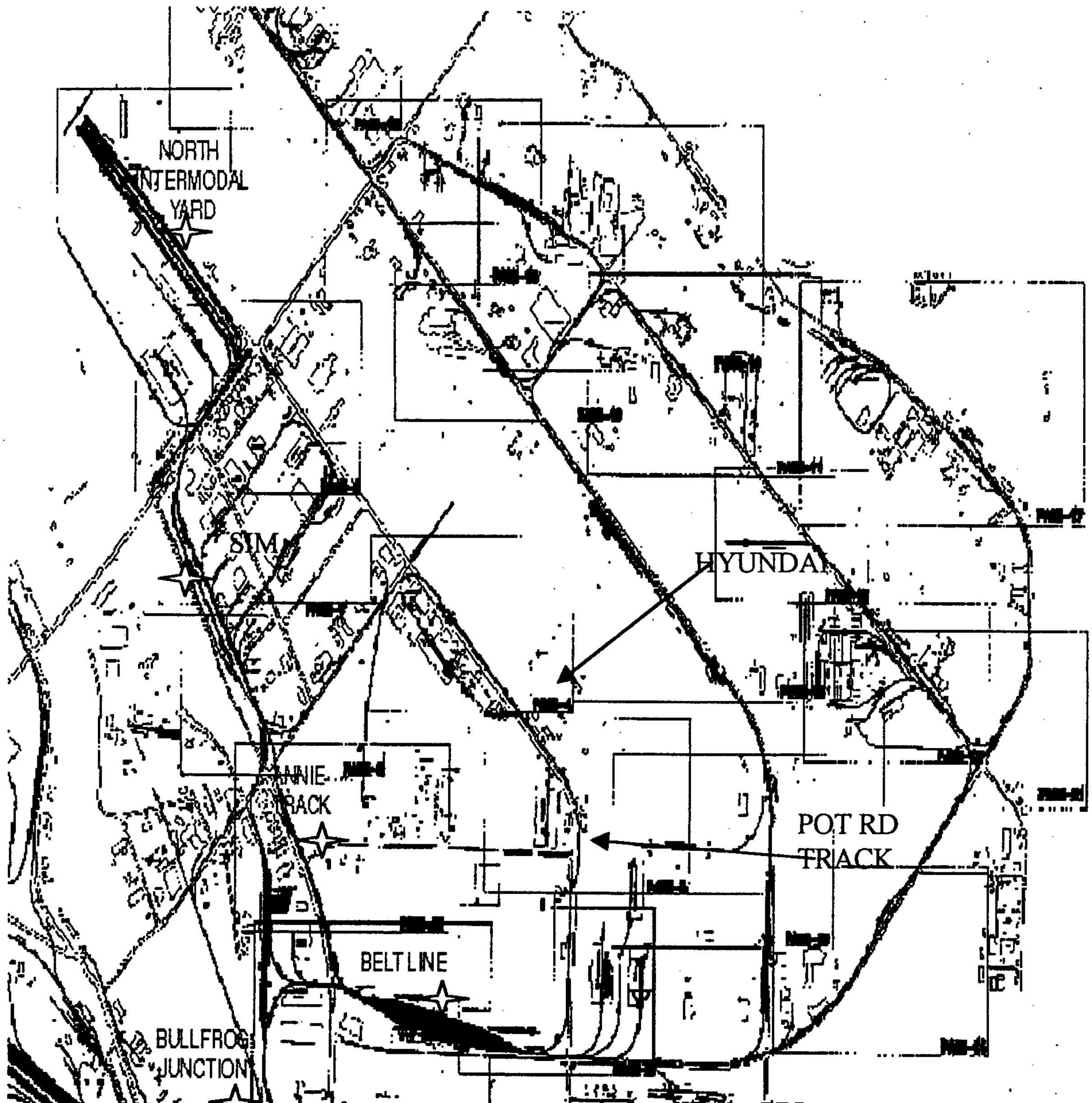
Hyarddelay. Expression represents the delay in the Hyundai Yard.

Fifedelay. Expression represents the delay in the Fife yard waiting for a main line or because of congestion.

Spotting time. Expression represents the amount of time to spot a train in the Hyundai yard.

All other expressions in the model follow the format SUN09. In this format the first three letters refer to the day of the week and the last two letters refer to the time of day. The expression SUN09 is used to determine usage of the Tacoma Rail yard for Sunday until 0900 hours. The next expression SUN16 goes into effect at 0900 and remains until 1600. This format is followed for the rest of the week with each day having three sections. These expressions may be changed because of changes in patterns in the real system or if there is increased analysis of time and a goodness of fit test points to another expression.

Appendix E Port Rail Map



Appendix F NIM Schedule

DAY	DATE	Yard Delay	Inte	Interchange Time	ASSEMBLE	Train Type	Train Length
WE	4/14	20	BF	7:45	6:30	1	4190
WE	4/14	30	BF	11:00	9:00	1	4815
WE	4/14	60	BF	13:45	12:00	1	5563
TU	4/13					2	1166
WE	4/14					2	2288
WE	4/14					2	938
WE	4/14					2	1166
TH	4/15	30	BF	20:00	18:30	3	3621
TH	4/15	-95	BL	16:00	14:30	3	3762
TH	4/15	475	BL	11:00	10:00	4	116
SA	4/17	75	F	16:09	14:00	5	3978
SA	4/17	105	F	14:45	12:00	5	4105
SA	4/17	15	BL	17:26	15:30	5	2212
SA	4/17	15	BL	17:26	15:30	4	1318
TU	4/7					2	977
WE	4/7					2	6038
WE	4/7	15	BF	20:03	18:00	1	6999
WE	4/7	75	BF	24:00:00	19:00	1	6012
WE	4/7	45	BF	2:00	19:00	1	4575
WE	4/7					2	1654
WE	4/7					2	784
WE	4/7					2	2065
TH	4/8	10	BF	19:33	18:15	3	4522
TH	4/8	190	BL	15:55	11:30		4897
FR	4/9					2	784
FR	4/9					2	1509
FR	4/9					2	3452
FR	4/9					2	1318
SA	4/10	45	F	22:26	20:30	5	4165
SA	4/10	60	F	2:00	23:00	5	3860
SA	4/10	30	BL	6:00	1:30	4	1725
MO	4/11	135	BL	15:45	13:30	3	2726
MO	4/11	135	BL	15:45	13:30	3	1899
TU	3/30					2	308
TU	3/30					2	2760
TU	3/30					2	6330
WE	3/31	5	BF	2:30	1:00	1	4921
WE	3/31	25	BF	5:25	3:45	1	6125
WE	3/31	30	BF	10:00	8:00	1	6405
WE	3/31					2	610
WE	3/31					2	1059
WE	3/31					2	391
TH	4/1	15	BL	12:45	11:30	3	2535
TH	4/1	15	BF	20:00	18:30	3	4581
TH	4/1	15	BL	12:45	11:30	3	232
FR	4/2	75	BL	11:30	10:00	3	377
FR	4/2	0	F	16:00	14:15	5	4092
FR	4/2	95	BL	18:00	16:45	3	2336
FR	4/2	95	BL	18:00	16:45	4	1362
TU	3/23					2	1699
TU	3/23					2	1677
WE	3/24					2	5458
WE	3/24					2	377
WE	3/24	-10	BF	4:30	2:25	1	4993
WE	3/24	0	BF	7:20	5:30	1	6735
WE	3/24	40	BF	9:10	8:30	1	5795
WE	3/24					2	1284
WE	3/24					2	1220
TH	3/25					2	2135
TH	3/25	20	BF	14:20	14:00	3	3187
TH	3/25	35	BL	16:35	16:00	3	2519
TH	2/25					2	7215

DAY	DATE	Train Type	Train Length	avail muni	spot NIM day	Spot NIM PLAN	Spot Nim Actual TIME
WE	4/14	1	4190				
WE	4/14	1	4815				
WE	4/14	1	5563				
TU	4/13	2	1166	18:00	WE	5:00:00	5:00:00
WE	4/14	2	2288	12:00	WE	14:30:00	30:30:00
WE	4/14	2	938	12:00	WE	14:30:00	31:10:00
WE	4/14	2	1166	12:00	WE	5:00:00	3:45:00
TH	4/15	3	3621				
TH	4/15	3	3762				
TH	4/15	4	116				
SA	4/17	5	3978				
SA	4/17	5	4105				
SA	4/17	5	2212				
SA	4/17	4	1318				
TU	4/7	2	977	13:00	WE	6:00:00	6:30:00
WE	4/7	2	6038	1:00	WE	6:00:00	6:30:00
WE	4/7	1	6999				
WE	4/7	1	6012				
WE	4/7	1	4575				
WE	4/7	2	1654	11:00	TH	6:00:00	6:30:00
WE	4/7	2	784	12:00	TH	6:00	6:00:00
WE	4/7	2	2065	18:00	TH	6:00	6:30:00
TH	4/8	3	4522				
TH	4/8		4897				
FR	4/9	2	784		FR	6:00	
FR	4/9	2	1509		FR	6:00	
FR	4/9	2	3452		FR	12:30	
FR	4/9	2	1318		FR	10:30	
SA	4/10	5	4165				
SA	4/10	5	3860				
SA	4/10	4	1725				
MO	4/11	3	2726				
MO	4/11	3	1899				
TU	3/30	2	308	11:00	WE	5:00	5:00:00
TU	3/30	2	2760	14:00	WE	5:00	8:00:00
TU	3/30	2	6330	18:00	WE	5:00	8:00:00
WE	3/31	1	4921				
WE	3/31	1	6125				
WE	3/31	1	6405				
WE	3/31	2	610	12:00	TH	4:00	6:00:00
WE	3/31	2	1059	13:00	TH	4:00	10:45:00
WE	3/31	2	391	14:00	TH	4:00	8:20:00
TH	4/1	3	2535				
TH	4/1	3	4581				
TH	4/1	3	232				
FR	4/2	3	377				
FR	4/2	5	4092				
FR	4/2	3	2336				
FR	4/2	4	1362				
TU	3/23	2	1699	0:01	WE	5:00	5:00:00
TU	3/23	2	1677	9:00	WE	5:00	5:00:00
WE	3/24	2	5458	3:00	WE	7:00	7:00:00
WE	3/24	2	377	6:00	WE	13:00	13:00:00
WE	3/24	1	4993				
WE	3/24	1	6735				
WE	3/24	1	5795				
WE	3/24	2	1284	13:00	TH	5:30	8:30:00
WE	3/24	2	1220	18:00	TH	5:30	8:30:00
TH	3/25	2	2135	12:00	TH	0:01	0:01:00
TH	3/25	3	3187				
TH	3/25	3	2519				
TH	2/25	2	7215	12:00	FR	3:00	3:00:00

DAY	DATE	Yard Delay	Inte	Interchange Time	ASSEMBLE	Train Type	Train Length
FR	3/26	-10	F	11:30	9:45	5	610
FR	3/26	-25	BL	16:00	14:30	3	5835
FR	3/26	-80	BL	16:00	14:30	4	1814
TU	3/16					2	1220
TU	3/16					2	5137
WE	3/17	20	BF	20:00	18:30	1	5226
WE	3/17	0	BF	23:00	21:00	1	6446
WE	3/17					2	3741
WE	3/17					2	915
TH	3/18	0	BF	15:45	14:30	3	3630
TH	3/18	-35	BF	20:00	18:00	3	2520
TH	3/18	-35	BF	20:00	18:00	1	2962
TH	3/18					2	363
TH	3/18					2	876
TH	3/18					2	3568
TH	3/18					2	395
FR	3/19	0	F	13:30	11:30	5	6460
FR	3/19	30	BL	15:45	14:30	3	2525
FR	3/19	-60	BL	17:00	16:00	4	768
FR	3/19					2	3660
FR	3/19					2	1023
FR	3/19					2	666
FR	3/19					2	4127
TU	3/9					2	1095
TU	3/9					2	493
TU	3/9					2	1723
WE	3/10	0	BF	3:30	2:00	1	1252
WE	3/10	65	BF	5:30	4:00	1	5236
WE	3/10	55	BF	7:30	6:00	1	4539
TH	3/11					2	4624
TH	3/11					2	4585
TH	3/11	20	BF	20:00	18:30	3	3760
TH	3/11	0	BL	16:00	12:40	3	913
TH	3/11					2	1936
TH	3/11					2	1143
TH	3/11					2	867
FR	3/12					2	1445
FR	3/12	60	BL	15:30	14:00	3	3823
FR	3/12					2	1975
FR	3/12					2	2792
SA	3/13					2	3442
SA	3/13	15	F	4:15	2:00	5	5104
SA	3/13	10	BL	16:30	15:30	3	840
SA	3/13	10	BL	16:30	15:30	3	1504
SA	3/13	15	BL	18:15	17:30	4	882
TU	3/2					2	1421
TU	3/2					2	6655
TH	3/4	-20	BF	8:00	6:00	1	4959
TH	3/4	40	BF	11:00	9:00	1	6417
WE	3/3					2	2731
TH	3/4	15	BL	16:30	14:30	1	2601
TH	3/4	15	BL	16:30	14:30	1	2778
WE	3/3					2	684
FR	3/5	35	BF	14:00	12:00	1	3998
FR	3/5	35	BF	14:00	12:00	1	1432
TH	3/4					2	698
TH	3/4					2	1047
FR	3/5					2	753

DAY	DATE	Train Type	Train Length	avail muni	spot NIM day	Spot NIM PLAN	Spot Nim Actual TIME
FR	3/26	5	610				
FR	3/26	3	5835				
FR	3/26	4	1814				
TU	3/16	2	1220	18:00	WE	5:00	5:00:00
TU	3/16	2	5137	23:00	WE	5:00	5:00:00
WE	3/17	1	5226				
WE	3/17	1	6446				
WE	3/17	2	3741	12:00	TH	5:00	5:00:00
WE	3/17	2	915	18:00	TH	5:00	5:00:00
TH	3/18	3	3630				
TH	3/18	3	2520				
TH	3/18	1	2962				
TH	3/18	2	363	12:00	FR	5:00	5:00:00
TH	3/18	2	876	12:00	FR	5:00	5:00:00
TH	3/18	2	3568	23:00	FR	5:00	5:00:00
TH	3/18	2	395	18:00	FR	5:00	5:00:00
FR	3/19	5	6460				
FR	3/19	3	2525				
FR	3/19	4	768				
FR	3/19	2	3660	10:00	SA	6:00	6:30:00
FR	3/19	2	1023	23:00	SA	6:00	6:30:00
FR	3/19	2	666	15:00	SA	6:00	6:30:00
FR	3/19	2	4127	18:00	SA	6:00	6:30:00
TU	3/9	2	1095	15:00	WE	5:00	12:00:00
TU	3/9	2	493	15:00	WE	5:00	11:20:00
TU	3/9	2	1723	23:00	WE	5:00	6:30:00
WE	3/10	1	1252				
WE	3/10	1	5236				
WE	3/10	1	4539				
TH	3/11	2	4624	7:00	TH	10:30	28:40:00
TH	3/11	2	4585	9:00	TH	10:30	10:30:00
TH	3/11	3	3760				
TH	3/11	3	913				
TH	3/11	2	1936	17:00	TH	24:00:00	24:00:00
TH	3/11	2	1143	17:00	TH	24:00:00	24:00:00
TH	3/11	2	867	23:00	FR	2:00	2:00:00
FR	3/12	2	1445	9:30	FR	12:00	12:00:00
FR	3/12	3	3823				
FR	3/12	2	1975	12:00	FR	17:00	17:00:00
FR	3/12	2	2792	12:00	FR	17:00	17:00:00
SA	3/13	2	3442	10:00	SA	23:00	23:00:00
SA	3/13	5	5104				
SA	3/13	3	840				
SA	3/13	3	1504				
SA	3/13	4	882				
TU	3/2	2	1421	17:30	WE	7:00	0:10:00
TU	3/2	2	6655	23:00	WE	7:00	7:00:00
TH	3/4	1	4959				
TH	3/4	1	6417				
WE	3/3	2	2731	15:00	TH	6:00	6:00:00
TH	3/4	1	2601				
TH	3/4	1	2778				
WE	3/3	2	684	12:00	TH	8:00	8:00:00
FR	3/5	1	3998				
FR	3/5	1	1432				
TH	3/4	2	698	18:00	FR	6:00	6:00:00
TH	3/4	2	1047	21:00	FR	6:00	6:00:00
FR	3/5	2	753	17:00	FR	23:00	18:30:00

DAY	DATE	Yard Delay	Inte	Interchar	ASSEMBLE	Train Typ	Train Length
SA	3/6	-10	F	18:45	16:45	5	2023
SA	3/6	10	BF	20:00	18:00	3	5970
SA	3/6	10	BF	20:00	18:00	3	2982
SA	3/6	30	BL	21:00	20:15	4	1202
TU	2/23					2	3395
WE	2/24	15	BF	20:00	18:15	1	5525
WE	2/24	30	BF	23:00	21:15	1	4815
WE	2/24	10	BF	2:00	0:30	1	4625
WE	2/24					2	3116
WE	2/24					2	1204
WE	2/24					2	1702
TH	2/25	55	BL	15:30	14:00	1	4077
TH	2/25	15	BL	17:30	16:00	1	3644
TH	2/25					2	2288
FR	2/26	0	F	14:00	12:00	5	6694
FR	2/26	30	BL	17:00	15:00	3	2330
FR	2/26	-30	BL	17:00	15:00	4	2591
WE	2/17					2	405
WE	2/17					2	5767
WE	2/17	5	BF	20:00	18:00	1	6392
WE	2/17	35	BF	23:00	21:00	1	5899
TH	2/18	80	BF	6:30	5:00	1	6358
WE	2/17					2	289
WE	2/17					2	709
WE	2/17					2	2597
TH	2/18	20	BF	18:00	16:30	1	3502
TH	2/18	20	BF	18:00	16:30	1	432
TH	2/18	30	BF	14:00	14:00	1	4938
TH	2/18	30	BF	14:00	14:00	1	960
FR	2/19					2	1380
TH	2/18					2	1622
TH	2/18					2	289
TH	2/18					2	1517
FR	2/19	360	BL	11:00	10:00	3	202
FR	2/19	20	BL	11:00	10:00	4	116
FR	2/19	20	F	4:30	2:30	5	6838
FR	2/19	0	BL	16:45	15:30	3	2357
FR	2/19	65	F	5:45	5:00	4	1075

DAY	DATE	Train Type	Train Length	avail mun	spot NIM	Spot NIM	Spot Nim
SA	3/6	5	2023				
SA	3/6	3	5970				
SA	3/6	3	2982				
SA	3/6	4	1202				
TU	2/23	2	3395	23:00	WE	3:00	6:55:00
WE	2/24	1	5525				
WE	2/24	1	4815				
WE	2/24	1	4625				
WE	2/24	2	3116	7:00	WE	13:00	12:50:00
WE	2/24	2	1204	12:00	TH	6:00	6:00:00
WE	2/24	2	1702	17:00	TH	6:00	6:00:00
TH	2/25	1	4077				
TH	2/25	1	3644				
TH	2/25	2	2288	22:00	FR	2:00	2:00:00
FR	2/26	5	6694				
FR	2/26	3	2330				
FR	2/26	4	2591				
WE	2/17	2	405	3:00	WE	10:00	10:00:00
WE	2/17	2	5767	6:00	WE	10:00	10:00:00
WE	2/17	1	6392				
WE	2/17	1	5899				
TH	2/18	1	6358				
WE	2/17	2	289	12:00	TH	4:00	4:00:00
WE	2/17	2	709	22:00	TH	4:00:00	4:00
WE	2/17	2	2597	23:59	TH	4:00:00	4:00
TH	2/18	1	3502				
TH	2/18	1	432				
TH	2/18	1	4938				
TH	2/18	1	960				
FR	2/19	2	1380	6:00	FR	8:00:00	8:00
TH	2/18	2	1622	15:00	FR	6:00:00	6:00
TH	2/18	2	289	23:00	FR	6:00:00	6:00
TH	2/18	2	1517	23:00	FR	6:00:00	6:00
FR	2/19	3	202				
FR	2/19	4	116				
FR	2/19	5	6838				
FR	2/19	3	2357				
FR	2/19	4	1075				

Appendix G SIM Schedule

DATE	DAY	Direction	ETA arrive	ETA Spot		SIMgate cutoff	Pull	Depart	length
3/18/99	TH	w	19:00	12:00	th				2753
3/19/99	fr	w	11:00	10:00	fr				1232
3/20/99	sa	w	18:00	9:10	sa				1848
3/21/99	su	w	0:10						58
3/17/99	we	w	11:00						1782
3/18/99	th	w	11:00						1801
3/19/99	fr	w	11:00						2855
3/20/99	sa	w	11:00						1306
3/11/99	th	w	13:00	18:00	we				905
3/12/99	fr	w	1:00	23:00	th				996
3/12/99	fr	w	15:00	12:00	fr				924
3/13/99	sa	w	0:01	10:13	sa				688
3/13/99	sa	w.	19:32						0
3/10/99	we	w	11:00						3650
3/11/99	th	w	11:00						2244
3/12/99	fr	w	11:00						1406
3/13/99	sa	w	11:00						847
3/4/99	th	w	23:00						2156
3/5/99	fr	w	5:04	18:00	th				2065
3/4/99	th	w	11:00						2431
3/5/99	fr	w	11:00						1213
3/6/99	sa	w	11:00						1156
3/8/99	mo	w	11:00						1441
2/25/99	th	w	14:21						2065
2/26/99	fr	w	14:57	4:00	sa				1232
2/27/99	sa	w	12:00						1647
2/25/99	th	w	11:00						380
2/26/99	fr	w	11:00						2022
2/27/99	sa	w	11:00						1666
4/1/99	th	w	12:00	12:30	th				2046
4/2/99	fr	w	16:00						4293
4/2/99	fr	w	22:57	10:30	sa				1701
4/4/99	su	w	17:00						1936
4/2/99	fr	w	11:00						2590
4/3/99	sa	w	11:00						1281
4/5/99	mo	w	11:00						2571

DATE	DAY	Direction	ETA arrive	ETA Spot	SIMgate cutoff	Pull	Depart	length
4/6/99	tu	w	11:00					3076
4/2/99	fr	e			12:00	14:00	19:30	1666
4/2/99	fr	e			21:00	23:59	2:00	6230
4/3/99	sa	e			17:00	19:00	1:30	72
4/3/99	sa	e			9:00	11:00	13:00	6178
4/3/99	sa	e			20:00	22:00	0:15	6947
4/5/99	mo	e			14:00	16:00	19:30	2067
3/19/99	fr	e			14:00	16:00	19:30	2046
3/19/99	fr	e			20:00	23:59	2:00	5796
3/20/99	sa	e			12:00	13:00	15:00	3186
3/20/99	sa	e			18:00	20:00	22:00	6195
3/12/99	fr	e			17:00	19:00	1:30	58
3/12/99	fr	e			14:00	16:00	19:30	2715
3/12/99	fr	e			20:00	23:59	2:00	6230
3/14/99	SU	E			18:00	20:00	22:00	6322
3/14/99	SU	E			4:00	6:00	9:30	4779
3/15/99	MO	E			12:00	13:00	15:00	616
3/15/99	MO	E			14:00	16:00	19:30	1792
3/15/99	MO	E			17:00	19:00	1:30	116
3/5/99	FR	E			14:00	16:00	19:30	3061
3/5/99	FR	E			20:00	23:59	2:00	5488
3/6/99	SA	E			14:00	16:00	19:30	2279
3/8/99	MO	E			14:00	16:00	19:30	1141
2/26/99	FR	E			14:00	16:00	19:30	525
2/26/99	FR	E			20:00	23:59	2:00	5397
2/27/99	SA	E			9:00	11:00	13:00	4418
2/27/99	SA	E			20:00	2:00	0:50	6108
3/1/99	MO	E			14:00	16:00	19:30	2517

Appendix H Containerized Cargo Projections

By Individual Customer Growth		Actual	Individual Straight Line Forecast						
Growth	Containers	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
5.00%	Evergreen	319	369	387	407	427	449	471	494
1.77%	TOTE	219	223	227	231	235	239	243	248
2.00%	SL-Intl	292	210	214	218	223	227	232	236
1.77%	Sea-AK	216	223	227	231	235	239	243	248
4.00%	Maresk		78	81	84	88	91	95	99
1.00%	K-Line	95	98	99	100	101	102	103	104
3.50%	Hyundai	0	150	208	228	236	244	253	262
3.00%	PCT (Note 2)					85	182	187	193
4.40%	East Blair								0
	Miscellen.	15							
	Total	1156	1351	1444	1499.6	1629.8	1773.7	1827.8	1884
Annual Growth, %:			#####	6.86%	3.87%	8.69%	8.83%	3.05%	3.07%
Net annual Growth (TEU):			195	93	56	130	144	54	56

By Individual Customer Growth		**2006**	**2007**	**2008**	**2009**	**2010**
Growth	Containers	519	545	572	601	631
5.00%	Evergreen	252	257	261	266	270
1.77%	TOTE	241	246	251	256	261
2.00%	SL-Intl	252	257	261	266	270
1.77%	Sea-AK	103	107	111	115	120
4.00%	Maresk	105	106	107	108	109
1.00%	K-Line	271	280	290	300	311
3.50%	Hyundai	199	205	211	217	224
3.00%	PCT (Note 2)	0	0	0	0	0
4.40%	East Blair					
	Miscellen.	1942.11	2002.42	2064.97	2130	2197
	Total					
Annual Growth, %:		58	60	63		
Net annual Growth (TEU):						

By Individual Customer Growth		2012	2013	2014	2015	2016	2017
Growth	Containers	696	731	767	805	846	888
5.00%	Evergreen	280	285	290	295	300	306
1.77%	TOTE	272	277	283	288	294	300
2.00%	SL-Intl	280	285	290	295	300	306
1.77%	Sea-AK	130	135	140	146	152	158
4.00%	Maresk	112	113	114	115	116	117
1.00%	K-Line	333	345	357	369	382	395
3.50%	Hyundai	237	245	252	259	267	275
3.00%	PCT (Note 2)	0	0	0	0	0	0
4.40%	East Blair						
	Miscellen.	2339	2415	2493	2574	2658	2745
	Total						
Annual Growth, %:							
Net annual Growth (TEU):							

By Individual Customer Growth		2018	2019	2020
Growth	Containers	932	979	1028
5.00%	Evergreen	311	317	322
1.77%	TOTE	306	312	318
2.00%	SL-Intl	311	317	322
1.77%	Sea-AK	164	171	178
4.00%	Maresk	118	120	121
1.00%	K-Line	409	424	438
3.50%	Hyundai	284	292	301
3.00%	PCT (Note 2)	0	0	0
4.40%	East Blair			
	Miscellen.	2836	2931	3029
	Total			
Annual Growth, %:				
Net annual Growth (TEU):				

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