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Railroad Classification Yard Technology Manual

Volume I: Yard Design Methods

FRA/ORD-81/20.I
Final Report

March 1981

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16. Abstract

This volume (Volume I) documents the procedures and methods associated with the design of railroad classification yards. Subjects include: site location, economic analysis, yard capacity analysis, design of flat yards, overall configuration of hump yards, hump yard track and switch layout, hump profile design, and hump trim-end design.

Volume II is concerned with the design and specification of the yard computer systems, i.e., yard inventory and process control computer systems.

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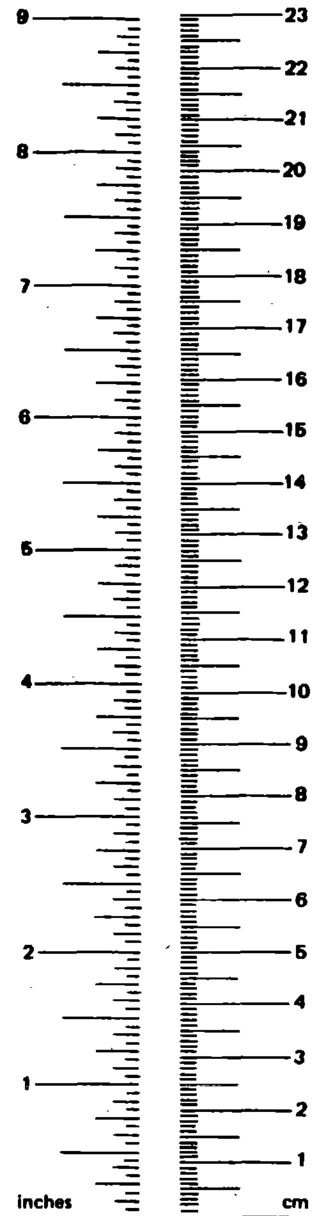
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

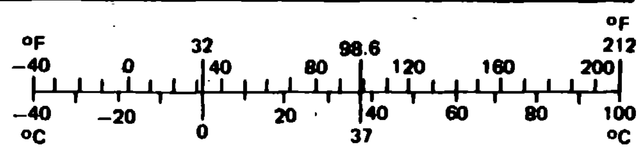
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in. = 2.54 cm (exactly). For other exact conversions and more detail tables see NBS Misc. Publ. 286. Units of Weight and Measures. Price $2.25 SD Catalog No. C13 10 286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This work was performed by members of the Transportation Operations and Information Systems Center of SRI International for the Department of Transportation's Transportation System Center (TSC), Cambridge, Massachusetts. Dr. John Hopkins of the TSC was technical monitor of the project (under contract DOT-TSC-1337). The effort was sponsored by the Office of Freight and Passenger Systems, Federal Railroad Administration (FRA), as part of a program managed by Mr. William F. Cracker, Jr.

The research was performed under the technical leadership of Dr. Peter J. Wong, Director, Transportation Operations Research Department. Dr. Masami Sakasita was the Assistant Project Leader. The project team consisted of the following members and their contributions:

- Ms. Carola V. Elliott: Trim-end design, design and development of CONFLICT computer model,
- Ms. Mary Ann Hackworth: Yard capacity and crew analysis,
- Dr. Masami Sakasita: Yard capacity and crew analysis, flat yard design, track and switch layout, hump profile design, trim-end design, and computer model specifications,
- Dr. William A. Stock: Yard capacity and crew analysis, hump profile design, design and development of PROFILE and CAPACITY computer models.
- Dr. Peter J. Wong: Tutorial description of yard operations, yard project organization, yard site location, yard economic analysis, deciding on flat vs. hump yard, overall yard configuration, and computer model specifications.

Much of the material in this volume is a result of our close working relationships with Mr. James Wetzel (CONRAIL) and Mr. Barney Gallacher (Southern Pacific); appreciation is expressed for their patience and assistance. In addition, substantial inputs and contributions were made by Mr. Hubert Hall (Santa Fe), Mr. Merrill Anderson (Union Pacific), Mr. Charles Yespelkis (CONRAIL), Mr. Tom Connors (Union Pacific), Mr. Alfred Dasberg (Retired, General Railway Signal), Mr. Bill Williamson (Retired, Southern Pacific), Mr. James Page (Retired, Penn Central), and Mr. Paul Van Cleve (Chessie).

Appreciation is expressed to the American Railway Engineering Association (AREA) Subcommittee 14 on Yards and Terminals for their encouragement and support during the course of the work, and to Mr. Bud Price (Bessemer and Lake Erie) who coordinated the subcommittee efforts.

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CHAPTER 1: INTRODUCTION

1.0 BACKGROUND

Recent studies (MIT, 1972) on car utilization and freight service reliability have concluded that the railroad yard can have a large negative impact on service reliability, car utilization, and damage liability. Furthermore, it has been estimated that as much as 25 to 40% of the time freight cars spend in classification yards is closely associated with deficiencies related to yard layout and design. This is roughly equivalent to a loss of 55 million to 85 million car-days per year, an under-utilization of approximately 210,000 freight cars. Consequently, yard design can have a substantial impact on the ability of a terminal to process cars.

Many railroads have deferred maintenance and capital improvements in yards, preferring instead to devote resources to the rehabilitation of mainline track or the purchase of locomotives. One reason for this choice is that it is often easier to understand the impact of track and motive power on service and revenues. However, it is now widely acknowledged that the yard is often the main culprit in service reliability problems, that freight car travel time is spent primarily in yards, and that yard costs represent a substantial portion of the total railroad transportation costs. (This last element is especially true for midwestern and eastern railroads). Perhaps even more important, capital outlay for mainline trackage and locomotives can be appropriated on a year-to-year basis and deferred in severe economic times, whereas a yard rehabilitation project requires a large capital commitment which must be implemented in its entirety, in a multiyear intensive building program. Furthermore, the planning, design, and engineering decisions for a yard project are inherently more complex and difficult to understand, thereby impeding the decision process.

For all the above reasons, many needed yard projects have been delayed too long. Thus, there are likely to be great pressures to rehabilitate yards in the future, simply because many yards are old and need reworking to be efficient. Also, changes in present and future traffic patterns and future mergers between railroads will necessitate changes in existing capabilities of yards. Some inefficient yards at improper locations may be shut down. However, the remaining yards at critical traffic junctions must be rehabilitated to handle increased switching requirements.

Yard design is a subject of both current and future interest to railroads. This is exemplified by the fact that in the last decade over 30 yard projects involving major rehabilitation have been undertaken (see Shaffer & Roberts, 1973; Welty, 1978; WABCO, 1976; GRS, 1976). Table 1-1 indicates yard projects completed or under way in the last decade.

A recent study (Petracek et al., 1976) estimates that over the next 25 years 200 classification yards will receive major reworking. This would include the planned massive project to restructure and consolidate terminals in the East St. Louis area (Lewis et al., 1977) and the original recommendations by the United States Railway Association (USRA) that over 20 yards should be rehabilitated on the CONRAIL system alone (USRA, 1975).

A major new yard may cost well in excess of $50 million, and a minor rehabilitation can reach $10 million or more. Consequently, it is imperative that yard planning and design procedures be available to produce the best return on the investment. Because yards have a physical life in excess of 30 years, a well-designed new or rehabilitated yard can influence the ability of the railroads to recapture lost revenues and profits well into the twenty-first century.

1.1 PURPOSE OF THE DESIGN MANUAL

Procedures for designing classification yards have evolved through trial and error over many decades. Thus, within a conventional framework of basic design principles, many crucial decisions may sometimes be based in part on personal intuition or persuasiveness simply because the required analytical tools are not available, and the cost of developing or acquiring them is not warranted for a particular project. The relative infrequency with which any one railroad builds a yard makes it difficult to maintain a core group of individuals who specialize in and can improve upon the design process. This is becoming a more acute problem as many of the most experienced yard designers reach retirement. On the other hand, scattered throughout the railroad industry there exists a large amount of yard design information and knowledge that could be of benefit to all railroads if it were aggregated and documented.

The fundamental objective of this design manual is to establish a set of practical guidelines, procedures, and principles, accompanied by a sufficiency of data, tables, computer programs, and other resources to improve significantly classification yard design and engineering and to enhance the efficiency of the design process. The design manual is applicable to the design of new yards, the rehabilitation of existing yards, and to the full range of yard types and sizes including both flat yards and hump yards, whether manual or highly automated.

In the yard design manual we have attempted to compile and document yard design procedures and practices that heretofore resided only in the minds of a small set of experienced railroad yard designers. This yard design knowledge was formerly gained essentially through an apprentice system of on-the-job training. Relatively little formal documentation of yard design procedure and practices existed before this manual. In addition, the design manual describes newly developed computer-aided design procedures. More specifically, a set of computer programs have been developed to aide the yard designer in three critical problem areas of yard design:

- Design of hump grade and retarder placement.
- Estimation of receiving, classification, and departure track capacity requirements and engine/crew utilization.
- Design of pull-out end of yard.

These computer-aided procedures allow better designs to be obtained more rapidly than with conventional procedures.

Consequently, many engineering design methods are presented in two forms: a manual design procedure and a computer-aided design procedure. The computer programs are fully documented and a user's guide has been prepared for each. Thus, depending on the preference of the user, the particular application, and his or her familiarity with using computer programs, the choice may be to implement a design procedure in either a manual or computer-aided form. The computer-aided design procedures will be faster and more accurate than the manual design procedures in most instances.

TABLE 1-1.-YARD PROJECTS: 1968-1979

Approximate Year in Service	Railroad	Yard Name and Location
1979	Southern	Linwood Yard, Salisbury, North Carolina
1978	Chessie	Queensgate Yard, Cincinnati, Ohio
1978	Licking River Terminal Co.	Licking River Yard, Wilder, Kentucky
1977	UP	Hinkle Yard, Hinkle, Oregon
1976	ATSF	Barstow Yard, Barstow, California
1976	L&N	Strench Yard, Louisville, Kentucky
1976	SCL	Rice Yard, Waycross, Georgia
1976	Southern	Brosnan Yard, Macon, Georgia
1974	DTS	Lang Yard, Toledo, Ohio
1974	SLSF	Tennessee Yard, Memphis, Tennessee
1974	BN	Northtown Yard, St. Paul, Minnesota
1974	TRRA	Madison Yard, Madison, Illinois
1973	SOU	Inman Piggyback Yard, Atlanta, Georgia
1973	SOU	Sheffield Yard, Sheffield, Alabama
1973	SP	West Colton Yard, Colton, California
1972	RFP	NB Potomac Yard, Alex, Virginia
1971	UP	East Los Angeles Yard, Los Angeles, California
1971	MP/TP	Centennial Yard, Ft. Worth, Texas
1971	N&W	Roanoke Yard, Roanoke, Virginia
1971	CN	Calder Yard, Edmonton, Alberta
1970	PC	Buckeye Yard, Columbus, Ohio
1970	NP	Pasco Yard, Pasco, Washington
1970	CP	Alyth Yard, Calgary, Alberta
1970	SCL	Rock Port Yard, Tampa, Florida
1970	SP	Englewood Yard, Houston, Texas
1969	PC	Morrisville Yard, Morrisville, New Jersey
1969	PC	Sharonville Yard, Sharonville, Ohio
1969	AT&SF	EB Argentine Yard, Argentine, Kansas
1969	CB&Q	North Kansas City Yard, Kansas City, Missouri
1969	Bethlehem Steel	Burns Harbor Yard, Burns Harbor, Indiana
1968	IC	Belle Helene Yard, Geismer, Louisiana
1968	D&TSL	Lang Yard, Toledo, Ohio
1968	New York Central	Perlman Yard, Selkirk, New York

It is anticipated that the design manual will be usable by any railroad, railroad supplier, or government planner who needs to make informed choices among a myriad of possible design alternatives. In particular, it is hoped that the procedures in the design manual will substantially increase the degree to which alternatives will be considered at the early design stages. This can allow consideration of a wider range of configurational, technical, and economic choices and make possible greater precision than is now customary in estimating potential costs and benefits. The goal of the design manual is to contribute to a reduction of design effort, reduced and/or more efficient expenditure of construction resources, and—most important—yard improvements that significantly enhance productivity and system levels of service.

A substantial amount of industry participation and interaction has been incorporated into the project effort. Development of the manual has drawn extensively upon the experience and insights of numerous individuals. In particular, the design manual could not have been produced without the generous cooperation of a number of railroad individuals (see Preface) and the American Railway Engineering Association (AREA) Subcommittee 14 on Yards and Terminals.

1.2 DEVELOPMENT OF THE DESIGN MANUAL

The design manual was developed as a result of a three-phase classification yard design methodology project directed by the Transportation Systems Center (TSC) under the sponsorship of the Federal Railroad Administration (FRA). During Phase 1, the factors and elements to be included in the design methodology and their level of precision were identified, and a preliminary methodology for the basic yard design process was developed.

In Phase 2, the preliminary methodology developed in Phase 1 was applied to actual yard design problems. This was done in cooperation with two railroads in a case-study application: CONRAIL's Elkhart Yard rehabilitation (Elliot, 1980) and Boston and Maine's East Deerfield Yard rehabilitation (Sakasita, 1980). The intent of Phase 2 was to test, refine, and modify the design methodology based on real-world yard design problems. Special effort went into assuring that the procedures are accurate and effective and can be applied in a practical case by knowledgeable railroad personnel.

In Phase 3, a final design methodology was developed as a result of the preliminary form prepared in Phase 1, the modifications made in Phase 2, and industry comment and feedback obtained throughout the project. The end result is this yard design manual.

REFERENCES: CHAPTER 1

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WABCO, "Railroad Freight Car Classification Yards: Installations 1924-1976," Bulletin 300, Union Switch and Signal Division, Westinghouse Air Brake Co., Swissdale, Pennsylvania (1976).

Welty, G., "The New Class Yards: How Are They Working?" Railway Age, pp. 21-28 (March 27, 1978).

CHAPTER 2: USING THE YARD DESIGN MANUAL

2.0 GENERAL

The yard design manual is not organized like a textbook in the sense that a user is expected to read the chapters in sequential order. Rather, it is organized in the form of a reference handbook wherein each chapter addresses a critical aspect of design, and insofar as possible is self-contained. Thus, depending on the design problem, the user is advised to choose the chapters and the sequence in reading them, which are appropriate to the problem at hand. With that approach in mind, this chapter is presented as a guide to the contents of the design manual, and includes suggested chapter sequences for some typical applications.

2.1 TOPICS COVERED

The yard design manual is intended to be treated as a reference manual rather than a textbook. It primarily addresses the planning, economics, and engineering aspects of site selection, yard configuration, track capacities, track layouts, grades, switches, turnouts, etc. Not all yard engineering design aspects are treated. Specific detailed civil engineering construction topics such as soil preparation and drainage, design of towers or bridges, etc., were considered beyond the scope of this manual. The reader interested in these topics should consult standard railroad and civil engineering textbooks on these subjects.

The topics discussed within each chapter of the manual are described below.

2.1.1 Chapter 1: Introduction

This chapter discusses the importance of yards to railroad service and productivity and the need for a yard design manual and new computer-aided design procedures. The background on the yard design methodology project which ultimately created the yard design manual is highlighted.

2.1.2 Chapter 2: Using The Design Manual

This chapter describes the organization of the design manual and the topics treated in each chapter. For specific design problems, a list of pertinent chapters is indicated as an aide to the user.

2.1.3 Chapter 3: A Brief Tutorial on Classification Yards and Their Operation

The design manual is not primarily intended to be a tutorial on yards and their operation. However, users not familiar with railroad and/or yard operations should read this brief chapter. Topics covered include flat and hump yard operation, processing of cars from inbound receipt to outbound departure, and the information and paper handling that must accompany each car.

2.1.4 Chapter 4: Organizing The Design Effort

A yard design project is a very complex undertaking requiring the supervision and coordination of many individual tasks and skills across many railroad departments. This chapter addresses the organization of the design effort. Topics include the makeup of the yard design team and project management and coordination.

2.1.5 Chapter 5: Choosing The Location for A Yard Project

Many times the site of a new yard or the rehabilitation of an old yard is already known by management based on obvious operational, engineering, and economic criteria. However, for those situations where a suitable site has not already been selected, this chapter describes a site selection methodology. The methodology essentially consist of the following two phases.

- Phase 1--Choose the proper system area (or region) where additional switching capability should be placed.
- Phase 2--Within the identified system area (or region) select the specific site for new yard construction or an existing yard for rehabilitation.

2.1.6 Chapter 6: Economic Analysis of Yard Projects

An economic analysis of the yard project is likely to be performed several times at various stages of the yard project, i.e., site selection, initial cost feasibility, and rate-of-return justification. In the initial stages of the project the data available are often limited in amount and accuracy, so that an approximate economic analysis is sufficient. However, as the project proceeds, the data become more accurate, permitting a more detailed analysis. This chapter describes a methodology leading ultimately to calculation of economic indicators such as rate of return, net present value, and years required to recover investment and capital costs.

2.1.7 Chapter 7: Estimating Yard Capacity and Crew Requirements

Early in the project, the specifications and compromises on yard performance, track capacity, and crew/engine resource requirements must be determined. This chapter describes two procedures to perform these tradeoffs: a traditional manual yard simulation procedure, and a procedure using a simulation model called CAPACITY.

2.1.8 Chapter 8: Deciding On Flat Versus Hump Yard

In many instances the decision on hump versus flat yard can be made on obvious operational, engineering, and economic considerations. This chapter addresses this issue and provides guidelines for decision making. The relatively new concept of "mini-humps" is discussed in this chapter.

2.1.9 Chapter 9: Geometric Design of Flat Yards

The design of various types of flat yards is discussed in this chapter. Topics include: flat yard configuration, multiple switching leads, grades, switches, turnouts, and ladder designs.

2.1.10 Chapter 10: Planning the Overall Hump Yard Configuration

In this chapter we are mainly concerned with planning the relationship and overall configuration of the receiving, classification, and departure yards, and location of support facilities in a hump yard. Topics

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covered include: in-line versus parallel yard configurations; configuration of receiving, classification, and departure yards; placement of diesel service, car repair, and caboose facilities; and location of towers, yard offices, roadways, and tunnels.

2.1.11 Chapter 11: Hump Yard Track and Switch Layout Considerations

This chapter is concerned with the proper specification of track layout, turnouts, and switches for various parts of a hump yard. Topics include track and switch considerations for the hump and trim-end of the yard, and a civil engineering tutorial on trackwork and switch hardware.

2.1.12 Chapter 12: Hump Grade Design and Retarder Placement

This chapter presents the basic design theory, considerations, and procedures for designing the hump grade and the placement of retarders. A traditional manual design procedure is described as well as a computer-aided procedure using a new computer model called PROFILE. Topics include: basic theory, car rolling resistance, vertical curves and grades, retarders, manual design procedures, and computer-aided design procedures.

2.1.13 Chapter 13: Hump Yard Trim-End Design

The design of the trim-end (pullout-end) of a hump yard is described in this chapter. A manual procedure for evaluating engine conflict and interference at the trim-end is described, along with a computer-aided procedure called CONFLICT. Topics include trim-end design alternatives for parallel and inline departure yards, operational alternatives, measures of effectiveness, a manual evaluation procedure, and a computer-aided procedure.

2.1.14 Appendix A: CAPACITY User's Manual and Documentation

This appendix documents and describes how to run the CAPACITY computer model. The CAPACITY model is a computer program to assist in evaluating yard capacity and crew resource requirements. Its use in the design process is described in Chapter 7.

2.1.15 Appendix B: PROFILE User's Manual and Documentation

This appendix documents and describes how to run the PROFILE computer program to assist in hump grade design and retarder placement. Its use in the design process is discussed in Chapter 12.

2.1.16 Appendix C: CONFLICT User's Manual and Documentation

The appendix documents and describes how to run the CONFLICT computer model. The CONFLICT model is a computer program to assist in the design and evaluation of alternatives for the trim-end or pull-out end of a hump yard. Its use in the design process is described in Chapter 13.

2.2 Organization and User's Guide

Figure 2-1 provides an organizational flowchart of the chapters in this manual. Chapters 1 through 8 deal with topics relevant to design in general and applicable to both flat and hump yards. Specific topics associated with the design of flat yards are treated in Chapter 9. Chapters 10 through 13 deal with design aspects of concern only for hump yards. The extensive material for hump yards reflects the complexity of current hump yard design and operation.

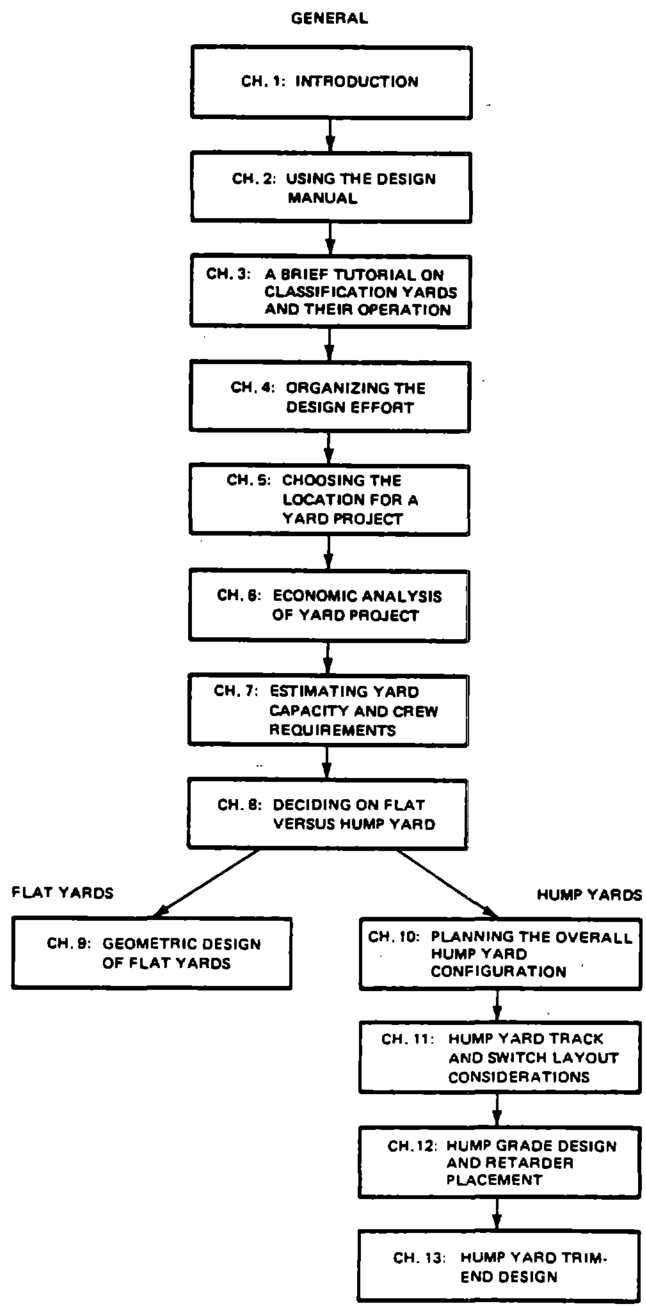

FIGURE 2-1. ORGANIZATIONAL FLOWCHART

Table 2-1 provides a user's guide to the most appropriate chapters to be read for a given yard design problem. For a given problem, the chapters are divided into two categories: primary and supplementary. Primary chapters are those which deal specifically with the problem at hand; supplementary chapters provide general material that is relevant to the problem.

TABLE 2-1.-USER'S GUIDE TO THE DESIGN MANUAL

Project	Main Chapters	Supplementary Chapters
Design Flat Yard	9	7,10
Design Hump Yard	7,10,11,12,13	
Select Yard Site	5	6
Deciding on Flat vs. Hump Yard	8	6
Redesign Hump Grade and Retarders	12	10,11
Redesign Pullout Area	13	10,11
Add Track Capacity	7	10,11,13
Perform Economic Analysis	6	
Evaluate Current Yard Capacity	7	13
Decide on Yard Configuration	10	11
Decide on Turnouts and Switches	11	10
Organize a Yard Project	4	10

CHAPTER 3: A BRIEF TUTORIAL ON CLASSIFICATION YARDS AND THEIR OPERATIONS*

3.0 GENERAL

This chapter briefly describes the physical and operational characteristics of classification yards. The purpose is to provide tutorial material for those not already familiar with railroad classification yards. The discussion is intended to be of value to individuals with specific professional and technical training applicable to yard planning and design (e.g., engineering, computers, costing) but with little experience in either railroads and/or yard operations.

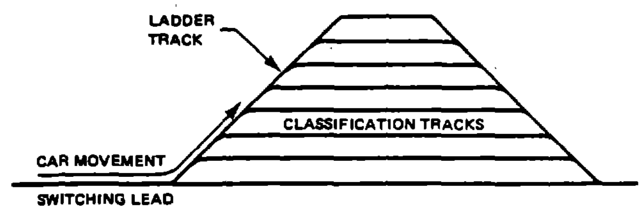

FIGURE 3-1. EXAMPLE FLAT YARD TRACK CONFIGURATION

3.1 PHYSICAL DESCRIPTION OF CLASSIFICATION YARDS

There are two basic types of classification yards: flat yards and hump yards. As the name suggests, a flat yard has a relatively flat vertical profile, whereas, a hump yard has a "hump" or raised portion of ground which dominates the vertical profile. Generally, flat yards, in which cars are pushed by locomotives, are applicable to small and medium volume operations. Flat yards are generally labor intensive, whereas hump yards are more automated.

A flat yard generally consists of a series of tracks connected by a ladder track and switching lead, as shown in Figure 3-1.† Most flat yards use the same tracks for receiving, classifying, and dispatching trains although many such yards do have separate receiving and/or departure tracks. The car-sorting process requires that the group of cars to be switched be pulled out to the switching lead where the switch engine at the rear end of the group will accelerate quickly toward the yard and then decelerate (brake). Just prior to the deceleration, the car at the end of the group away from the locomotive will be uncoupled and the deceleration of the switch engine and the cars coupled to it will cause the uncoupled car at the head end to separate. This procedure is called giving the car a "kick." The car which is kicked will travel along the switch lead and ladder track until switched onto the appropriate classification track. Switches in most flat yards are generally thrown manually. To improve operations, flat yards are often somewhat saucer shaped so that the cars will tend to accumulate in the center of the yard when switching from both ends of the yard. Such gradients also reduce the frequency of cars stopping short on the ladder track or classification track.

Since cars need only little individual handling and the process is well-suited to automation, hump yards can classify a large volume of cars more efficiently than a flat yard. Typically a hump yard has separate receiving, classification, and departure yards. Figure 3-2 shows a configuration in which the receiving, classification, and departure yards are in line (in series); parallel (or side-by) configurations exist. Inbound trains are stored in the receiving yard. The classification process requires that a hump engine take a group of cars from the receiving yard and push these cars over a raised portion of track called the hump. Cars are uncoupled at the hump crest and begin to accelerate down the hump grade, thereby separating from the yard engine and the remaining cars. Referring to Figure 3-2, as the cars roll down the hump grade, braking devices, called retarders, control the speed of the cars, and the appropriate switches are thrown to route the cars into the designated classification tracks. Master, group, and tangent-point retarders are shown in Figure 3-2; however, there exist many other types of retarder configurations, of which the most common is to have only master and group retarders. Outbound trains are built in the departure yard by

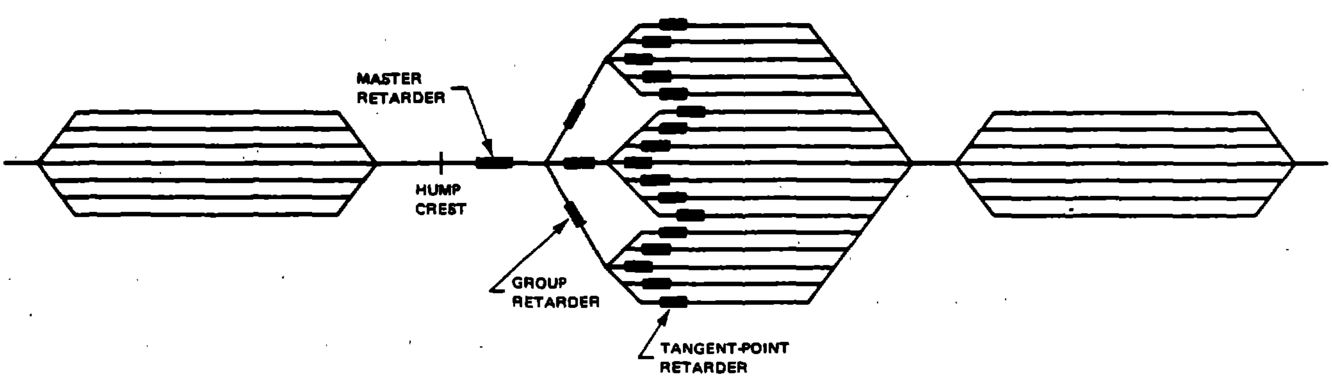

FIGURE 3-2. SCHEMATIC REPRESENTATION OF A HUMP YARD

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*The material for this section of the yard computer handbook draws liberally from tutorial material found in "Railroad Classification Yard Technology: A Survey and Assessment," S. J. Petracek, et al., SRI Final Report (July 1976).

†A large flat yard may have the "top" half of the yard configured as in Figure 3-1, with the "bottom" half a mirror image.

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having a makeup engine successively pull/push cars from the classification yard into the departure yard.

3.2 DESCRIPTION OF THE CAR-HANDLING PROCESS

The operations in a classification yard are keyed to the processes involved in receiving and breaking up inbound trains, classifying or sorting cars, and making up outbound trains. Most of the major actions involved in moving a car through a classification yard are depicted in Figure 3-3. Referring to this operational flowchart, it can be seen that groups of individual freight cars usually arrive on road-haul trains, transfer trains, or industrial drags, and they are placed on one of the yard tracks, if available. Most hump yards and a number of flat yards will dedicate certain tracks or groups of tracks for receiving inbound trains. If the incoming train is too long to be yarded on one track, it will be broken up and yarded on two tracks. This "doubling" process requires between 10 and 20 minutes and can often be performed by the road-haul crew if consistent with labor agreements and other considerations. After an incoming road-haul train has been yarded, the locomotive units and caboose are detached and moved to a service area. In some yards, however, the caboose is not detached but is actually humped (or switched) and sorted at the same time as the rest of the cars on the train.

After the incoming train or "drag" of cars has been yarded and the engines and caboose have been detached, the airbrake systems on the cars are ready for bleeding. Yard employees must release the compressed air reservoir to deactivate the air brake system so that switch engines can freely push cars to the hump or along the switch lead. The airbrakes are bled by carmen who walk along one side of the train and stop at each car to open valves that release the air. Occasionally, however, the release rod may be broken on the carman's side and he must climb or crawl between cars to use the release rod on the other side.

Generally, while the airbrake reservoir is being bled, the individual cars will be inspected for mechanical or physical defects. Some common defects include dragging equipment; mechanical failure of the airbrake system; cracked or broken wheels, bearings, and journals; and broken couplers, door and seal problems and car structural damage. Other defects, such as damaged or shifted loads, are also identified. After the "bad order" cars are identified they are sorted out from the others during the normal switching or classification process.

The switching or classification process is the central activity in classification yards. It involves sorting the cars, which have arrived grouped together on a train or industrial drag, into appropriately assigned classification (or "class") tracks. The assignment of these cars to the class tracks is generally based on the car's destination or commodity and the sorting policy of the yard. For example, in one yard, all cars bound for Chicago may be placed on Track 9 and all cars bound for Buffalo and Boston may be shunted to Track 4 and grouped together. Other track assignments may be based on car condition, such as whether it needs to be cleaned or repaired. Cars in transit through a yard often must be reswitched or rehumped for a number of reasons. For example, cars that require special processing (such as cleaning or repairing) usually must be reswitched after such processing has been completed. In addition, many yards do not have enough tracks to assign dedicated tracks to each of the blocks being made up in the yard. This forces yard personnel to mix blocks together on a slough track and then reswitch these cars when a track becomes available.

After being switched onto the correct class track, the cars generally wait while others are being sorted among the various class tracks. The time spent on a classification track waiting for enough other similarly bound cars to make a train is referred to as "accumulation time."

After enough cars have been accumulated to make a train or because of a specific departure schedule, they will be assembled into a train or industrial drag. In this process the blocks of cars that are on a number of different class tracks are joined together on a departure track that is long enough to hold all the cars for the train. After the cars and blocks have been coupled, carmen will connect the airbrake hoses, turn the brake valves, and inspect for bad-order or misswitched cars that must be switched out of the train. After the cars and airbrake hoses have been connected, the train's airbrake system is charged. There are three methods for charging the air lines. The first (generally the fastest and most desirable) is to use sources of compressed air that are located near the departure tracks. When such facilities are not available the "airing" can be done by a switch engine or by the road-haul engines after they have been attached. The airbrake system is then checked for leaks.

At this time the locomotives and caboose are attached and the train is physically ready to depart. There are a number of factors, however, that can delay departure; these include lack of road-haul crew or power, lack of documentation (waybills, etc.) or traffic congestion within the yard or on the main line.

Although this description has been organized in a step-by-step operational sequence, in most classification yards these operations are performed simultaneously on different cars and trains. While one train is being received into a yard another train or group of cars may be in the process of being classified while still other cars are being assembled into an outbound train.

3.3 DESCRIPTION OF THE INFORMATION AND DOCUMENTATION PROCESS

The actual movement of cars through a classification yard is usually accompanied by the processing of information and paperwork within the yard. In fact, the transference and processing of information is an essential supportive part of the car-classification and train-makeup processes. The purpose of these activities is to control the movement and identify the location of cars in the yard. Without such information the classification would not be adequately controlled. The information and paper-handling process is described in the sequence in which cars physically move through the yard.

The first information received by a yard concerning an inbound train is its inbound consist, which is a description of the makeup of the train. At most large- and moderate-size yards within modernized railroad networks, this consist information is usually received before the actual arrival of the train. Although this may allow the yardmaster some advance operations planning, this possibility is often limited by the quality of the received information or the amount of confidence the yardmaster has in it. The advance inbound consist is composed of the outbound consist of the last yard at which the train stopped. If the train picked up or set out any cars or blocks of cars after passing that terminal, the advance consist would be in error.

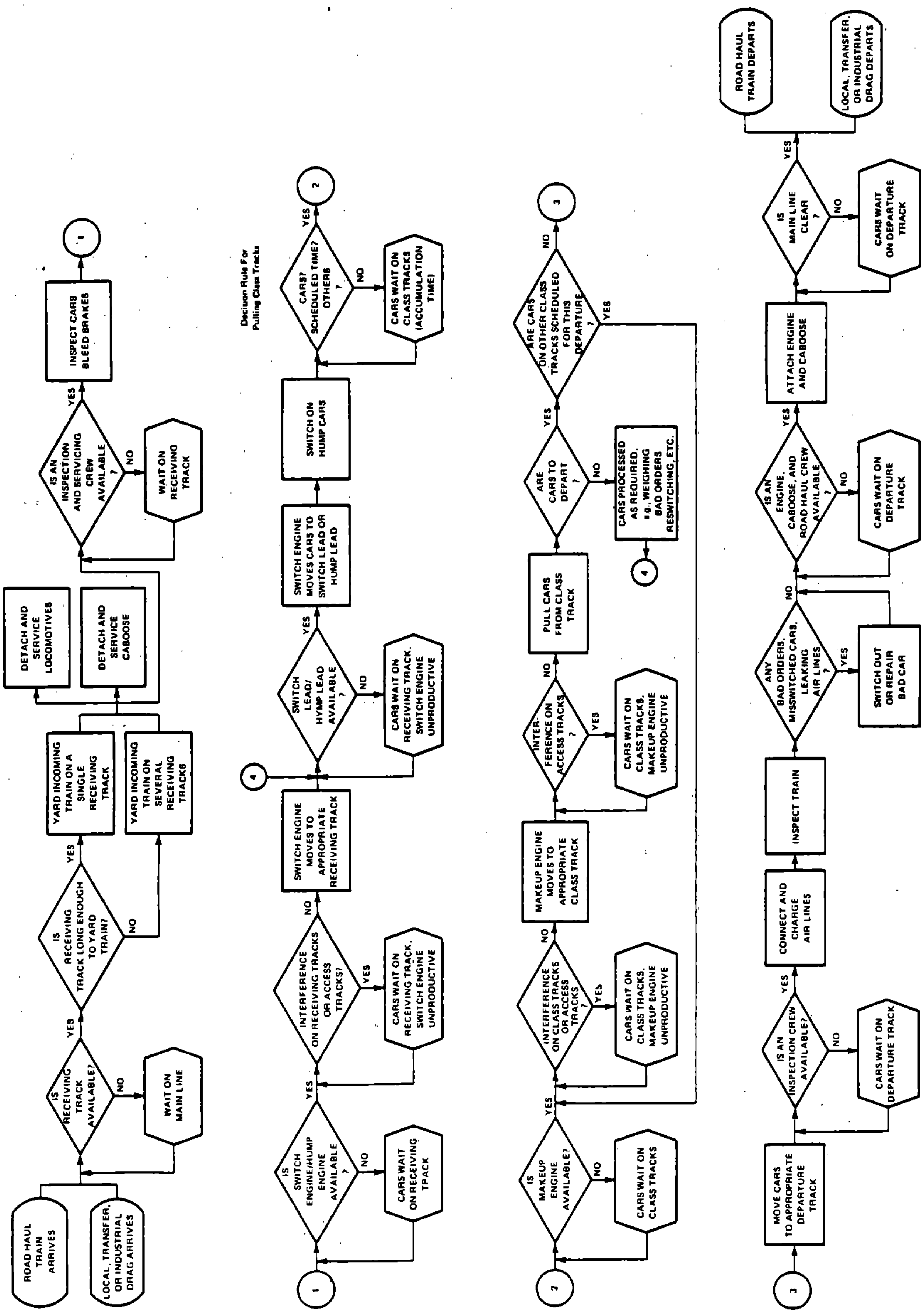

FIGURE 3-3. CAR HANDLING PROCESSES IN CLASSIFICATION YARDS

Additional information is obtained with the actual arrival of the train. The identification numbers of the cars in the train are noted and recorded using closed-circuit television and video tape, audio tape, or by pencil and paper. These numbers can be checked against the advance consist information, and corrections can be made on an exception basis. Waybills and/or bills of lading also arrive with the train. A bill of lading is the agreement between the shipper and the railroad concerning the transportation of the shipper's goods. A waybill is a receipt that details the shipment and routing inventories. Locally originated traffic is often accompanied only by bills of lading, thereby requiring the preparation of waybills; inbound road-haul traffic is generally accompanied only by waybills. All of this paperwork is the responsibility of the train conductor until reaching the yard, at which time it is turned over to a yard office clerk. Waybills are then prepared from bills of lading for those cars that require them and, in some yards, computer cards are punched. The waybill and the other recorded information are then used to update the advance consist information. From this enhanced information, class tracks are assigned and the switch lists are prepared. A switch list (also known as a cut list or hump list in hump yards) assigns a classification track for each car or cut of cars. From this procedure, it can be seen that the actual switching of a train cannot begin until all of the above information processing has been accomplished. There is a potential for delay, therefore, if the information processing takes longer than the brake bleeding and car inspection; it also tends to limit the speed with which high-priority trains are processed. Slow rates of information processing may also reduce the effectiveness of high-speed car inspection systems.

After the switch lists have been completed, they are distributed to the yardmasters, hump foremen, retarder operators, switchmen, and the switchengine crews. Any changes are then manually recorded on these lists; an example of such a change would be the reassignment of a car from a specific class track to a bad-order track because of deficiencies discovered during the initial car inspection.

The next step in the classification yard procedure is the assembling of cars from different class tracks into an outbound train. The waybills for the cars on the outbound train are also assembled. The car numbers and waybills are then compared in an outbound check and the necessary corrections to the consist are completed. The waybills are then transferred to the outbound train conductor. When the train departs, the outbound consist is transmitted to a central processing location or to the next yard where it becomes the advance inbound consist for the train.

There are two major types of yard inventory systems which monitor car location and track status in the yard: manual and computer-based. An example of a manual system is the PICL system (perpetual-inventory and car-location system). In this system, computer cards are punched for each car. A box (or rack) of pigeonholes is used to represent each track in the yard. A yard office clerk, by referring to the switch list, manually sorts the waybills and computer cards into the pigeonholes corresponding to the tracks onto which the individual cars are switched. In this system the waybills and cards simulate the physical car movement from track to track by moving from pigeonhole to pigeonhole. The cars on any track can be identified by looking at the cards in the corresponding pigeonhole. The computer inventory system is often referred to as a disc-PICL system, and the manual approach is called a card-PICL system. The computer keeps track of car location and status as cars are physically moved. Normally cars are moved in the computer according to a switch list or a prescribed classification track assignment table. The computer systems are much faster, more flexible, and more accurate than the manual systems; they normally can provide a track inventory, locate cars, and produce many types of management reports.

Information processing procedures vary with each yard, even for yards on the same railroad. Part of this variance is the result of differences in the procedures used by the various railroad companies and in the computer systems available at specific locations.

CHAPTER 4: ORGANIZING THE DESIGN EFFORT

4.0 GENERAL

The design of a new yard or rehabilitation of an existing yard may cost tens of millions of dollars, and will have an impact on a railroad's competitive position for the lifetime of the yard by directly influencing railroad service and operating costs. Consequently, the decisions regarding a new yard or rehabilitation of an old yard are critical and their effects are long lasting.

A yard design effort may be one of the more important and major engineering projects undertaken by a railroad. However, the organization and management of a yard project can be difficult for the following reasons. First, because major yard projects may occur infrequently on a railroad, the resident in-house experience from previous yard projects to organize and perform certain aspects of the work may be limited. Second, a successful yard project generally requires the cooperation and expertise of all the major railroad departments; thus, communication and coordination among the team members is vitally important.

In this chapter we describe guidelines for organizing a yard project team and suggest procedures to aid in the management of the project.

4.1 YARD DESIGN TEAM

The structure and organization of a design team varies significantly among railroads and even among design projects of the same railroad, depending on whether or not the project involves a major design effort.

At least two large railroads have formed permanent terminal planning groups under the operations department whose personnel are dedicated solely to terminal planning, operations evaluation, and design. These groups generally constitute the nucleus of a formal design team for major yard design projects. The design team is supplemented by other individuals with experience and expertise in particular technical areas and by persons representing other organizations within the railroad that may be affected by the yard design.

However, the majority of railroads have not established a special group for terminal planning. At these railroads, a yard design effort may require that a special design team be organized. The composition of a typical design team may include representatives from the following departments or areas of expertise:

- Operations
- Engineering
- Mechanical
- Communications and Signaling
- Information Systems
- Marketing
- Finance.

The project leader is usually a person in middle- to upper-level management who has direct access to the president and vice presidents and a great deal of autonomy and authority in his conduct of the design effort. Because the operating department must operate the yard and live with the consequences of design decisions, they should play a major role in influencing design decisions. Consequently, the project leader should either come from the operating department or have the confidence and support of this department. The ideal choice would be a person with yard operations experience in addition to an engineering background.

4.2 MANAGEMENT AND COORDINATION

4.2.1 Regular Project Meetings

A well-managed yard design team is concerned not only with making the best design and engineering decisions, but also with making the decisions in a manner that secures the full participation and cooperation of the affected railroad departments. It cannot be too strongly emphasized that the yard design team should seek to make decisions in a manner which promotes team spirit rather than factionalism among the departments. This spirit of cooperation will not only ensure the best overall design, but will ensure that all departments work together on opening the yard for operation on schedule.

It is suggested that the full project team meet regularly during the course of the project (say every two weeks) and that working groups be established to perform specific tasks. Most of the detailed work will be done in the working groups. Recommendations from the working groups will be presented to the full project team for discussion and critique to ensure that all departments are kept informed of the progress of important decisions and to input their comments as appropriate.

It is desirable to record the significant aspects of each regular meeting of the project team and to distribute this record to team members and other cognizant people. The minimum information to be included in this meeting record is displayed in Table 4-1.

TABLE 4-1.-MEETING RECORD

(1) Meeting date and time

(2) Meeting place

(3) Attendees

(4) List of discussion topics, for each topic as appropriate:

- Brief description
- Issues raised and plan for resolution
- Recommendations and decisions

(5) List of action items, for each item as appropriate:

- Brief description
- Person responsible
- Date for action.

4.2.2 Statement of Need, Objectives, and Constraints

The first regular meeting of the project team should address itself to a clear statement of the need, objectives, and constraints of the project.

Need--The fact that a yard project team was formed indicates an awareness by top-level management of certain specific operating problems needing attention. To the extent possible, these perceived needs by top-level management should be discussed so that the entire project team is aware of the scope of management's concern.

Objectives--Based on a perception of management's concern, a statement of the project's objectives should be developed. This statement will provide a point of focus and communication for the team members as well as for management. For projects which are large in scope, the statement of the objectives at this first meeting may necessarily be of a general nature. The design process itself will lead to a more precise statement of objectives; as appropriate the statement of objectives should be continually redefined during the project to reflect a more precise understanding of the problem. For example, the initial statement of the objective may be to design a new yard or rehabilitate an existing yard so that system-level classifications and industrial switching for a specific region are more adequately handled. At some point in the project, a more precise quantitative statement of project objectives should be stated. For instance, a more precise statement may be to design a yard which can on the average process 2,000 cars per day, make 75 classifications, receive 20 trains, and depart 19 trains with an average car detention time of 20 hours. Thus, as early as possible a statement of objectives should be drawn up in as specific terms as possible. This statement should be made more specific as the project proceeds.

Constraints--The first meeting should also make explicit any a priori project constraints (e.g., funding limitations) and performance schedules (e.g., design and construction to be completed in 24 months) which have been imposed either by higher management or external sources (e.g., local community concerns, government regulations). These constraints will set limits on design alternatives, and should be understood at an early stage by all team members.

4.2.3 Determination of Specific Tasks

As early as appropriate, the overall design work should be broken down into a set of specific tasks. The specification of the tasks depends on the particular nature of the yard project. Table 4-2 lists a hypothetical set of tasks for a typical hump yard design process. It is likely that a particular yard project will require the performance of a subset of these tasks. Therefore, these tasks are briefly described below.

TABLE 4-2.-LIST OF YARD DESIGN TASKS

- Traffic Analysis
- System Blocking Plan
- Site Selection
- Yard Traffic Loading
- Yard Capacity Requirements
- General Yard Configuration
- Hump Design and Speed Control
- Detailed Track Layout
- Computer Specifications
- Repair and Service Facilities
- Office Buildings and Roads
- Communications, Signaling, and Lighting
- Economic Analysis

Traffic Analysis--A design effort in most instances would require projected changes to the current traffic levels to serve as a traffic demand base for the design effort. This should take into account changes in the current customer traffic base and estimates for new traffic. The new traffic could reflect shipments obtained at the expense of other carriers or from a new market segment. Ultimately, the traffic analysis should project the car and load shipments for a "design day." The design day can be an average day or a peak day. However, the specification of this design day should be made clear at the outset (e.g., design day equals 130% of average day).

System Blocking Plan--Based on the projected traffic demand, a system blocking plan should be developed for existing plant conditions. For this "base case," the system blocking plan should indicate for each yard the estimated loading in terms of the number of cars to be switched per day, and for each line-haul segment the number of car movements per day. An examination of the base case indicates the system's ability to handle the traffic with no yard improvements. The base case will provide insight as to where a new yard should be built on the system, or alternatives for rehabilitating existing yards. For each of the alternatives, a system blocking plan must be developed. The alternate system blocking plans are required for the evaluation of various site selections.

Site Selection--For each alternative site and the associated system blocking plan, an economic analysis should be performed to assist in the selection of the best site. At this stage of the design process only approximate cost data based on a rough-cut design for each site is likely to be available, since a detailed design for each site is probably too prohibitive in terms of time and effort.

Yard Traffic Loading--After a specific yard has been selected, a detailed traffic scenario for the yard should be developed, using the associated system blocking plan. This traffic scenario should be sufficiently detailed to specify all aspects of the desired yard loading needed for the purposes of design, i.e.,

- List of classifications to be made.
- Inbound train schedule: for each train the number of cars for each classification.
- Outbound train schedule: for each train the classifications carried.

Again, the notion of a design day must be clearly specified.

Yard Capacity Requirements--Based on the yard traffic loading and assumptions concerning crew and engine resources, the number and length of tracks in the receiving, classification, and departure yards should be estimated. Sensitivity analysis on the traffic loading should be conducted to see the effects of the track capacity requirements.

General Yard Configuration--Given the constraints of the site; the requirements for the receiving, classification, and departure yards; the need for repair, service, and support facilities; and the constraints imposed by connecting to the mainline and perhaps other support yards, the general configuration and relationship of the major elements of the yard should be developed. This would specify the location of various subyards and support facilities so as to maximize engine and crew productivity and minimize logistic and supervision requirements.

Hump Design and Speed Control--The hump grades and the retarder location and their lengths are designed to meet a specific humping speed, tolerance of coupling speeds on the class track, and allowable percent of misswitched cars. This design must interface closely with the detailed layout of the switching area.

<u>Detailed Track Layout</u>--The detailed track and switch layout for the entire yard is based on the general yard layout. The various areas of concern include: main line entrance to receiving tracks, hump leads and hump access from receiving tracks, switching area, pullout to departure area, main line exit from departure tracks, various routes to service areas, and escape routes for yard engines to get to various parts of the yard. The layout should minimize engine travel and conflict.

<u>Computer Specification</u>--The process control functions of switching and retarder control can either be manual, semiautomatic, or fully automatic. The car inventory functions can rely on a manual card PICL system or be automated in an MIS computer. The options are myriad and the tradeoff considerations complex. Cost considerations are likely to dictate the level of computer sophistication for the yard.

<u>Repair and Service Facilities</u>--Facilities for repairing or servicing freight cars, engines, and cabooses must be well planned in order to support the yard operations. The location of these facilities must be such as to minimize travel, logistic, and interference problems with other yard activities.

<u>Office Buildings and Roads</u>--Based on the general yard layout and the location of the yard tower, any office buildings and support roads should be specified. The detailed plans for any buildings must take into account logistic requirements for supervisory personnel and crews and computer and communication facilities. The roads should be placed so as to cause minimum conflict and interference with engine movements.

<u>Communications, Signaling, and Lighting</u>--The communication and signaling system (e.g., speaker phones, signal lights) to coordinate yard engine and ground crew activities is critically important to insuring a well supervised yard with minimum personnel. Proper placement and sufficient lighting facilitates supervision and enables work to be accomplished in an efficient and safe manner.

<u>Economic Analysis</u>--A detailed economic analysis of the costs and benefits of the yard project will be presented to top-level management after the yard has been designed for their approval. It is likely that this will entail several iterations of modifying the design and economics to meet cost constraints.

4.2.4 <u>Formation of Working Groups for Specific Tasks</u>

To insure at the beginning that a department is represented on the appropriate task working group, a task department staffing matrix such as shown in Figure 4-1 should be developed, where the major tasks are listed along the side and the departments involved are listed along the top. The "x" in each box signifies which department is to be represented in the working group for that particular task. Such a matrix openly discussed and explicitly displayed at an early date will facilitate coordination and cooperation of all departments throughout the project. The task leader can also be indicated on this matrix.

4.2.5 <u>Aids for Planning and Management Control</u>

In order for a design project to proceed smoothly on schedule, it is important that everyone on the project team knows <u>who</u> is to do <u>what</u> and <u>when</u>.

There are a number of planning and management aids for project scheduling and control. These aids take the form of some type of diagram or chart which displays the relevant aspects of who, what, and when.

TASKS \ DEPARTMENTS	OPERATING DEPARTMENT	ENGINEERING DEPARTMENT	MECHANICAL DEPARTMENT	COMMUNICATIONS/SIGNALING	INFORMATION SERVICES	MARKETING DEPARTMENT	FINANCE DEPARTMENT
TRAFFIC FORECAST	X					X	
SYSTEM BLOCKING PLAN	X						
SITE SELECTION	X	X				X	X
GENERAL YARD CONFIGURATION	X	X	X	X	X		
YARD TRAFFIC LOADING	X						
YARD CAPACITY REQUIREMENTS	X	X		X	X		
HUMP DESIGN AND SPEED CONTROL	X	X		X	X		
DETAILED TRACK LAYOUT	X	X	X	X	X		
COMPUTER SPECIFICATIONS	X		X	X	X		
REPAIR/SERVICING FACILITIES	X	X	X	X			
OFFICE BUILDING AND ROADS	X	X	X	X	X		
COMMUNICATION, SIGNALING, AND LIGHTING	X		X	X			
ECONOMIC ANALYSIS	X					X	X

FIGURE 4-1. TASK DEPARTMENT STAFFING MATRIX

The planning process of initially constructing these diagrams is just as important as the finished product, since the planning and construction processes force the project leader and task leaders to think through the entire project. Early in the project interdependencies between tasks will be recognized and limitations in the design effort in terms of time, staff, or money will be uncovered.

Once these planning/management aids are constructed they will become the means of monitoring and controlling the progress of the design effort. They will be the focus of communication between team members since they succinctly display responsibilities, deliverables, and timing considerations. It is likely that when modifications to the initial project plan are contemplated, their effects on the entire effort will be analyzed by modifying these planning/management aids. Consequently, their usefulness is multifold and will increase with the size and complexity of the project.

<u>Bar Chart</u>--There are many forms of bar charts. Figure 4-2 displays one particular example. Along the top of the chart is a time scale and along the side is a list of task descriptions. Associated with each task underneath the time scale is a bar which indicates the beginning and ending of each task. For each task, the scheduled time of any reports or findings is attached to the respective bars in the form of a numbered box. Also, the scheduled time of key decisions is indicated with numbered circles along the time scale. At the bottom of each chart, the anticipated description of each report for finding and key decision is detailed.

<u>Task Flowchart</u>--The bar chart presents scheduling and timing information, but does not present the interrelationships and interdependencies between tasks. Figure 4-3 shows one of many types of task flowcharts. In each box is a description of each task. If a task needs to be performed before another task can begin, this is indicated by solid arrows (e.g., Task 5 requires the completion of Tasks 2 and 3 before it can start).

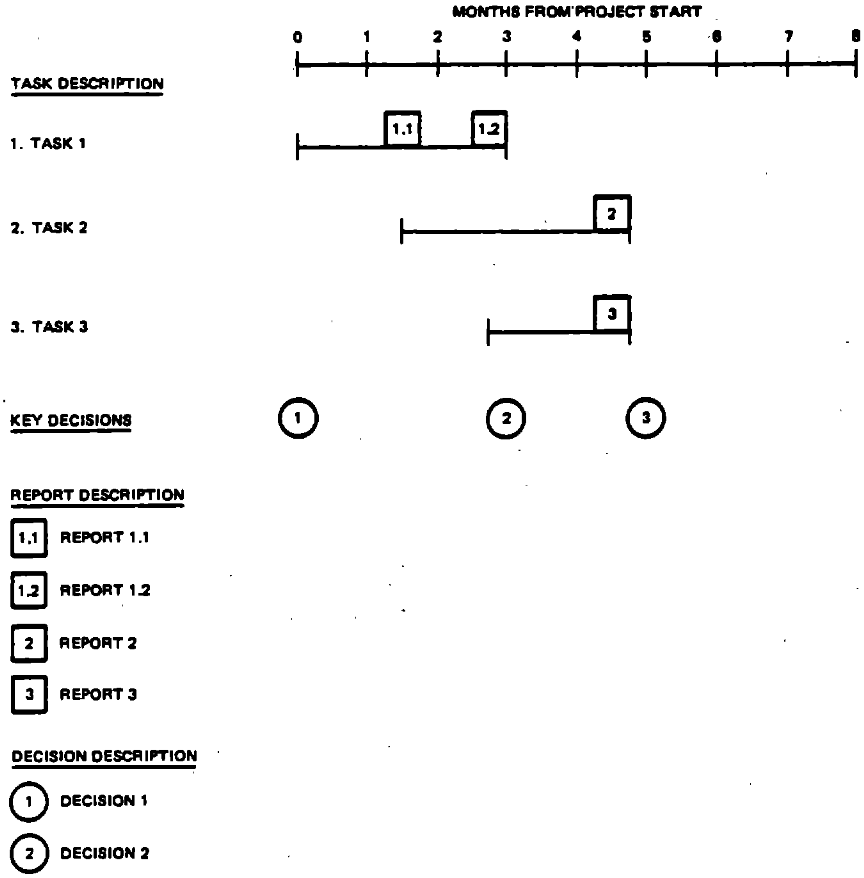

FIGURE 4-2. EXAMPLE OF A BAR CHART

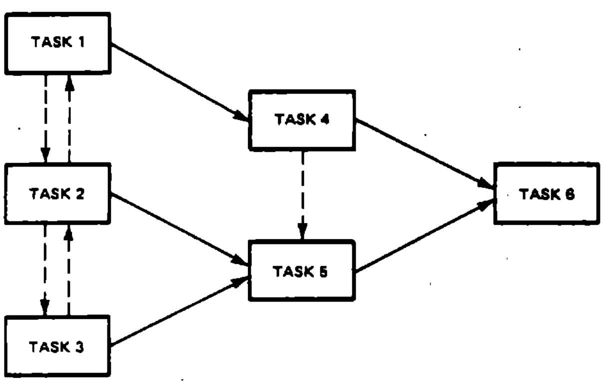

FIGURE 4-3. EXAMPLE TASK FLOWCHART

Tasks which require information from another task are indicated by broken arrows (e.g., Task 5 requires information from Task 4). Double broken arrows indicate a two-way interchange of information and a close coordination between tasks (e.g., Tasks 1 and 2).

Time-Activity Diagram--The bar chart and task flowchart are relatively simple; however, each displays different useful aspects of a project. A time-activity diagram such as the one displayed in Figure 4-4 attempts to display all the information on one diagram. (Note, a very large sheet of paper may be required.) Along the bottom of the diagram is a time scale. There are three basic types of symbols used in this particular diagram, and the placement of the symbol above the time line indicates start and due dates. The start of a project is represented by a "begin task" symbol in which the task description, leader, staff, and start date are recorded. The end of the task is indicated by a "final report" symbol in which the anticipated description or specification of a task report or finding is noted with the due date (intermediate reports or findings from the task are indicated in a similar manner). A solid arrow interconnects "begin task" symbol and "report" symbols for the same task. The "key decision" symbol indicates the anticipated nature of the decision and due date. Broken arrows indicate which reports or findings of one task are needed for another task; broken arrows also indicate for each "decision" symbol which reports or findings are required. (Note, solid arrows are used to connect symbols of one task, broken arrows connect symbols outside the task.) In this type of diagram, the nature and timing of final reports and interim findings required from each task (and which tasks or decisions need them) are explicitly displayed. This will facilitate coordination among tasks. Although more complicated than the other planning aids, it has the advantage of displaying all the information on one diagram.

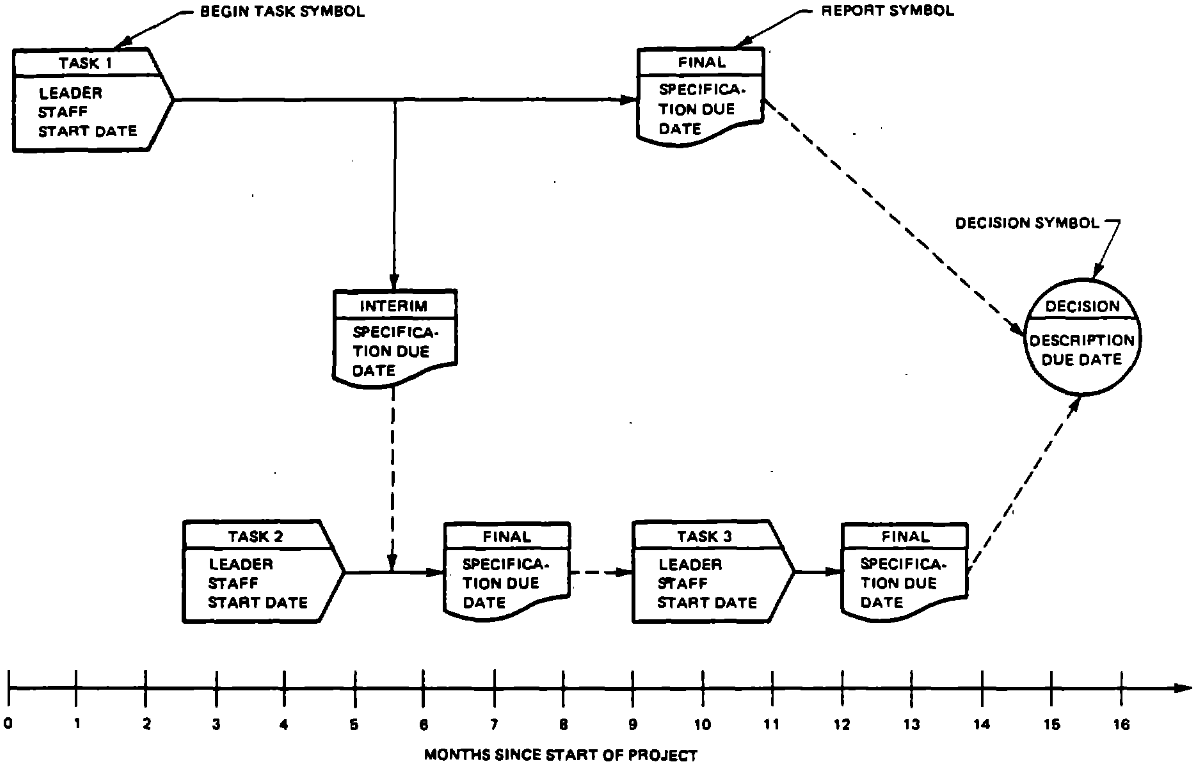

FIGURE 4-4. TIME-ACTIVITY DIAGRAM

CHAPTER 5: CHOOSING THE LOCATION FOR A YARD PROJECT

5.0 INTRODUCTION AND OVERVIEW

In many cases the location of a new yard or the choice of which existing yard to rehabilitate requires no formal analysis and has been decided by management based on obvious engineering, operating, and cost considerations. However, there are many cases where this location issue is not clear. This chapter addresses this question.

We envisage the ultimate decision as to where a new yard should be placed or which yard should be rehabilitated as involving the following two phases.

- Phase 1: Choose Proper System Area--Choose the proper system area (or region) where additional switching capability should be placed.
- Phase 2: Select Specific Site--Within the identified system area (or region) select the specific site for a new yard construction or an existing yard for rehabilitation/rebuilding.

In some instances, the desired system location has already been determined, and the appropriate site must be selected. However, in most cases, the identification of the proper system area for additional switching capability is of major concern and importance. These two phases are detailed below.

An overview of the overall decision process involving the two phases is depicted in Figure 5-1.

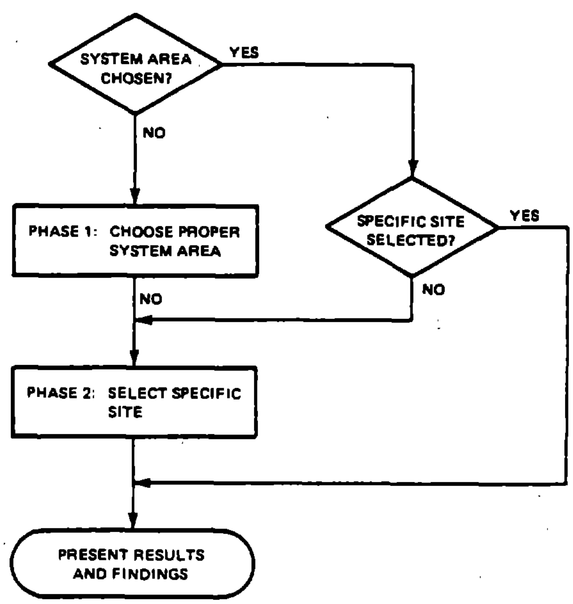

FIGURE 5-1. OVERVIEW OF DECISION PROCESS FOR CHOOSING THE LOCATION FOR A YARD PROJECT

5.1 PHASE 1: CHOOSE PROPER SYSTEM AREA

5.1.1 General

The reasons for building a new yard or rehabilitating an existing yard may be due to many factors, including traffic growth, reduction of operating costs, increased productivity and efficiency, elimination of congestion, and improvement in service. The ultimate purpose of a yard is to provide the necessary switching, traffic consolidation, and train building capability to support a system operating plan which provides desired levels of service (e.g., trip time and trip time reliability) at minimum operating costs.

In many cases, it is obvious in what system area or region of the network additional yard capability is needed. For example, a region which is not adequately served by either an industrial yard or system switching yard may be projected to have increased traffic growth and therefore warrants a yard. In the case where the proper system area to locate a yard project is known, the reader can skip Phase 1 (Choose Proper System Area) and go directly to Phase 2 (Select Specific Site).

Choosing the proper system area to locate a new yard project should be viewed fundamentally as selecting the system area or region in the network where additional switching (classification), traffic consolidation, and train building capability is needed. If the system area has an existing yard which is suitable for rehabilitation or rebuilding, then the rehabilitation of an existing yard should be considered. If the system area has no existing yards, then a new yard should be considered. The ultimate choice will be a tradeoff between the system benefits of various alternative areas versus the capital cost requirements to place a yard with suitable capability in each area.

In the following, we present an approximate method for evaluating the costs and system benefits of the various alternatives for locating a yard project. In most cases the choice of the proper system area will become obvious during this approximate process. If not, then the more detailed economic analysis as decribed in Chapter 6 (e.g., rate-of-return calculation) must be performed for each alternative location and the economic results compared.

It should be noted that the detailed economic analysis process (described in Chapter 6) is normally performed after the yard location has been selected, detailed preliminary yard designs have been completed, and preliminary yard and system operations have been specified, since this level of detailed specification is needed to accurately estimate costs and quantify system benefits. Consequently, the detailed economic analysis is tedious and time consuming. In particular, to gather the data and perform the detailed economic analysis could take as long as 6 months for a single yard alternative. Normally, the detailed economic analysis procedure is used to justify a capital investment project to corporate officers once most of the preliminary engineering decisions have been made. The analysis is used to determine the economic attractiveness of a specific yard project in relation to alternative capital improvement projects or investment decisions at the corporate level. For this reason, the approximate process to choose between alternative system areas when locating a yard is to be preferred over the use of the detailed economic analysis since it is quicker, and detailed analysis of the cost and system benefits are not likely to be required to choose between alternatives.

The approximate evaluation procedure is discussed in the following steps, and is based on evaluating the cost and system benefits of a proposed set of alternative areas in which to locate a yard.

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- Step 1: Select Alternative System Areas
- Step 2: Estimate Yard Capabilities
- Step 3: Estimate Cost Requirements
- Step 4: Estimate Systemwide Operational Impact
- Step 5: Estimate Economic System Benefits
- Step 6: Evaluate Alternatives.

To assist in explaining and performing the evaluation process, a number of example worksheets are provided. The worksheets are examples only; the information required and formats should be changed to reflect the particular railroad situation.

5.1.2 Step 1: Selecting Alternatives

The proposed evaluation procedures are based on evaluating the costs and system benefits of a small set of competing system area locations. There currently does not exist a systematic procedure to define these competing alternatives to meet a railroad's system operating requirements. Part of the problem may be that these requirements are difficult to define precisely.

The reasons or need for new yard capability are varied and should be expressed as precisely as possible; these include:

- Existing yard is old and inefficiently designed and may incur unacceptable loss and damage; it must be rehabilitated and automated or the switching capability transferred to other points in the system.
- A particular region has insufficient industrial switching capability to meet projected traffic growth; additional industrial switching capability is needed from a new yard or rehabilitated yard.
- There are new requirements to interchange traffic with a foreign railroad at a specific point in the system; the capability to handle interchange traffic may require modification of an existing yard or the building of a small interchange yard.
- There does not exist adequate system level switching for traffic generated in a certain region of the system. This results in an inefficient system blocking strategy that in turn results in certain traffic sent through too many yards, carried on too many trains, and/or sent in a circuitous route from system origin to system destination. Additional system level switching capability is needed from a new yard or rehabilitated yard.
- Some yards in the system are over utilized and saturated, resulting in an inefficient operation and/or long terminal detention time for cars. Additional system level switching capability is needed from a new yard or rehabilitated yards to increase efficiency and reduce terminal detention times.
- Train operating costs are excessive and/or locomotive utilization is low because traffic consolidation and train building occurs inefficiently on the system. Additional traffic consolidation and train building capability is needed at strategic locations to minimize train operating costs.
- Mainline trackage is being downgraded or taken out of service because of changing traffic patterns. Consequently, the system switching capability is at the wrong place for efficient operations. A new yard and/or rehabilitated yards are needed to realize an efficient operation for the restructured railroad.

Based on a description of the need for a yard, it may be obvious as to the system area and/or the specific site in which the yard should be located. However, if this is not the case we assume that a number of alternative plans for the location of additional switching capability can be suggested by railroad personnel based on operating experience, engineering judgement, and knowledge of the physical plant. We further assume that top-level management has selected a small set of these alternative plans for further evaluation. The question of determining system area then amounts to evaluating the competing alternative plans for the location of additional switching capability. For those alternatives which do not have an existing yard, new yard construction is envisioned. For those locations which have an existing yard, a yard rehabilitation or new yard construction are possibilities.

5.1.3 Step 2: Estimate Yard Capabilities

It is necessary to estimate the "additional" yard capabilities for each potential yard in each system area in order to estimate approximate costs and system benefits. If the system area has an existing yard suitable for rehabilitation, then the additional rehabilitated capability must be estimated. However, if a new yard is contemplated, then the capability of the new yard is to be estimated.

Because determining the yard location is one of the first decisions to be made in the entire yard design process, it is likely that only an approximate estimate of yard capability can be obtained. This may be based on operational and engineering judgement, experience with other yards having similar functions, or perhaps "quick-and-dirty" analysis.

What is required is simply a sufficient characterization of the yard so that approximate estimates of costs and system benefits can be obtained that are accurate enough to choose among alternative system area locations. Because the estimates are intended to be rough, it is probably sufficient to estimate the following characteristics:

- Receiving Yard
  - Number of tracks
  - Longest track
  - Shortest track
  - Car capacity
- Classification Yard
  - Number of tracks
  - Longest track
  - Shortest track
  - Car capacity
- Departure Yard
  - Number of tracks
  - Longest track
  - Shortest track
  - Car capacity
- Processing
  - Number of cars switched
  - Number of classifications
  - Number of inbound trains
  - Number of outbound trains

If the yard is a rehabilitation project, then where appropriate the total capability of the rehabilitated yard is estimated along with the additional capability due to rehabilitation; these characteristics are indicated with an an asterisk (*). Figure 5-2 is an example worksheet to be filled out as part of this step.

5.1.4 Step 3: Estimate Cost Requirements

In Step 1 and Worksheet 1 (see Figure 5-2) the approximate capabilities of each alternative have been estimated. Based on these estimated capabilities, the capital and operating costs for each alternative must be estimated.

Because the estimated yard capabilities are rough cut at this stage of the yard project, the estimated costs are only approximate. The cost estimates can be derived from informed judgements based on engineering and operating experience, suitably adjusting the costs of other yards with similar characteristics, and/or performing a simple back-of-the-envelope cost analysis. The estimates should be sufficiently accurate, however, to distinguish between the "relative" cost requirements of each alternative. Thus, attention should be placed in ensuring that the relative cost differences between the alternatives are reasonably accurate, since the purpose is to provide costs data to choose between alternatives. At a later time, after the selected yard alternative has been chosen and undergone analysis and design, a detailed economic analysis is performed to justify the project. This detailed economic analysis process is discussed in Chapter 6.

Figure 5-3 shows example Worksheet 2, in which the capital improvement costs for each alternative are estimated. The categories of capital costs are:

- Land
- Grading
- Track
- Signals
- Buildings
- Other structures
- Communications
- MIS and process control computers
- Relocation/removal of facilities
- Utility construction
- Mainline
- Miscellaneous
- Total capital costs.

The above cost categories are relatively straightforward in interpretation, except perhaps the "mainline"

Yard/Capabilities	Alternative 1	Alternative 2	Alternative 3
Receiving Yard			
Number of tracks*			
Longest track			
Shortest track			
Car capacity*			
Classification Yard			
Number of tracks*			
Longest track			
Shortest track			
Car capacity*			
Departure Yard			
Number of tracks*			
Longest track			
Shortest track			
Car capacity*			
Processing			
Number cars switched*			
Number classifications*			
Number inbound trains*			
Number outbound trains*			

*For rehabilitation project, estimate total and additional capability as a result of the rehabilitation.

FIGURE 5-2. WORKSHEET 1
COMPARISON OF YARD CAPABILITIES

Capital Improvement	Alternative 1	Alternative 2	Alternative 3
Land			
Grading			
Track			
Signals			
Buildings			
Other structures			
Communications			
MIS and Process control computers			
Relocation/removal of facilities			
Utility construction			
Mainline			
Miscellaneous			
Total capital costs			

FIGURE 5-3. WORKSHEET 2

SUMMARY OF ESTIMATED CAPITAL IMPROVEMENT COSTS

category. A particular yard alternative may require that a portion of the mainline be upgraded to accommodate perhaps a new operating plan. The required mainline capital investment must be taken into account.

Figure 5-4 shows example Worksheet 3, in which the additional operating costs for each alternative are estimated. The categories of operating costs are:

Additional Operating Costs	Alternative 1	Alternative 2	Alternative 3
Property taxes			
Insurance			
Additional yard forces			
- Carmen			
- Crew			
- Signalmen			
- Clerks			
- Supervisors			
- Others			
Additional yard engines			
Additional maintenance			
- Engines			
- Signal			
- Retarders			
- Communications			
- Electrical			
- Others			
Mainline			
Miscellaneous			
Total operating costs			

FIGURE 5-4. WORKSHEET 3

SUMMARY OF ESTIMATED ADDITIONAL OPERATING COSTS

- Property Taxes
- Insurance
- Additional Yard Forces
  - Carmen
  - Crew
  - Signalmen
  - Clerks
  - Supervisors
  - Others
- Additional Yard Engines
- Additional Maintenance
  - Engines
  - Signal
  - Retarders
  - Communications
  - Electrical
  - Others
- Mainline
- Miscellaneous
- Total Operating Costs

5.1.5 Step 4: Estimate System-wide Operational Impact

Based on the estimated yard capabilities for each alternative, the system-wide operational impact from each alternative must be estimated. This impact assessment will identify operational changes to yards, trains, and service quality; this will be in primarily noneconomic terms.

The system impact must be estimated either based on the judgements of experienced engineering/operating personnel, and/or a manual (or computer) simulation of the network operating plan (i.e., blocking and train makeup strategy) for each alternative. Again, it must be remarked, that at this point in the yard project, the accuracy in analyzing system impact must be sufficient simply to choose between alternatives. After the alternative has been chosen and the detailed engineering design is well underway, a more detailed system impact evaluation is needed to economically justify the project (see Chapter 6).

Figure 5-5 displays example Worksheet 4 which categorizes the operational impact for each alternative. (This worksheet is to be filled out for each alternative.) Each entry in the worksheet requires two numbers: The first number indicates the status with the alternative and the second number (placed in parentheses) indicates the status quo condition (i.e., without any alternative). The categories in the worksheet are:

- Effect on Other Yards--This category estimates the effect on other yards in the system. The "before and after" effect on the following yard parameters is estimated.
  - Number of inbound trains
  - Number of outbound trains
  - Number of classifications (or blocks)
  - Number of total cars switched (or humped)
  - Average terminal detention time per car.
- Effect on Each Route--This category estimates the effect on train operations by route segments. For each route segment the "before and after" effects on the following are estimated:
  - Terminal train delay
  - Number of trains
  - Percent locomotive utilization.
- Effect on Service--This category estimates the effect on service by traffic type (i.e. shipper, commodity, or origin-destination pair). For each traffic type, the "before and after" effects on the following are estimated:
  - Trip time (mean)
  - Trip time reliability (variability).

Effect on Other Yards	Yard 1	Yard 2	Yard 3	Yard 4	Yard 5
- No. of inbound trains					
- No. of outbound trains					
- No. of classifications					
- No. of cars switched					
- Car detention					
Effect on Each Route	Route 1	Route 2	Route 3	Route 4	Route 5
- Terminal delay					
- Number of trains					
- Locomotive utilization					
Effect on Service	Traffic 1	Traffic 2	Traffic 3	Traffic 4	Traffic 5
- Trip time					
- Trip time reliability					
Others					
- Interchange					
- Foreign switching					

FIGURE 5-5. WORKSHEET 4

SYSTEM OPERATIONAL IMPACT: ALTERNATIVE 1

- Others--This category reflects the impact on other aspects of the system operation. Examples include the "before and after" effects on:
  - Interchange
  - Foreign switching.

5.1.6 Step 5: Estimate Economic System Benefits

At the end of the system-wide operational impact analysis (Step 4), Worksheet 4 (filled out for each alternative) will display the operational change associated with each alternative. This step will translate these operational changes into economic terms. Again, it must be emphasized that the economic analysis must be sufficiently accurate only to discriminate between the relative system benefits of each alternative. When the alternative has been selected and after more detailed design and analysis are accomplished, a more detailed economic analysis to justify the yard project is justified (see Chapter 6).

Figure 5-6 shows an example worksheet in which the categories of economic benefits are:

- Labor Benefits
  - Switch engine reductions
  - Force reductions
- Car Benefits
  - Per diem
  - Car utilization
- Train Benefits
  - Train consolidations
  - Locomotive utilizations
  - Terminal delay allowance
- Others
  - Interchange
  - Foreign switching.

Annual dollar savings are to be estimated for each category for each alternative. At this stage of the yard project engineering/operational judgements with perhaps simple "back-of-the-envelope" analysis is probably sufficient. A detailed explanation of Worksheet 5 is presented on the following page.

Yard Benefits--Worksheet 4, under "Effect On Other Yards," lists a rough specification of the new operating environment for each yard. Operational judgements must translate these specifications into annual cost savings due to switch engine reductions and force reductions. Switch engine reductions include the operating cost savings of eliminating a switch engine shift but, also, the equivalent annual capital cost savings of eliminating the use of an engine from yard. (Note, if three shifts can be eliminated at a yard then an engine can be eliminated). Force reductions include the elimination of clerks, carmen, and supervisors because of a reduction in work. If a yard is being rehabilitated through automation, then the elimination of retarder operators, etc., must be included.

Car Benefits--Worksheet 4, under "Effects On Other Yards," estimates the reduction in car detention time for each yard. This needs to be translated into economic benefits. Essentially, the total car detention hours saved must be first split between foreign-cars and own-cars. An average per diem cost is applied to the foreign-car hours and entered under per diem. An equivalent capital cost factor is applied to own-car hours, and entered under car utilization.

Train Benefits--Worksheet 4, under "Effect on Each Route," provides a rough specification of the change in train operations by route for each alternative. If trains are eliminated due to train consolidations, then the savings in crew costs are entered under train consolidations. The more efficient utilization of locomotives must be translated into annual locomotive hours saved; this is multiplied by the equivalent

Estimated System Benefits	Alternative 1	Alternative 2	Alternative 3
Yard Benefits			
- Switch engine reductions			
- Force reductions			
Car Benefits			
- Per diem			
- Car utilization			
Train Benefits			
- Train consolidations			
- Locomotive utilizations			
- Terminal delay allowance			
Others			
- Interchange			
- Foreign switching			
Total System Benefits			

FIGURE 5-6. WORKSHEET 5
SUMMARY OF ESTIMATED SYSTEM BENEFITS

hourly capital costs for a locomotive and entered under locomotive utilization. The reduction in terminal train delay (in annual hours saved) is multiplied by an average cost for constructive train allowance; this is entered under terminal delay allowance.

Others--This category lists other economic system benefits. This may include the reduced cost of interchange activities entered under interchange, or the reduced cost of foreign railroads performing switching (because of a lack of switching capability) entered under foreign switching.

5.1.7 Step 6: Evaluate Alternatives

Figure 5-7 shows Worksheet 6 which provides a summary of costs and benefits for each alternative. The yard capital costs are taken from Worksheet 2 and converted to equivalent annual capital costs. The yard operating costs are taken from Worksheet 3, and the system benefits are taken from Worksheet 5. It is anticipated that at this point the best alternative will be self-evident. However, if a rate-of-return calculation is required (see Chapter 6), then the information in Worksheet 6 will become the basis of this more refined analysis.

Worksheet 6 displays only the quantifiable economic benefits. Other benefits, such as improved service to the shipper and improved competitive position of the railroad, are difficult to quantify but are nevertheless important considerations. These nonquantifiable considerations are important in choosing between alternatives.

The process presented herein is meant to be an approximate screening process conducted early in the yard project to select between alternative system areas. The worsheets are examples only, the information required and format should be changed to reflect the particular situation.

A more detailed economic analysis process normally used later in a yard project to justify building a particular yard is discussed in Chapter 6. This process may take several people six months to perform for a specific yard. Because of the complexity and resource requirements of this process, it is normally not used in detail for selecting between alternative system areas. However, the procedures discussed in Chapter 6 can be used in lieu of those discussed here if a more sophisticated procedure is required.

5.2 PHASE 2: SELECTING THE SPECIFIC SITE

5.2.1 General

In the earlier part of this chapter we were concerned with choosing the proper system area in which to build a new yard or rehabilitate an existing yard. The identification of the proper system area was not site-specific, but identified the gross region within the network in which more switching capability is required to implement a desired system operating plan.

Within this system area there may be many alternatives for the selection of a specific site on which to build a yard. The first alternative would be to examine existing yards in the system area to determine whether an existing yard can be rehabilitated or completely rebuilt.*

	Alternative 1	Alternative 2	Alternative 3
Costs (Annualized dollars)			
Yard capital costs			
Yard operating costs			
Total yard costs			
System Benefits (Annualized dollars)			
Switch engine reductions			
Force reductions			
Per diem			
Car utilization			
Train consolidations			
Locomotive utilization			
Terminal delay allowance			
Interchange			
Foreign switching			
Others			
Total system benefits			

FIGURE 5-7. EXAMPLE WORKSHEET 6

SUMMARY OF COSTS AND BENEFITS

*If the old yard is in a central urban area with high land values, one possibility is to sell the old yard for development after a new yard is built in a cheaper location. Also, there may be potential difficulties in keeping the old yard operational while being rehabilitated.

In the event that no existing yard site is suitable, then a new site must be acquired in the desired system area.

An overview of the site selection process is shown in Figure 5-8. One of the main factors in determining whether an existing yard or new yard site is suitable for the yard under consideration is whether the site has sufficient room. Guidelines for estimating acreage requirements are discussed in the next section. This is followed by a discussion of factors to consider in evaluating new sites and a worksheet process for selecting a new site.

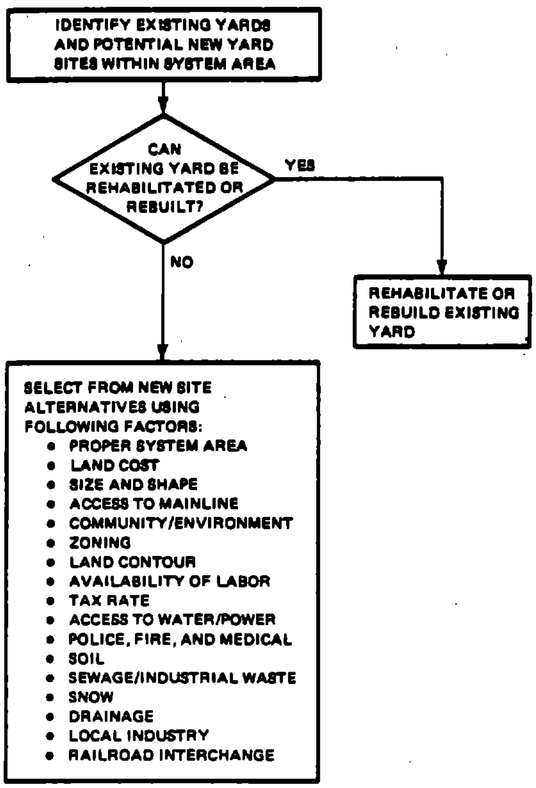

FIGURE 5-8. SITE SELECTION PROCESS

5.2.2 Approximate Estimate of Land Requirements

One of the main considerations determining whether an existing yard is suitable to be rehabilitated or to be completely rebuilt, or whether a new site is suitable for new yard construction, is the determination if there is sufficient room to build the desired yard.

Generally, as part of the system impact analysis to choose the proper system area to locate a yard, an approximate specification of the yard's capabilities is derived in terms of:

- Number of switchings per day (estimated from number of daily trains/cars in or out of the yard, plus reswitchings).
- Number of classification tracks (estimated from number of system-level and industry classifications to be made).
- Number of receiving and departure tracks (estimated from number of daily mainline trains received and built, and industry and interchange movements).
- Requirements for auxiliary facilities, such as locomotive servicing and car repair facilities.

The most accurate method to determine whether an existing yard or new site has sufficient room is to do a rough-cut layout of the yard based on the specifications of yard facilities. The role of the designer will be to try to fit all the parts of the yard within the space available at the site. The more space he is given, the more flexibility he has to design an operationally efficient yard which minimizes engine travel and conflicts between various yard activities. Consequently, the land requirements for a desired yard may very greatly depending on the desired yard capabilities, required auxiliary facilities, and the compromises made by the designer in the yard layout.

Although every yard is unique and ultimately should be laid out on the sites under consideration, a rough-cut screening as to whether a site has sufficient room to warrant further evaluation can be obtained by examining the acreage requirements of similar yards which may exist on own or foreign railroads. Table 5-1 provides rough guidelines on the approximate acreage required of a representative spectrum of flat and hump yards. The variability in land requirements is affected not only by the number of classification tracks, but the number and size of receiving/departure tracks. These track requirements vary depending on whether the yard performs system switching, receives and builds mainline trains, or is mainly an industrial or interchange yard. Furthermore, the variability in requirements for larger yards depends on whether there are auxiliary servicing and shop facilities at the yard. The designer should keep these caveats in mind when examining the approximate data presented in Table 5-1.

TABLE 5-1.-APPROXIMATE LAND REQUIREMENT FOR VARIOUS YARDS

Type	No. Tracks*	No. Daily Switchings	No. Acres
Very small flat	3 combined	120	25-30
Small flat	12 combined	500	50-80
Large flat	40 combined	1200	90-150
Mini hump	14 class	1100	50-80
Medium hump	32 class	2200	300-400
Large hump	64 class	3100	400-500

*Flat yards are designated with a combined classification, receiving, and departure track.

5.2.3 Factors in Evaluating New Sites

If we assume there is no existing yard in the system area which can be rehabilitated or whose site can be used to build a new yard, then a new site must be chosen. The factors to consider in choosing among alternative sites are discussed below.

Proper System Area

The main consideration in the selection of a specific site for a new yard is whether the site is in the proper system area. The building of a new yard is predicated on being able to perform a specified system-wide classification and blocking strategy. This can only be accomplished if the yard is in the proper system area within the network to implement the desired system-wide operating plan. If the site is not in the proper system area, then the system-wide operating effects will not be as desired.

Land Costs

Of primary importance is the cost of the land and the ease with which the land can be acquired. It stands to reason that land farthest away from commercial and residential development would be the cheapest. Also, it is desirable that the site be under single ownership so that it can be acquired by negotiating with a single entity. Purchasing a site which has multiple ownerships may require more time and expense.

Size and Shape

The site under consideration must be of adequate size to accommodate a yard of the proper storage and throughput capability (see Table 5-1). Also, the shape of the site has great influence on the ultimate layout of the yard and therefore is of prime importance. If an in-line yard is desired, then the site should be relatively long and narrow. However, if parallel receiving and departure yards are desired, then the site need not be as long but it must have greater width.

Access to Mainlines

When comparing sites, access and distance to the mainlines should be considered. The amount of trackwork, tunnels, and bridges necessary for conflict free entrance and exit of trains to the mainlines should be taken into account. As discussed in Chapter 10, a yard that can be oriented perpendicular to the mainline generally allows a better yard design in terms of conflict-free access of trains to the mainline.

Community and Environmental Impact

There has been increasing concern over noise and air quality in the neighborhood of railroad yards. To minimize community complaints, the site should be situated as far as possible from current and future residential development. In the event this is impossible, the additional cost of erecting noise barriers must be considered.

Zoning

The site under consideration should be properly zoned to accommodate a yard. If not, there should be a high probability of a favorable zoning change. If the site is in a rural area, changes in zoning are likely to be more easily obtained. However, in nonrural areas obtaining the proper zoning may be a major obstacle.

Land Contour

A certain amount of grading will be necessary for the new yard. One particular site may have a natural slope to the land which will facilitate the building of a hump yard with minimum grading. This is likely to be a secondary consideration when selecting among alternative yard sites.

Availability of Labor

A new yard should have ready access to skilled labor. This essentially means that a yard site should be located a reasonable commuting distance from a town or city.

Tax Rate

The probable tax rate for the site should be investigated. A lower tax rate will be obtained if the site is outside the city or town limits.

Access to Water and Power

The site should have access to water and power. Water is needed mainly for industrial purposes, such as washing and servicing locomotives and shop/maintenance operations. The site should have access to utilities such as electricity and perhaps natural gas. The cost and difficulty of acquiring water and power should be considered as part of the site selection process.

Availability of Police, Fire Protection, and Medical Care

A yard requires the availability of police, fire protection, and medical care. In many instances a yard may be self-sufficient and have its own police, fire, and medical care. However, to the extent that these services can be obtained from a neighboring community, then the yard would incur less cost to be completely self-sufficient in these services. For example, if a hospital is nearby, then less on-site medical care need be provided.

Soil Stability

Soil samples from the various sites should be taken and an analysis performed. It is important that the soil be sufficiently stable so that track gradients can be maintained. Otherwise, the additional costs of stabilizing the soil at the site must be considered.

Sewage and Industrial Waste

The local ordinances with respect to sewage and industrial waste treatment should be considered. The additional cost of more sophisticated treatment at one site versus another site should be taken into account.

Snow

The local history of the site in terms of the severity of snow fall and the depth of snowdrifts should be considered. Often because of the local terrain, geographical features, and the local wind patterns, two sites which are relatively close together may exhibit different characteristics in terms of the depth of the snow drift. Information on this subject is perhaps best obtained by talking to the local residents.

Drainage

The location and characteristics of the site in terms of yearly water runoff must be considered. For example, if the site is in a flat area at the base of a series of hills, then there may be the potential for periodic flooding. In this case, the costs of providing a more elaborate drainage system (e.g., drain pipes and catch basins) must be taken into account.

Proximity to Local Industry

If the site is in proximity to local industry, then the yard can serve both as an industrial yard and a system classification yard. If the industrial area is growing, then a stratigic placement of the yard may facilitate capturing additional traffic and customers.

Proximity of Foreign Railroads for Interchange

If the site is close to yards of a foreign railroad, then the yard can serve both an interchange function and a system classification function.

5.2.4 Worksheet for Selecting a New Site

In the previous section we described many factors which should be considered in the selection of a new site. The land cost of the various sites can be quantified and compared, but the adequacy of each site with respect to most of the other factors requires subjective judgments. Furthermore, combining the various factors into a selection process is something akin to comparing apples and oranges.

Nevertheless, it is useful and instructive to attempt to quantify all the factors into a systematic site selection process. Table 5-2 shows an example worksheet with the factors listed down the side and three alternative sites listed along the top. The factors have been divided into two groups, namely, primary and secondary factors. The groupings shown in Table 5-2 are somewhat arbitrary. What are primary and secondary factors is one of the main decisions in the site selection worksheet process. Each box in the worksheet has been divided in half by a diagonal line. The decision makers should place in the top part of each box a numerical rating from 1 to 10 representing the adequacy of each site in fulfilling each factor. The bottom part of each box is reserved for amplifying or explanatory comments.

As in many such systematic exercises, the benefit is in the process of filling out the worksheet rather than in the filled-out worksheet. The worksheet process itself forces all those concerned to consider the relative merits of each site with respect to a systematic set of factors. Furthermore, filling out the worksheet creates a climate of communication among those involved in the decision-making process. In many cases the site to be selected becomes intuitively obvious and a consensus is arrived at before the worksheet is actually finalized. The filled-out worksheet then becomes the mechanism and rationale by which the site selection decision is explained to upper management for their approval.

TABLE 5-2.-EXAMPLE SITE SELECTION WORKSHEET

Primary Factors	Site 1	Site 2	Site 3
Proper system area			
Land costs			
Size and shape			
Secondary Factors			
Access to mainline			
Community and environmental considerations			
Zoning			
Land contour			
Availability of labor			
Tax rate			
Access to water and power			
Availability of police, fire, and medical			
Soil			
Sewage and industrial waste			
Snow			
Drainage			
Proximity to local industry			
Foreign railroads for interchange			

CHAPTER 6: ECONOMIC ANALYSIS OF YARD PROJECTS

6.0 GENERAL

This chapter describes the economic analysis and justification procedures needed to gain top-management and corporate-level approval of a yard project. Normally, these procedures involve estimating capital and operating cost requirements for the yard project, determining the economic benefits of the yard project on a system-wide basis, and estimating the cost-effectiveness of the yard project through the calculation of an economic indicator, such as discounted cashflow rate of return, net present value dollars, and/or years required to recover investment and capital costs.

In the methodology described here, we are careful to distinguish between two categories (or types) of system benefits: cost reduction and cost avoidance. Cost reduction benefits are often referred to as actual cash benefits, since the implementation of the yard project will normally result in a realization of these cash savings. Cost avoidance benefits are often called efficiency benefits; they represent potential cash savings if the railroad can utilize increased efficiency or productivity to avoid future capital or operating costs and to handle increased traffic. It is common policy in many railroads to calculate the economic indicators (e.g., rate of return) assuming two cases: (1) cost reduction benefits alone, and, (2) both cost reduction and cost avoidance benefits. These two cases provide both a conservative and optimistic economic evaluation of the yard project. Whether the cost reduction or cost avoidance benefits are larger depends on the goals and objectives of the yard project. It is likely that in a yard rehabilitation, the cost reduction benefits may be larger than the cost avoidance benefits; alternatively, when building a new yard the reverse may be true.

The economic analysis procedures described herein may take several people 4-6 months to gather the necessary data and perform the analysis. Consequently, this process is quite tedious and time consuming. Normally, it is initiated after the yard location and site have been selected, a preliminary design of the yard has been completed, and a preliminary system-wide operating plan incorporating the new yard project has been established. The economic procedures are used to justify the project on economic grounds, and allow corporate management to evaluate the yard project along with alternative investment decisions (other railroad or nonrailroad projects). It may be the case that after a rate of return is calculated, the yard project will not be able to meet a desired rate of return (e.g., commonly 20 to 30%). In this case, work may be required to modify the original yard design so that capital costs will be reduced to achieve the desired rate of return.

In Chapter 5 an approximate economic analysis procedure was described to evaluate alternative yard locations. The more detailed process discussed here could be used instead of the procedures in Chapter 5. In this case, the procedure to justify a single yard is repeated for each yard alternative, and the economic indicators for each alternative are used to select the best one. However, the user must be reminded that the process described here requires more resources and time to perform and requires more detailed information about the yard design and system operating plan than may be available in the early stages of a yard project, when yard location decisions are of concern. Furthermore, it is expected that the selection of the proper yard location will be obvious using approximate procedures, thus obviating the need for more detailed analysis.

In the following, we describe the economic analysis procedures in three steps:

- Step 1: Estimate cost requirements
- Step 2: Estimate system benefits
- Step 3: Calculate economic indicators.

6.1 STEP 1: ESTIMATE COST REQUIREMENTS

The procedures for estimating the costs and operating expenses of the yard project will be described in terms of the four worksheets shown in Figures 6-1 to 6-4, namely:

- Worksheet 1: Initial Facility Construction Costs
- Worksheet 2: Additional Operating Costs
- Worksheet 3: Additional Capital Costs
- Worksheet 4: Summary of Annual Costs

6.1.1 Initial Facility Construction Expense

Figure 6-1 shows an example worksheet to record the initial facility construction expense for an assumed two-year construction period encompassing 1980 and 1981. The costs are estimated for each year in the following categories:

- Land
- Grading
- Buildings
- Shops
- Bridges, overpasses, culverts
- Electrical
- Track
- Signal
- Communication
- MIS and process control computers
- Others

The facility costs for each category are separated into two types: property investment and railroad construction expenses. The property investment expenses represent facility costs paid to an outside party or contractor for material and services. The railroad construction expenses represent that portion of the facility construction expense accomplished by using railroad-supplied labor or materials. For example, it is not unusual for the railroad to supply almost all the labor for the facility construction, except perhaps for grading, installing culverts, and constructing buildings and support structures. The separation between property investment and railroad construction expenses allows management to identify clearly what portion of the facility construction is to be spent within the railroad itself.

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*We are indebted to Mr. Tom Connors (Union Pacific) who was responsible for the Hinkle Yard and North Platte Westward Yard economic analyses and evaluations.

	Construction Period					
	1980		1981		Total	
Category	Prop Inv	R.R. Const	Prop Inv	R.R. Const	Prop Inv	R.R. Const
Land						
Grading						
Buildings						
Shops						
Bridges, overpass, culverts						
Electrical						
Track						
Signal						
Communication						
MIS and process control computers						
Others						
Total	____	____	____	____	____	____

*Includes property investment and railroad labor

FIGURE 6-1. WORKSHEET 1: INITIAL FACILITY CONSTRUCTION COSTS

If used equipment or materials are employed in the construction, then the costs must reflect the associated opportunity costs. For example, if second-hand rail is used in the yard, then the value of the second-hand rail must be taken into account as an expense. The opportunity costs for used equipment or materials is accounted for under railroad construction costs.

The cost of providing the equivalent yard switching capability because of yard disruption during the construction period should be reflected in the railroad construction costs category during this period.

The cost of any yard rehabilitation that has been avoided by this yard project will be taken into account in the avoided rehabilitation category of the cost analysis.

6.1.2 Additional Operating Expense

Figure 6-2 shows an example worksheet to record the additional operating expense for the yard. We assumed in this example a 22-year economic life of the project, reflecting a construction schedule encompassing two years and 20 years of benefits. Although the physical life of most yards is in excess of 30 years, increasing uncertainty associated with projecting operating costs, benefits, and future replacement expenditures beyond 20 years establishes a practical limit on the project life for purposes of economic analysis.

The additional operating costs represent added operational expenses in the case of a yard rehabilitation project or the total operating costs when a new yard is constructed where no yard formerly existed. The categories include:

- Labor--The labor costs of yard forces, including carmen, engine crews, signalmen, clerks, supervisors, and others are included in this category.
- Maintenance—The materials portion only of normal maintenance expense (e.g., retarder brake shoes) is included in this category; the labor portion is included under "Labor." Additional maintenance expense is required for yard engines, signal equipment, retarders, communications and electrical equipment, and others.
- Taxes and Insurance—Property taxes and insurance are included in this category.
- Utilities—The cost of electricity, natural gas, or coal is included in this category.
- Miscellaneous—Those operating expenses not covered in the above are included in this category.

Normally, the price for both labor and material are estimated for the first year of operation, then assumed inflation rates are used to adjust these expenses in subsequent years.

6.1.3 Additional Capital Costs

Figure 6-3 shows an example worksheet to record the additional capital expense for the yard for the 22-year period under consideration. The categories include:

- Replacement--We assume that most initial facilities do not need replacement during the assumed 20-year economic life; however, this category allows for replacement expenditures of computers, retarders, etc.
- Expansion--Because of traffic growth, the long-term project plan may include expanding the yard at a future date (e.g., adding more classification tracks). These expansion costs are included in this category.
- Equipment--The capital cost of yard equipment not included in the property investment expenses are included in this category (e.g., yard engines, cars, and trucks).

Year	Labor	Maintenance*	Tax/Insurance	Utilities	Miscellaneous	Total Operating Costs
1980						
1981						
1982						
1983						
1984						
1985						
1986						
1987						
1988						
1989						
1990						
1991						
1992						
1993						
1994						
1995						
1996						
1997						
1998						
1999						
2000						
2001						

*Maintenance expenses are for materials only.

FIGURE 6-2. WORKSHEET 2: ADDITIONAL OPERATING COSTS

- Miscellaneous—Those capital expenses not covered in the above are included in this category.

In estimating the additional capital costs for specific replacement or expansion projects, one must estimate the year (or years) this activity will take place. Also, one must adjust the future cost with an inflationary factor.

6.1.4 Summary of Annual Costs and Avoided Rehabilitation

Worksheet 4 (depicted in Figure 6-4) summarizes the annual costs over the two-year construction period and 20-year economic life of the project. This worksheet essentially accumulates the total initial facility cost, the total additional operating cost, and the total additional capital costs for each year from each of the three previous worksheets. However, in addition there is a column labeled "avoided rehabilitation" to take into account the cost savings of avoided yard rehabilitation planned for the future if the yard project under consideration is not undertaken.

We have chosen in this procedure to treat avoided rehabilitation as a "negative" cost in which the cost cashflow is decreased rather than as a benefit. Whether avoided rehabilitation is treated as a negative cost or as a benefit depends on corporate philosophy.

If avoided rehabilitation is treated as a benefit, then a choice must be made whether to treat it as a cost reduction (actual cash) benefit or as a cost avoidance (efficiency) benefit. This decision is also subject to corporate philosophy. If the avoided rehabilitation is certain, then it might be treated as a cost reduction benefit; however, if the avoided rehabilitation depends on other factors such as increased traffic, then it might be treated as a cost avoidance benefit.

6.2 STEP 2: ESTIMATE SYSTEM BENEFITS

The benefits of a yard project have been divided into two types: cost reduction and cost avoidance. Cost reduction benefits represent actual dollar savings, whereas cost avoidance benefits represent potential savings due to increased operational efficiency. Cost avoidance benefits can be realized by handling increased traffic with the same resources.

Separating the benefits into these two types allows a conservative economic analysis to be performed with cost reduction benefits alone, or a more optimistic economic analysis with both cost reduction and cost avoidance benefits.

The purpose and objectives of the yard project often dictate the proportion of cost reduction and cost avoidance benefits. For example, it is likely that a yard rehabilitation will result in larger cost reduction

Year	Replacement	Expansion	Equipment	Misc.	Total Capital Costs
1980					
1981					
1982					
1983					
1984					
1985					
1986					
1987					
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					

FIGURE 6-3. WORKSHEET 3: ADDITIONAL CAPITAL COSTS

Year	Initial Facility	Avoided Rehabilitation	Additional Operations	Additional Capacity	Total Cost
1980					
1981					
1982					
1983					
1984					
1985					
1986					
1987					
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					

FIGURE 6-4. WORKSHEET 4: SUMMARY OF ANNUAL COSTS

benefits, whereas, a new yard construction will result in larger cost avoidance benefits.

6.2.1 Cost Reduction Benefits

Cost reduction benefits represent actual dollar benefits. They include the following categories:*

- Switch engine shift reductions
- Force reductions
- Per diem
- Terminal delay train allowance
- Train consolidations
- Miscellaneous

Worksheet 5 (Figure 6-5) should be filled out not only for the yard being rehabilitated but for all yards in the system whose operations are impacted. In the following, we describe each category of cost reduction benefits.

6.2.1.1 Switch Engine Shift Reduction. This category estimates the actual cash benefits of reducing switching work at a yard. The dollar benefits can be actually realized only if an entire shift of a switch engine crew can be eliminated and/or an entire engine can be eliminated from the yard. The need for an extra switch engine can be eliminated if three switch engine shifts can be eliminated.

The equivalent annual costs of eliminated crews and engines is recorded under Switch Engine in Worksheet 5. Assumed inflation rates are used to increase costs (as appropriate) over the 20-year economic life of the project.

The method for estimating switch engine shift reductions in the yard being rehabilitated is to simulate yard activities either manually or with a computer model (see Chapter 7).

One can also estimate switch engine shift reductions in satellite yards via manual or computer simulation. However, because there may be a large number of satellite yards affected, the following procedure may be easier:

1. Go to each satellite yard and talk to the trainmaster (or yardmaster).
2. Specify the new operating plan for the satellite yard, including:
   - Inbound and outbound train schedule
   - Train consists
   - Classifications strategy.
3. Use experience of trainmaster (or yardmaster) to estimate reduction of switch engine shifts to perform work.

Year	Switch Engine	Force Reduction	Per Diem	Term Allowance	Train Consolidation	Misc.	Total Reduction
1980							
1981							
1982							
1983							
1984							
1985							
1986							
1987							
1988							
1989							
1990							
1991							
1992							
1993							
1994							
1995							
1996							
1997							
1998							
1999							
2000							
2001							

FIGURE 6-5. WORKSHEET 5: COST REDUCTION BENEFITS BY SPECIFIC YARD – YARD 1

*See Section 6.1.4 for a discussion on avoided rehabilitation expense, whether it should be treated as a "negative" cost or benefit.

6.2.1.2 Yard Force Reductions. This category estimates the actual cash benefits of reducing yard personnel (except switch engine crews) because of the yard project. Personnel might include supervisors, carmen, signalmen, clerks, etc. For a yard rehabilitation project, force reductions are likely to occur because of automation (e.g., eliminate manual retarder operator).

The equivalent annual costs of eliminated personnel is recorded under Force Reductions in Worksheet 5. Assumed inflation rates are used to increase costs (as appropriate) over the 20-year economic life of the project.

The force reduction must be estimated for the yard being rehabilitated and any impacted satellite yards.

6.2.1.3 Per Diem. This category estimates the actual cash benefits of reduced per diem payments as a result of reducing the terminal car detention time in yards.

The amount of reduced per diem payments are recorded under Per Diem in Worksheet 5. The per diem payments are increased (as appropriate) over the 20-year economic life of the project to reflect inflation in the per diem rates and traffic growth.

The methods for calculating the per diem benefits in the yard to be rehabilitated are as follows:

1. Simulate yard activities manually or by computer (see Chapter 7), and estimate the difference in total car detention time per day.
2. For that yard, estimate the percent of foreign cars versus own and private cars.
3. Estimate the reduced car detention time for foreign cars per day.
4. Multiply the estimated reduced foreign car detention time per year by an average per diem rate of cars through the yard.

Estimating the per diem benefits in a satellite yard can be accomplished via a yard simulation (manual or computer) or more likely by obtaining the informed judgments of a trainmaster (or yardmaster) at the satellite yard. The latter procedure is described as follows:

1. Talk to the trainmaster (or yardmaster) and specify:
   - Inbound and outbound train schedule
   - Train consists
   - Classification strategy.
2. For each outbound classification, estimate the total switching time.
3. Estimate effects on improved departure time of trains, i.e.,:
   - Manifest trains actually leaving on time
   - Nonmanifest trains leaving early.
4. Estimate the reduction in car detention time per day.
5. For that yard, estimate the percent of foreign cars versus own and private cars.
6. Estimate the reduced car detention time for foreign cars per day.
7. Multiply the estimated reduced foreign car detention time per year by an average per diem rate of cars through the yard.

6.2.1.4 Terminal Train Delay Constructive Allowance. This category estimates the actual cash benefits of reduced constructive allowance to train crews for either initial or final terminal delays. For the yard under rehabilitation, these benefits may accrue from a more efficient receiving or departure yard design and/or increased classification and trimming rates. For the satellite yards, these benefits may be due to a more efficient classification and blocking strategy at the satellite yard due to increased capability at the rehabilitated yard, e.g., preblocking cars for the satellite yard.

The equivalent annual saving due to reduced terminal train delay constructive allowance is recorded under Terminal Allowance in Worksheet 5. Assumed inflation rates and projected traffic growth are used to increase costs (as appropriate) over the 20-year economic life of the project.

The factors causing initial terminal delay (i.e., delay to outbound train) may include:

- Delay in waiting for sufficient cars on the departure track to form an outbound train.
- Delay to mainline locomotives arriving at departure track from the roundhouse because of conflict with yard engines enroute.
- Delay in the air test.
- Delay in departure due to conflict with other traffic enroute to the mainline.

Engineering judgment and/or industrial engineering time and motion studies are used to estimate the reduction in initial terminal delay due to changes in the yard design and/or yard operating strategy. For example, the new yard design may minimize conflicts and interference, allow faster air testing, and/or build trains on departure tracks more quickly. Annual estimates in reduced initial terminal delay are multiplied by an average constructive allowance factor.

The factors causing final terminal delay (i.e., delay to inbound train) may include:

- Inbound train waits at yard limits because there are no receiving tracks available.
- Delays in the mainline locomotives in going from receiving yard to roundhouse due to conflict and interference with yard engines.

Engineering judgment and/or industrial engineering time and motion studies are used to estimate the reduction in final terminal delay due to changes in the yard design and/or yard operating strategy. For example, the new yard design may have more available receiving tracks, faster switching rate, and be designed to minimize conflict and interference. Annual estimates in reduced final terminal delay are multiplied by an average constructive allowance factor.

6.2.1.5 Train Consolidations. This category estimates the actual cash benefits of not running certain trains by consolidating under-tonnage trains. The equivalent annual savings is recorded under Train Consolidation in Worksheet 5. Assumed inflation rates are used to increase costs (as appropriate) over the 20-year economic life of the project.

The basic method for estimating train consolidations is to manually redispatch all trains impacted by the yard project, both at the main yard and satellite yard.

The redispatched trains are compared to actual trains. The crew cost only of eliminated trains are assigned to this category. Fuel costs are not included because it is assumed (to first-order) that the fuel required to move a car a given distance is approximately the same whether it is moved in one large train or two smaller trains.

The locomotive capital and operating costs are not included here under "train consolidation" benefits but will be included later under "locomotive utilization" benefits (described under cost avoidance benefits) since these savings are assumed to be efficiency benefits rather than actual cash benefits.

6.2.1.6 Miscellaneous. This category allows for actual cash benefits from items not covered under previous cost reduction categories. They are recorded under Miscellaneous in Worksheet 5. Inflation rates and traffic growth factors are used (as appropriate) to increase benefits over the 20-year economic life of the yard.

6.2.2 Cost Avoidance Benefits

Cost avoidance benefits represent efficiency benefits which may or may not be realized as actual dollar benefits depending on actual traffic growth and/or other factors. They include the following categories:*

- Car utilization
- Locomotive utilization
- Miscellaneous.

Worksheet 6 (Figure 6-6) should be filled out not only for the yard being rehabilitated but for all yards in the system whose operations are impacted. In the following, we describe each category of cost avoidance benefits.

Car Utilization

This category estimates the efficiency benefits of improved car utilization to own or private cars as a result of reducing the terminal car·detention time in yards.

Year	Car Utilization	Locomotive Utilization	Miscellaneous	Total Avoidance
1980				
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990				
1991				
1992				
1993				
1994				
1995				
1996				
1997				
1998				
1999				
2000				
2001				

FIGURE 6-6. WORKSHEET 6: COST AVOIDANCE BENEFITS BY SPECIFIC YARD – YARD 1

*See Section 6.1.4 for a discussion on avoided rehabilitation expense--whether it should be treated as a "negative" cost or benefit.

The amount of car utilization benefits are recorded under Car Utilization in Worksheet 6. The car utilization benefits are increased (as appropriate) over the 20-year economic life of the project to reflect inflation in the cost of own or private cars and traffic growth.

The method for calculating the car utilization benefits in the yard to be rehabilitated are as follows:

- Simulate yard activities manually or by computer (see Chapter 7) and estimate the difference in total car detention time per day.
- For that yard, estimate the percent of own and private cars versus foreign cars.
- Estimate the reduced car detention time for own and private car detention time per year by an equivalent cost factor based on the average value of own and private cars through the yard.

Estimating the car utilization benefits in a satellite yard can be accomplished via a yard simulation (manual or computer) or more likely by obtaining the informed judgments of a trainmaster (or yardmaster) at the satellite yard. The latter procedure is described as follows:

1. Talk to the trainmaster (or yardmaster) and specify:
   - Inbound and outbound train schedule
   - Train consists
   - Classification strategy.
2. For each outbound classification, estimate the total switching time.
3. Estimate effects on improved departure time of trains, i.e.:
   - Manifest trains actually leaving on time
   - Nonmanifest trains leaving early.
4. Estimate the reduction in car detention time per day.
5. For that yard, estimate the percent of own and private cars versus foreign cars.
6. Estimate the reduced car detention time for own and private cars per day.
7. Multiply the estimated reduced own and private car detention time per year by an equivalent cost factor for own and private cars through the yard.

Locomotive Utilization

This category estimates the efficiency benefits of improved utilization of yard and mainline engines due to the yard project.

The amount of locomotive utilization benefits are recorded under Locomotive Utilization in Worksheet 6. The locomotive utilization benefits are increased (as appropriate) over the 20-year economic life of the project to reflect inflation in the cost and operation of locomotives.

The method for calculating locomotive utilization benefits for yard engines is as follows. Using the procedures discussed in Section 6.2.1, Switch Engine Shift Reduction, the reductions in switch engine shifts are estimated for the yard being rehabilitated and satellite yards. As was discussed previously, if a switch engine is completely eliminated from the yard, this is a cost reduction (actual cash) benefit, and the cost of the eliminated engine is recorded under Switch Engine shift reductions in Worksheet 5 (Figure 6-5). However, the partial reduction in engine hours does not result in direct cost reduction, but in cost avoidance due to less engine maintenance and a prolonged engine life. Therefore, this partial reduction in engine hours is assigned to a cost avoidance benefit. The total annual yard engine hours reduction is multiplied by an equivalent cost factor which accounts for engine capital and maintenance costs.

The method for calculating locomotive utilizaton for mainline engines is as follows. The number of locomotive hours saved as a result of train consolidation is a major part of this benefit. It is calculated by examining which trains are consolidated (see Section 6.2.1, Train Consolidation) and using horsepower-to-weight ratio calculations to assign locomotives to trains. Also included is the number of locomotive hours saved as a result of reduced initial and Terminal Train Delay Constructive Allowance (Section 6.2.1). The total annual mainline locomotive hours saved as a result of train consolidation and reduced terminal train delay is multiplied by an equivalent cost factor accounting for locomotive capital and maintenance costs.

Miscellaneous

This category allows for efficiency benefits from items not covered under previous cost avoidance categories. They are recorded under Miscellaneous in Worksheet 6. Inflation rates and traffic growth factors are used to increase benefits over the 20-year economic life of the yard.

6.2.3 Summary of Benefits

The cost reduction and cost avoidance benefits tabulated by yard in Worksheets 5 and 6 are summarized on a total system basis in Worksheet 7 (Figure 6-7). It may also be convenient to summarize these benefits on an individual yard basis as shown in Worksheet 8 (Figure 6-8).

6.3 STEP 3: CALCULATE ECONOMIC INDICATORS

In the two previous steps, the projected timing of costs and benefits were calculated. By combining Worksheets 4 and 7, the cash flow over the economic life of the project is determined. (Note: Costs are treated as negative cash flows.)

In order to proceed with the cash flow analysis and calculation of economic indicators, the following issues must be addressed:

- Salvage value of individual property investments after 20 years of economic life.
- Estimated after-tax cost of capital used to discount future dollars to present dollar values.
- Depreciation of property investment and calculation of Federal and State income tax.
- Local area property taxes on incremental capital expenditure.

These issues are complex, requiring sophisticated treatment, and therefore must be addressed by each railroad for each specific yard project.

The three typical economic indicators include:

- Discounted cash flow return on investment (or, rate of return)--Defined to be that discount

	Cost Reduction							Cost Avoidance				
Year	Switch Engine	Force Reduction	Per Diem	Term Allowance	Train Consolidation	Misc.	Total Reduction	Car Utilization	Locomotive Utilization	Misc.	Total Avoidance	Total Benefits
1980												
1981												
1982												
1983												
1984												
1985												
1986												
1987												
1988												
1989												
1990												
1991												
1992												
1993												
1994												
1995												
1996												
1997												
1998												
1999												
2000												
2001												

FIGURE 6-7. WORKSHEET 7: TOTAL BENEFITS

or interest rate at which the present value of discounted benefits is just equal to the present value of discounted costs.

- Net present value (or, net present worth)—Defined to be the difference in the present value of discounted costs and benefits.
- Years required to recover the investment plus capital costs—Defined to be the number of years required for the present value of discounted cost and benefits to be equal.

A number of textbook descriptions of these methods exist.[1] (Reference 1 is considered a classic treatise on these subjects.) Also, portable hand-held calculators and financial worksheets exist that are specifically designed to perform these financial calculations.

It should be noted that the above three economic indicators do not include the benefit-cost ratio method. This method has been primarily used on government projects and has not been widely accepted by the financial community. Consequently, the benefit-cost ratio techniques and the ratios themselves lack meaning and significance to the financial community. Furthermore, the benefit-cost ratio is arbitrary with respect to whether cost reduction or savings should be called benefits or negative costs, thus affecting the numerical value of the ratio.[1]

[1]Grant, E. L., W. G. Ireson, and R. S. Leavenworth, Principles of Engineering Economy, Sixth Edition, 1976, The Ronald Press Company, New York.

Once the economic indicators are calculated, a sensitivity analysis on critical assumptions is advised. In particular, the effect on each economic indicator of the following is suggested:

- Traffic Growth Sensitivity Analysis
  - No traffic growth
  - 25% of anticipated growth
  - 50% of anticipated growth
  - 75% of anticipated growth.
- Initial Facility Cost Overrun Sensitivity Analysis
  - 10% cost overrun
  - 20% cost overrun
  - 30% cost overrun
- Overstatement of Benefits Sensitivity Analysis
  - 10% overstatement
  - 20% overstatement
  - 30% overstatement

Worksheet 9 (Figure 6-9) provides a typical format for presenting the economic indicators and the results of the sensitivity analysis.

6.4 CONCLUDING REMARKS

This chapter has presented methods and procedures to perform an economic analysis of a yard project. The economic analysis can be a tedious and time consuming effort if performed properly. Consequently, the

Year	Yard 1			Yard 2			Yard 3			Yard 4			Total Benefits
	Reduction	Avoidance	Total	Reduction	Avoidance	Total	Reduction	Avoidance	Total	Reduction	Avoidance	Total	
1980													
1981													
1982													
1983													
1984													
1985													
1986													
1987													
1988													
1989													
1990													
1991													
1992													
1993													
1994													
1995													
1996													
1997													
1998													
1999													
2000													
2001													

FIGURE 6-8. WORKSHEET 8: SUMMARY BENEFITS BY YARD

	DCF-ROI	Net Present Value	Years Recover Investment
1. Yard project as anticipated			
2. Traffic growth sensitivity			
- No growth			
- 25% of anticipated growth			
- 50% of anticipated growth			
- 75% of anticipated growth			
3. Initial facility cost sensitivity			
- 10% cost overrun			
- 20% cost overrun			
- 30% cost overrun			
4. Benefits sensitivity			
- 10% overstatement of benefits			
- 20% overstatement of benefits			
- 30% overstatement of benefits			

FIGURE 6-9. WORKSHEET 9: RESULTS OF ECONOMIC ANALYSIS

procedures described herein are recommended to justify a project to corporate management after the location has been decided and a preliminary design and operating plan exist. However, the procedures can be used to choose yard location if the simpler steps described in Chapter 4 are inadequate. In this case, the economic analysis described here is conducted for each alternative yard location.

It may be the case that after the economic analysis is completed, the desired rate of return is still not satisfied. In this case, the reduction in facility cost required to meet the necessary rate of return is calculated. This reduction in facility cost must be translated into a modified yard design and operating plan. A second economic analysis must be performed under these modified conditions.

CHAPTER 7: ESTIMATING YARD CAPACITY AND RESOURCE REQUIREMENTS AND PERFORMANCE*

7.0 GENERAL

This chapter describes a method for estimating the capacity and resource requirements of a yard which is to be newly built or rehabilitated. The yard capacity and resource requirements estimation is a key task in the entire yard design process; it relates to almost all aspects of the yard design process. As shown in Figure 7-1, the yard capacity and resource requirements analysis is related to four other major tasks of yard design. They are:

- Alternative Sites Analysis--Alternative sites analysis assumes rough yard capacity and resource requirements. The validity of these assumptions must be examined later in the yard capacity and requirements analysis. If excessive errors in the assumptions are found at this stage, the alternatives analysis may have to be performed again.
- Economic Analysis--The results of the capacity and resource requirements analysis will be used to conduct the economic analysis. The major outputs from the capacity and resource requirements analysis impact the economic analysis in terms of the capital cost, the operations cost, and the per diem cost (as derived from car detention hours). The economic analysis results may force the designer to modify the yard design.
- Hump Profile Design--In the capacity and resource requirements analysis the hump speed is assumed as a given parameter. The exact operational hump speed is estimated after designing the hump profile. The hump profile design results may prove that the assumed hump speed is not a reasonable operational value. If so, then the capacity and resource requirements analysis must be conducted again using whatever hump speed was obtained from the hump profile design process.

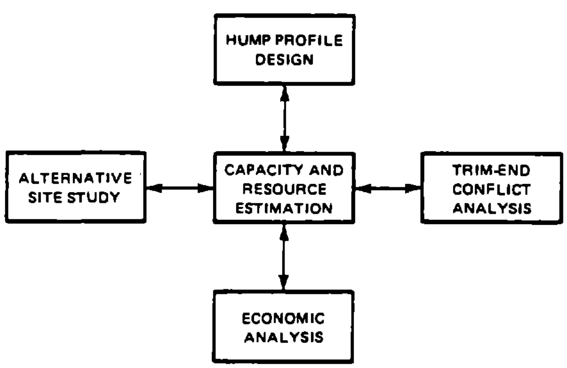

FIGURE 7-1. RELATIONSHIP OF YARD CAPACITY AND RESOURCE REQUIREMENT ANALYSIS WITH OTHER TASKS

- Trim-End Design--The yard capacity and resource requirements analysis is conducted using assumed yard throughput operations characteristics. An analysis dealing with trim-end design must be conducted along with the yard capacity analysis. The results of each analysis affect the other.

The yard capacity and resource requirements analysis involves several iterations using a trial and error approach. This trial and error approach becomes essential mainly because there are various parameters to be considered in the yard design process. As described above, the results of all the four other major tasks not only affect the capacity and resource requirements analysis, but also may make it necessary to iterate the entire study process over again.

The sequence of work involved in designing a yard involves selection of the yard location, estimation of the number of cars handled through the yard, a sketch design of the yard, and evaluation of the yard using a manual or computer-assisted yard evaluation method. The overall structure of the capacity and resource requirements analysis process is shown in Figure 7-2.

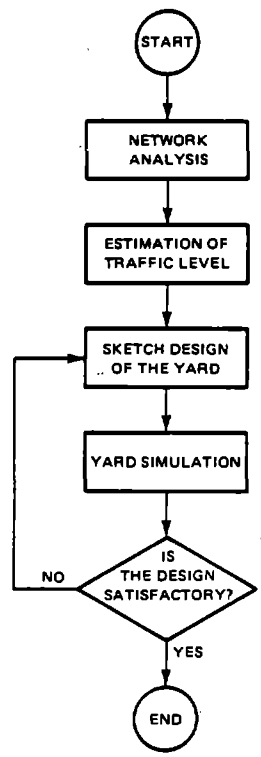

FIGURE 7-2. OVERALL STRUCTURE OF CAPACITY AND RESOURCE REQUIREMENT ANALYSIS

The actual work involved may differ from one yard to another depending on the situation the specific yard is facing. Basically, there are two major cases; one is the case where a new yard is built at a new location, and the other is the case where an old yard is rehabilitated. In the former case a complete network analysis may be necessary to estimate the traffic volume to be handled at the yard. The yard physical layout and method of operation may be chosen from a wide variety

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*This material was developed with the generous cooperation of J. Wetzel (CONRAIL), R. Convey (Santa Fe), D. Koretz (Boston and Maine), M. Anderson (Union Pacific), and B. Gallacher (Southern Pacific).

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of options. In the latter case the traffic volume to be handled at the yard may be identical to that of existing traffic or may be different, but estimation of traffic volume to be handled at the yard will be much simpler than in the former case. The physical and operational characteristics of the yard may be somewhat more constrained in the latter case.

In this chapter we describe two ways of estimating yard capacity and resource requirements. One is a manual method and the other is a computer-assisted method. The conceptual approach of the manual method and the computer-assisted method are similar; both approaches try to simulate traffic movements in the yard by recording the event occurrence times and the number of cars accumulated on each track.

Because of characteristics in the nature of work, the work required may vary. Portions of this chapter may not be applicable to every case. Sections of this chapter which are not applicable to the specific problem the designer is facing may be skipped in the analysis.

This chapter consists of four sections. The topics covered in these sections are:

- Estimating Traffic Characteristics
- Specifying the Yard Characteristics
- Manual Evaluation
- Computer-Assisted Evaluation

The first topic, Estimating Traffic Characteristics, describes the method of estimating the traffic characteristics to be used in the yard design stage. The traffic characteristics discussed here deal not only with the case of yard rehabilitation, but also with the case of an entirely new yard. This section describes a method of estimating inbound traffic characteristics, outbound traffic characteristics, and the rehumping traffic characteristics.

The second topic, Specifying the Yard Characteristics, describes the parameters to be considered in defining the yard characteristics. Default values of parameters are suggested, whenever applicable.

The third topic, Manual Evaluation, describes a manual method of evaluating a yard design. Inputs obtained from United States railroads are utilized in this section.

The fourth topic, Computer-Assisted Evaluation, describes a method of evaluating a yard design using a computer model, CAPACITY, which was developed for this purpose under a Federal Railroad Administration contract.

7.1 ESTIMATING TRAFFIC LEVEL

7.1.1 Traffic Level Used in Analysis

The estimation of the traffic pattern used in the yard design is closely related to the network analysis, which should be conducted at least at one point of the yard design analysis process. The methods of estimating the traffic pattern and volume to be used in the yard capacity and resource requirements analysis may be quite different depending on the circumstances, particularly whether the yard is at an entirely new location or if the project requires rehabilitation of an older yard.

The traffic pattern used in this yard design process is affected by:

- Whether the new yard is to be built at a new location or is a rehabilitation of an existing yard.
- Whether the new yard will classify the same traffic which is classified by the old yard or not.
- Design year of the yard and the trend in the freight movements which pass through the yard.

Strictly speaking, a network analysis is desired whenever construction of a new yard or a rehabilitation of an existing yard is planned. The traffic pattern and volume to be classified at the planned yard can be accurately predicted only after analyzing the network.

The traffic level used for design purposes must take into account possible traffic increases in the future. To determine the traffic trend over a long time period, an analysis of historical traffic trends as well as estimation of trends in future traffic becomes critically important. Historical traffic trends are useful to understand how traffic may increase (or decrease) when there are no sudden changes in railroad freight demand due to various types of policy changes or other factors. For example, expected increases in coal traffic due to the current energy crisis should increase railroad freight traffic dramatically on certain railroad lines.

The traffic estimation must include all of the following types of traffic (see Figure 7-3):

- Existing traffic.
- Induced traffic due to construction of the yard.
- Increased or decreased traffic due to policy changes of the railroad or of the national or regional government.

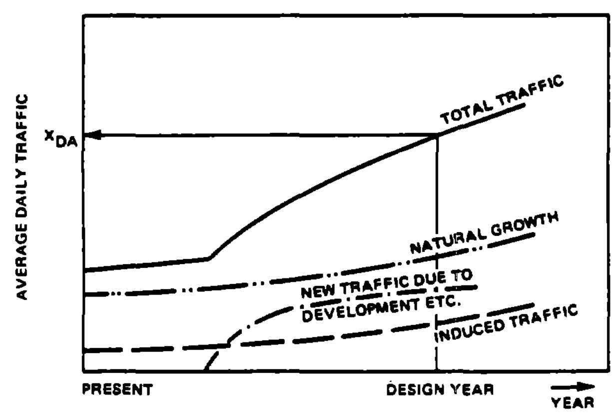


FIGURE 7-3. ESTIMATION OF TRAFFIC DEMAND CHANGES

When a growth of traffic is expected, the horizon year for which the design of the yard is aimed becomes an important issue. For example, in highway design it has been customary to use a design year 20 years after the construction of the facility. This design year is determined based on various factors such as, for example, the competitiveness of the railroad against other modes of freight traffic, the life span of present types of yard hardware. If the method of classification used in the design is expected to become obsolete from a technical or material standpoint in a certain time period, then it certainly would be an important factor in determining the design year. It has been customary for the railroad industry to use 30 years as the life span of heavy facilities such as classification yards. Considering all the elements involved in determining the design year, a time span between 20 and 30 years seems adequate to be used as the design year. However, no specific recommendations will be made as to how many years each railroad company should use for investment planning purposes.

After having determined the design year, and having estimated the traffic trends, the next task is to estimate daily and seasonal traffic variations.

The basic principle in designing the yard is to design it so that its size is reasonably "adequate." The judgement as to what size is adequate can be different from one case to another. If the daily traffic of the potential classifications at a planned new yard is known, then this decision becomes much easier. In this situation, the daily traffic will be counted for each day and the daily volumes will be arranged from the highest of the year to the lowest. (A graph which shows the daily traffic volumes arranged in a descending order can be plotted as shown in Figure 7-4.) The design volume can be determined based on the corporate decision as to how many days the yard can be oversaturated in a year. If, for example, 10 days are selected, then pick the 10th highest traffic volume in the graph.

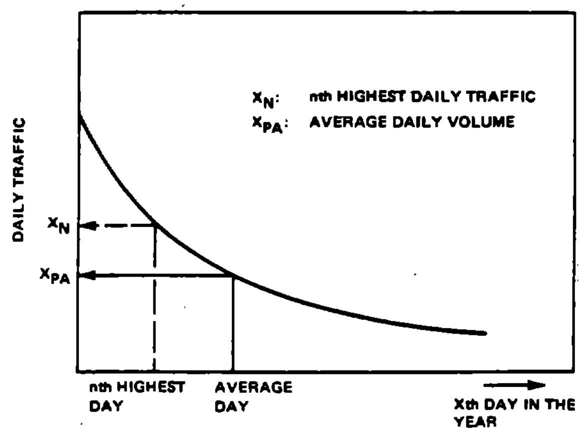


FIGURE 7-4. RANKED DAILY VOLUME THROUGHOUT THE YEAR

The decision on the number of days the yard can be oversaturated may be different depending on the traffic variation characteristics. One extreme case may be that the daily and seasonal traffic variations in a year are very small, and the highest volume observed in a year is not much larger than the average daily volume of the year (see Figure 7-5a). Another extreme case will be just opposite to the above condition, where the daily traffic variations are large and the ratio between the highest volume and the average volume exceeds two or more (see Figure 7-5c). The former case generally applies to those areas or routes where a steady flow of freight is carried all year round. Regions with large urbanized areas are considered to have this type of traffic variation characteristic. The latter case applies to those areas or lines where the freight transported has heavy seasonal variations. The agricultural areas are considered to have traffic variation characteristics of this type. Three types of typical traffic volume variation diagrams are given in Figure 7-5.

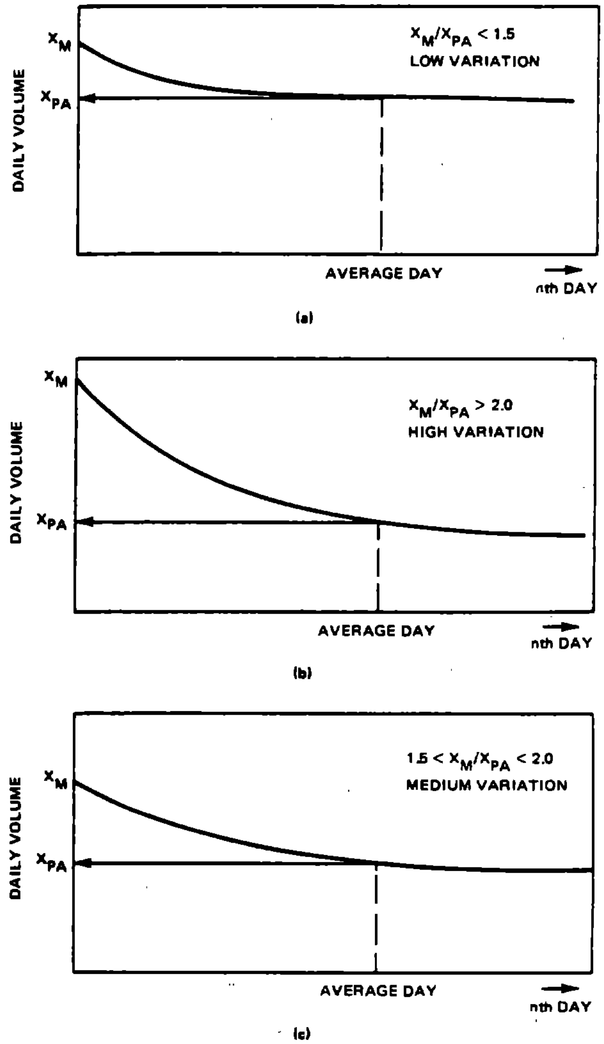


FIGURE 7-5. RANKED DAILY VOLUME THROUGHOUT THE YEAR : VARIATIONS

The "design oversaturated days" for the yard are determined based on experience, company policy, and traffic variation characteristics. At those yards where the daily traffic variations are very small, it may be cost-effective to design for no oversaturation of the yard; i.e., to design the yard for the most congested day of the year. However, at those yards where the traffic variation can be extremely large, the railroad may have to compromise the number of days the yard is expected to be oversaturated. The trade-offs of using various "design oversaturated days" can be studied using diagrams such as shown in Figure 7-4.

This above type of traffic variation can be utilized directly in designing a yard if it is intended to handle the existing traffic at the location of a present yard. However, in reality the designer must often design a yard for future traffic at a completely new location.

If a yard is built at a new location, the analysis is more complex. The traffic variations must somehow be estimated based on the network flow data available. A hypothetical traffic variation curve must be constructed based on whatever data are available. Here[6] two types of basic elements of traffic are described. Those two elements, the long-term traffic trend, and the short-term traffic variation, must be combined together. The method of combining these two factors is described below in a step by step manner:

1. Determine the design year.
2. Estimate (or observe) the present daily average traffic: X_{PA}.
3. Estimate the average daily traffic at the design year: X_{DA}.
4. Determine the number of days permitted to oversaturate the yard: n.
5. Estimate the n^{th} highest daily traffic of the current year: X_N.

The design daily traffic X_D is expressed as

$$X_D = X_{DA} \frac{X_N}{X_{PA}} . \quad (7.1)$$

7.1.2 Inbound Schedule and Consist

Most of the information related to the train schedules must be obtained through the network analysis, unless the yard is constructed at a site where an old yard already exists and the traffic handled at the new yard is very similar to the existing traffic.

Here, the main concerns are the time of train arrivals, the blocks carried by each train, and the number of cars for each block. All the data should be available and a complete network analysis is conducted using the design traffic flow. However, in reality complete data will not always be available. If available data are incomplete, the planner or designer must cleverly estimate the information required to proceed with the analysis. A possible method of estimating required values is roughly described below:

- Arrival Times of Trains--The simplest way of estimating arrival times of trains will be to assume that the existing train schedules are a satisfactory approximation of the arrival times for the proposed yard. If the new yard happened to bring in induced traffic (possibly transfer from the other lines), then these new traffic volumes must be counted and the arrival times must be estimated.
- Blocks Carried by Each Train--The blocks carried by the existing trains may be considered as the blocks to be classified at the new yard. Block types due to new traffic must be identified.
- Number of Cars in Each Train--The number of cars in each train may be obtained either by simply multiplying the existing traffic volume by the growth factor of traffic, or by adding extra trains. The simpler method of the above two is the former; this is the growth factor method. However, this method can become unrealistic if the existing trains are already long and/or if the growth factor is rather large. Under these circumstances, each train must be carefully checked and additional trains must be created. This procedure will obviously affect the train arrival times, and the blocks carried by each train described above. This work involves the judgement of railroad transportation staff who understand the system operations aspect of the study.

The inbound train information may be summarized in a table as shown in Table 7-1. The table shows the time of arrival trains and the blocks they carry in a matrix form.

TABLE 7-1.-ARRIVAL TRAIN BLOCK IDENTIFICATION TABLE

Arrival trains (train ID, arrival time)	Blocks								
	1	2	3	4	5	6	7	...	...
TI1, 8:20	5	3	2	5	2	0	2		
TI2, 9:10	0	0	2	1	15	2	1		
TI3, 10:15	0	5	2	0	0	2	2		
:									
:									
:									
:									
:									
Total	15	34	22	6	37	4	27	...	...

7.1.3 Outbound Schedules and Classifications

Two types of information are required for each outbound train: the departure time and the blocks to be carried. The number of cars is not required for the analysis; this is obtained through the capacity analysis of the yard.

Just as for the inbound train information, the ideal way of obtaining this information is to conduct a network analysis. This is because the departure times of trains are not only affected by the operations at the yard under consideration, but are also affected by the yard operations at the destination yards. However, if the departure schedule is not given and the company policy is to not conduct the network flow analysis, then the planner or the designer must somehow create the departure schedule to be used for the analysis.

Two phases are involved in this work. One is to identify trains by sets of blocks, and the other is to identify trains by departure times. By doing so, the designer can identify the departure times of departing trains and the blocks carried by them.

Two types of tables must be prepared. One is the departure train block identification table (see Table 7-2). In this table blocks carried by each departure train are identified. Here the departure times and the number of cars carried by a departure train are not known yet.

The other table is the arrival and departure train matrix (see Table 7-3). This table is made using the information in Tables 7-1 and 7-2. In Table 7-3 the arrival train information (train IDs and their arrival times) is listed down the far left column and the departure train information (train IDs and their departure times to be determined) is listed across the top row. Each cell in the rest of the matrix gives the block information: block IDs, the number of cars

TABLE 7-2.-DEPARTURE TRAIN BLOCK IDENTIFICATION TABLE

Departure trains	Blocks								
	1	2	3	4	5	6	7	...	...
TD1	X		X						
TD2				X	X				
TD3		X					X		
TD4					X	X			
:									
:									
:									
:									
:									

in the blocks, and the possible departure time. The cell which is at the i^{th} row and the j^{th} column indicates that the blocks indicated in the cell arrive at the yard on the i^{th} arrival train and will depart from the yard on the j^{th} departure train.

The method of departure schedule estimation will be to assume that every block processed in the new yard will have the same expected detention time at the yard for those blocks which are not rehumped. If there is no rehumping the method of estimating departure times and blocks carried by departure trains is quite simple. Here a method is described which can be applied to the general case. The method of filling in the matrix is:

1. Fill in arrival train IDs and arrival times.
2. Fill in departure train IDs.
3. For each block of an arriving train identify the departure trains which can carry the block, using Tables 7-1 and 7-2. Fill in the block IDs and the number of cars in an appropriate cell in Table 7-3.
4. If the same block can be carried by more than one departing train, circle the block ID and the car number.
5. Determine the lower limit at traffic to allocate a classification track in terms of the number of cars per day.
6. From Table 7-1 find the total number of cars in the block in one day. Use this total to identify those blocks which must be sluffed for the first switching.
7. In Table 7-3, if the block being dealt with is the sluffed block, make a check mark on the block ID and the car number. Those blocks with small numbers of cars are candidates for reswitching.

TABLE 7-3.-ARRIVAL DEPARTURE TRAIN MATRIX

Arrival trains (train ID, arrival time)	Departure trains (train ID, departure time)				
	TD1 14:10	TD2 18:15	TD3 15:15	TD4 18:15	
TI1, 8:20	Block 1, 5 cars Block 3, 2 cars Tp = 8:20 + 5.00 = 13:20	✓ Block 4, 5 cars (Block 5, 2 cars) Tp = 15:15 + 3.00 = 18:15	Block 2, 3 cars Block 7, 2 cars Tp = 8:20 + 5.00 = 13:20	~~(Block 5, 2 cars)~~	
TI2, 9:10	Block 3, 2 cars Tp = 9:10 + 5.00 = 14:10	✓ Block 4, 1 car (Block 5, 15 cars) Tp = 15:15 + 3.00 = 18:15	Block 7, 1 car Tp = 9:10 + 5.00 = 14:10	✓ Block 6, 2 cars ~~(Block 5, 15 cars)~~ Tp = 15:15 + 3.00 = 18:15	
TI3, 10:15			Block 2, 5 cars Block 7, 2 cars Tp = 10:15 + 5.00 = 15:15	✓ Block 6, 2 cars Tp = 15:15 + 3.00 = 18:15	
: : : : :					

Note: It was assumed that net processing time of nonrehumping blocks is 5 hours, the start rehumping time for both blocks 5 and 6 is 15:15, and that the net processing time after rehumping is 3 hours.

8. Estimate the process time at the yard for those blocks without rehumping.*

9. Calculate for those blocks whose cells do not have any check marks the possible departure times, which are given as the arrival times plus the process time.

10. For rehump blocks, determine the time of rehumping. Based on this rehumping time determine the possible departure times of these blocks.† Try to schedule rehumping when the hump is idle.

11. Determine the departure time of each departing train. This is done by finding the latest possible departure time among the blocks to be carried by that departing train. If the possible departure times are spread uniformly across 24 hours, then a break must be made somewhere. Under such circumstances the designer should try to schedule the departing time in such a manner that accumulated cars on the classification tracks do not overflow the track capacities, even though it may not always be possible. Erase the car numbers of those blocks which are circled but not taken by the departing train heading that column.

7.1.4 Estimation of Rehumping Time

One of the input types to be prepared for the yard study is the time required for rehumping. Two cases are considered there: when the departure train schedule is fixed and when the departure schedule is unknown. In the former case the starting time for rehumping will be determined based on the departure schedule of the train which is to carry these rehumped blocks. In the latter case, the designer must estimate roughly the starting time for rehumping. One way of choosing the rehumping time is to select a time period when the hump is not utilized. This section is devoted to a description of this method. To do this analysis, it is necessary to draw a diagram as shown in Figure 7-6.

Figure 7-6 consists of four types of diagrams which are closely related to one another. The top diagram of the figure, Figure 7-6a, shows the train arrival information. This diagram shows the number of cars carried by each arrival train and the time of each train arrival. In this diagram the horizontal axis indicates the time of the day and the vertical axis indicates the number of cars.

The center diagram, Figure 7-6b, shows the cumulative input-output diagram. In this figure, the curve marked "arrival" shows the cumulative number of cars received along the time of the day. This curve is constructed

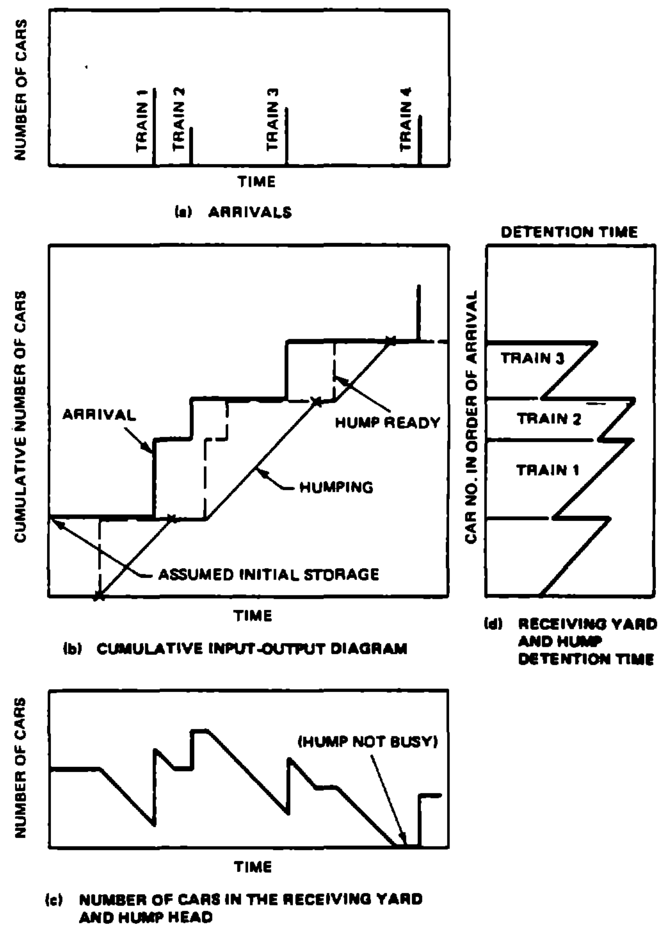


FIGURE 7-6. INPUT-OUTPUT DIAGRAM

using graph (a) of the same figure. In graph (b) the curve marked "hump" indicates the cumulative number of cars processed by the hump. The humping can start after inspection of arrival trains. To construct the cumulative hump diagram, first draw a cumulative inspection completion diagram. (This is shown by a broken line in the figure.) The time of inspection completion of each train can be roughly estimated by the designer. This curve indicates the earliest time humping can be started. The inspection end time of each arrival train is indicated by an X mark in the cumulative car diagram. The cumulative hump curve is obtained by drawing a straight line with the slope of net humping rate (cars/min) starting from the first X mark. Extend the line until it hits the broken line, the cumulative inspection end curve. If the cumulative hump curve hits the cumulative inspection end line, then draw a horizontal line until it comes to another X mark. Continue drawing the cumulative hump curve in this same manner.

Graph 7-6c shows the number of cars in the departure yard and the hump lead along the time of day. This diagram is constructed from 7-6b. The number of cars in the departure yard and the hump lead are obtained by measuring the vertical distance between the arrival curve and the hump curve in 7-6b. The curve shows that the number of cars in the departure yard and the hump yard jumps up to a higher number whenever a new train arrives in the receiving yard, and the number gradually declines while the humping operation is being conducted. Thus the times when the hump is utilized are identified. The times of rehumping can be adjusted so that no other train is being humped. The designer should look for flat spots when the hump is idle.

*The average process time for no rehump blocks can be roughly estimated as the sum of the inbound inspection time, humping time, trimming time, outbound inspection time, including net delay for any or all of the above activities.

†The possible departure times of rehumped blocks can be estimated from the starting time of rehumping and the average rehump block process time. The average rehump block process time for rehump blocks can be roughly estimated as the sum of humping time, trimming time, outbound inspection time including net delay or any or all of the above activities.

Graph 7-6d may not be critical for this analysis. However it is presented here simply because it is interesting. The graph shows the time duration each train has spent in the receiving yard and the hump. This can be obtained by measuring the horizontal distance between the arrival curve and the hump curve in 7-6b.

7.1.5 Classification Track Utilization

If the number of blocks classified at a yard does not exceed the number of classification tracks, and each block has a sufficiently high rate of traffic, then each track may be assigned to a block of cars. However, in reality the number of blocks is often greater than the number of classification tracks that could possibly be planned. Two ways of operating a yard under this situation are discussed. They are dynamic track assignment and multiple stage classification (or rehumping).

7.1.5.1 Dynamic Track Assignment. Under dynamic track assignment, blocks are assigned to classification tracks dynamically according to traffic pattern and train service requirements. For example, if a train is scheduled to depart at 8 p.m., class tracks may not be assigned to the blocks that make up the train until 11 a.m. so that they can be used for making up other blocks during the rest of the day. As a result, the dynamic assignment of class tracks can effectively increase not only the number of blocks or classifications but also the utilization of those tracks. It is also an integral part of such other yard processes as multistage switching.

The implementation and operation of the dynamic class track assignment process varies among yards because its efficient use depends on many yard-specific factors. Among these are the availability and reliability of advance consist information, train arrival and departure patterns, and the distribution of the traffic processed through the yard.

7.1.5.2 Multistage Switching (or Rehumping). Multistage switching is the process of sorting and sequencing cars and groups of cars by more than one classification operation per car. Multistage switching allows a given yard to make up many more classifications than for which it has tracks. Many U.S. railroads have used some form of multistage switching to increase the classification capabilities of various yards.

There are various ways of sorting cars in multiple stages. Here the sorting method most widely used in the U.S. is described. The method is called the initial sorting by outbound train strategy.

In the initial sorting by outbound train strategy, cars that are to be dispatched in the same train are initially grouped together on the same track; thus, all cars for Train A would be grouped on one track, all cars for Train B on another track, and so forth. (In a variation of this strategy, cars for two outbound trains may be grouped on one track--cars for Trains A and B on one track, cars for Trains C and D on another track, and so on. Because this variation subsequently requires more available class tracks during the second stage or additional switching and sorting, it is not generally used.) As shown in Figure 7-7, after first stage switching, the cars, although sorted by outbound trains, are randomly mixed and are not separated or sequenced in block order.

We use the following definitions and symbols, which are keyed to individual outbound trains that are to be

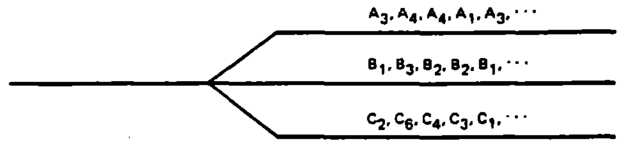


FIGURE 7-7. CAR GROUPING AFTER FIRST-STAGE SWITCHING

formed and dispatched from the yard. Uppercase letter (such as A, B, C, ...) denote specific outbound trains. Each outbound train is made up of cars that have been sorted and grouped into blocks that are then sequenced to form the train. These blocks are identified by subscripted uppercase letters that denote which outbound train the block of cars is to depart with, and the subscript specifies the sequence or location of the block within the train; and thus, A_1 refers to the first block from the head end of outbound Train A, and D_3 refers to the third block of cars from the head end of outbound Train D.

The switching scheme at the second stage may vary depending on the number of blocks to be classified and the number of available classification tracks. If the number of blocks sorted does not exceed the number of classification tracks available for that purpose, then the simple sorting strategy can be used, i.e., each block is classified onto a different classification track. An example is shown in Figure 7-8. In the example, outbound Train B is sorted using the simple sorting scheme.

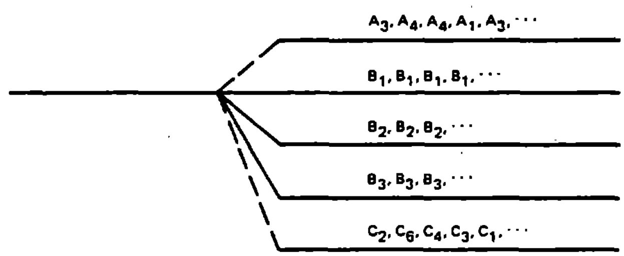


FIGURE 7-8. CAR GROUPING AFTER SECOND-STAGE SWITCHING (TRAIN B—FEW BLOCKS)

If the number of blocks sorted exceeds the number of classification tracks, then two more stages of sorting become necessary. Here a case where Train A carries 9 blocks and three classifications is done as shown in Figure 7-9. The figure shows that the cars carried by Train A are pulled from a classification track and classified onto three different classification tracks in a predetermined order in the second stage. Those blocks are pulled again for rehumping, and finally in

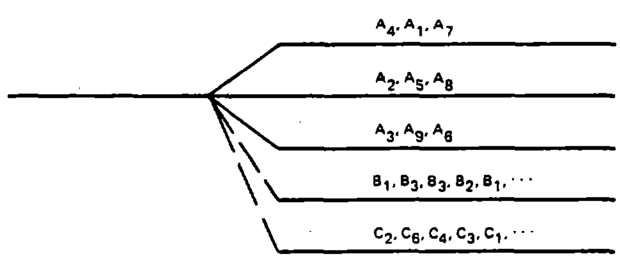


FIGURE 7-9. CAR GROUPING AFTER SECOND-STAGE SWITCHING (TRAIN A — MANY BLOCKS)

the third stage the blocks are ordered in the desired order for Train A (see Figure 7-10).

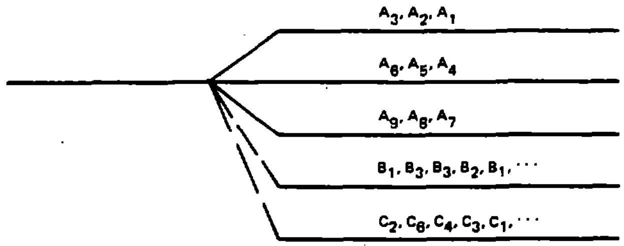


FIGURE 7-10. CAR GROUPING AFTER THIRD-STAGE SWITCHING (TRAIN A – MANY BLOCKS)

7.2 SPECIFYING THE YARD CHARACTERISTICS

Yard characteristics are specified in two categories: yard geometry and yard operations. Here, the designer will specify the types of yards being considered and how the yard may be operated. When the data required to specify the yard characteristics are not available, some assumed values must be used to conduct either the manual or computer-assisted evaluation study (with some exceptions). A method for the rough estimation of yard requirements is also described in this section.

7.2.1 Geometric Characteristics

7.2.1.1 Type of Yard. This type of yard indicates its overall layout, including the number and type of receiving yard(s) (in-line or parallel), the number of humps (single or dual), the number and type of departure yards(s) (in-line or parallel), and how the facility will be operated.

7.2.1.2 Number of Receiving and Departure Tracks and Their Lengths. The number of receiving and departure tracks and their lengths do not necessarily have to be known for either the manual or computer-assisted yard evaluation procedures. This is because for both methods the number of receiving and departure tracks and their lengths can be estimated as a part of the overall simulation process. However, the manual method and the computer method are slightly different, and in the manual method the given data related to the receiving and departure tracks can be directly evaluated in the simulation process.

7.2.1.3 Number of Hump Leads. The hump lead design affects the efficiency of the hump utilization, and as a consequence it affects the capacity of the entire yard.

7.2.1.4 Hump Speed. The actual hump speed estimation process is complex. It requires design and evaluation of the hump profile and retardation system. In the yard capacity and requirements estimation process, the hump speed is estimated as a given value without going through an elaborate analysis of the hump profile and retarder system.* The required hump speed for a given traffic level can be estimated based on the assumption that approximately 60 to 70% of the time the hump is busy humping cars.

7.2.1.5 Number of Classification Tracks and Their Lengths. The exact number of classification tracks and their lengths are not required to conduct the analysis. However, the number of classifications (or the blocks to be classified onto the same track) and the usage of tracks for rehumping must be specified for both the manual and the computer-assisted methods.

7.2.1.6 Number of Pullout Leads and Rough Sketch of the Throat. The number of pullout leads and a rough sketch of the throat geometry are required to estimate the travel times of the trim engines between the classification yard and the departure yard.

7.2.1.7 Other Yard Geometric Information. Other yard geometric information required for the analysis will be information such as whether or not a wash track or repair track is required in the yard. Any information which may affect the yard geometric characteristics must be specified.

7.2.2 Operational Characteristics

7.2.2.1 Data Related to Inbound Inspection Crews. The data required to specify the inbound inspection crew characteristics are the number of inspection crews, the crew shift time and crew breaks, inspection rate, and the inspection constant (computer approach), or the travel time between inspections (manual method). The values used for each parameter will be different from yard to yard.

7.2.2.2 Data Related to Hump Engines. The hump engine related data include the travel time of hump engines between the receiving yard and the hump, the number of hump engines, and the hump engine crew shift-change and break times.

7.2.2.3 Data Related to Trim Engines. The trim engine related data include the coupling rate, the travel times of trim engines between the classification yard and the departure yard, the number of trim engines, and the trim engine crew shift-change and break times.

7.2.2.4 Data Related to Outbound Inspection Crews. The data related to outbound inspection crews include the number of inspection crews, crew shift times and breaks, inspection rate, and the inspection constant (computer approach), or the travel time between inspections (manual approach).

7.3 MANUAL EVALUATION

Prior to the availability of computerized simulation methods, the manual evaluation method was the only way to evaluate the yard capacity and resource requirements. The manual simulation method is still widely used in the railroad industry. Manual simulation involves a time consuming, tedious process. It basically consists of recording all car movements on a large sheet of paper. The basic concept of manual simulation is identical to that of any computerized simulation. The major difference of these two methods will be in how the work is done and in the accuracy of resolution in the representation of activities.

*The hump profile design process is documented in Chapter 12.

7.3.1 Description of Method

Manual simulation is conducted on a large sheet of paper as shown in Figure 7-11. The overall manual simulation diagram consists of inventory diagrams of the receiving tracks, the classification tracks, the departure tracks, and other facility utilization diagrams. A track inventory diagram depicts the number of cars stored on a track by the time of day. It also indicates the car movements between tracks. A facility utilization diagram indicates the time duration when a yard facility, such as the hump or trim engine, is utilized. The types of facilities to be included in the diagram may differ, depending on the accuracy required in simulation. For example, the occupancy diagram for each classification-track lead in the pullout end of the yard, the hump engine/trim engine utilization diagram, and the crew utilization diagram can be considered. The more elements considered, the finer accuracy that can be obtained. However, this implies that the work involved in preparing the simulation diagram will generally become more time consuming as the number of elements grow.

An introductory overview of the manual simulation diagram is given in the following paragraphs using a sample simulation diagram, which depicts the operations of the Yermo yard of the Union Pacific railroads.

In Figure 7-11 the horizontal axis indicates the time of the day, and each row indicates different tracks or a yard facility. In this example, the yard has 5 receiving tracks whose lengths vary from 89 to 153 cars, 29 classification tracks whose lengths vary from 34 to 56 cars, and 3 departure tracks whose lengths vary from 142 to 155 cars. The hump utilization diagram is drawn between the rows representing the receiving tracks and the classification tracks. The switch engine utilization diagram is drawn at the bottom of the diagram. The mainline track utilization diagram is drawn at the top of the diagram. The choice of locating facility utilization diagrams is up to the designer who actually draws the simulation diagram.

In this case the number of tracks in the receiving and departure yards and their lengths have been specified before the diagram was drawn. If the number of tracks in these subyards is not known, a reasonable number of rows may be reserved for each subyard. The designer then can assign a proper track to each arrival or departure train as the simulation process proceeds. The general rule of arrival and departure track assignments is to try to assign a track, which has already been created to store a previous train but is now vacant, to a new train. If no tracks are available, then a new track is created and assigned to the train. By doing so, the number of tracks can be minimized.

Figure 7-11 shows that the traffic has not reached a steady state yet. Under the steady-state condition the same traffic accumulation pattern repeats every day for every track of the yard. Instead of trying to achieve a steady-state condition, the designer in this case used actual track inventory data from the pre-existing yard as the initial conditions for the simulation.

It should be noted that tracks C-22 through C-25 are used for two-stage classifications. It also should be noted that the overtime work is done by the second shift engine crew. The diagram may look simple, but it contains much information related to the yard capacity and resources requirements.

As described in Section 7.2, the physical and operational characteristics of the yard must be defined, in theory, before the manual simulation, with some exceptions such as receiving yard characteristics. In reality there are so many variables to be considered that it is impossible to estimate the optimum yard requirements before the simulation. Therefore, many iterations of a trial and error process will be necessary. In the trial and error process, the designer uses assumed values for unknown variables and proceeds with the simulation. The simulation results are examined later and the assumed values are modified if they do not seem to be appropriate. The next simulation starts using the modified values. And thus the simulation can go on in several stages.

A detailed description of how to perform the manual simulation is given in the following sections.

7.3.1.1 Receiving Yard Simulation.

The simulation of the receiving yard uses the following parameters:

- Time of train arrivals.
- Number of cars in each train: NC.
- Rate of inbound inspection: RI (cars/min).
- Inbound inspection constant: IC (min).
- Inbound inspection time: TI (min).
- Travel time of an inspection crew from one track to another: TW (min).
- Travel time of a train to the hump: TT (min).
- Travel time of an engine from the hump to the receiving yard: TR (min).
- Humping rate: HR (cars/min).
- Time required to hump a train: TH (min).
- Time lost between humping trains: TL (min).

The first step is to estimate the key activity time periods of the arrival trains based on the number of cars in each train and the yard's operational characteristics. The manual simulation diagram is then prepared in the second step using the key time periods, which are obtained from the first step. The types of activities of concern are inbound inspection, travel to hump, and humping. The time intervals required to do these activities are obtained as follows.

Inbound Inspection Time Interval (TI)

The inbound inspection time interval, TI, is estimated from the number of cars in the train, NC, and the rate of inspection, RI, and given as

$$TI = NC/RI + IC \quad (7.2)$$

The time interval TI includes the time required for the crew to actually inspect the train, the time required to do the paperwork of receiving the train, and other miscellaneous delays between receiving and inspection. The recommended value for RI is 2.0 car/minute. This inspection time is drawn in the bar chart of the receiving track occupancy diagram. The inspection work is assumed to start immediately after the arrival of a train if an inspection crew is available. The inbound inspection constant IC includes the time required to do the paperwork of receiving the train and any other miscellaneous delays. The recommended value for IC is 5 minutes. The inspection of a train does not start in the diagram unless an inspection crew is free. The movements of inspection crews from one train to another are also traced in the manual simulation diagram.

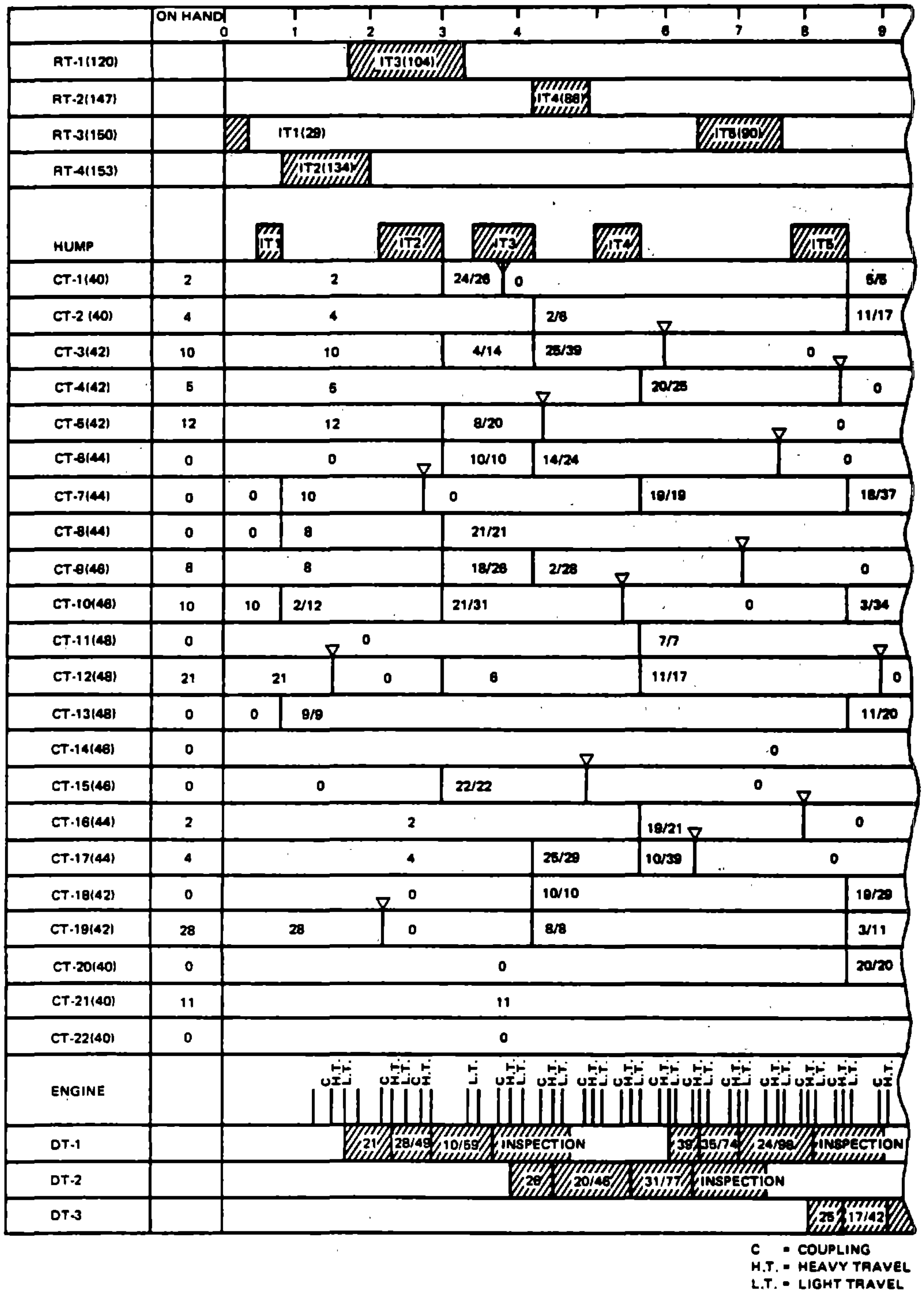


FIGURE 7-11. MANUAL SIMULATION DIAGRAM

Travel Time of an Inspection Crew From One Train to Another (TW)

A certain time interval is spent by inspection crews in walking from one train to another between inspections. The actual time spent in walking may be different depending on the relative locations of the two trains and their lengths. In the manual simulation, a constant value for this parameter, LH, may be assumed. If there is no more specific value available, the recommended value to be used for LH is 5.0 minutes.

Travel Time to and from the Hump (TT, TR)

The travel time of each train from the receiving yard to the hump, TT, is estimated by the designer. The travel time is determined by the geometry of the yard. A single estimated value can be assumed. If the travel time to the hump cannot be estimated easily, a default value of 10 minutes is recommended.

The hump engine must travel from the hump to the receiving yard when it finishes humping a train. This time interval TR is also estimated by the designer. A recommended value for this parameter is 5 minutes.

Hump Time Interval (TH)

The hump time interval for each train, TH, is estimated by the designer based on the number of cars in the train, NC, the humping rate, HR, and the loss time between humping trains, TL. It is expressed as:

$$TH = NC/HR + TL \quad (7.3)$$

The humping rate and the loss time between humpings also must be estimated by the designer. Here, it is assumed that the loss time between humpings does not include loss time due to hump engine travel. It only includes some delays associated with the starting delay and some other delay factors while humping is in operation. A default value for LH is suggested as 5 minutes.

Preparing a Manual Simulation Diagram: Receiving Yard to the Hump

A manual simulation diagram is drawn using the time intervals calculated with the parameter values set as specified above. The method of preparing a simulation diagram between the receiving yard and the hump is described using a sample problem.

Figure 7-12 shows a sample simulation diagram between the receiving yard and the hump. Some of the key time elements shown in the figure are listed below.

- Train 1 finishes inspection at 11:59. The inspection duration is calculated from Eq. (7.2).
- It takes 10 minutes for the train to travel from the receiving yard to the hump.
- Train 1 starts humping at 12:09 and finishes humping at 12:39. The humping duration is calculated from Eq. (7.3).
- Train 2 arrives at 12:03 on receiving track 1, but must wait till 12:09 for the start of inspection, because the inspection crew is not available until then.
- Train 2 finishes inspection at 13:29.

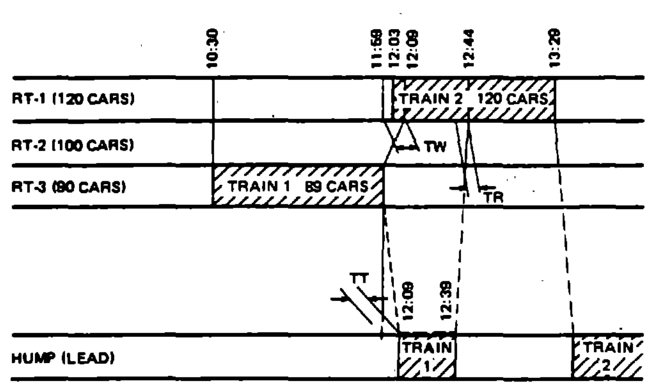


FIGURE 7-12. SAMPLE MANUAL SIMULATION DIAGRAM FOR RECEIVING YARD AND HUMP

- The hump engine travels from the hump to receiving track 1 and is ready to pull train 2 at 12:44. However, the engine must wail until the completion of the train inspection.
- The hump engine starts pulling train 2 at 13:39.

The movements of the inspection crew and the trim engine are traced in the diagram by a solid line and a broken line, respectively. However, the final version of the diagram does not have to include these lines. The diagram also indicates the time point values for the purposes of demonstration. These parameters also may be eliminated from the final diagram.

This example assumed that the number of receiving tracks and their lengths are known before the simulation. The track assignment for arrival trains is done in the same manner as in the real world, i.e., assign the shortest available track.

This example uses one inbound inspection crew and one hump engine. If more than one inspection crew (or more than one hump engine) is assumed, the first available crew (or the engine) is assigned to the next arrival train.

7.3.1.2 Classification and Departure Yards Simulation. Simulation of the classification and departure yards involves simulating activities of trim engines, classification yard car cumulation, departure yard inspection, and departure yard occupancy. It is assumed that the cars of a train start to occupy the classification tracks when the humping of the train starts, and may continue to accumulate cars from time to time until the classification track is closed for coupling. The block on a classification track is pulled to the departure yard by the same trim engine that did the coupling work. The trim engine travels back and forth between the classification yard and the departure yard pulling blocks from the classification yard to the departure yard. At the departure yard, the inspection crew starts inspecting trains immediately after the outbound train is made up.

The parameters associated with classification yard simulation are:

- The number of cars on a classification track: NN (cars).
- The rate of coupling: RC (cars/min).
- The coupling time: TC (min).

- Travel time of a trim engine from the classification yard to the departure yard: TP (min).
- Travel time of a trim engine from the departure yard to the classification yard: TE (min).
- The number of cars on a departure train: MC (cars).
- Outbound inspection time: TO (min).
- Outbound inspection constant: OC (min).
- Travel time of an inspection crew from one train to another: TW (min).
- Rate of outbound inspection: RO (cars/min).

Calculation of time interval for each event is described in the following.

Coupling Time (TC)

The coupling time TC is computed from the number of cars in the block, NN, and the coupling rate RC, and is expressed as

$$TC = NN/RC \ . \qquad (7.4)$$

A reasonable value to be used for the rate of coupling is 2.0 cars/minute.

Travel Times Between Classification Yard and Departure Yard (TP, TE)

The estimation of travel times between the classification yard and the departure yard is based on the experience of the designer. The value used for the loaded engine, TP, and that for the light engine, TE, will usually be different. The travel time may vary as a function of the number of cars in the block the engine is pulling. However, because it is so cumbersome, a variable travel time for the manual simulation is not recommended. When no appropriate values are available for the travel times, values of 10 minutes for the loaded engine (from the class yard to the departure yard) and 5 minutes for the light engine (from the departure yard to the class yard) are recommended.

Departure Yard Inspection Time Interval (TO)

The inspection time interval at the departure yard, TO, is estimated based on the number of cars in the departing train, MC, and the rate of outbound inspection, RO, using the formula

$$TO = MC/RO + OC \ . \qquad (7.5)$$

The outbound inspection time, TO, includes not only the inspection, but also the air test and other miscellaneous work associated with the departing train. The number of cars in the outbound train, MC, must be obtained as the sum of all the cars in the blocks pulled from the classification yard. The outbound inspection rate, RO, must be estimated by the designer. If a better value is not available for the outbound inspection rate, 2.0 cars/minute is recommended for use. The outbound inspection constant, OC, includes any miscellaneous delays related to outbound inspection of a train. The recommended value of OC is 1 minute.

Travel Time of an Inspection Crew From One Train to Another (TW)

The same parameter values used for the travel time of an inspection crew in the receiving yard applies to the outbound inspection crew.

Preparing the Classification and Departure Yard Simulation Diagram

The manual simulation diagram of the classification yard and the departure yards is made using the time intervals calculated based on the rules shown in this section. Figure 7-13 shows a sample simulation diagram created for demonstration purposes. In this figure the simulation starts with an initial inventory of 10 cars on classification track 1 (CT-1), 0 cars on CT-2, 15 cars on CT-3, 1 car on CT-4, and 10 cars on CT-5.

Inbound train 1 starts humping cars at 12:09 and ends humping at 12:39. Of 89 cars on train 1, 25 are classified on CT-2, 10 onto CT-3, and 5 onto CT-4. Then the total number of cars on each track is CT-1, 10; CT-2, 25; CT-3, 25; CT-4, 6; and so forth. The cut-off time point of departure for train 1 is 13:05, and at that time CT-2 and CT-5 are closed for humping. Immediately after closing the track for humping, coupling activities start on CT-5 and end at 13:18. Then the trim engine starts pulling cars on CT-5 to the departure yard, and sets out cars on departure track 1 (DT-1) at 13:28. The trim engine comes back to the classification yard on CT-2 at 13:35. The engine starts coupling cars on that track immediately and finishes the coupling activity at 13:49. Then it starts to pull the block. The engine reaches the departure yard at 13:59 and sets out the block on DT-1. The trim engine continues to travel back and forth between the classification yard and the departure yard in this manner.

In this example, the trim engine finishes the pulling operations at 13:59. Now the train is ready for inspection and air testing. In this example, the crew is available at that time and starts inspecting the outbound train. The inspection ends at 14:17, which is before the scheduled departure time.

The trim engine activities are recorded on a special row that is kept for this purpose. The trim engine movements and the inspection crew movements can be traced just in the same manner as was shown for the receiving yard.

Basically two types of situations are possible in evaluating classification and departure yard capacity requirements. One is the case in which the number of classification and departure tracks and their lengths are known beforehand. In this case, the manual simulation must be done in such a manner that these constraints are not violated. Then, by conducting the simulation the adequacy of the design is evaluated.

In the other case, in which the classification yard capacity characteristics are not given, they are roughly planned before the simulation and the designer evaluates the feasibility of that plan. In this case the design is not treated as absolute, so the designer can violate the constraints pertaining to the number or the lengths of the classification tracks assumed earlier. The design obtained in this process is a modified version of the initial plan.

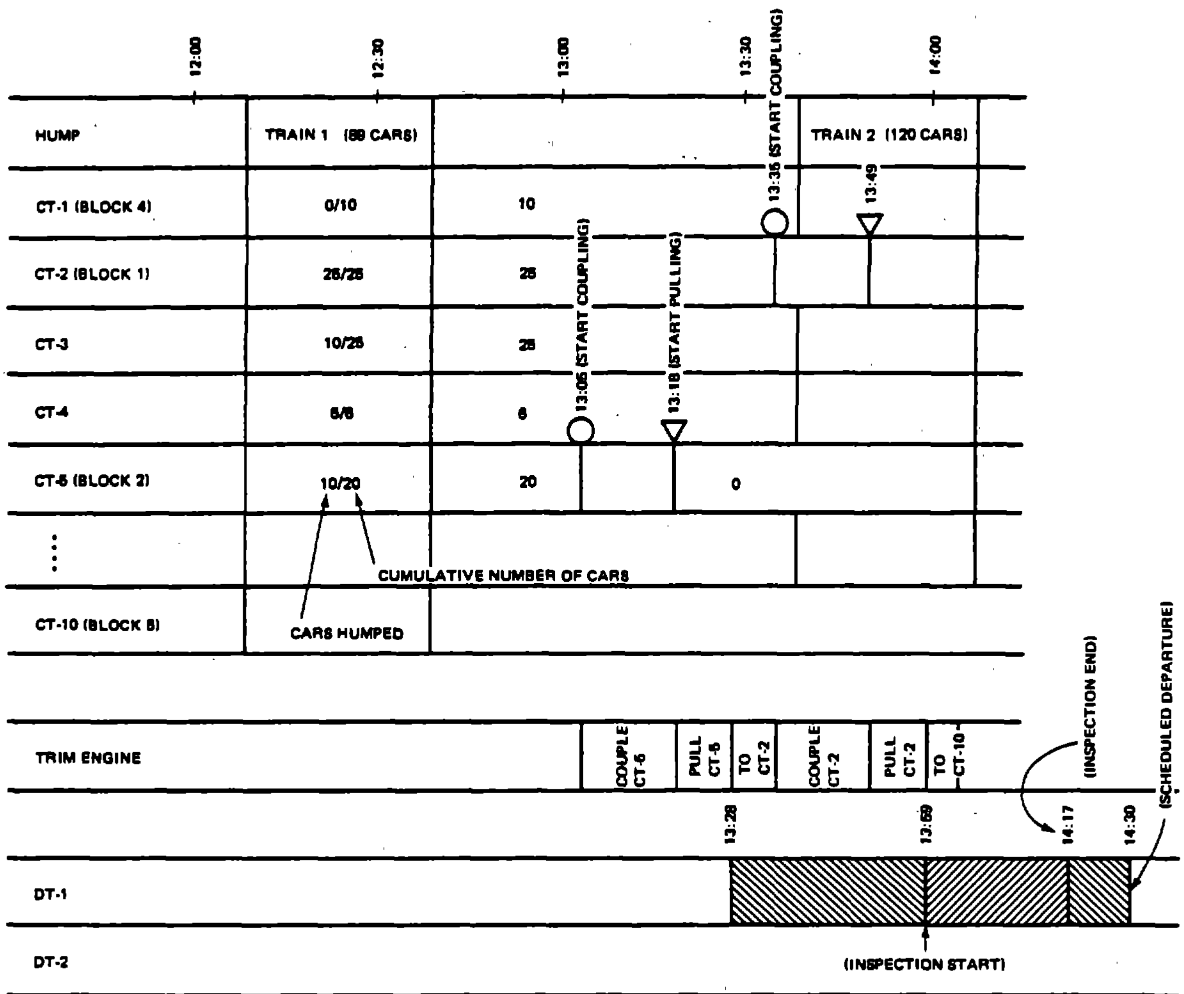


FIGURE 7-13. SAMPLE MANUAL SIMULATION DIAGRAM FOR CLASSIFICATION AND DEPARTING YARDS

The estimation method of the track requirements of the departure tracks is identical to that used for the receiving yard. For the receiving and departure yards the designer does not have to plan the yard's track capacity characteristics before the simulation.

7.3.1.3 Overall Yard Simulation Diagram. The two sub-yard simulation diagrams detailed above are combined into one overall yard simulation diagram as was shown in Figure 7-11. The diagram shows all of the yard activities at a glance. This diagram is the final output of the manual simulation. It should be noted that the diagram does not contain various time points and lines used to indicate the durations of various activities.

The simulation can be started from the yard condition with either no cars on the tracks or with estimated numbers of cars on each track. If zero cars is assumed as the initial condition, the simulation work must be done for at least a two-day period. Then the results from the second day may be used for evaluation.

The method of presenting the classification and departure yard simulation diagram can vary widely. Some designers may prefer to indicate only the cumulative number of cars on each track. Some may prefer much more detail. The diagram fulfills its purpose so long as it represents the track occupancy status correctly.

7.3.2 Interpretation of Simulation Results

Various factors related to yard capacity and operational requirements can be extracted from the manual simulation diagram. The key elements to be analyzed using the manual simulation output are:

- Receiving track occupancy
- Hump utilization
- Classification track car accumulation
- Departure track occupancy
- Inbound/outbound inspection crew utilization
- Hump/trim engine utilization
- Departure train delays
- Average car detention time.

The purpose of the analysis is to understand to what degree the yard facilities and resources, on which the simulation was based, are utilized. The yard should not be overdesigned because this is not economical, but the yard should not be underdesigned because this will create operational problems. The analysis of the items above must ensure that the yard facilities are utilized reasonably well.

For receiving and departure yards the designer must ensure that each train can be stored on a track with a sufficient time gap between trains, and a sufficient capacity margin on the track. The effect of train length and arrival/departure time variations can be examined on the diagram by assuming longer trains and earlier arrivals/later departures. For the classification track it is important to examine whether or not the maximum accumulation of cars on each track can be accommodated by a single track.

The resource utilization rates must be calculated by hand using the simulation diagram. It should be realized that no resources can be expected to be 100% efficient. A utilization of 60% to 70% is considered to be close to the limit in most cases.

The departure delay is one measure to be used to judge the adequacy of trim-end or departure yard resource allocations. Excessive delays indicate that either more trim engines or more outbound inspection crews are needed.

The average car detention time is an indicator to show the efficiency of the overall yard operations. This value must be calculated for each block type by hand use of the simulation diagram.

7.3.3 Example Application of the Manual Method

The manual method was applied to the yard capacity and resource requirements evaluation work of the Yermo yard of the Union Pacific. The purpose of the work was to evaluate the adequacy of the planned facilities and resource allocations for the existing traffic. The simulation was conducted using actual observed inbound train information data and initial yard inventory for December 9, 1978.

7.3.3.1 Description of the Planned Yermo Yard.

Yard Configuration

Yermo yard is a Union Pacific hump yard in Southern California which is designed to handle about 800 cars per day. The proposed yard will consist of a parallel receiving yard, a classification yard, a parallel departure yard, and two rip tracks of varying lengths. A list of Yermo's simulated track capacities is given in Table 7-4.

Crew Resources

Yard work is accomplished in three crew shifts starting at 2400, 0800 and 1600 hours. Simulated scheduled crew breaks include a 10 minute crew change at the start of each shift and a 25 minute lunch break approximately 4-1/2 hours after the start of each shift. Crews perform overtime work as required in the simulation. Separate crews are utilized to perform train inspections and other yard work. The rates for inspecting trains are: (1) 5 minutes per train plus 0.5 minutes per car for arriving trains, and (2) 1 minute per train plus 0.5 minutes per car for outbound inspections.

Engine and Crew Resources

One switch engine is utilized to perform all switching and trim-end work. A second engine is utilized when overtime work is required. This example used the following parameters associated with yard operations for manual simulation:

- 20 minutes for the engine to go down into the receiving yard, pick up a cut of cars, and return to the hump.
- 22 minutes for the engine to travel from the departure yard to the classification yard, pick up a cut of cars (not including trimming time) and bring it to the departure yard.
- Coupling rate of 4 cars/minute.
- Humping rate of 4 cars/minute.
- Cut-off time period to begin making up trains of 3 hours before the actual train's departure of that day.

Yard Operations

Trains arriving at Yermo yard for switching are stored on the three receiving tracks where they are inspected and detained until the switch engine is available to hump the cars. Run-through trains are detained on the main line except for two trains that are filled at

TABLE 7-4.-LIST OF YERMO YARD TRACK CAPACITIES

	Capacity (60' Cars)
Rip Tracks	
RT-1	123
RT-2	89
Receiving Yard	
REC-1	147
REC-2	148
REC-3	153
Hump Lead	115
Classification Yard	
C-2	57
C-3	53
C-4	53
C-5	52
C-6	52
C-7	49
C-8	49
C-9	51
C-12	48
C-13	44
C-14	44
C-15	43
C-16	43
C-17	41
C-18	41
C-19	43
C-22	40
C-23	36
C-24	36
C-25	36
C-26	36
C-27	34
C-28	34
C-29	36
Departure Yard	
D-1	157
D-2	155
D-3	142

Yermo. They are stored and departed from one of the rip tracks in the manual simulation.

Yermo makes approximately 29 major classifications per day using 24 classification tracks. Each classification is assigned to a classification track. Three sets of tracks (C7 and C8, C17 and C18, C23 and C26) accumulate multiple classifications. Three times daily cars are pulled from a set of multiple classifications. Three times daily cars are pulled from a set of these tracks and are reswitched into the same tracks in block order shortly before their scheduled departure. A reswitch of the track containing bad order and hold cars (C-28) is also performed once per day.

The switch engine is utilized to perform both front-end and trim-end work. When the number of cars in a classification track approaches capacity, additional cars of that classification to be humped are either sorted into an empty track or the full track of the cars is coupled and pulled early to a departure track for train make-up.

7.3.3.2 Description of Train Schedules, Initial Inventory, and Classification Track Assignment.

Inbound Trains

Inbound trains consisted of one train arriving late on December 8 and 11 trains arriving on December 9. A total of 867 cars were received, of which 81 cars by-passed the receiving yard to the repair or departure tracks. A detailed listing of the arriving trains input data is contained in Table 7-5.

TABLE 7-5.-ARRIVING TRAIN ACTIVITIES

Train	Arrival Time	No. Cars	End Hump Time
CLS	2230(12/8)	54	0035
LVE	0050	134	0310
CN	0157	104	0430
SSS*	0410	21	—
1st Rehump		49	0705
2nd Rehump		57	0805
PLA5	0820	86	1045
SDV	1100	56	1340
LAD*	1209	35	—
OLGAM	1345	84	1550
3rd Rehump		15	1655
PLA6	1555	67	1805
4th Rehump		49	1915
VGLAM	1825	58	2000
SLE	1835	73	2320
LVE	2100	95	2400

*Run-through train filled at Yermo Yard. It was stored on a rip track in the manual simulation.

Initial Yard Inventory

There were 253 cars on hand at the start of December 9. An inventory of these cars is summarized below:

- 29 cars in receiving track REC-1
- 188 cars in 19 classification tracks
- 36 cars in departure track D-3.

The 29 cars in REC-1 and 25 cars in D-3 comprised the CLS train which had arrived on December 8 and was not humped yet in the manual simulation. The list of initial inventory on each classification track is given in Table 7-6.

TABLE 7-6.-CARS ON HAND IN THE CLASSIFICATION YARD AT THE START OF THE 24 HOUR SIMULATION (0:00 DECEMBER 9, 1977)

Classification Track No.	Number of Cars
C-2	2
C-3	31
C-4	0
C-5	12
C-6	30
C-7	27
C-8	15
C-9	5
C-12	0
C-13	5
C-14	1
C-15	15
C-16	9
C-17	15
C-18	7
C-19	0
C-22	3
C-23	0
C-24	0
C-25	3
C-26	2
C-27	1
C-28	1
C-29	5
Total	189

Classification Track Assignments

As mentioned earlier, each classification is assigned to a classification track. Each car is assigned to the same classification track with the exception of the LA TOFC and North Platte blocks. Table 7-7 lists the Yermo classification track assignments input to both simulations.

In this simulation the LA TOFC block was stored on the swing track C-29 and was also stored on track C-12, which was clear of the assigned Hinkle block.

The North Platte (NOP) classification contained more cars than any other classification handled on December 9. In the simulation, the NOP block was assigned to track C-1. However, during the day, NOPs were also switched into clear tracks C-19 and C-27 which are usually designated for east loads and restricted empties, respectively.

Outbound Trains

Eleven trains were made up at Yermo yard in the manual simulation. The manual simulation produced outbound train data that included the train history make-up of each train, the number of cars, block mix, and departing time. The schedule of outbound trains is shown in Table 7-8.

TABLE 7-7.-YERMO CLASSIFICATION TRACK ASSIGNMENTS

	Block Name	Block No.	Class Track Assignment
	North Platte (NOP)	1	C2
	Salt Lake	2	C3
	LA Zones and Anaheim	3	C4
	LA S.P.	4	C5
	Colton - S.P.	5	C6
2-Stage	Clearfield	6	C7
2-Stage	Green River	7	C7
2-Stage	Ogden	8	C8
2-Stage	Denver	9	C8
	Provo	10	C9
	Hinkle	11	C12
	Albina	34	C12
	Seattle	35	C12
	Pocatello	12	C13
	Barstow	13	C14
	LA ATSF	14	C15
	LA Junction	15	C16
2-Stage	Victorville	16	C17
2-Stage	Colton - U.P.	17	C17
2-Stage	City of Industry	18	C18
2-Stage	Pedley	19	C18
2-Stage	Mira Loma	36	C18
2-Stage	Ontario	37	C18
2-Stage	Pomona	38	C18
	Unassigned (east loads)		C19*
2-Stage	San Pedro	20	C22
2-Stage	Yermo	21	C23
2-Stage	Nevada Shorts	22	C23
2-Stage	Blue Diamond	23	C23
2-Stage	Henderson	24	C24
2-Stage	Las Vegas	25	C24
2-Stage	Apex	26	C24
2-Stage	Arrolime	27	C25
2-Stage	Moapa	28	C25
2-Stage	Utah Shorts	29	C25
	Bad Orders	30	C26
	Cabs	31	C26
	Unassigned (restricted empties)		C27*
	Holds	32	C28
	LA TOFC (swing)	33	C29†

*Classification tracks C19 & C27 were used for storage of North Platte cars.

†Track C29 was designated as a swing track. However, it was used to accumulate LA TOFC cars.

TABLE 7-8.-SCHEDULE OF OUTBOUND TRAINS

Train	Scheduled Departure Time
CLS	0025
SSS	0520
CN	0650
BNVG	1150
BNSL	1200
LAD	1245
BNLAC	1505
BNVAN	1805
BNLA	2030
BNSP	2055
BNCS	2225

7.3.3.3 Manual Simulation Diagram. The resultant manual simulation diagram is presented in Figure 7-11. The yard activities and status of tracks are graphically documented on this simulation diagram. A detailed discussion on this diagram is given in Section 7.3.1.

7.4 COMPUTER-ASSISTED EVALUATION

As part of the yard design methodology study sponsored by the Federal Railroad Administration, a computerization of the manual capacity and resource requirements evaluation procedure with additional enhancements was developed. This computer model is called CAPACITY. The purpose of the CAPACITY model is to provide the yard designer with an interactive computer tool which can ease the work performed in the yard capacity and resource requirements evaluation process. (See Appendix A for further details.)

7.4.1 Model Description

CAPACITY is a deterministic computer simulation model which traces the building and departure of trains, blocks, and cars in the various portions of the rail yard. It does this task by tracing the movement of these trains, blocks, and cars throughout the yard. Since the emphasis in CAPACITY is rather more on the yard design than on yard operations, some of the yard operating rules are simplified. The result of this approach is that CAPACITY is a very economical model that can be run again and again at low cost.

The model input is designed to run from planning level data. To this end, detailed consists from every arriving train need not be given; rather, trains may be classified into "Consist Mix Groups" in which consists are given on a percentage basis. Process control parameters, such as rate of humping, are required, but to simplify use of the model it should be noted that all such parameters have internal defaults. Only the block IDs taken by departing trains need be specified; the model actually builds the blocks for the departing trains.

The empahsis in the output is determined by the interest of the designer. For example, rather than simulating queueing and back-up within the yard,* the model creates receiving, classification, and departure tracks as the demand requires. The model reports the number and lengths of these tracks that are required as part of the output.

CAPACITY represents the block movements in the yard following a given set of rules. The basic flowchart of the model is given in Figure 7-14. Note in particular the sequential structure of the program. The lack of loops, particularly between the front- and back-end simulations, aids efficiency greatly.

CAPACITY is generally run for three days, starting from an empty yard. Experience with numerous runs made with the model indicates that a steady-state condition is normally reached by the end of the second day (assuming that the yard is not oversaturated). At the user's option, results for the "warm-up" days need not be printed.

CAPACITY optionally allows the user to specify dual receiving yards, dual lead humps, dual class yards, and dual departure yards. These are nominally designated to and within the model as east and west; however, it should be realized that these designations are entirely arbitrary. When the user has only a single rather than dual facility, the user enters all references to that facility as "east" (or "west," so long as he is consistent).

Figure 7-15 shows the maximum overall yard system as simulated in CAPACITY. In examining Figure 7-15, it should be kept in mind that any or all of the dual E and W facilities may be collapsed to single facilities. The flow of traffic, as simulated in CAPACITY, moves from left to right across this figure. The exact operational procedures in each of the boxes in Figure 7-15 may differ from yard to yard. CAPACITY deals with this problem by accepting variable time lengths for each simulated operation within the boxes and across the entire yard. The operational functions are then chronologically linked together as shown in Figure 7-15. Essentially what the computer model does is to represent car

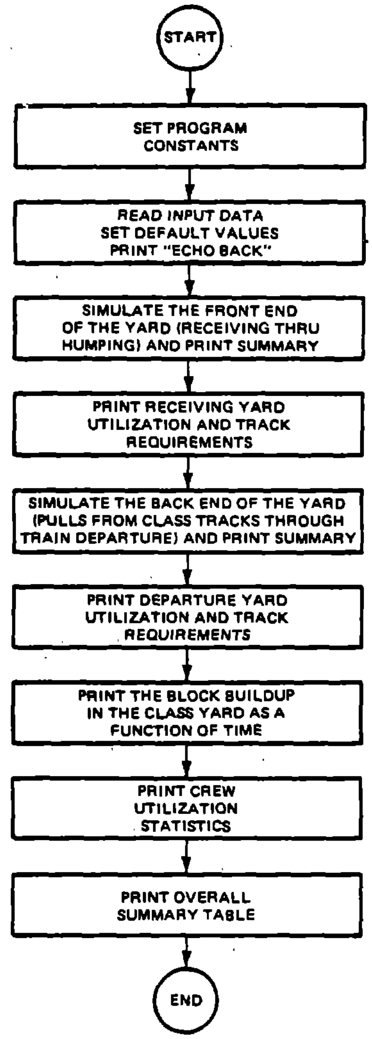


FIGURE 7-14. FLOWCHART OF CAPACITY

movements in the yard by following the sequence of operations. CAPACITY optionally allows the user to specify crew break periods for the yard. However, pieces of work are not interrupted for the scheduled crew breaks. For example, the crew working the hump will finish humping a train and then take the required crew break in its entirety. It is also assumed that all engine movement is uninterrupted by external activities, i.e., movements to the engine house, yardings of trains, caboose movements, engine turnaround, and so on.

The simulation of the yard is divided into front end and back end simulations. The front end simulation includes the portion of Figure 7-15 from the "Arriving Trains" box through the "Hump" boxes. A simplified flowchart of the front end processing is given in Figure 7-16. Trains arrive and may skip inspection or the entire receiving yard (e.g., rehumps). The trains that must wait for inspection (if this is being done) must next queue to be humped. If the yard has dual hump leads and the train is being humped to both the E and W classification yards (spray train), an additional delay may be occasioned since only one of the humps can be active in such a circumstance. At the user's discretion, a further hump delay may also be assessed against each train to simulate moves not otherwise accounted for in the model.

*Queueing and back-up can occur, however, due to hump and departure yard engine availability constraints, or if the traffic load oversaturates the yard.

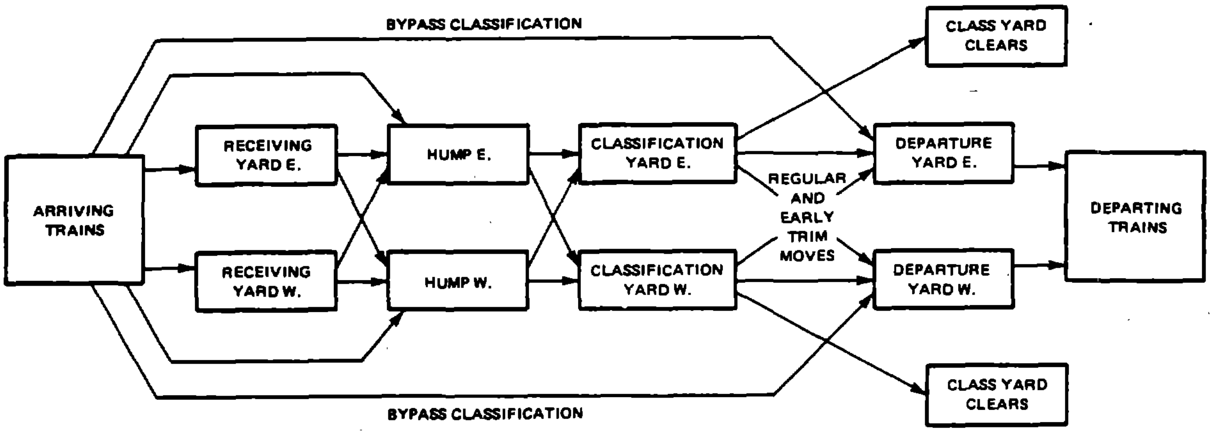


FIGURE 7-15. CLASSIFICATION YARD SYSTEM AS SIMULATED BY THE CAPACITY MODEL

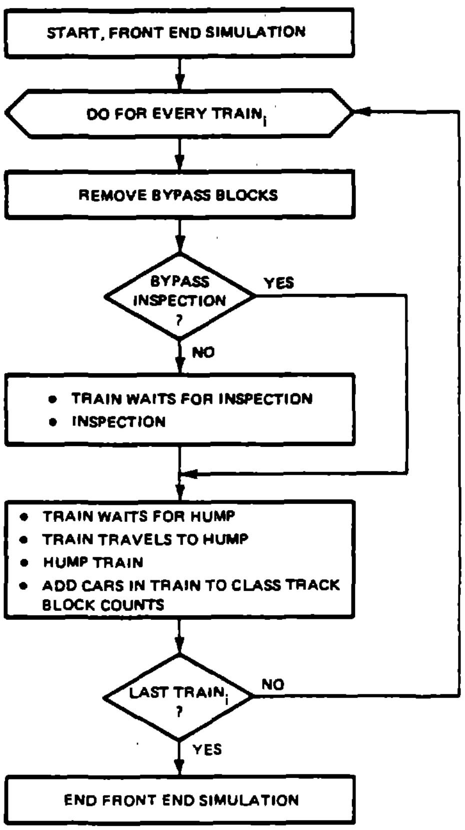


FIGURE 7-16. SIMPLIFIED PROCESSING OF ARRIVAL TRAINS

CAPACITY allows the user to designate certain blocks as being preclassified "Bypass" blocks. These blocks go directly from the receiving yard to the departure yard, bypassing the hump and storage on the class track. Instead, these blocks are effectively stored on the departure tracks. It should be noted that unless a departing train soon takes these bypass blocks, such a scheme can constitute an inefficient utilization of the departure tracks, considerably increasing the track requirements there.

The back-end simulation extends from "Classification Yard" through the "Departing Trains" (or "Class Yard Clears") boxes. A simplified self-explanatory flowchart of this process is given in Figure 7-17. Not shown in the flowchart are several user options which may be invoked. If the classification yard is becoming filled, the user may designate "early trim" moves, which remove blocks of cars from the class yard to the departure yard to await a departing train whose make-up occurs much later. Like bypass block moves, these early trim moves can increase departure yard track requirements. As an aid to simulating reswitching and the departure of trains directly from the class yard (e.g., local turns), the user may designate departing trains as "class yard clears" which depart directly from the class yard, bypassing the departure yard and departure inspection.

The net accumulation of cars in the classification tracks is computed during the back-end simulation by subtracting the cars trimmed from the accumulative car build-up over time computed during the front-end simulation (see Figure 7-18). The net accumulation of cars in any class track is given by the height of the shaded region in Figure 7-18; the car hours is given by the area of the shaded region. CAPACITY optionally allows the user to specify a track length for each block in the classification tracks. When this length is exceeded, the model interprets this event as implying that an extra track of the same length will be available to store the block. The model assumes that as many tracks as are required to store the block will be made available. During the trimming and departure yard simulation, additional pulls will be made for each track on which the block is stored until all the cars in the block have been placed on the departing train, or until an optional user-specified car limit for that block on the departing train has been attained (whichever occurs first). This train length is also used by the model to compute an approximate number of departure tracks required for the block.

Blocks may be optionally grouped in two contexts. The first context applies to the classification tracks. The interpretation in this context is that the blocks share a single class track (or group of class tracks). Rehumping to separate the randomly ordered cars of the block into cars ordered by the blocks can be manually simulated using the CAPACITY model. The second context in which blocks may be grouped applies to the pulls for the departing train makeup. Blocks so grouped are

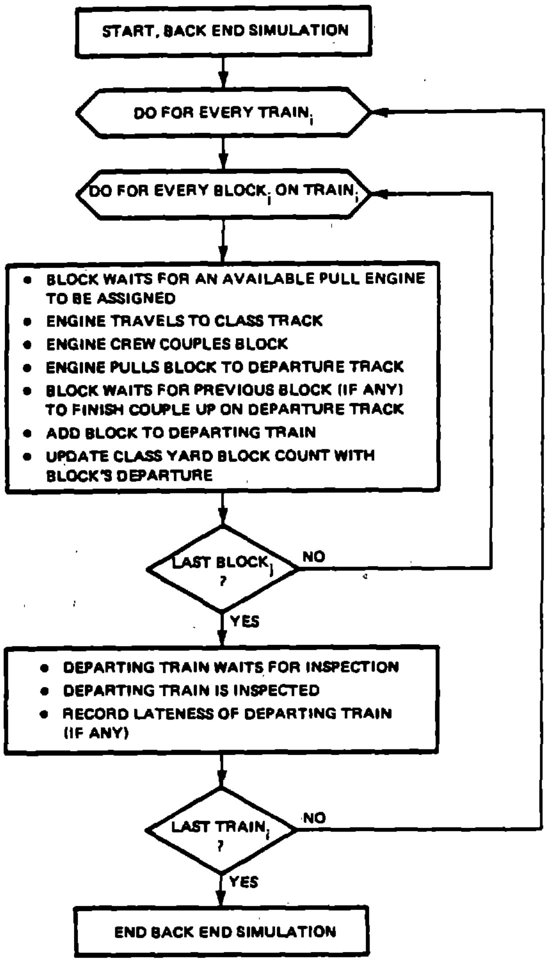


FIGURE 7-17. SIMPLIFIED PROCESSING OF DEPARTURE TRAINS

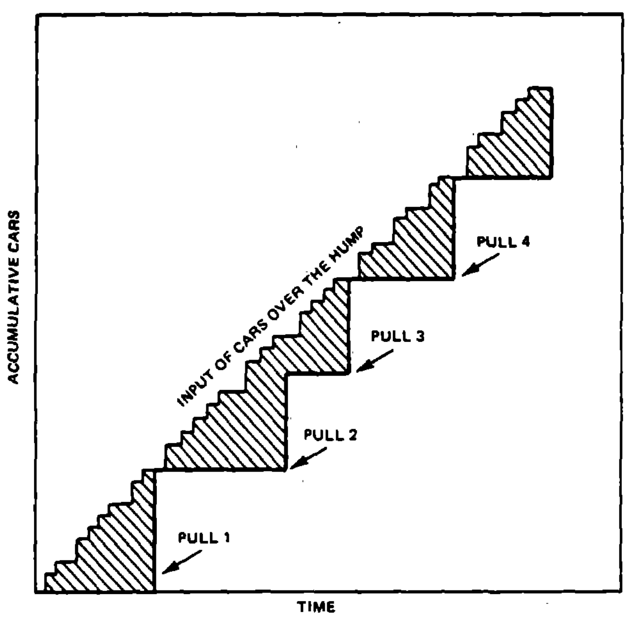


FIGURE 7-18. EXAMPLE OF CLASS TRACK ACCUMULATION

assumed to be pulled together in one trim movement to the departing train. These two block group contexts are specified entirely independently to the model, and need not agree. Of course, the user can always specify the groupings in the two contexts to be identical, a course most users will probably want to follow.

Finally, it is important to note the unidirectional flow indicated in Figure 7-15--reswitching, such as rehumping, is not simulated directly by the model. This is in keeping with the planning level emphasis of the model; it also permits the model to run at a negligible computer cost (e.g., $2 to $3 per run) so that it can be used in an iterative and interactive manner. However, reswitching moves can be easily handled using a manual process whereby a rehumping move is entered into the model as a class yard clear followed by an arriving train bypassing the receiving yard. In real-life applications of the model, reswitchings have been readily simulated in this manner. CAPACITY contains optional features which the user can invoke to facilitate this process.

7.4.2 Input of the Model*

Five types of input data are required to run the model. These inputs are related to:

- Yard geometry
- Yard operations
- Arriving trains
- Class yard assignment
- Departing trains.

The input types are briefly described below.

Yard Geometry--The inputs regarding yard geometry consist of the number of receiving yards, the number of classification yards, and the number of departure yards. Trim engine IDs which are assigned for each departure yard are also defined here. The yard geometric characteristics such as number of tracks and track length are not included in the input.

Yard Operations--Various parameters related to yard operations are used in the computations. The model user can either input the most appropriate values of these parameters or use the default values which are preset in the computer program. The input data related to yard operations are:

- Preinspection delay constant: Time period between the end of actual inspection of a track and beginning of actual inspection of another track. (Default value = 10 minutes.)
- Inspection rate: The number of cars to be inspected in a minute when the inspection crew is actually working. (Default value = 2 cars/minute.)
- Travel time to hump: The travel time from the receiving yard to the hump. Two values are defined for double receiving yards. (Default values = 10 minutes.)
- Hump speed: Rate of humping when actually humping a train. (Default value = 3.33 cars/minute.)

*The worksheets for CAPACITY inputs are given in Exhibit 7-1, presented at the end of this chapter.

- Hump break constant: Time lapsed between finish of humping a train and beginning of humping the next. (Default value = 10 minutes.)
- Engine travel time: Time for a pullout engine to travel between classification yard and departure yard. The travel times to be defined are:
  - From class yard 1 to departure yard 1: default value = 10 minutes.
  - From class yard 1 to departure yard 2: default value = 15 minutes.
  - From class yard 2 to departure yard 1: default value = 15 minutes.
  - From class yard 2 to departure yard 2: default value = 10 minutes.
  - From departure yard 1 to class yard 1: default value = 5 minutes.
  - From departure yard 1 to class yard 2: default value = 10 minutes.
  - From departure yard 2 to class yard 1: default value = 10 minutes.
  - From departure yard 2 to class yard 2: default value = 5 minutes.
- Engine delay parameter: The average delay time for an engine between finishing one pull and starting another. (Default value = 5 minutes.)
- Inspection Rate: The rate of inspection expressed as minutes per car. (Default value = 0.25 minutes per car.)
- Cut-off time duration: The time interval between the scheduled departure time and the scheduled cut-off time point of the train. (Default value = 180 minutes.)
- Block make-up time interval: Time interval between blocks set out on the same departing track. (Default value = 20 minutes.)

Arriving Trains--No default values are included for arriving trains. The input data related to arriving trains are:

- Train ID.
- Arrival time.
- Total number of cars in the train.
- Consist mix ID: The number of cars for each block in a train is computed using block mix patterns given by the user. This variable indicates the block consist pattern to be used for each train.
- Train direction: Identifies the receiving yard to be used.
- Bypass blocks: Identifies the blocks of a train to bypass the hump.
- Block mix pattern: Indicates the mix of blocks in a given block mix ID. Block types and the percentages are included.

The input data define the number of cars in each arriving train and the block consist pattern independently. From these two types of data, the program computes the number of cars for each block type in each train.

Class Yard Assignment--The class yard assignment is specified by the user input. The data required to specify the yard assignment consist of:

- Class yard direction.
- Block ID number.

The program does not simulate the dynamic track assignment strategy. However, a possibility of this strategy can be examined using the output from the program.

Departing Trains--The input data related to the departure train schedule are:

- Train ID
- Scheduled departure time
- Block numbers carried by the train in the order of pull
- Train direction: Identifies the departure yard to be used.

7.4.3 Output of the Model

The output from CAPACITY consists of five parts. The first part is an "echo-back" of the input data, which include (1) variables related to yard operational parameters (see Figure 7-19), (2) variables related to arrival trains (see Figure 7-20), and (3) variables related to departure trains (see Figure 7-21). The second part is the arrival train history, which shows the receiving yard occupancy and the hump utilization. This output presents a summary of the history of the utilization of each yard. Both graphical and numerical outputs are given (see Figures 7-22 and 7-23). From this output it is possible to estimate the required number of receiving tracks and their lengths.

The third part is a numerical output of trim-end simulation (see Figure 7-24). Here all activities of the trim engine are reported.

The fourth part is the departure yard track requirement diagram. Graphical output similar to the one for the receiving yard is given.

The fifth part is the block build-up scenario for the classification yard (see Figure 7-25). This output presents the accumulation of cars of each block over time. This output will be useful in estimating the required number of classification tracks and their lengths.

7.4.4 Model Output Interpretation

The computer model produces several types of outputs. By studying these outputs one can learn how the yard activities were conducted, and how cars were moved from one subyard to another. The major output types to be analyzed are:

- Receiving track occupancy
- Hump utilization
- Classification track car accumulation
- Departure track occupancy
- Inbound/outbound inspection crew utilization
- Hump/trim engine utilization
- Departure train delays
- Average car detention time.

The focus of the analysis is to estimate the track requirements, hump facility evaluation, yard crew requirement evaluation, and yard performance evaluation in terms of detention time.

The receiving and departure yard occupancy diagrams of the computer output show how long each train occupied a track (see Figure 7-23).

```
SRI RAIL YARD CAPACITY SIMULATION MODEL

EAST DEERFIELD CAPACITY DATA--RUN EXTRAS71 UPDATED STRATEGY, HEAVY+SPFLD=6.56

OUTPUT CONTROL -
 CODE TO PRODUCE OUTPUT FOR *CAPCON*/*CONFLICT*                          =      0

TIME CONTROL PARAMETERS -
 NUMBER OF SIMULATED DAYS                                                =      4
 DAY TO START PRINTED OUTPUT                                             =      6

CREW BREAK TIME PERIODS -
 BREAK PERIOD  1 START                                                   =    300
 BREAK PERIOD  1 DURATION                                                =     45
 BREAK PERIOD  2 START                                                   =    450
 BREAK PERIOD  2 DURATION                                                =     30
 BREAK PERIOD  3 START                                                   =    925
 BREAK PERIOD  3 DURATION                                                =     15
 BREAK PERIOD  4 START                                                   =   1200
 BREAK PERIOD  4 DURATION                                                =     30
 BREAK PERIOD  5 START                                                   =   1450
 BREAK PERIOD  5 DURATION                                                =     30
 BREAK PERIOD  6 START                                                   =   1630
 BREAK PERIOD  6 DURATION                                                =     15
 BREAK PERIOD  7 START                                                   =   1830
 BREAK PERIOD  7 DURATION                                                =     30
 BREAK PERIOD  8 START                                                   =   2240
 BREAK PERIOD  8 DURATION                                                =      5

FRONT END OF YARD PARAMETERS -
 TRAVEL TIME REC. TO DEP. YARDS (BYPASS BLOCKS), HOURS MINUTES           =      1
 RECEIVING YARD TYPE CODE                                                =      2
 PRE-INSPECTION DELAY CONSTANT, MINUTES                                  =      5
 RATE OF INSPECTION, MINUTES/CAR                                         =      1.00
 TRAVEL TIME TO HUMP (EAST RECEIVING YARD), MINUTES                      =     20
 TRAVEL TIME TO HUMP (WEST RECEIVING YARD), MINUTES                      =     15
 HUMP BREAK CONSTANT, MINUTES                                            =     20
 HUMPING RATE, MINUTES/CAR                                               =      0.37
 NUMBER OF HUMP LEADS                                                    =      1

BACK END OF YARD TRAVEL TIME PARAMETERS -
 FROM CLASS YARD E TO DEPARTURE YARD E, MINUTES                          =     15
 FROM CLASS YARD E TO DEPARTURE YARD W, MINUTES                          =      1
 FROM CLASS YARD W TO DEPARTURE YARD E, MINUTES                          =      1
 FROM CLASS YARD W TO DEPARTURE YARD W, MINUTES                          =      5
 FROM DEPARTURE YARD E TO CLASS YARD E, MINUTES                          =      5
 FROM DEPARTURE YARD E TO CLASS YARD W, MINUTES                          =      1
 FROM DEPARTURE YARD W TO CLASS YARD E, MINUTES                          =      1
 FROM DEPARTURE YARD W TO CLASS YARD W, MINUTES                          =      1
 FROM CLASS YARD E TO CLASS CLEAR DEST. E, MINUTES                       =      1
 FROM CLASS YARD E TO CLASS CLEAR DEST. W, MINUTES                       =      1
 FROM CLASS YARD W TO CLASS CLEAR DEST. E, MINUTES                       =     15
 FROM CLASS YARD W TO CLASS CLEAR DEST. W, MINUTES                       =     10
 FROM CLASS CLEAR DEST. E TO CLASS YARD E, MINUTES                       =      8
 FROM CLASS CLEAR DEST. E TO CLASS YARD W, MINUTES                       =     10
 FROM CLASS CLEAR DEST. W TO CLASS YARD E, MINUTES                       =      1
 FROM CLASS CLEAR DEST. W TO CLASS YARD W, MINUTES                       =      5

BACK END OF YARD ENGINE UTILIZATION PARAMETERS -
 NUMBER OF ENGINES WORKING ONLY EAST DEPARTURE YARD                      =      1
 NUMBER OF ENGINES WORKING ONLY WEST DEPARTURE YARD                      =      1
 NUMBER OF ENGINES WORKING BOTH DEPARTURE YARDS                          =      0
 NUMBER OF AUXILIARY ENGINES WORKING ONLY EAST CLASS CLEAR DEST.         =      0
 NUMBER OF AUXILIARY ENGINES WORKING ONLY WEST CLASS CLEAR DEST.         =      0
 NUMBER OF AUXILIARY ENGINES WORKING BOTH CLASS CLEAR DESTS.             =      0
 ENGINE BREAK CONSTANT, MINUTES                                          =      1
 ENGINE INTERFERENCE FACTOR                                              =      1.06
 ENGINE UTILIZATION METHOD                                               =      1

BACK END OF YARD MISCELLANEOUS PARAMETERS -
 CUT-OFF TIME PERIOD, HOURS MINUTES                                      =     30
 CUT-OFF TIME PERIOD (BYPASS BLOCKS), HOURS MINUTES                      =     20
 CUT-OFF TIME PERIOD (PREV. PULL BLOCKS), HOURS MINUTES                  =     30
 COUPLING START-UP DELAY CONSTANT, MINUTES                               =      1
 COUPLING RATE, MINUTES/CAR                                              =      0.50
 BETWEEN BLOCK MAKE-UP BREAK CONSTANT, MINUTES                           =      1
 OUTBOUND PRE-INSPECTION DELAY CONSTANT, MINUTES                         =      5
 OUTBOUND RATE OF INSPECTION, MINUTES/CAR                                =      0.50
```

FIGURE 7-19. ECHO BACK OF INPUT VARIABLES (VARIABLES RELATED TO YARD OPERATIONS)

EAST DEERFIELD CAPACITY DATA--RUN EATRAST; UPDATED STRATEGY, HEAVY+SPFLD+0.5E

ARRIVAL TRAIN INPUT DATA -

ARRIVAL TRAIN NO.	E/W	SKIP REC. YARD	EXTRA DELAY TO HUMP	CONSIST MIX ID.	ARRIVAL TIME	NO. CARS	---BYPASS BLOCK IDS---
LOC3	E	1	10	36	30	18	
DMID2	E	1	0	16	40	72	
LM1	E	0	0	1	20	55	
CPV04	E	0	0	8	130	38	
YFT	F	0	0	2	235	85	
DWRTS	E	1	15	12	500	31	
SE5	E	0	0	7	430	97	
DAMLI	F	1	0	13	715	52	
RE30	E	0	0	3	525	64	
DAML2	E	1	0	14	920	52	
LOC1	E	1	10	37	720	22	
CVAP3	E	0	0	6	615	59	
WE2	E	0	0	9	700	64	
CANDR	E	1	0	39	1300	42	
LOC2	E	1	10	38	1320	29	
SP2	E	0	0	35	1400	37	
FEX	E	0	0	10	1500	23	
DERT1	E	1	0	17	1715	118	
AP3A	E	0	0	11	1635	32	
SE1	E	0	0	19	1759	61	
DERT2	E	1	0	18	2007	118	
CV447	E	0	5	20	1900	40	
DMID1	E	1	10	15	2155	73	
CV391	E	0	0	21	2112	48	
NY10	E	0	0	4	2130	68	7
CP917	E	0	0	35	2300	37	

BLOCK PERCENTAGES FOR CONSIST MIX ID 1 SUM TO 52.000 PERCENT
PERCENTAGES SCALED TO SUM TO 100.

BLOCK PERCENTAGES FOR CONSIST MIX ID 2 SUM TO 80.000 PERCENT
PERCENTAGES SCALED TO SUM TO 100.

BLOCK PERCENTAGES FOR CONSIST MIX ID 3 SUM TO 61.000 PERCENT
PERCENTAGES SCALED TO SUM TO 100.

BLOCK PERCENTAGES FOR CONSIST MIX ID 4 SUM TO 83.000 PERCENT
PERCENTAGES SCALED TO SUM TO 100.

BLOCK PERCENTAGES FOR CONSIST MIX ID 6 SUM TO 60.000 PERCENT
PERCENTAGES SCALED TO SUM TO 100.

BLOCK PERCENTAGES FOR CONSIST MIX ID 7 SUM TO 86.000 PERCENT
PERCENTAGES SCALED TO SUM TO 100.

BLOCK PERCENTAGES FOR CONSIST MIX ID 8 SUM TO 36.000 PERCENT
PERCENTAGES SCALED TO SUM TO 100.

BLOCK PERCENTAGES FOR CONSIST MIX ID 9 SUM TO 60.000 PERCENT
PERCENTAGES SCALED TO SUM TO 100.

BLOCK PERCENTAGES FOR CONSIST MIX ID 10 SUM TO 22.000 PERCENT
PERCENTAGES SCALED TO SUM TO 100.

FIGURE 7-20. ECHO BACK OF INPUT VARIABLES (VARIABLES RELATED TO ARRIVAL TRAINS)

EAST DEERFIELD CAPACITY DATA--RUN EATRAST; UPDATED STRATEGY, HEAVY+SPFLD+0.5E

DEPARTURE TRAIN INPUT DATA -

DEPART. TRAIN NO.	E/W	TRAIN TYPE CODE	SCHED. DEPART. TIME	---BLOCKS PULLED FOR THIS TRAIN (CAR LIMIT ON TRAIN OF EACH BLOCK)---			
LOC3	W	0	100	13(0)	-12(0)	-14(0)	-17(0)
CPV17	E	0	115	2(0)	39(0)	-38(0)	-40(0)
AP3	E	0	300	10(0)			
EP1	E	2	300	1(0)			
FW1	E	0	400	37(0)	-36(0)		
DWRTS	W	0	530	5(0)			
DAML1	E	0	630	20(0)	-15(0)	-16(0)	
RH30	E	0	730	51(0)	-52(0)	-53(0)	-7(0)
DAML2	E	0	840	24(0)	-23(0)	22(0)	-21(0)
LOC1	W	0	900	13(0)	-12(0)	-14(0)	-17(0)
ES2	F	0	1000	8(0)	25(0)		
EP9	E	2	1000	9(0)			
E6	E	1	1000	27(0)			
E2	E	1	1000	26(0)			
BM7	E	0	1300	55(0)	-9(0)		
EP10	F	2	1345	10(0)			
LOC2	W	0	1400	13(0)	-12(0)	-14(0)	-17(0)
EP11	E	2	1430	11(60)			
DERT1	E	0	1600	6(0)	-3(0)	-1(0)	
DERT2	E	0	1824	41(0)	-42(0)	43(0)	-44(0)
LM1	F	0	1900	10(80)			
CV447	E	0	2000	11(0)	-4(0)		
EY8	E	0	2100	45(0)	-46(0)		
ES6	E	0	2130	47(0)	-48(0)		
DMID1	W	0	2130	30(0)			
EP2	E	2	2130	2(0)			
DMID2	E	0	2215	35(0)	-34(0)	33(0)	-32(0)

FIGURE 7-21. ECHO BACK OF INPUT VARIABLES (VARIABLES RELATED TO DEPARTURE TRAINS)

EAST DEERFIELD CAPACITY DATA—RUN EXTRAS71 UPDATED STRATEGY, HEAVY+SPFLU+6.5%

ARRIVING TRAIN HISTORIES —

NO.	TRAIN	L/W	NO. BYPASS CARS	NO. HUMP CARS	NO. TOTAL CARS	ARR. TIME	START INSP.	INSP. PERIOD	END INSP.	QUEUE TIME TO HUMP	EXTRA DELAY TO HUMP	START HUMP	HUMP PERIOD	END HUMP	END REC. YD. OCC.
78	CP917	E	0	37	37	32300	32305	37	32342	10	0	40012	14	40026	32352
79	LUC3	E	0	18	18	40030		BYPASS REC.	YD.	16	10	40056	7	40103	
80	DM102	E	0	72	72	40040		BYPASS REC.	YD.	43	0	40123	27	40150	
81	LM1	E	0	55	55	40020	40025	55	40120	30	0	40210	20	40230	40150
82	CP904	E	0	38	38	40130	40135	38	40213	17	0	40250	14	40304	40230
83	YE7	E	0	85	85	40235	40240	125	40405	0	0	40425	31	40456	40405
84	DWRTS	E	0	31	31	40500		BYPASS REC.	YD.	16	15	40531	11	40542	
85	SES	E	0	97	97	40430	40435	137	40612	0	0	40632	36	40708	40612
86	DAML1	E	0	52	52	40715		BYPASS REC.	YD.	43	0	40758	19	40817	
87	RB30	E	0	64	64	40525	40530	104	40634	163	0	40837	24	40901	40817
88	DAML2	E	0	52	52	40920		BYPASS REC.	YD.	1	0	40921	19	40940	
89	LUC1	E	0	22	22	40726		BYPASS REC.	YD.	255	10	41025	8	41033	
90	CVAP3	E	0	59	59	40615	40620	59	40719	314	0	41053	22	41115	41033
91	ME2	E	0	64	64	40700	40725	104	40829	246	0	41135	24	41159	41115
92	CANDK	E	0	42	42	41300		BYPASS REC.	YD.	0	0	41300	16	41316	
93	LUC2	E	0	29	29	41320		BYPASS REC.	YD.	16	10	41346	11	41357	
94	SP2	E	0	37	37	41400	41405	37	41442	0	0	41502	14	41516	41442
95	FEX	E	0	23	23	41500	41525	23	41548	0	0	41608	9	41617	41548
96	DERT1	E	0	118	118	41715		BYPASS REC.	YD.	0	0	41715	44	41759	
97	AP3A	E	0	32	32	41635	41650	32	41722	37	0	41819	12	41831	41759
98	SE1	E	0	61	61	41759	41804	101	41905	0	0	41925	23	41948	41905
99	DERT2	E	0	118	118	42007		BYPASS REC.	YD.	1	0	42006	44	42052	
100	CV447	E	0	40	40	41900	41905	40	41945	107	5	42117	15	42132	42052
101	DM101	E	0	73	73	42155		BYPASS REC.	YD.	0	10	42205	27	42232	
102	CV391	E	0	48	48	42112	42117	48	42205	27	0	42252	18	42310	42232
103	NY10	E	41	47	88	42130	42135	47	42222	53	0	42335	17	42352	42315
104	CP917	E	0	37	37	42300	42305	37	42342	10	0	50012	14	50026	42352
			41	1451	1492			1344		1705	100		900		

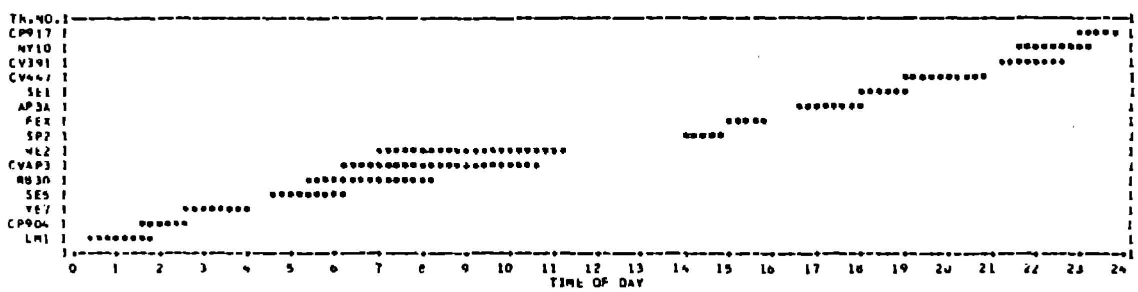
RECEIVING YARD SUMMARY STATISTICS STRICTLY OVER THE 24 HOURS OF THE REQUESTED PRINT PERIOD —

	BYPASS	HUMP	BOTH
CARS IN	41	1414	1455
CARS OUT	41	1414	1455
TOTAL CAR HOURS	0.68	2593.85	2594.53
AVERAGE DETENTION TIME, HOURS	0.02	1.83	1.76
HUMP UTILIZATION, PERCENT (1 HUMP)	NA	36.53	NA

FIGURE 7-22. RECEIVING YARD AND HUMP UTILIZATION HISTORY

EAST DEERFIELD CAPACITY DATA—RUN EXTRAS71 UPDATED STRATEGY, HEAVY+SPFLU+6.5%

EAST RECEIVING YARD OCCUPANCY DIAGRAM FOR DAY 4 -



EAST RECEIVING YARD TRACK REQUIREMENTS -

TRACK NO.	MIN. LENG. REQUIRED (CARS)
1	97
2	64
3	59

FIGURE 7-23. RECEIVING YARD TRACK REQUIREMENTS

EAST DEERFIELD CAPACITY DATA--RUN EXTRAS7; UPDATED STRATEGY, HEAVY+SPFLD+6.5%

DEPARTING TRAIN MAKE-UP SCENARIOS --

NO.	TRAIN OR MOVE NAME	DEST. E/W	BLOCK NO.	BLOCK E/W	PULL TYPE	ENGINE NO. ASSUR.	ENGINE E/W/B	START COUPLE	START PULL	END PULL	NO. CARS	TOTAL CARS	START OCC. DP. TRK.	START INSP.	END INSP.	SCHED.	LATE
82	LOC3	W	13	E	MULT. PULL						4						
82	LOC3	W	12	E	MULT. PULL						12						
82	LOC3	W	17	E	CLASS PULL	2	W	40032	40042	40043	3						
												19	40043	40048	40058	40100	0
83	CP917	E	2		PREV. PULL						71						
83	CP917	E	2	E	CLASS PULL	1	E	40133	40141	40156	16						
83	CP917	E	39	E	MULT. PULL						5						
83	CP917	E	36	E	MULT. PULL						19						
83	CP917	E	40	E	CLASS PULL	1	E	40203	40216	40231	1						
												112	40005	40236	40332	40115	217
84	AP3	E	10	E	CLASS PULL	1	E	40238	40251	40306	25						
												25	40306	40350	40403	40300	103
85	EP1	E	1	E	EARLY PULL	1	E	40358	40422	40437	47						
												47					
86	EW1	E	37	E	MULT. PULL						11						
86	EW1	E	36	E	CLASS PULL	1	E	40444	40508	40523	36						
												47	40523	40528	40552	40400	152
87	DWRTS	W	5	E	CLASS PULL	2	W	40502	40517	40518	29						
												29	40518	40523	40538	40530	8
88	DAML1	E	20	E	MULT. PULL						46						
88	DAML1	E	15	E	MULT. PULL						4						
88	DAML1	E	16	E	CLASS PULL	1	E	40606	40631	40646	0						
												50	40646	40725	40750	40630	120
89	RB30	E	7		BYPASS						41						
89	RB30	E	51	E	MULT. PULL						6						
89	RB30	E	52	E	MULT. PULL						18						
89	RB30	E	53	E	MULT. PULL						7						
89	RB30	E	7	E	CLASS PULL	1	E	40726	40801	40816	39						
												111	32131	40821	40917	40730	147
90	DAML2	E	24	E	MULT. PULL						20						
90	DAML2	E	23	E	CLASS PULL	1	E	40823	40836	40851	6						
90	DAML2	E	22	E	MULT. PULL						15						
90	DAML2	E	21	E	CLASS PULL	1	E	40858	40911	40926	11						
												52	40851	40945	41011	40840	131
91	LOC1	W	13	E	MULT. PULL						5						
91	LOC1	W	12	E	MULT. PULL						12						
91	LOC1	W	17	E	CLASS PULL	2	W	40832	40841	40842	0						
												17	40842	40847	40856	40900	0
92	ES2	E	8	E	CLASS PULL	1	E	40948	41016	41031	56						
92	ES2	E	25	E	CLASS PULL	1	E	41038	41053	41108	30						
												86	41031	41113	41156	41000	156
93	EP9	E	9	E	EARLY PULL	1	E	41115	41154	41209	77						
												77					
94	E6	E	27	E	CLASS CLR.	1	E	41246	41252	41253	11						
												11					
95	E2	E	26	E	CLASS CLR.	1	E	41303	41307	41308	7						
												7					

FIGURE 7-24. DEPARTING TRAIN MAKE-UP SCENARIO

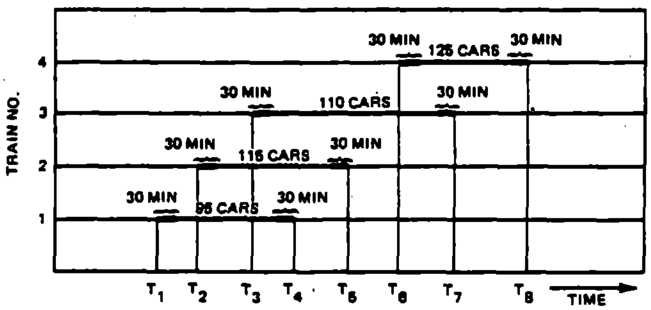
EAST DEERFIELD CAPACITY DATA--RUN EXTRAS7; UPDATED STRATEGY, HEAVY+SPFLD+6.5%

EAST CLASS YARD BLOCK BUILD-UP MATRIX FOR DAY 4

BLK. NO.	GRP. NO.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MAX FOR DAY	NO. TRNS. REQD.	CARS IN	CARS OUT	CAR HRS.
		MAXIMUM NUMBER OF CARS FOR HOUR BEGINNING AT																												
1	1	27	27	29	47*	1	1	1	8	8	16	18	33	33	33	33	33	33*	0	0	6	6	6	6	27	47	1	80	80	375
2	2	16	16*	9	9	14	14	14	23	23	24	24	30	30	30	30	46	50	50	53	53	53	68	68	71*	71	1	87	87	718
3	3	6	6	6	8	8	8	9	9	8	8	8	21	21	21	21	21	21*	0	0	0	0	0	0	6	21	1	21	21	187
5	4	21	21	21	29	29	29*	0	1	1	2	2	12	12	12	12	12	12	12	12	15	15	15	15	21	29		29	29	292
51	4	0	0	0	0	0	6	6	6*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6		6	6	10
SUM	4	21	21	21	29	29	35	6	7	1	2	2	12	12	12	12	12	12	12	12	15	15	15	15	21	35	1	35	35	302
4	5	6	6	6	6	11	11	11	11	11	11	11	11	11	11	11	14	14	14	20	20	20*	3	3	3	20	1	20	20	237
6	6	14	14	14	15	15	15	15	15	15	15	15	17	17	17	17	17	17*	0	0	2	2	2	2	14	17	1	17	17	260
7	7	35	35	35	35	38	38	38	39*	0	0	0	1	1	2	2	2	5	5	5	30	30	31	31	35	39		39	39	425
53	7	0	0	0	0	0	7	7	7*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7		7	7	12
SUM	7	35	35	35	35	38	45	45	46	0	0	0	1	1	2	2	2	5	5	5	30	30	31	31	35	46	1	46	46	437
8	8	21	21	44	46	49	49	49	56	56	56*	0	16	16	17	17	17	17	17	17	17	17	17	17	21	56	1	56	56	624
9	9	21	21	23	26	46	46	46	54	54	54	54	77*	16	17*	0	0	2	2	10	10	10	11	11	21	77	1	94	94	529
10	10	24	24	25*	2	33	33	33	71	71	71	71	74	74	75*	0	0	5	5	8	10	10*	8	6	24	75	1	105	105	688
11	11	36	36	44	44	56	56	56	58	58	60	60	63	63	63	63*	21	27	27	32	32	32*	17	17	18	63	1	92	92	975
20	12	46	46	46	46	46	46	46*	8	8	24	24	26	26	31	31	31	34	34	35	42	42	42	42	46	46		46	46	795
15	12	4	4	4	4	4	4	4*	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	4	4		4	4	33
SUM	12	50	50	50	50	50	50	50	8	8	24	24	26	26	31	31	31	34	34	35	44	44	44	44	50	50	1	50	50	626
30	13	3	3	6	7	8	8	8	19	19	31	31	37	37	70	70	70	70	70	71	74	74	74*	0	3	74		74	74	768
31	13	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4		1	0	73
SUM	13	5	6	9	10	11	11	11	22	22	34	34	40	40	73	73	73	73	73	74	77	77	77	4	7	77	1	75	74	841
21	14	0	0	0	0	0	0	0	0	11*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11		11	11	8
32	14	18*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	16	18		18	18	44
36	14	0	36	36	36	36*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36		36	36	104
40	14	0	1	1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		1	1	0
44	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	30	30*	0	0	0	0	30		30	30	40
46	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	16	16*	0	16		16	16	22
55	14	0	0	0	0	0	0	0	0	0	4	4	4	4	4*	0	0	0	0	0	0	0	0	0	0	4		4	4	15

FIGURE 7-25. BLOCK BUILD-UP SCENARIO

No particular tracks are assigned to trains in this diagram. The computer model internally computes the required number of receiving or departure tracks and their lengths. The values found on the computer printouts are the minimum requirements. Realistically the values to be used in designing the yard must have some sort of safety margin which will prevent minor traffic flow fluctuations from oversaturating the yard. A rough sensitivity analysis can be conducted using the receiving or departure yard occupancy diagram. Earlier arrivals of trains and late departures to/from the yard (or later departures of trains in the case of a departure yard) can be hand drawn as shown in Figure 7-26 with slightly longer trains than observed in the diagram. The required number of receiving (or departure) tracks and their lengths under such circumstances can be estimated from the modified diagram.



TIME / TRACK	T_1-T_2	T_2-T_3	T_3-T_4	T_4-T_5	T_5-T_6	T_6-T_7	T_7-T_8	MAX.
1	95	115	115	115	110	125	125	125
2		95	110	110		110		110
3			95					95
4								

FIGURE 7-26. RECEIVING YARD TRACK REQUIREMENTS: SENSITIVITY ANALYSIS

The method of estimating track requirements is described using an example diagram. Figure 7-26 is a receiving yard occupancy diagram, which includes 30 minutes of allowance for each train's arrival and travel to hump. The track requirements with the time allowances are also listed in the figure.

The columns of the table in Figure 7-26 indicate time intervals of the day and the rows of the table indicate the number of tracks. The numbers in the table indicate the required track lengths in cars. The columns of the table are filled by the train lengths, from the largest train to the smallest train, from top to bottom.

Figure 7-26 shows that in time interval $T_1 - T_2$, the required number of tracks is 1, and the required track length is 95 cars long. The required number of tracks becomes largest between times T_3 and T_4. In that time interval, the number of tracks required is 3, and the required track lengths are 125, 110, and 95. The required length of each track is obtained as the maximum value of each row of the table. Thus, the track requirements with extra time allowances are obtained.

The classification track requirements are clearly shown in the block build-up matrix of the computer output. Here the lengths of the classification tracks are defined as a user input. The required number of tracks is computed from the maximum number of cars accumulated for each block and the track length.

The hump, engine, and crew utilization values are given in the computer output. It should be noted that no facilities/crews can be utilized with 100% efficiency all the time. These values should not exceed a reasonable rate, such as 60 to 70%.

The departure train delay is used to evaluate the efficiency of the trim-end and departure track activities. The designer must check whether or not there are any excessive delays.

The average car detention time is used to estimate the overall yard performance. The detention time is one of the most important single measures of effectiveness, since it shows clearly the overall efficiency of the yard.

7.4.5 Example Application of the CAPACITY Model

The CAPACITY model was used in the yard capacity and resource requirements evaluation for the East Deerfield yard rehabilitation study at the Boston and Maine (B&M) Railroad. The purpose of the analysis was to roughly estimate the level of traffic volume that can be handled at the East Deerfield yard under the proposed design and operating conditions.

The model is used as a tool in the yard design process. The yard design process is a trial-and-error process in which the yard designer evaluates his trial designs using this model. In the East Deerfield yard design, only one trial design was evaluated. However, four different traffic levels were tested to determine the level of traffic to be handled by the yard.

The following four scenarios were simulated:

- Scenario I--An average day in East Deerfield Yard, with the addition of traffic resulting from a suspension of switching operations at Springfield Yard: 628 cars/day.
- Scenario II--A heavy day in East Deerfield Yard, with the addition of traffic resulting from a suspension of switching operations at Springfield Yard: 779 cars/day.
- Scenario III--Same input as Scenario II, with traffic increased 6.5%: 828 cars/day.
- Scenario IV--Effects of abnormally heavy traffic. Additional capital investments as well as more intensive switching operations were assumed. Basic traffic was roughly equivalent to that of Scenario II, with abnormally heavy traffic added, but a revamped schedule was developed to utilize East Deerfield as the hub of the four-spoke system: 1,111 cars/day.

7.4.5.1 Description of the Proposed East Deerfield Yard.

Proposed Yard Configuration

Figure 7-27 shows a schematic layout of the proposed yard configuration. There is one receiving/departure yard consisting of 8 tracks with a total physical capacity of almost 600 cars (2 tracks hold 94 cars and the others average 65 cars). There are 18 classification tracks (averaging 68 cars in length) served by a single hump. In addition, there are car cleaning tracks, a car repair area, and a locomotive fueling and repair area.

Proposed Operating Plan

Several sets of operational parameters to handle the various classifications looked promising. One operating plan for the proposed East Deerfield yard was chosen to be simulated by the CAPACITY model.

Use of Hump Engine

The hump engine is generally used to perform all humping and reswitching functions, if available, including pulling cars from the classification yard back over the hump and rehumping. One hump engine was assumed for the first three scenarios and two hump engines for the fourth scenario.

Use of Trim Engine

One trim engine was used at the East Deerfield yard for the first three scenarios and two trim engines were used for the fourth scenario. The trim engine can double over class tracks when feasible in performing the task of pulling cars from the classification tracks to the receiving/departure yard. The trim engine does the following work:

- Couples (trims) and pulls cars from the classification tracks to the departure tracks.
- Couples (trims) and pulls cars from the classification tracks to the receiving tracks for reswitching by the hump engine (when the hump engine is unavailable or when the cut is too heavy for the hump switcher to pull back up the hump grade).
- Pulls blocks from the classification to departure tracks for holding.
- Couples (trims) local trains that are to depart directly from the classification yard.
- Sets out tracks of cars for local (Greenfield to East Deerfield) customers.

Classification Track Assignment

Cars are initially classified and humped into the following classification tracks.

Track	Classification
1	Boston, Yard 21, W. Cambridge, Gardner, Gardner PW, Fitchburg, Ayer, Worcester, Worcester PW (Fitchburg mainline classifications).
2	CP.
3	Nashua, Manchester, Concord (New Hampshire North).
4	Lowell, Lawrence, Dover (West Routes).

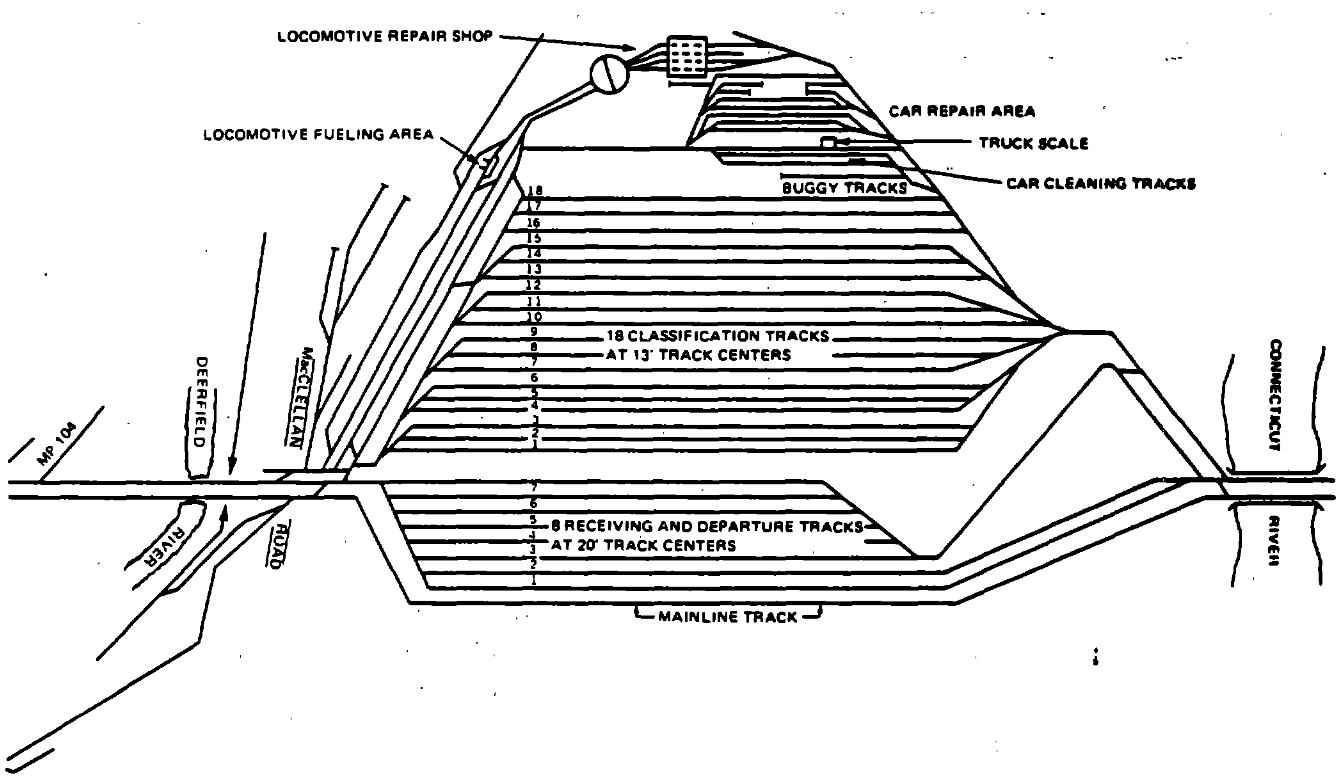


FIGURE 7-27. PROPOSED SCHEMATIC LAYOUT OF EAST DEERFIELD YARD

Track	Classification
5	CV.
6	Chelsea, Lynn Salem (East Routes).
7	Rigby.
8	Springfield CR.
9	CR-Rotterdam Junction.
10	D&H
11	CN.
12	Holyoke, Springfield B&M, E6, E2, E3, So. Deerfield, Northampton, Mt. Tom, Easthampton, Athol, Orange, Erving, Chicopee, Millers Falls, Bernardston, VTR, Mechanicsville town. (AM locals.)
13	Brattleboro CV, Brattleboro B&M, E7 (Dennis-Jamison, Suburban Propane, Agway, Book Press, Case Brothers, Westminster, Bellows Falls, Hinsdale, Ashuelot, Winchester, Keene), Claremont (C&C), White River Junction, Littleton, Whitefield, Groveton, Berlin. (Midnight Locals.)
14-17	Reswitch tracks.
18	B&M cleaners, cripplers, weighers, miscellaneous local blocks.

When further classification is not required, cars are trimmed and pulled from their respective classification tracks by the trim engine at the appropriate scheduled cut-off time and set out and inspected in the receiving/departure yard. Early pulls of full tracks are made by the trim engine and stored in the departure yard.

When further classification is necessary, groups of blocks can be either pulled from the classification tracks back over the hump by the hump engine or pulled to a receiving track by the trim engine for reswitching. Several times each day, up to 16 blocks were reswitched using Tracks 14-17 to make up several trains at one time. Two of these trains departed directly from the classification yard, thus requiring only coupling by the trim engine. The following block groupings require reswitching:

- Fitchburg mainlines (Track 1).
- New Hampshire North (Track 3).
- West Routes (Track 4).
- East Routes (Track 6)
- AM locals (Track 12).
- Midnight locals (Track 13).
- Cleaners, cripples, weighers, and miscellaneous local blocks (Track 18).

7.4.5.2 Traffic Scenarios Tested. Example listings of arrival and departure train schedules used in one of the four scenarios are given in Figures 7-16 and 7-17, respectively.

7.4.5.3 Assumptions Used for CAPACITY Model Simulation. Two types of assumptions are involved in CAPACITY model application. One is the type of assumptions inherent in the CAPACITY model, and the other is the type of assumptions specifically adopted in each application. The following are inherent in the CAPACITY model:

- Pieces of work are not interrupted for scheduled crew breaks. For example, the crew working the hump will finish humping a train and then take the required crew break in its entirety.
- All engine movement is uninterrupted by external activities, i.e., movements to the engine house, yardings of trains, buggy movements, engine turnaround, and so on.

Other assumptions used by the B&M as inputs to CAPACITY are as follows:

- The receiving/departure yard consists of eight tracks.
- The classification yard consists of 18 tracks, of which tracks 13-17 are used for reswitching.
- Front-end inspections are 5 minutes per train plus 1 minute per car.
- One hump engine works per shift for Scenarios I, II, and III.
- Two hump engines work per shift for Scenario IV.
- The humping rate is 2.7 cars per minute.
- Reswitch movements are made by hump and trim engines.
- One trim engine works per shift in Scenarios I, II, and III.
- Two trim engines work per shift in Scenario IV.
- Early pulls are made by the trim engine.
- Trains made up from multiple tracks leave from the receiving/departure yard.
- Trimming is simulated at 0.5 minute per car.
- A standard cut-off time is applied to all departing trains.
- The durations of hump closure vary according to the amount of work required for each reswitching by the hump engine and the duration of crew breaks.
- No humping is performed while a hump engine is performing work in the bowl.
- The hump engine has enough power to pull cars back over the hump for reswitching.
- Outbound inspections are 5 minutes per train plus 0.5 minute per car.
- A cut-off time period of 30 minutes is applied to departing trains. That is, trains can begin being made up 30 minutes prior to their scheduled departure time. Making this constant small enabled better simulation of reswitches and the like.
- Eight crew-break time periods were selected to approximate actual breaks. In the first three scenarios, the breaks for each shift consisted of 30 minutes for crew change, 30 minutes for lunch, and a 15-minute coffee break. In Scenarios II and III, late-night work kept second-shift personnel busy until the end of their shift. Thus, only 5 minutes was lost as third-shift crews came out with fresh engines to relieve the homeward-bound men. In Scenario IV, the breaks were much shorter, to simulate the effect of overlapping shifts.
- The following travel times were determined through analysis of the proposed yard layout:

- Twenty minutes for the hump engine to go down into the receiving yard, pick up a cut of cars, and return to the hump.
- Twenty-two minutes for the trim-end engine to travel from the departure yard to the classification yard, pick up a cut of cars (not counting trimming time) and bring it to the departure yard.
- Nine minutes for the trim-end engine to travel from one classification track to another (assuming worst case).

The values of input variables used in the East Deerfield yard study are listed in Figure 7-15.

7.4.5.4 Analysis of CAPACITY Output. Estimation of the East Deerfield yard capacity under the four scenarios was conducted by examining:

- Receiving/departure track requirements.
- Hump and trim engine utilization and number of cars handled by the trim engine.
- Class track requirements.
- Departure train delays.
- Average car detention time in the yard.

Receiving/Departure Track Requirements

The number and length of tracks required in the receiving/departure yard for each scenario were determined by combining the receiving and departure yard occupancy diagrams and track length requirements. The durations of inbound and outbound train occupancies on a receiving and departure track were plotted over a 24-hour period. The number of tracks required to accommodate the traffic for a given scenario is at least the greatest number of trains that occupy receiving/departure tracks simultaneously, and additional tracks are required (1) for trains that are longer than the normal track length, and (2) when block swapping occurs. Figure 7-28 shows for one of the four scenarios, the simulated receiving/departure yard occupancy over a 24-hour period. Trains requiring track lengths greater than 80 cars were assumed to occupy two tracks.

Hump and Trim Engine Utilization and Number of Cars Handled by the Trim Engine

CAPACITY reports the movement of engines at front and back ends of the yard, i.e., between the receiving yard and the hump and between the departure yard and the classification yard. Various types of facility (or crew) utilization rates (or times) were computed in the CAPACITY output. The measures used for the analysis are:

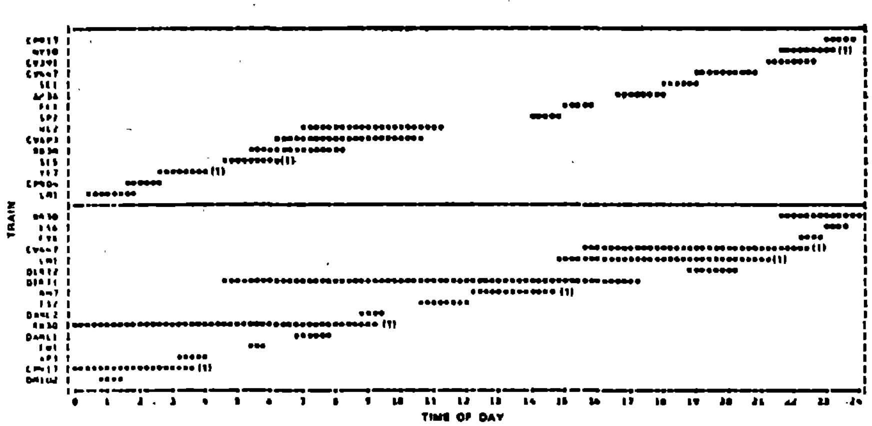
- Hump Utilization--Actual time that cars are moving over the hump, divided by 24 hours.
- Hump Engine Utilization--Time that hump engine is moving or doing work, divided by 24 hours.
- Hump Crew Utilization--Time that hump engine is moving or doing work, divided by time crew is working (24 hours minus shift changes, lunch hours, etc.).
- Trim Engine Utilization--Time that trim engine is moving or doing work, divided by 24 hours.
- Trim Crew Utilization--Time that trim engine is moving or doing work, divided by time crew is working (24 hours minus shift changes, lunch hours, etc.).

Classification Track Requirements

The proposed 18 classification tracks constraint was tested. The proposed capacities of the classification tracks vary, averaging 68 cars in length. When specified classification track lengths are exceeded, the model reports the number of extra tracks of the same length required to store the block of cars. During the iterative process, optional early pulls were simulated until most of the specified track limits were maintained.

Departure Train Delays

Train delays are reported in the CAPACITY train makeup scenarios. Train delays were evaluated for reasonableness and effect on the overall operation of the yard. Table 7-9 summarizes the departure of all the trains during the 24-hour period.



(1) Train has greater than 80 cars, thus requiring 2 tracks.

NOTE: The following trains were reswitch trains temporarily stored on receiving/departure tracks prior to humping: DERT2, DERT1, DAML2, DAML1, and DMID2.

FIGURE 7-28 RECEIVING/DEPARTURE YARD OCCUPANCY FOR SCENARIO III

TABLE 7-9.-DEPARTURE TRAIN OUTPUTS

Departure Train	Time	Cars
CP917	0332	112
AP3	0403	25
EW1	0552	47
RB30	0917	111
ES2	1156	86
E6	1323	11
E2	1338	8
BM7	1438	98
LM1	2116	80
CV447	2220	112
EY8	2242	56
ES6	2338	62

Average Detention Time

The average detention time is an excellent indicator of a yard's efficiency, but is heavily dependent on the operational strategy utilized. For example, moving classifications out of the yard more than once a day does much to reduce average detention time. An average time cars spend in that East Deerfield yard during a 24-hour period was given in CAPACITY reports (see Figure 7-22).

Estimation of Yard Capacity and Resource Requirements

The yard capacity and resource requirements were estimated using the CAPACITY model outputs for the various levels of traffic volumes. Sample worksheets and schedules for CAPACITY Input, called Exhibit 7-1, are given in the following pages. The CAPACITY model outputs used for the analysis are track, engine, and crew requirements. The outputs from the model, such as average detention time and crew requirements, were also used as the measures of effectiveness to estimate the benefits from constructing the yard.

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Exhibit 7-1

SAMPLE WORKSHEETS FOR CAPACITY INPUT

FRONT END OF YARD PARAMETERS

Crew Parameters:

Crew Type (Inspection or Hump Crew)	Yard Crew Works* (E, W, B)	Rate of Inspection or Humping**	Crew Breaks (up to 8 breaks)							
			Start Time and Duration		Start Time and Duration		Start Time and Duration		Start Time and Duration	

*E = East; W = West; B = Both

**You can either apply inspection and humping rates to all or individual crews.

Engine Travel Times:

FROM	TO	TRAVEL TIME	
Receiving Track	Departure Yards		←(Bypass Blocks)
East Receiving Track	Hump		
West Receiving Track	Hump		
Hump	Receiving Track		
Optional: Hump	Class Track		} Rehumps
Class Track	Hump or Receiving Track		} Rehumps

Receiving Yard Type: In-Line or Pull-Out Lead __________

Pre-Inspection Delay (min/train) Constant: __________

Rate of Inspection (min/car): __________

Humping Rate (min/car): __________

Number of Hump Leads: __________

BACK END OF YARD PARAMETERS

Crew Parameters:

Crew Type (Inspection/ Trim/Auxiliary Trim Crew)	Yard Crew Works* (E, W, B)	Rate of Inspection or Coupling	Crew Breaks (up to 8 breaks)							
			Start Time and Duration		Start Time and Duration		Start Time and Duration		Start Time and Duration	

*E = East; W = West; B = Both

Engine Travel Times:

FROM: \ TO:	East Class Yard	West Class Yard	East Departure Yard	West Departure Yard	East Other Destination	West Other Destination
East Class Yard						
West Class Yard						
East Departure Yard						
West Departure Yard						
East Other Destination						
West Other Destination						

Identify "Other Destination:" E = ____________________

W = ____________________

YARD ENGINE MISCELLANEOUS PARAMETERS:

Engine Break (min/pull) Constant in Making Up Departing Train: ________________

Engine Utilization Method:

1. One engine makes up entire departing train. ☐

2. First available engine makes each pull in making up departing train. ☐

Cut-Off Times* for:	Time Period (hours, minutes)
Regular Departing and Early Pull Trains†	
Putting Blocks that Bypass Hump on Departing Train	
Putting Early Pull Blocks on Regular Depart Train (Blocks that are pulled early to a departure track to hold for a departing train)	
Coupling Start-up Delay Constant (min/pull)	
Coupling Rate (min/car)‡	
Lost Time Between Block Make-Up Constant (min/pull)	
Outbound Pre-Inspection Delay Constant (min/train)	
Outbound Rate of Inspection (min/car)	

*The cut-off time periods can be overridden by assigning individual cut-off times to each departing train in the departing train schedule.

†The cut-off time is the earliest time before a departing train's scheduled depart time that a call for an engine to make up the train is made in the model.

‡You can specify inspection and coupling rates separately by crew.

ARRIVING TRAIN SCHEDULE

Train ID	Arrival Time	Receiving Yard (E or W)	Total Number of Cars	Train Not Inspected	Train Not Inspected and Bypasses Receiving Yard	Extra Delay on Hump*	Comments

*Duration of hump closure prior to humping this train. It allows time for hump engine to go into bowl and bring up a cut of cars ("train") for reswitching, for example.

ARRIVING TRAIN CONSIST INPUT DATA

	Number of Cars of Each Block (Train Consist)†																								
Train ID*																									

*A train consist may be used for more than one arriving train. The model converts number of cars to percent cars automatically.

†Identify blocks of cars that bypass the hump and are sent directly to a departure track.

CLASSIFICATION TRACK ASSIGNMENTS*

Class Yard (E or W)	Optional		Blocks (Optional: Include Maximum Number Cars/Block/Track)
	Assigned Class Number	Class Track Limit (Number of Cars)	

*Identify which blocks are reswitched and identify onto which tracks they are switched.

DEPARTING TRAIN SCHEDULE INPUT DATA

Train ID	Scheduled Depart Time	Cut-off Time	Destination		Special Trains		Make-Up Engine* (T or A)	Blocks Assigned to Departing Train in Order of Pull†
			Depart Yard (E or W)	Other (E or W)	Early Pull	Train Not Inspected		

*Make-up engine; T = Trim engine; A = Auxiliary engine.

†Indicate blocks that are pulled together (i.e., multiple class track assignments or tracks that are doubled over before pulling to the departure yard).

CHAPTER 8: DECIDING ON FLAT VS. HUMP YARD

8.0 GENERAL

In this chapter we attempt to address the questions of whether a flat yard or hump yard should be built, or perhaps more importantly, whether an existing flat yard should be rehabilitated into a hump yard.

One can classify a flat yard as a labor-intensive facility, whereas a hump yard is a capital-intensive facility. For this reason, it has been traditional to build flat yards for low-volume terminals (i.e., less than 1000 cars per day) and to build hump yards for high-volume terminals (i.e., greater than 1500 cars per day). However, the traditional rules of thumb need to be re-examined because of the rapid inflation of labor costs in the last decade and the innovation in the design of so-called "mini-hump" yards. In particular, Southern Pacific has pioneered the development of small mini-hump yards which are claimed to be economical for small- and medium-sized yards, i.e., those classifying from 500 to 1500 cars per day.

8.1 ALTERNATIVES FOR SMALL YARDS

In this section we briefly describe the alternatives for small yards. These include the flat yard and three versions of the mini-hump yard.

8.1.1 Flat Yard

A flat yard generally consists of a series of tracks connected by a ladder track and switching lead, as shown in Figure 8-1.* Most flat yards use the same tracks for receiving, classifying, and dispatching trains although many such yards do have separate receiving and/or departure tracks. The car sorting

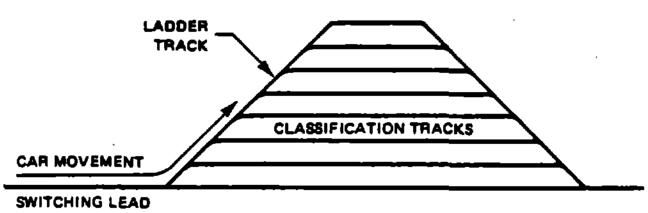

FIGURE 8-1. EXAMPLE FLAT YARD TRACK CONFIGURATION

process requires that a group of cars be pulled out to the switch lead where the switch engine will accelerate quickly toward the yard and then decelerate. Just prior to the deceleration, a car or group of cars will be uncoupled and the deceleration of the switch engine and the cars coupled to it will cause one or more of the uncoupled cars to separate from the rest. This procedure is called giving the cars a "kick." The switch engine generally continues kicking cars toward the classification tracks until reaching the ladder track, at which point it will pull the remaining cars back along the switch lead and resume the process. The cars and groups of cars that have been kicked will travel along the switch lead and ladder track until switched onto the appropriate classification track. Switches in most flat yards are generally thrown manually. To improve operations, the grades of flat yards are often somewhat saucer-shaped so that the cars will tend to accumulate in the center of the yard when switching from both ends of the yard. Such gradients also reduce the frequency of cars stopping short on the ladder track or classification track.

8.1.2 Hump Yards

8.1.2.1 General Hump Yard Description. Hump yards can classify a large volume of cars more efficiently than a flat yard. To handle efficiently the large volume of cars, a hump yard typically has separate receiving, classification, and departure subyards. The classification process requires that a yard engine take a group of cars from the receiving yard and push these cars over a raised portion of track called the hump. Cars are uncoupled at the hump crest and begin to accelerate down the hump grade, thereby separating from the yard engine and the remaining cars. Referring to Figure 8-2, as the cars roll down the hump grade, braking devices called retarders control their speed, and the appropriate switches are thrown to route the cars into the designated classification tracks.

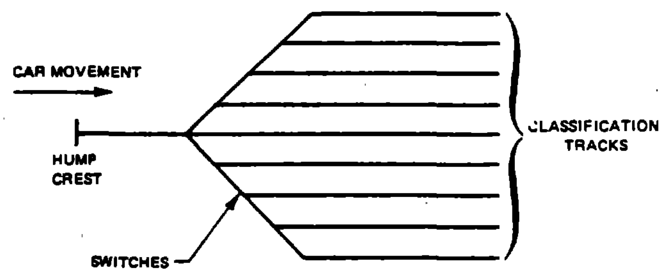

FIGURE 8-2. EXAMPLE TRACK CONFIGURATION FROM HUMP CREST TO CLASSIFICATION TRACKS

8.1.2.2 Mini-Hump Design Alternatives. The performance of a mini-hump design should be specified in terms of a given humping rate (without misswitches and stalling) and a range of coupling impact speeds on the classification tracks for all cars between design-specified hardest and easiest rolling resistance cars (specified in pounds/ton or equivalent percent grade).

For small yards (i.e., 8 to 16 class tracks), Figure 8-3 shows three alternatives for a mini-hump yard design. The alternatives shown are:

- Master retarder only design
- Group retarder only design
- Tangent-point retarder only design.

Conventional hump yard designs for medium or larger yards normally contain a master and group retarders, and if a high hump rate is desired may have in addition tangent-point retarders (e.g., Southern Pacific's West Colton Yard).

The design of low-cost mini-hump yards was made feasible by the development of relatively inexpensive weight-responsive hydraulic retarders and low-cost speed measuring devices (i.e., doppler radar and sonic

*A large flat yard may have the "top" half of the yard configured as in Figure 8-1, with the "bottom" half a mirror image.

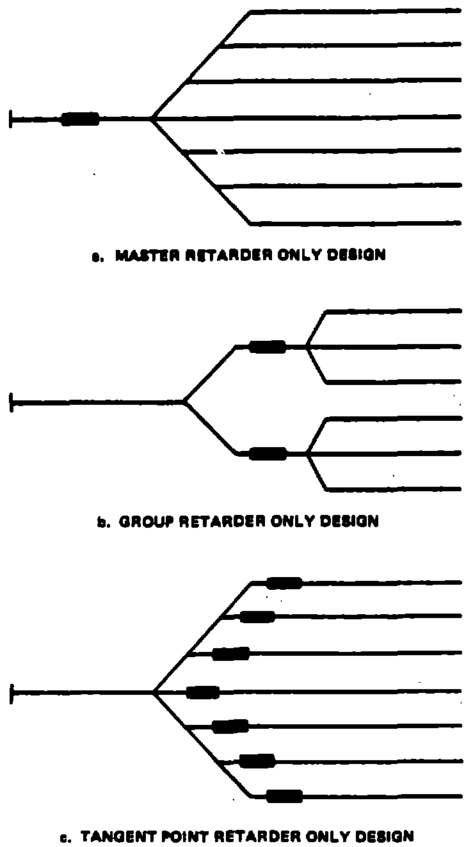

FIGURE 8-3. MINI-HUMP DESIGN ALTERNATIVES

notched-rail devices). Conventional hump yards traditionally use pneumatic, electric, or electro-hydraulic heavy-duty retarders, which are considerably more expensive than weight-responsive hydraulic retarders.

The master retarder only design presented in Figure 8-3a shows a single weight-responsive hydraulic master retarder. Because the distance to couple and the curves negotiated enroute to the various classification tracks vary, additional sensors and computer logic to calculate rolling resistances, track fullness, and variable retarder release speeds based on distance to couple should be incorporated in order to achieve a high humping rate while maintaining proper coupling speeds. The need for this additional sophistication to maintain a high humping rate and proper coupling speeds becomes more acute as the number of classification tracks controlled by the single master retarder increases. As the number of classification tracks increases, the uncontrolled distance for a car's roll from the master retarder to the classification tracks increases, thus making it more difficult to achieve a high humping rate while maintaining sufficient headway between cars to throw switches; the extra distances and curvature to the outside tracks makes accurate coupling on the classification tracks difficult. In this design it is critical to bring all the clear points as close to the master retarder as possible to minimize the uncontrolled distance. However, a master retarder which is too close to the hump crest will constrain the humping rate, since not enough distance is allowed for cars to gain sufficient separation to avoid two cars being in the retarder simultaneously; normally the master retarder is placed at least 70 feet from the crest and preferably slightly farther away.* The hump height for this design is approximately 7 feet for a 12 classification track yard; the actual height varies depending on the hardest rolling resistance for the design and the number of classification tracks.

To keep the uncontrolled distance of a car's roll from the retarder to the outside classification tracks within a reasonable limit so as not to let performance suffer, it is obvious that one solution is to limit the number of classification tracks being controlled by a given retarder. This philosophy gives rise to the group retarder only design shown in Figure 8-3b, in which two or more weight-responsive hydraulic retarders are used to control two or more groups of classification tracks. Thus, the group retarder only design can be considered as an evolution of the master retarder only design when one wants to achieve higher performance by limiting the number of classification tracks under the control of a single retarder. In this design it is not only critical to minimize the uncontrolled distance from the group retarder to the clear point of the outside tracks, but it is also imperative to minimize the uncontrolled distance of a car's roll from the hump crest to each group retarder. The group retarders should be sufficiently close to the hump crest to avoid the need for a master retarder ahead of the group retarders since this adds to the cost. In an attempt to place the group retarders as close to the hump crest as possible, the first-divide switch should not be so close as to constrain the humping rate. In particular, if the first-divide switch is too close to the hump crest, the humping rate will be limited because not enough distance is allowed for cars to gain sufficient separation to throw the switch. Normally the first-divide switch is placed at least 100 feet from the crest and preferably slightly farther. Again, the performance of this design can be enhanced by additional sensors and computer logic to calculate rolling resistances, track fullness, and variable retarder release speeds based on distance to couple.

The Southern Pacific (SP) has pioneered the development of the tangent-point retarder only design; they currently have six of these types of yards on their property.† Figure 8-3c shows the design favored by SP in which weight-responsive hydraulic retarders are placed at each tangent point. The initial grades are designed to deliver the hardest rolling car to the tangent point at approximately 4.0 mph; the tangent point retarders are designed to slow and release easier rolling cars at a preset release speed of approximately 4.0 mph. The yards can achieve 3 cars per minute over the hump. The key to the design (as claimed by SP) is that the tangent point retarders squeeze the wheels and straighten out the trucks, thus narrowing down the "band" of rolling resistances on the class tracks and giving superior coupling performance. The classification track grade is a "maintaining" grade for the easiest rolling car; therefore, no coupling impact speeds are greater than 4.0 mph. The hardest rolling car generally goes about a third of the way into the class track; because their wheels have been straightened they easily get "bumped" further into the class track by succeeding cars. An important factor for a successful operation is a "tight" design in which the uncontrolled distance of a car's roll from the hump crest

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*As a function of distance from the hump crest, the separation between cars increases to a maximum before decreasing.

†Mr. Barney Gallacher of SP is designer of this type of yard.

to clear point on the outside track is kept to a minimum. However, once again the first-divide switch should not be so close as to constrain the humping rate. SP claims that a 24-classification track yard could be designed as long as the maximum distance from crest to clear could be kept at less than 550 feet. The hump for this design is approximately 6 feet high for a 12-classification track yard; the actual height varies depending on the hardest rolling resistance assumed for the design and the number of classification tracks. Because the tangent point retarders have a simple preset release philosophy, no sophisticated sensors or computers are needed to calculate rolling resistance, track fullness, or variable retarder release speeds to maintain high performance. Thus, even though there are more "feet" of retarders involved in this design as compared to the master retarder only or a group retarder only designs, the cost of this design may not be substantially greater, especially if coupling performance is considered.

Which of the above mini-hump designs is best for a given mini-hump performance specification depends on the assumptions of rolling resistance and the local operational environment. In any event, the detailed hump grade and retarder placement design procedures discussed in Chapter 11 should be used to analyze and evaluate the various design alternatives.

8.2 DECIDING ON FLAT VERSUS HUMP YARD

The decision to construct either a new flat yard or hump yard, or to rehabilitate an existing flat yard into a hump yard should not be based on a simple car volume count, but rather on an economic evaluation of the alternatives. In the case of a flat yard versus a hump yard, the economic analysis involves a tradeoff of the higher operating expenses of a flat yard versus the higher capital expenses of a hump yard. Assumptions on the interest rates for capital and the inflation rate of wage scales can be critical to this evaluation. The detailed economic analysis procedures discussed in Chapter 6 should be used where Alternative 1 is a flat yard and Alternative 2 is the most cost-effective mini-hump design.

The economic evaluation procedure discussed in Chapter 6 can be a very involved process if carefully performed. Before embarking on such an analysis it may be desired to have a rough-cut procedure to determine whether or not one should proceed with the more detailed economic analysis. One rule of thumb used by a particular railroad is that a mini-hump yard is attractive if it can eliminate one yard engine and crew per shift. An alternative approximate procedure is based on the simple worksheet shown in Figure 8-4. This worksheet attempts to calculate the economic savings for a mini-hump yard. If the annual savings look attractive as a percentage of the additional capital investment required for a mini-hump yard, then one should proceed with the more detailed economic analysis. The desired percentage of dollar savings to additional capital investment for the mini-hump yard to look attractive is a function of the desired rate of return, interest rate for capital, and the amortized life of the investment. In any event, a simple threshold percentage in conjunction with the worksheet shown in Figure 8-4 can be used as a rough-cut procedure to determine whether a more detailed economic analysis is justified.

Item Expense	Flat Yard	Hump Yard	Hump Yard Eliminates	Dollar Savings Per Unit	Annual Savings
Number of Locomotives Per 24 Hours					
Number of Locomotive Crews Per 24 Hours					
Number of Supervisory Personnel Per 24 Hours					
Per Diem				Note 1	
				TOTAL SAVINGS	

Note 1: Estimated per diem car savings per day = (Estimate of reduced yard time per car)
× (Estimate of average hourly per diem rate per car)
× (Average number of cars processed per day)

FIGURE 8-4. SIMPLIFIED WORKSHEET TO CALCULATE SAVINGS OF MINI-HUMP YARD VERSUS FLAT YARD

CHAPTER 9: GEOMETRIC DESIGN OF FLAT YARDS*

9.0 GENERAL

This chapter describes the general considerations to be addressed in the flat yard geometric design process. The flat yard is becoming increasingly less attractive, partially due to the flat yard's labor-intensive nature, and partially because of technical innovation in small yard retainer systems. At present it is believed that a flat yard is economically more viable than a mini-hump yard for a traffic level of 500 cars/day or less (see Chapter 8). This number will probably decrease in the future. However, we cannot totally ignore flat yard design since the majority of yards in the nation are still flat yards, so the designer will have to continue to deal with flat yards well into the foreseeable future.

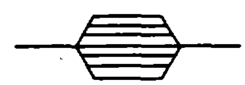
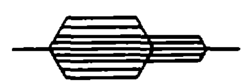
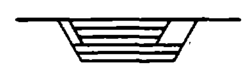
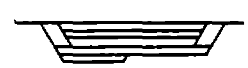
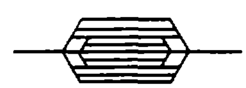
9.1 VARIOUS TYPES OF FLAT YARDS

In general a flat yard consists of a set of parallel tracks connected by a ladder track at each end. Most flat yards use the same tracks for receiving, classifying, and departing trains, though some flat yards have separate receiving and departure tracks. Flat yards can be classified into categories as shown in Table 9-1. In the table, flat yards are categorized by the number of sides, number of switching leads, and use of tracks. Each yard type is briefly described below.

9.1.1 One-Sided Flat Yard

The class yard is located on one side of the switching lead (see Figure 9-1). A crossover (or a set of crossovers) is placed outside of the class track ladder at each end of the yard to enable trains to enter and exit the yard. A switch lead is placed at both ends (or either end) of the class track ladder. Switching and/or trimming activities can be performed at both ends of the yard simultaneously. We have found examples having as many as 16 tracks on one side of the yard. Usually the track lengths vary from 30 to 100 cars. Ideally the tracks must be sufficiently long to accommodate all of the receiving and departure trains, and also the tracks must be sufficiently short to facilitate switching. With this type of yard it is often hard to satisfy both requirements.

TABLE 9-1.—CATEGORIZATION OF FLAT YARDS

Yard type number	One-sided or two-sided	No. of switching leads	Separate or non-separate R&D tracks	Schematic Geometry
1	One-sided	One/each end	No separate R&D tracks	
2	One-sided	One/each end	Separate R&D tracks	
3	Two-sided	one/each end/side	No separate R&D tracks	
4	Two-sided	One/each end/side	Separate R&D tracks	
5	One-sided	Multiple leads	No separate R&D tracks	
6	One-sided	Multiple leads	Separate tracks	
7	Two-sided	Multiple leads	No separate R&D tracks	
8	Two-sided	Multiple leads	Separate R&D tracks	

*The authors would like to acknowledge the contributions to this chapter of Messrs. J. Wetzel and C. C. Yespelkis of CONRAIL and B. Gallacher of Southern Pacific Transportation Company.

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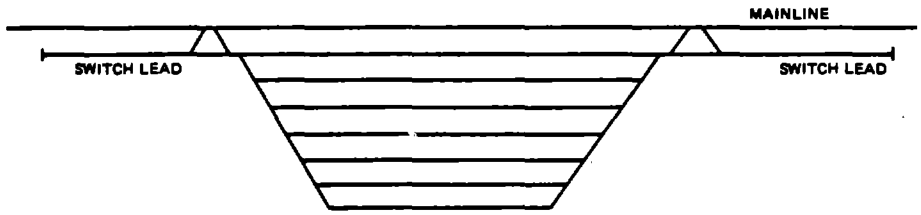


FIGURE 9-1. ONE-SIDED FLAT YARD WITH NO SEPARATE RECEIVING AND DEPARTURE TRACKS

The above dilemma can be solved by installing longer tracks for receiving and departure and shorter tracks for classification (see Figure 9-2). With this design, it is necessary that crossovers be properly placed at both ends of the yard to facilitate efficient entrance and exit of trains to and from the yard. The switching and trimming tasks can be performed at both ends of the yard.

Multiple leads are found in some flat yards (see Figures 9-3 and 9-4). This yard type is designed for a particular switching methodology.

First, every train is switched into the first track group by one switch engine. The last track of the first track group is a slough track* for blocks which must be switched into tracks on the following track groups. Then a second switch engine will couple the cars on the slough track and switch them into the second track group. In this manner the cars which are to be classified onto a track in the n^{th} track group must be switched n times. It is obvious that this yard type is inefficient, since it requires many classification operations.

Two versions of the above type of yard, one without separate receiving and departure tracks and the other with separate receiving and departure tracks are presented in Figures 9-3 and 9-4. The most efficient use of this yard type is attained by minimizing possible conflicts of engine movements. This implies that the tracks are laid out in such a manner that the routes from the mainline to the designated receiving tracks

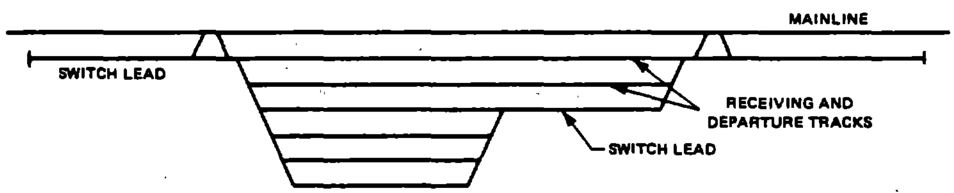


FIGURE 9-2. ONE-SIDED FLAT YARD WITH SEPARATE RECEIVING AND DEPARTURE TRACKS

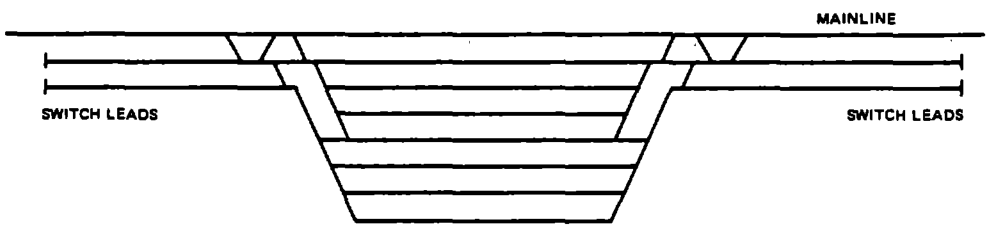


FIGURE 9-3. SCHEMATIC LAYOUT OF FLAT YARD WITH MULTIPLE SWITCH LEADS
(NO SEPARATE RECEIVING AND DEPARTURE TRACKS)

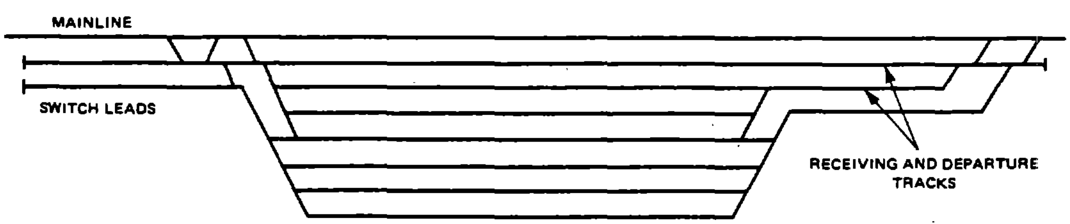


FIGURE 9-4. SCHEMATIC LAYOUT OF FLAT YARD WITH MULTIPLE SWITCH LEADS
(SEPARATE RECEIVING AND DEPARTURE TRACKS)

*The term "slough" or "sluff" track is railroad terminology; in some railroads it is called a "for-now" track. Cars in these tracks are miscellaneous and generally must be reswitched.

do not share any part of the switch leads, permitting simultaneous switching operations on each switching lead.

9.1.2 Two-Sided Flat Yard

For this class of flat yard the class tracks are located on both sides of the switching leads. As shown in Figure 9-5, the mainline usually bypasses the class yard to avoid conflicts between through trains and switching movements. Each side of the yard can have its own switch leads or can share the same switch leads; the tangent tracks (or track) in the center of the yard are (or is) used as a switch lead. When there is only one switch lead at each end of the yard, cars are obviously switched into both sides of the yard. When two center tracks are used as switch leads, accessibility from either switch lead into either side of the yard is attained by installing a set of crossovers at each end of the yard. Usually the maximum number of switch engines that can work simultaneously is identical to the number of switch leads in the yard.

The design variations of a two-sided flat yard are almost identical to those of the one-sided flat yard. These yards can have separate receiving and departure tracks and multiple lead designs, just as for the one-sided yards.

9.2 DETERMINING THE YARD SIZE

The size of the yard is basically determined by the characteristics of the traffic sorted at the yard. The factors affecting the yard size will include the number of cars processed per day, the number of blocks processed, train sizes, and the peaking characteristics of train arrivals and departures.

The design elements to be considered in the yard size determination are:

- The number of receiving and departure tracks and their lengths.
- The number of classification tracks and their lengths.
- The overall yard configuration.

The yard size estimation for flat yards is especially complicated because blocks are seldom permanently assigned to a classification track, and thus the switching process requires a repetition of reswitching maneuvers.

The yard size can be estimated either by using the CAPACITY model or by a manual method. In either method the key problem is to identify the method of operations at the yard clearly so the analysis can be properly conducted. The definition of the reswitching method becomes especially critical in this process. For example, the geometric switching method is one of the possibilities.

The use of CAPACITY will require clever manipulation of the model and proper interpretation of the model output. Some of the points to be noted in using the CAPACITY model for flat yard design are:

- Instead of the humping rate, the switching rate is used.
- Receiving and departure yards are not usually separated in flat yards.
- Rehumping of the flat yard operations can be simulated by creating dummy arrival trains.

Except for these irregularities, the flat yard physical capacity requirements estimation process is very close to the one used for hump yards. A detailed discussion on estimation of yard capacity is given in Chapter 6.

A rough estimation of yard size is possible by a manual method. In this method, first the average detention time is identified. Next, the average number of cars to be stored in the yard is estimated from the average detention time and the average daily traffic volume:

Let V_D = daily traffic volume (cars/day),

T_D = average detention time (hours),

V_Y = the average number of cars detained at the yard (cars).

Then, V_Y may be approximated as

$$V_Y = V_D \cdot T_D/24. \qquad (9.1)$$

The V_Y includes the cars stored on the receiving and departure tracks, the cars stored on the classification tracks, and the cars being sorted. In (9.1) if the daily traffic volume is 500 cars and the estimated average detention time is 20 hours, then the average number of cars at the yard is estimated as 417 cars. The yard must be large enough to store this number of cars statistically, and also must have a sufficient number of tracks to switch cars. Ideally the receiving and departure tracks must be long enough to accommodate the longest train processed at the yard. For the purpose of design, the designer must consider the daily variation of traffic, the long-term traffic trends, and also the peaking characteristics of traffic.

9.3 FLAT YARD DESIGN SPECIFICS

There are some rules to be followed in designing a flat yard. They are briefly described below.

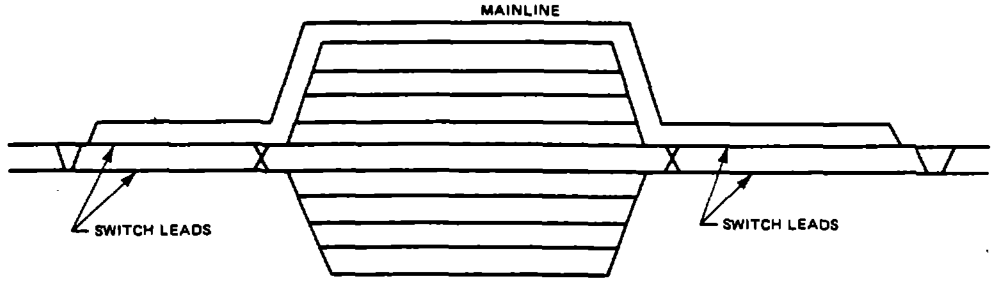


FIGURE 9-5. SCHEMATIC LAYOUT OF TWO-SIDED FLAT YARD

9.3.1 Mainline

The mainline should not pass through a flat yard because of potential conflict problems between switching moves and linehaul moves, thus adversely affecting the yard's productivity. The interchange track between the bypassing mainline and the yard should be designed so that there is minimum interference between traffic. The bypassing mainline can be either single track or double track. The decision as to which alternative is selected is based on the traffic level and pattern and the cost associated with the installation of the two alternatives.

9.3.2 Number of Tracks

The maximum number of tracks per switch lead is determined based on the class track center spacings, the maximum ladder length, and the turnout number used in the class track ladder. The recommended distance between track centers is 14 feet, based on car inspection on foot. Ideally the ladder length (or the distance between the first switch and the clear point of the outermost track) should be less than 1000 feet. If this rule is rigorously followed, then the maximum number of tracks per switching lead can be calculated to be 12 (assuming turnout number 8). However, many flat yards can be found with more than 12 tracks per switch lead. As the number of class tracks increases, the probability that the switch engine has to perform switching operations on the ladder track becomes higher.

9.3.3 Grades of Class Track and Ladder

The bowl tracks should be designed with a saucer shape profile. The desirable grade of class track ladder is between 0.2 to 0.3%, and the desirable grade of class tracks is between 0.08 and 0.15%. The grade on the connecting curves between a ladder and a class track is between 0.2 and 0.3%. If the yard is designed to perform switching at both ends, then the profile geometry should be symmetric as shown in Figure 9-6. However, if switching is performed only at one end of the yard, then the profile geometry should be asymmetric as shown in Figure 9-7.

9.3.4 Switches and Turnouts

In general the type of switch to be used in flat yards is the standard split switch. The turnout numbers most commonly used are 7 to 10. Turnout number 10 is used at the receiving and departure ends of the yard. Turnout numbers 7 to 9 are most commonly used at the class track ladder.

FIGURE 9-6. VERTICAL PROFILE OF CLASS TRACK (SWITCHING AT BOTH ENDS)

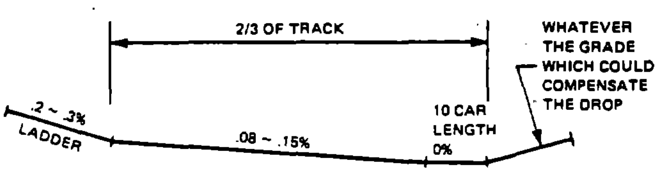


FIGURE 9-7. VERTICAL PROFILE OF CLASS TRACK (SWITCHING AT ONE END)

9.3.5 Switching Speed

The rate of switching per engine in an average flat yard is somewhere between 1 to 1.25 cars/minute. The kicking speed can be much higher than this range, and varies from 2 to 8 mph. If the kicking speed is much faster than the walking speed, then the pinpuller must ride the car in order to pull a pin.

9.3.6 Single Ladder Versus Tandem Ladder

It is believed by some that the single ladder is suitable for manual operation of switches because all the switch machines can be installed in an equal spacing, facilitating the switchman's work. On the other hand, some designers believe that the tandem design makes the job easier for a switchman because the walking distance is shorter. Detailed discussions on the ladder design are given in Chapter 11: Yard Design and Track Layout Considerations.

9.3.7 Horizontal and Vertical Curves

The maximum degree of curve recommended for horizontal curves is 12° 30', independent of the car speed. The recommended minimum length of curve is described in Chapter 11.

9.3.8 Operational Considerations

The switch engine crew operational procedures can affect the design philosophy of flat yards. Some railroads desire that the pinpuller pull the pin from the right side of the moving cut so that the front knuckle of a car is opened which minimizes the number of uncoupled cars on the classification tracks (note, pulling the pin from the left side opens the rear knuckle of a car). In this situation, a "right-handed" ladder, which extends from the right side of the switching lead (see Figure 9-8), is preferred since the pinpuller is on the same side of the cut as the direction of car movement down the ladder, thus maximizing visual sighting down the ladder and communication with the switchmen. If the pinpuller pulls pins from the right on a left-handed ladder, which extends from the left side of the switching lead (see Figure 9-9), then it is claimed by some railroads that the sighting down the ladder and communication with the switchmen is hindered because the cut of cars is between the pinpuller and the ladder and switchmen. Some railroads do not consider this a problem; however, for those which do consider it a problem, right-handed ladders are preferred.

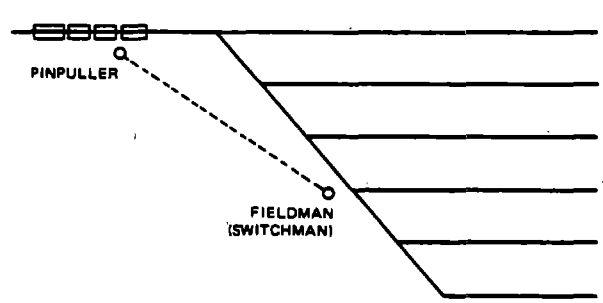


FIGURE 9-8. RIGHT-HANDED LADDER

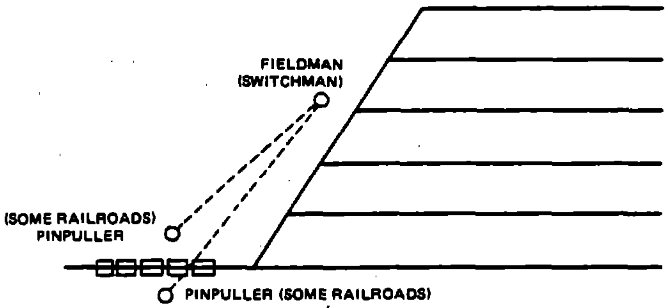


FIGURE 9-9. LEFT-HANDED LADDER

9.4 FLAT YARD LADDER PROFILE DESIGN

Because there are no retardation mechanisms in the flat yard, the car with a low rolling resistance value (easy roller) tends to accelerate as it rolls along the ladder track, and the car with high rolling resistance (hard roller) tends to decelerate along the ladder track. The objective in designing the ladder track is to find the grade which allows the hard roller to travel as far as possible, while simultaneously allowing the easy roller to travel subject to certain speed constraints. The design process of flat yard classification ladders is quite different from that for the hump profile. However, the basic theory of physics applied in each design process is common for the two cases. Derivation of the energy head equation shown in Sections 12.1.2 through 12.1.3 of Chapter 12: Hump Design and Retarder Placement, can be applied to the flat yard also. The main difference in the flat yard ladder profile design from the hump profile design is that in flat yards there are no retarders. Instead of repeating the derivation, we will simply show the energy head equation with all the necessary adjustments given in Eq. (12.25) in Chapter 12. The energy head at point 2 is expressed as

$$H_{e,2} = H_{e,1} + Y_L - \mu_k X_L - S_W - C_R - W_R \, , \qquad (9.2)$$

where

$H_{e,1} = V_1^2/2gk$ = energy head at point 2 (ft),

$H_{e,2} = V_2^2/2gk$ = energy head at point 1 (ft),

k = rotational head correction factor,

$Y_L = y_2 - y_1$ = drop from 1 to 2 (ft),

μ_k = static car rolling resistance (lbs/lbs),

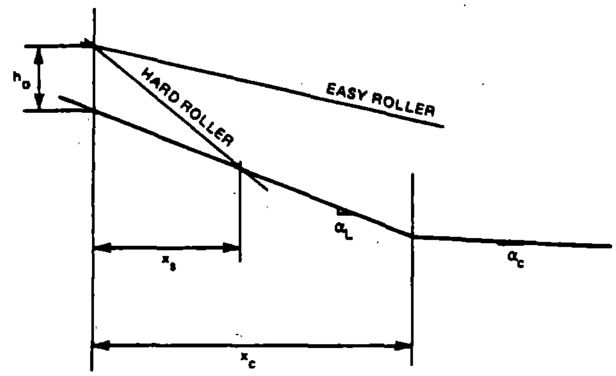
S_W = switch loss (ft),

C_R = curve loss (ft),

W_R = wind loss (ft), and

$X_L = X_2 - X_1$ = horizontal distance between points 1 and 2.

Figure 9-10 shows the velocity head diagram on a ladder track. The figure consists of the ladder profile and two velocity head curves, one for the easy roller and one for the hard roller. The horizontal distance indicates the distance from the point where the cars are given a kick, and the vertical distance indicates the velocity heads. At the point where the cars are given a kick, the velocity head is identical to the velocity head at the kicking speed. As seen in the figure, the velocity head of the easy roller increases, while that



h_o = velocity head at kicking (ft)
r_e = rolling resistance of easy roller (lbs/ton)
r_h = rolling resistance of hard roller (lbs/ton)
α_L = grade of class track ladder (percent)
α_c = grade of class track (percent)
x_s = the distance from the point where the car is given a kick to the point where the hard roller stalls (ft)
x_c = the distance between the point where the car is given a kick and the tangent point of a class track (ft)

FIGURE 9-10. VELOCITY DIAGRAM ON A LADDER TRACK

of the hard roller decreases and at some point it crosses the ladder profile (the car speed becomes zero at that point).

The speed of a car along the ladder track is expressed as*

$$S = \sqrt{(\alpha_L/100 - r/2000)\ 2g' \cdot d + v_o^2} \qquad (9.3)$$

where

α_L = grade of the ladder (percent)

r = rolling resistance value (lbs/ton),

g' = adjusted gravity given as $k \equiv W/(W+I)$ (ft/sec^2)

W = gross weight of a car (lbs),

I = additional weight reflecting the rotational energy of the car's wheels and axles (lbs),

d = distance traveled (ft), and

v_o = kicking speed.

In Eq. (9.3), if $r/2000 > \alpha_L/100$, then the car will eventually stall. For the car that has a higher rolling resistance than the resistance equivalent of ladder grade, the distance the car travels is expressed as

$$X_s = \frac{v_o^2}{2g'\ (r/2000 - \alpha_L/100)} \qquad (9.4)$$

Tables 9-2 and 9-3 present the rolling speed of an easy roller at various points along the ladder calculated using Eq. (9.3). The rolling resistance values used for Table 9-2 is 2.0 lbs/ton and 4.0 lbs/ton for Table 9-3. The parameters varied are the kicking speed, the ladder grade, and the distance along the ladder.

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*In Eqs. (9.3) and (9.4) it was assumed that the velocity head loss due to switches is zero if a car is traveling along the straight lead.

TABLE 9-2.-ROLLING SPEED OF EASY ROLLER ALONG THE LADDER (mph)*
(r = 2.0 lbs/ton)

d (ft)	v_o = 3 mph		v_o = 5 mph†		v_o = 7 mph†	
	α_L = 0.20	α_L = 0.30	α_L = 0.20	α_L = 0.30	α_L = 0.20	α_L = 0.30
200	3.8	4.5	5.5	6.0	7.4	7.8
400	4.5	5.6	6.0	6.9	7.8	8.5
600	5.1	6.6	6.5	7.7	8.1	9.1
800	5.6	7.4	6.9	8.4	8.5	9.7
1000	6.1	8.1	7.3	9.0	8.8	10.3
1200	6.6	8.8	7.7	9.7	9.1	10.8
1400	7.0	9.4	8.1	10.2	9.4	11.3

r = Rolling resistance value of a car (lbs/ton).

v_o = Kicking speed (mph).

α_L = Ladder grade (percent).

d = Distance from the kicking point (ft).

*Adjusted g value of 30.6 ft/sec^2 used.

†Pinpuller is assumed to ride a car in order to pull a pin.

TABLE 9-3.-ROLLING SPEED OF EASY ROLLER ALONG THE LADDER (mph)*
(r = 4.0 lbs/ton)

d (ft)	v_o = 3 mph		v_o = 5 mph†		v_o = 7 mph†	
	α_L = 0.20	α_L = 0.30	α_L = 0.20	α_L = 0.30	α_L = 0.20	α_L = 0.30
200	3.0	3.8	5.0	5.5	7.0	7.4
400	3.0	4.5	5.0	6.0	7.0	7.8
600	3.0	5.1	5.0	6.5	7.0	8.1
800	3.0	5.6	5.0	6.9	7.0	8.5
1000	3.0	6.1	5.0	7.3	7.0	8.8
1200	3.0	6.6	5.0	7.7	7.0	9.1
1400	--	7.0	--	8.8	—	9.4

r = Rolling resistance of a car (lbs/ton).

v_o = Kicking speed (mph).

α_L = Ladder grade (percent).

d = Distance from the kicking point (ft).

*Adjusted g value of 30.6 ft/sec^2 used.

†Pinpuller is assumed to ride a car in order to pull a pin.

Table 9-2 shows, for example, that a car with 2.0 lbs/ton rolling resistance will roll at a speed of 7.7 mph for v_o = 5 mph, α_L = 0.30 percent, and d = 600 feet.

Table 9-4 presents the distance to be traveled by a hard roller for different combinations of key parameters. This table was constructed using the relationship in Eq. (9.4). The parameters varied in the table are the kicking speed, v_o, the ladder grade, α_L, and the rolling resistance value, r. The table shows, for example, for v_o = 5 mph, α_L = 0.30 percent, and r = 12.0 lbs/ton, the distance to be traveled is 292.9 feet.

These two tables can be employed by a designer to estimate the rolling speed of the easy roller along the ladder and the distance to be traveled by the hard roller.

For example, Table 9-4 shows that to have a travel distance of 570 feet or more by a hard roller of 12 lbs/ton, the ladder must be greater than 0.30 percent and the kicking speed must be 7 mph or more (see the number circled in Table 9-3). For a ladder grade of 0.30 percent, a kicking speed of 7 mph, and for a distance from the kicking point of 600 feet, the rolling speed of the easy roller with 2.0 lbs/ton rollability is estimated from Table 9-2 to be approximately 9.1 mph. (See the circled numbers in Table 9-2.) The dilemma in flat yard ladder design is that the hard roller tends to stall at too short a distance from the kicking point and the easy roller tends to travel with too high a speed after a certain distance traveled. It implies that the switch engine may have to perform switching on the ladder and that a rider may be required.

TABLE 9-4.-STOPPING DISTANCE OF HARD ROLLER
(feet)*

r(lbs/ton)	v_o = 3 mph		v_o = 5 mph†		v_o = 7 mph†	
	α_L = 0.20	α_L = 0.30	α_L = 0.20	α_L = 0.30	α_L = 0.20	α_L = 0.30
18.0	45.2	52.7	125.4	146.5	246.0	287.0
16.0	52.7	63.3	146.5	175.7	287.0	344.4
14.0	63.3	79.1	175.7	219.7	344.4	430.6
12.0	79.1	105.4	219.7	292.9	430.6	574.0
10.0	105.4	158.1	292.9	439.3	574.0	861.1
8.0	158.1	316.3	439.3	878.6	861.1	1722.2

v_o = Kicking speed (mph).

α_L = Ladder grade (percent).

r_h = Rolling resistance value of a car (lbs/ton).

*Adusted g value of 30.6 ft/sec^2 used.

†Pinpuller is assumed to ride a car in order to pull a pin.

CHAPTER 10: PLANNING THE OVERALL HUMP YARD CONFIGURATION*

10.0 GENERAL

In this chapter we discuss considerations pertinent to planning the overall hump yard configuration. In Chapter 11 we discuss the engineering details of laying out the tracks and switches once the overall configuration has been determined. Consequently, we will be mainly concerned here with planning the relationship and overall configuration of the receiving, classification, and departure yards and location of support facilities.

In actual practice, the overall yard configuration may be constrained and dictated by the size, shape, and terrain of the available yard site. The size and shape of the site may dictate the choice between inline and parallel receiving or departure yards; the natural terrain may constrain the location of the hump and classification yard that will minimize the amount of grading required. However, even within site constraints there may be several possible alternative configurations. This chapter is intended to provide guidelines so informed choices can be made.

10.1 BASIC PRINCIPLES

The ultimate goal of a well-designed yard is to process the desired levels of switching and train receiving/departing activity with minimum investment and operational costs. Stated in another way, the yard should be designed to perform a specified level of work while maximizing the productivity and utilization of various yard personnel (i.e., supervisors, engine crews, inspection crews).

At this point, the above statement of design objectives is somewhat nebulous and is therefore difficult to implement within a design context. Below we shall discuss specific basic principles of yard design which emanate from and are a natural outgrowth of the objective to maximize productivity and minimize operational costs.

The applications of all these principles are not mutually independent. In some cases, one can achieve a high degree of implementation of one principle only by sacrificing one of the others. Thus, the design of a yard, which involves compromising and balancing the principles, is as much of an art as a science. Therefore, there is no such entity as the perfect yard; all yards are a compromise between design principles within the context of prespecified constraints.

10.1.1 Principle 1: Minimize Conflicts and Interference

The yard can be pictured as a network of crisscrossing movements of inbound trains, outbound trains, hump engines, makeup engines, line-haul locomotives, inspection crews, and yard support personnel. A conflict (interference) occurs when one activity movement blocks another because these movements must use the same portion of track, or there is a crossing point. When a conflict occurs, one of the activities is nonproductive; therefore, a yard should be laid out to minimize movement conflicts between yard activities. It is virtually impossible to design a conflict-free yard;† therefore, certain movements must wait for others. Because of the investment and operating costs of trains and yard engines, it is critical that the yard be designed to facilitate conflict-free operation of receiving and departing trains, and hump and makeup engine activities. We state the above principle as follows:

> Principle 1: Minimize Conflicts and Interference--The yard layout should facilitate the conflict-free movement of all activities. Of critical importance are the conflict-free operations of receiving and departing trains, and hump and makeup engine activities.

10.1.2 Principle 2: Minimize Engine Travel

One of the basic principles of an efficient yard layout is to minimize yard engine travel, and therefore maximize yard engine productivity. This implies that we want to design the yard so that the pulling and shoving distances for the hump and makeup engines are minimized. Because pulling is a faster operation than shoving, in the event that tradeoffs must be made between pulling and shoving distances, the minimization of shoving distances is to be favored. Also, a "light-engine" (i.e., no cut of cars) can travel faster than a "heavy-engine" (i.e., with a cut of cars). In the event of a tradeoff between light- and heavy-engine travel distances, the minimization of heavy-engine travel distances is to be favored. We state the above principle as follows:

> Principle 2: Minimize Engine Travel--The yard layout should minimize engine pulling and shoving distances. In the event that a tradeoff must be made between pulling and shoving distances, the minimization of shoving distances is to be favored. If there is a tradeoff between light- and heavy-engine travel distances, then the minimization of heavy-engine travel distances is to be favored.

10.1.3 Principle 3: Adaptability‡ to Various Operating Conditions Design

In order to insure high productivity under all expected operating environments, the yard should be designed to operate efficiently under reasonable changes to traffic levels and patterns. In particular, traffic levels and patterns are likely to change throughout the yard's lifetime. In order for the yard investment to pay off in the long-term, adaptability must be designed into the yard to handle these changes. The yard design must also be adaptable from an operating practices standpoint. One should not design a yard assuming that a prescribed operating plan will be rigidly followed. Mistakes and poor operating decisions do occur (i.e., misclassification, bad-order cars on classification or departure tracks) and must not be allowed to seriously degrade yard performance. Furthermore, the yard must be designed to be adaptable with respect to severe weather conditions and accidents (e.g., derailments, broken switches). In particular, the yard should be designed to continue to operate (perhaps in a degraded

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*This material was developed with the generous cooperation of J. Wetzel (CONRAIL), M. Anderson (Union Pacific), B. Gallacher (Southern Pacific), and H. Hall (Santa Fe).

†In theory a conflict-free yard could be built with extensive bridges and tunnels separating rights-of-way; however, this is expensive.

‡The term adaptable is used in lieu of flexible, robust, and fault-tolerant.

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node) under all (even unplanned) situations. This adaptability can be enhanced by designing expansion capability into the yard and by designing alternate routes to get to various points in the yard. The above concepts are summarized in the following principle:

Principle 3: Adaptability to Various Operating Conditions--The yard layout should be adaptable and continue to operate effectively with respect to changes in traffic levels and patterns, deviations from desired operating practices, severe weather conditions, and accidents. This adaptability can be enhanced by designing expansion capability into the yard and by designing alternate routes to get to various points in the yard.

10.1.4 Principle 4: Flexible Engine and Crew Utilization

The major yard operating costs are associated with yard engine crews and inspection crews. The yard should be designed to minimize the number of crews required to operate it. This can be enhanced if the yard is configured so that there are short travel distances and ease of movement between various primary areas of work for engines and inspection crews (e.g., receiving yard, departure yard, pull-out end of classification yard, repair tracks). With the ease of movement between work areas, there exists the flexibility that engine and inspection crews can move efficiently between several jobs during a shift as workload dictates. This flexibility of scheduling work can maximize the productive work of engines and crews during a shift. This principle is summarized as follows:

Principle 4: Flexible Engine and Crew Utilization--To allow engines and crews flexibility in their utilization (thus maximizing productive work) a yard should be configured so that there are short distances of travel and ease of movement between primary areas of work, e.g., the receiving yard, departure yard, pull-out end of classification yard, repair tracks.

10.1.5 Principle 5: Design for Supervision

One of the critical factors in an efficiently run yard is effective supervision of engines and crews. The design of a yard can enhance supervision by the proper placement of a tower, yard office, and a communications system (e.g., speakers, radios). In particular, it is desirable that the configuration of the yard and tower be such that as much as possible of the critical working areas (e.g., receiving, classification, and departure tracks) are under direct visual supervision of the yardmaster (and bowlmaster if one exists). This direct visual supervision will ensure that engines and crews are productively working. This principle can be summarized as follows:

Principle 5: Design for Supervision--The yard should be laid out to enhance supervision of engines and crews. This can be assured by placing as much as possible of the key working areas (e.g., receiving, classification, and departure tracks) under direct visual supervision.

10.2 INLINE AND PARALLEL YARD CONFIGURATIONS

Whether the receiving and departure yards are inline or parallel with respect to the classification yard is often constrained by the size and shape of the site. However, within the freedom of choice which exists, informed decisions can be made. In the following pages we present information and guidelines to facilitate these decisions.

10.2.1 Basic Design Alternatives

Figure 10-1 shows a portion of the myriad of configurations that can be developed with combinations of inline and parallel receiving and departure yards. The first five designs (Designs 1 to 5) incorporate single departure yards and are applicable to large hump yards; the last two designs (Designs 6 and 7) incorporate two departure yards and are applicable to very large yards or when the traffic conveniently allows a separation of switching activities by traffic direction (e.g., east-west operation, north-south operation).

The designs shown in Figure 10-1 are briefly discussed below:

Design 1: Inline Receiving/Inline Departure--The receiving and departure yards are inline with the classification yard; this is also referred to as a tandem or series design. Examples of similar designs include:

- Roseville Yard (Southern Pacific),
- "Old" Syracuse Yard (CONRAIL).

Design 2: Inline Receiving/Parallel Departure--The receiving yard is inline and the departure yard is in parallel with the classification yard. A parallel departure yard is also referred to as a "pull-back," "wrap-around," or "side-by-side" departure yard. Examples of similar designs include:

- Barstow Yard (Santa Fe),
- Selkirk Yard (CONRAIL),
- Scheffield Yard (Southern),
- Linwood Yard (Southern).

Design 3: Parallel Receiving/Parallel Departure--The receiving and departure yards are both in parallel with the classification yard. A parallel receiving yard is also referred to as a "pull-back," "wrap-around," or a "side-by-side" receiving yard. Examples of similar designs include:

- Avon Yard (CONRAIL),
- Indianapolis Yard (CONRAIL),
- Columbus Yard (CONRAIL),
- North Platte West Yard (Union Pacific),
- Hinkle Yard (Union Pacific).

Design 4: Parallel Receiving/Inline Departure--The receiving yard is parallel and the departure yard is inline with the classification yard. Examples of similar designs include:

- Eugene Yard (Southern Pacific),
- Eastbound Kansas City Yard (Santa Fe).

Design 5: Inline Receiving/Combined Classification-Departure--The receiving yard is inline and the rear-end of the departure yard is combined with the classification yard. Examples of similar designs include:

- West Colton Yard (Southern Pacific),
- Queensgate Yard (Chessie).

Design 6: Inline Receiving/Double Parallel Departure--The receiving yard is inline, and the two

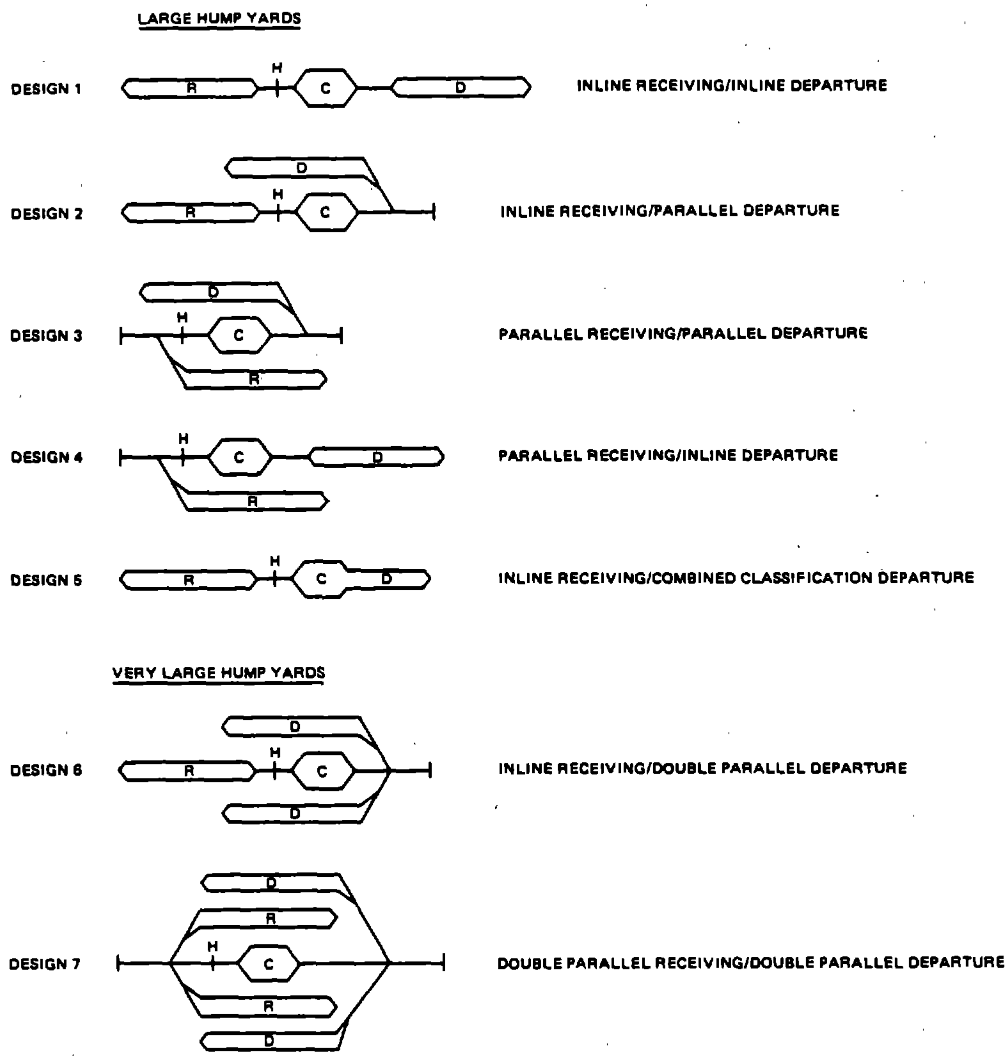

FIGURE 10-1. BASIC DESIGN ALTERNATIVES

departure yards are parallel on both sides of the classification yard. Examples of similar designs include:

- Elkhart Yard (CONRAIL).

Design 7: Double Parallel Receiving/Double Parallel Departure--The two receiving and departure yards are both in parallel with the classification yard. Examples of similar designs include:

- Houston Yard (Southern Pacific)
- Winnepeg Yard (Canadian National).

10.2.2 Critique of Specific Designs

Below we present a case study of the first five designs shown in Figure 10-1. This critique will take the form of listing advantages and disadvantages of each design.

10.2.2.1 Parallel Receiving/Parallel Departure (See Figure 10-2).

Advantages:

- If there is primarily one direction of traffic, such as from the west in the Figure 10-2, there are no conflicting moves for arriving and departing trains.

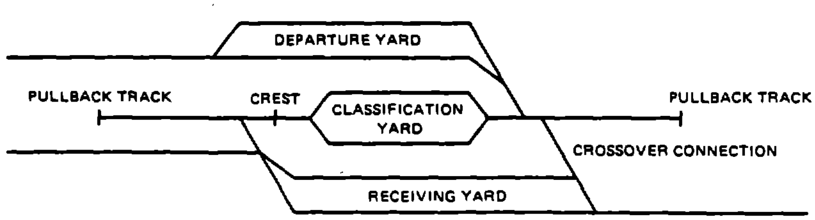

FIGURE 10-2. PARALLEL RECEIVING/PARALLEL DEPARTURE

- Overflow blocks from classification yard can be set to departure yard and then easily put in their proper location on the train at a later time.
- The early setting out of part of a train on the departure yard allows carmen to work this portion of the train early, speeding departure time when the train is completed.
- Pulling back the train prior to humping warms up journals and bearings, which provides better rolling characteristics on cars during humping. This speeds the humping process.
- Crossover connection to receiving yard allows one to fill a train that has bypass blocks. Also, when reducing a train the slough is in the proper place to go to the hump.
- Shortest length requirement for west end of departure yard to east end of receiving yard.
- This type of configuration also allows better access to receiving and departing trains as leads are occupied a minimum amount of time.

Disadvantages:

- Requires the widest area at classificaton yard location of any configuration.
- Moving power from receiving and departure yards requires crossing pull-back leads which, if volume is great enough, may require a power overpass or underpass to move power from receiving yard to diesel shop and back to departure yard.

10.2.2.2 Inline Receiving/Parallel Departure (See Figure 10-3).

Advantages:

- If there is predominantly one direction of traffic, such as from the west in Figure 10-3, there are no conflicting moves for arriving and departing trains.
- Overflow blocks from classification yard can be set to departure yard and then easily put in their proper location on the train at a later time.
- The early setting out of part of a train on the departure yard allows carmen to work this portion of the train, speeding departure time when the train is completed.
- Receiving yard to hump is a straight shoving operation.
- Connection to receiving yard allows you to fill a train that has bypass blocks. Also, when reducing a train the slough cars are in the proper place to go to the hump.
- This type of configuration also allows better access to receiving and departing trains as leads are occupied a minimal amount of time.
- Requires less width at the center of classification yard than the parallel receiving and parallel departure.

Disadvantages:

- Requires nearly the same distance from east end of pullback track to west end of receiving yard as inline receiving and inline departure yard.
- Conflict between receiving trains from east and humping operations.

10.2.2.3 Parallel Receiving/Inline Departure (See Figure 10-4).

Advantages:

- If bidirectional traffic is run through this configuration, westbound traffic should run out the north half of the departure yard to avoid conflict.
- Pulling back trains prior to humping warms up journals and bearings, which provides better rolling characteristics on cars during humping. This speeds up the humping process.
- Crossover connection to receiving yard allows one to fill a train that has bypass blocks. Also, when reducing a train, the slough is in the proper place to go to the hump.
- Requires less width at the center of the classification yard than the parallel receiving and parallel departure.

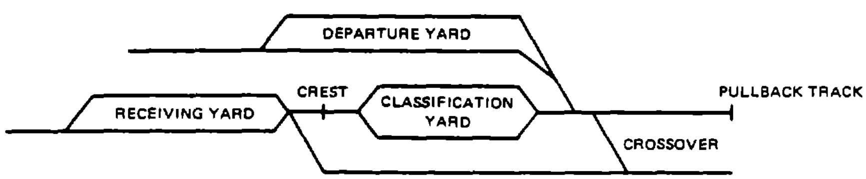

FIGURE 10-3. INLINE RECEIVING/PARALLEL DEPARTURE

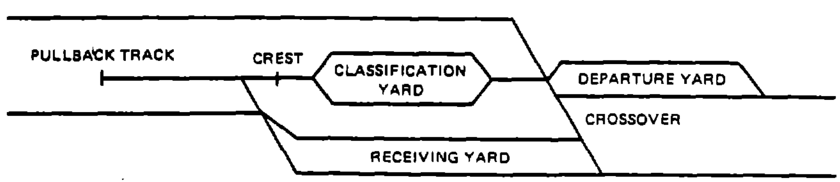

FIGURE 10-4. PARALLEL RECEIVING/INLINE DEPARTURE

Disadvantages:

- Requires nearly the same distance from west end of pullback track to east end of departure yard as inline receiving and inline departure yard.
- Requires all blocks to be in bowl at time the train is to be made up. (Some yards use cross-overs in departure yard and fill the track as blocks become available.)
- Slows the trimming process by requiring switch engine to make bidirectional moves with a large number of cars on last moves to make up train.
- If bidirectional traffic is received in this configuration, special provision will be required to eliminate inbound moves from the west over humping track.
- Conflict with trimming operations and westbound departures could be a problem.

10.2.2.4 Inline Receiving/Inline Departure (See Figure 10-5).

Advantages:

- This requires the least width of any classification configuration.
- This configuration usually works best with one direction of traffic to minimize the conflict at the hump end of the receiving yard and the trim end of the departure yard.

Disadvantages:

- This configuration requires the most length from west end of the receiving yard to east end of the departure yard.
- Requires all blocks to be in bowl at time train is to be made up. (Some yards use crossovers in departure yard and fill the track as blocks become available.)
- Slows the trimming process by requiring switch engine to make bidirectional moves with a large number of cars on last moves to make up the train.
- Conflicts can occur between westbound receiving/humping and westbound departure/trimming.

10.2.2.5 Inline Receiving/Combined Classification-Departure (See Figure 10-6).

Advantages:

- This requires the least width of any classification configuration.
- This configuration usually works best with one direction of traffic to minimize the conflict at the hump end of the receiving yard and the trim end of the departure yard.
- Combined classification-departure yard allows the rear-end of the train to be humped directly into the appropriate classification-departure track, thus saving the movement of one block of cars for each departing train.

Disadvantages:

- This configuration requires considerable length from west end of receiving yard to east end of departure yard.
- Requires all blocks to be in bowl at time train is to be made up. (Some yards use crossovers in departure yard and fill the track as blocks become available.)
- The pulling and shoving distances are longer than in a parallel departure yard for the last moves to make up a train.
- This configuration requires a more sophisticated operating plan, and therefore more discipline on the part of yard personnel to make it work. If classification tracks are not properly assigned to the correct blocks, then the makeup operation can suffer.
- Westbound departures could conflict with humping and trimming operations.

10.2.3 General Inline Versus Parallel Configuration Guidelines

It is very difficult to give specific guidelines on inline versus parallel yard configurations which are general purpose and apply to all situations. The best choice for any particular size and shape of site is critically dependent on access of the site to the main-line, traffic characteristics (e.g., train sizes,

FIGURE 10-5. INLINE RECEIVING/INLINE DEPARTURE

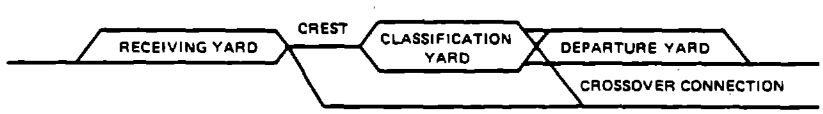

FIGURE 10-6. INLINE RECEIVING/COMBINED CLASSIFICATION DEPARTURE

number of blocks), and the operating philosophy of a particular railroad. The best design procedure would be to lay out several alternative designs and evaluate each alternative against the basic principles described earlier and other operating/design considerations to be discussed later in this chapter. However, a set of general purpose guidelines regarding inline versus parallel configurations can be seen to emerge from the earlier design critiques. These guidelines are discussed systematically below.

10.2.3.1 Preference for Parallel (Pullback) Departure Yard. An inline departure yard usually requires that the makeup engine make one pulling operation of the entire cut of cars to be placed on the departure track. (Note that an engine pulling a second cut of cars to be set out on the same track would be trapped behind the earlier cut unless elaborate crossovers for escape were provided.)* Thus, the entire cut of cars to be set out on the departure track must be ready at the same time. Also, if the cut is to be made up from cars on multiple classification tracks, then the makeup engine would be required to double-over and triple-over to accumulate the cut for the single pulling operation to the departure track. Furthermore, a makeup engine would have to travel heavy the entire length of the departure track in setting out the cars, and return the entire length of the departure track light.

Because a cut of cars is shoved into the departure tracks (rather than pulled) in a parallel or pullback departure yard, a makeup engine can make multiple setouts on the departure track. This allows a particular classification track to be pulled several times as the classification track fills up. Also, whether a makeup engine pulls a single classification track, doubles-over, or triples-over before proceeding to the departure track is flexible; this decision is based on operating considerations and not constrained by the yard design. Furthermore, the engine travel distances in a parallel departure yard are substantially less than in an inline departure yard.

For the above reasons, a parallel (pullback) departure yard is generally preferred over an inline departure yard.

10.2.3.2 Preference for Inline Versus Parallel Receiving Yard Depends on Weather and Inbound Train Sizes. Whether an inline yard or a parallel receiving yard is best depends on the specifics of the situation:

1. An inline receiving yard requires a straight shove to the hump. A parallel receiving yard requires a pullback and then a shove to the hump; this is normally a slower operation than a straight shove.
2. For the parallel configuration, however, the engine travel from the hump to get into position for a pullback is short (engine travels light), whereas in the inline configuration the engine travel from the hump to get into position for a shove is relatively long (engine travels light).
3. If the yard receives long road trains, then the considerations of Item 1 generally dominate Item 2; consequently, an inline receiving yard may be desirable.
4. If the yard receives relatively short road trains or does a lot of industrial work where relatively short cuts of cars are received, then the considerations of Item 2 generally dominate Item 1; consequently, a parallel receiving yard may be desirable.
5. In cold weather, it has been experienced that the pullback and shove operation required in the parallel configuration tends to loosen up the wheels so that the cars roll more easily down the hump, thus improving the humping operation.
6. In a high-volume yard, one must consider minimizing the time between humping succeeding cuts. In a parallel configuration, one can expect some conflict between humping and pullback operations.

For the above reasons, the preference of an inline versus a parallel receiving yard depends on the specific conditions. For yards anticipating long inbound trains, an inline yard is preferred; a parallel yard is preferred for short inbound trains. However, in cold climates, experience indicates that the pulling and shoving operation of a parallel yard produces better rolling cars.

10.2.3.3 Specific Design Recommendations. Each yard configuration selected should be based on the specifics of the situation. However, based on the above discussion, the following two yard configurations are recommended for special consideration:

- Inline receiving and parallel departure (Design 2 in Figure 10-1).
- Parallel receiving and parallel departure (Design 3 in Figure 10-1).

For very large yards, where the traffic separation and volume require two separate departure yards, special consideration is recommended for:

- Inline receiving and double parallel departure (Design 6 in Figure 10-1).

In comparison to the double parallel receiving and double parallel departure (Design 7 in Figure 10-1), the recommended design is less complicated both physically and operationally, provides flexibility in the allocation of receiving tracks in the single receiving yard, and allows the optimum placement of the departure and classification tracks to minimize pulling and shoving distance. (This third point is discussed at length later in this chapter.)

10.3 CONFIGURATION GUIDELINES FOR SUBYARDS

There are a number of guidelines for the configuration of the classification, receiving, and departure yards which have been established as good design practice through accumulated design experience. Below, we attempt to systematically present these guidelines with an associated rationale. More detailed track and switch layout design considerations are discussed in Chapter 11.

10.3.1 Classification Yard

Once the approximate number and length of classification tracks have been determined (see Chapter 7), there exist several alternatives in the way the classification yard can be configured. These alternatives are discussed below.

*If crossovers are used, generally the operation is very inefficient. A train could be built one or two blocks at a time from the rear of the departure tracks.

10.3.1.1 Hump End of Classification Yard. The hump end of the classification yard is generally organized into groups of tracks and each group is controlled by a group retarder (see schematic in Figure 10-7). Generally, there is a master retarder preceding the group retarders. There may in addition be tangent-point retarders at the tangent points of each class track.

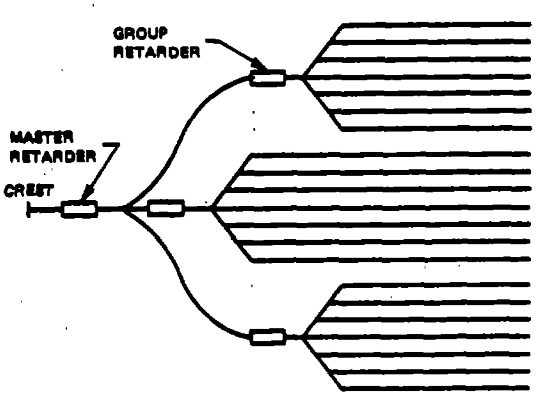

FIGURE 10-7. HUMP-END OF CLASSIFICATION YARD

The general rule of thumb is to lay out the hump end of the classification yard so as to minimize the distance from the clear point of each classification track to the hump crest. The reason for this is to minimize the distance over which one must exercise control over a free-rolling car;* this will generally result in the cheapest control system. Because the clear point of the two outside tracks is generally the farthest away, it is sufficient to minimize this distance.

A car's rolling resistance increases on curved track in relationship to the degree of curvature. In addition, the car's rolling resistance, and therefore the control over a car's roll, becomes more unpredictable on curved track due to skewing of trucks. This is especially true of reverse curves. Thus, a general rule of thumb is to minimize the degrees of curvature and the total central angle of curvature, and avoid reverse curves.

However, one cannot simultaneously minimize the distance from crest to clear point and avoid tight curves and reverse curves. Generally, the tradeoff is to minimize distance from crest to clear point at the expense of tight curves and reverse curves. If possible, an attempt should be made to put all the tight curves (and any reverse curves) before the last control point (e.g., group retarder) if this will not significantly lengthen the distance from the crest to clear point. The rationale is that we want the car's roll from the last control point to the point of coupling to be as predictable and controllable as possible, thereby insuring good coupling performance. The design problem is simpler if tangent-point retarders are used, since the last control point is at the beginning of the classification track, and generally the classification track is relatively free of curvature.

*Minimizing crest to clearance distance allows faster separation of cars, and, thus, faster humping rates.

Historically, the number of tracks in a group range from 6 to 10 tracks, with 8 tracks being the most common. The more tracks in each group, the fewer group retarders that are required, and therefore the cheaper the control system. There is nothing sacred about 6 or 10 track groups; the size of the group should be determined by the ability to control coupling performance. However, as you get more tracks in a group, the crest to clearance point distance is increased, thereby making car speed and separation control more difficult. Also, there is no reason why groups must be of uniform size. In fact, because there is generally less curvature associated with tracks in the middle groups, and therefore cars rolling into the middle groups are easier to control, a desirable strategy may be to have the middle groups larger than the outside groups.

We have mainly tried to present guidelines in the design of the hump end of the classification yard. The actual design process is a successive redesign and evaluation procedure which attempts to balance various considerations. Chapter 11 details track and switch layout considerations; Chapter 12 discusses the design of the hump profile.

10.3.1.2 Pullout End of Classification Yard. In Figure 10-8 three basic configurations of the pullout end of a classification yard are shown schematically, i.e.,

- Half-fishtail design (e.g., CONRAIL's Indianapolis Yard).
- Fishtail design (e.g., CONRAIL's Elkhart Yard and East Buffalo Yard).
- Teardrop design (e.g., CONRAIL's Selkirk Yard, Santa Fe's Barstow Yard).

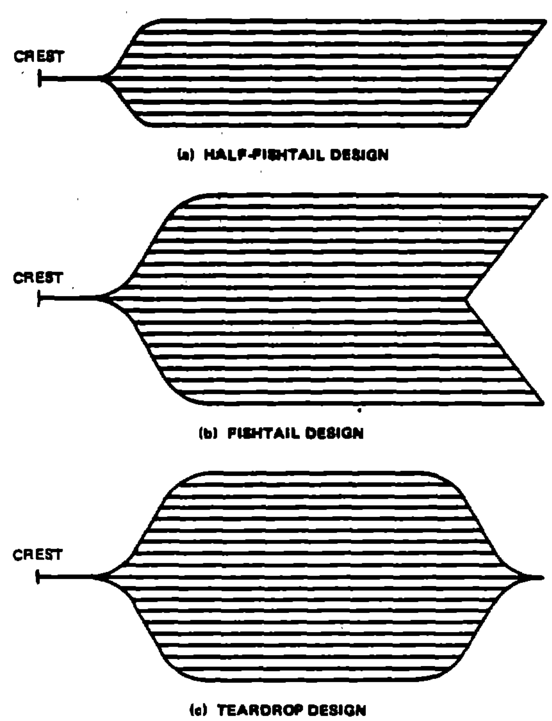

FIGURE 10-8. BASIC CONFIGURATIONS OF PULLOUT END OF CLASSIFICATION YARD

The half-fishtail design has been used where there is a parallel departure yard adjacent to the longest classification track. The fishtail design has been used when there are two parallel departure yards on either side of the classification yard, and the teardrop design has been used with all yard configurations.

Generally, a teardrop design is to be favored for the following reasons:

Easier Control of Cars on the Longest Tracks—In a teardrop design, the longest class tracks are in the center of the classification yard. The route to the center tracks is shortest, has the least curvature, and little if any reverse curvature. Consequently, in a teardrop design most of the cars go into the center tracks, which are easier to predict and control. Conversely, in a fishtail or half-fishtail design the longest class tracks are on the outside of the class yard; the route to the outside tracks is thus the most difficult to control. Consequently, in a fishtail or half-fishtail design most of the cars go into the tracks which are difficult to predict and control.

More Flexibility for Crossover Moves--In a teardrop design with parallel departure yards on either side of the classification yard, it is relatively more convenient to pull a classification track on one side of a yard and take the cars to the departure yard on the other side than it is with a fishtail design. Crossover moves occur regularly in yard operations and the ease of handling such moves affects trim-engine productivity. Consequently, trim-engine productivity should be better in a teardrop design used in conjunction with two parallel departure yards.

However, situations do occur in which it may be desirable to have the longest classification tracks on the outside, as in a fishtail or half-fishtail design. This may be due to the desire to store a large amount of special traffic such as piggyback or coal cars on the outside tracks for direct accessibility and ease of pulling to a parallel departure track.

The number of independent leads into the classification tracks determines the number of engines that can work independently without severe interference or conflict. As shown schematically in Figure 10-9, it is often desirable to segment access to the classification tracks into groups called pockets with multiple independent leads so as to allow several engines to work on each lead without severe conflict. However, the flexibility of doubling over from a track in one pocket to a track in another pocket is constrained. The number of independent leads should be based on the number of engines desired to work in the trim and makeup operation.

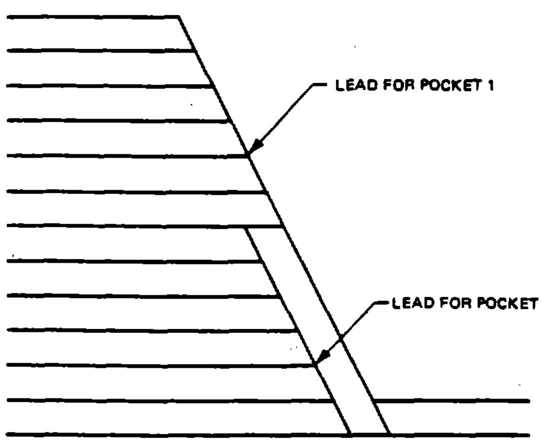

FIGURE 10-9. MULTIPLE LEADS AT PULLOUT-END OF CLASSIFICATION YARD

10.3.1.3 Classification Tracks. It is desirable to avoid curves on the classification track because the control for coupling becomes more difficult (i.e., cars rolling on curves are more difficult to control). Also, cars coupling on severe curves could cause mis-couplings or broken couplers because the couplers are not engaging straight-on. Passed drawbars result in some derailments and overturned rail.

The length of the classification track normally varies from 30 to 60 car lengths in a master-group retarder design. Assuming a teardrop design, the outside tracks would be the shortest and the center tracks the longest. The maximum length of a classification track is determined by the maximum distance from the last control point over which car coupling speeds can be controlled. If this last control point is the group retarder, then 60 car lengths is the maximum. Because a tangent-point retarder places the last control point at the entrance of the classification tracks, longer classification tracks are possible. Southern Pacific's West Colton Yard uses tangent-point retarders; the longest classification track there is 70 car lengths.

10.3.2 Receiving and Departure Yards

The approximate number and length of receiving and departure tracks are determined using the procedures described in Chapter 7. Alternatives and guidelines in the configuration are discussed below.

10.3.2.1 Alignment of Parallel Receiving and Departure Yards. The second principle of yard design discussed earlier (i.e., minimize pulling and shoving distances) can greatly influence the proper way subyards should be aligned relative to each other. In particular, the following rules can be developed for parallel (pull-back) receiving and departure yards.

- Rule 1: The shove end of a parallel departure yard should be aligned with the pullout end of the classification yard (see Figure 10-10a). This will minimize the pulling and shoving distances of the makeup engine.
- Rule 2: The pullout end of a parallel receiving yard should be aligned with the hump (see Figure 10-10b). This will minimize the pulling and shoving distances of the hump engine.

If one combines Rules 1 and 2, then the classic designs --parallel receiving and/or departure designs--shown in Figure 10-1 result. Because the receiving and departure yards are typically twice the length of the classification yard and therefore "overhang" the classification yard, the design of a double parallel receiving and double parallel departure yard (Design 7 in Figure 10-1) does not allow the optimum alignment of either the receiving (or departure) yards without interference with the departure (or receiving) yards. For this reason, as stated earlier, the inline receiving and double parallel departure yards (Design 6 in Figure 10-1) are generally to be preferred over double parallel receiving and double parallel departure yards for very large yards.

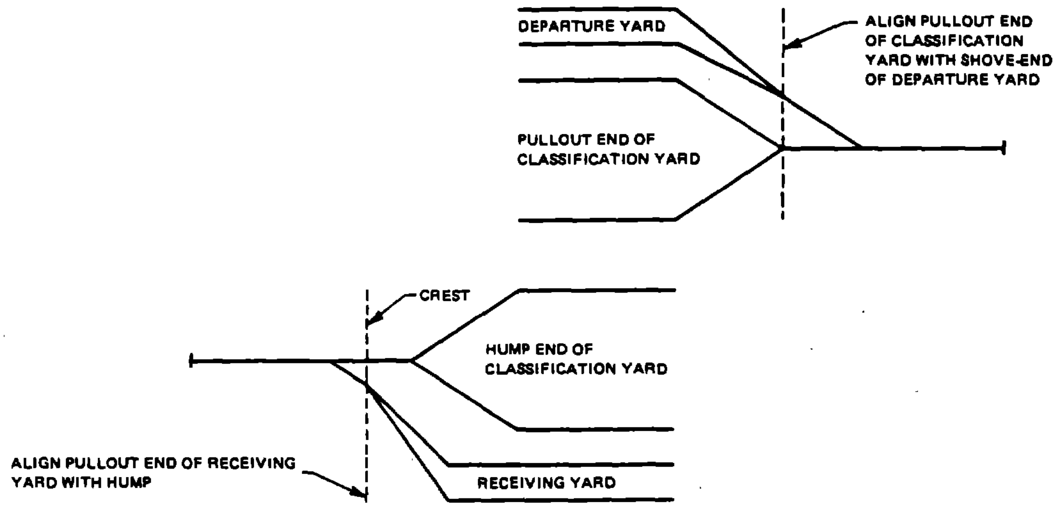

FIGURE 10-10. ALIGNMENT OF PARALLEL RECEIVING AND DEPARTURE YARDS

10.3.2.2 The Yard "Throat". The yard "throat" commonly refers to that region between the classification yard and the departure yard. In this region, a large number of classification tracks (e.g., 48 tracks) are funneled into a much smaller number of departure tracks (e.g., 12 tracks). The throat is often the bottleneck in yard throughput; the largest potential conflict and interference problem between engine moves is in the throat. For this reason, it is critical that the throat be designed to allow the train makeup operation to proceed with minimum interference.

Figure 10-11 provides examples of a typical design of the pullback track configuration (also called pulling leads or drill tracks) for a single and double parallel departure yard.

The throat design for the single parallel departure yard shown in Figure 10-11 assumes that in normal operation cars from the east classification yard use pulling lead 2 and shove into departure group 2; cars from the west classification yard use pulling lead 1 and shove into departure group 1. This normal operation allows an east and a west makeup engine to work simultaneously with the minimum interference. However, for purposes of flexibility, the design allows an engine to travel from any classification track to any pulling lead to any departure track.

The throat design for the double parallel departure yard shown in Figure 10-11 assumes that in normal operation pulling leads 1 and 2 are used to pull cars from classification pockets 1 and 2 into the east departure yard; pulling leads 2 and 3 are used to pull cars from classification pockets 3 and 4 into the west departure yard. The design affords minimum interference for three makeup engines: one engine pulling pocket 1 using pulling lead 1, one engine pulling pockets 2 and 3 using pulling lead 2, and one engine pulling pocket 4 and using pulling lead 3. A fourth engine is likely to experience interference, most likely for the center pulling lead; this can be alleviated with a design featuring four pulling leads.

Figure 10-12 provides an example of a typical design of the throat configuration of an inline departure yard which facilitates the operation of four makeup engines. In normal operation, interference is minimized if:

- One makeup engine pulls cars from classification pocket 1 via pulling lead 1 to the upper tracks in departure group 1.
- One makeup engine pulls cars from classification pocket 2 via pulling lead 2 to the lower tracks in departure group 1.
- One makeup engine pulls cars from classification pocket 3 via pulling lead 3 to the upper tracks in departure group 2.
- One makeup engine pulls cars from classification pocket 4 via pulling lead 4 to the lower portion of departure group 2.

The crossovers have been placed so that a makeup engine can pull from any classification track to any departure track. The two outside departure tracks are running tracks for the return of light engines; crossovers in the throat facilitate the return of light engines to the classification yard with minimum interference.

Chapter 13 discusses the design of the yard throat in more detail and describes procedures for evaluating design alternatives.

10.3.2.3 Humping Leads and Receiving Yard. The humping process represents a critical bottleneck in the classification procedure. The theoretical upper limit in the humping process is established by the designed humping rate (i.e., expressed in cars per minute or mph). The designed humping rate is in turn specified by the hump grades, retarder placement and control, and switch layout. However, the humping rate cannot be sustained 60 minutes out of each hour. Humping time is lost in the logistics of sending a hump engine to the receiving tracks for a cut of cars, and perhaps waiting while another hump engine is humping cars. Normally, an average hump utilization of 75% (45 minutes out of an hour) is the upper boundary that can be expected for a well-designed hump operation. It is therefore incumbent on the yard designer to insure that the heavy engine movements between receiving yard and hump crest (and light engine return) be as short in travel distance and as conflict-free as possible.

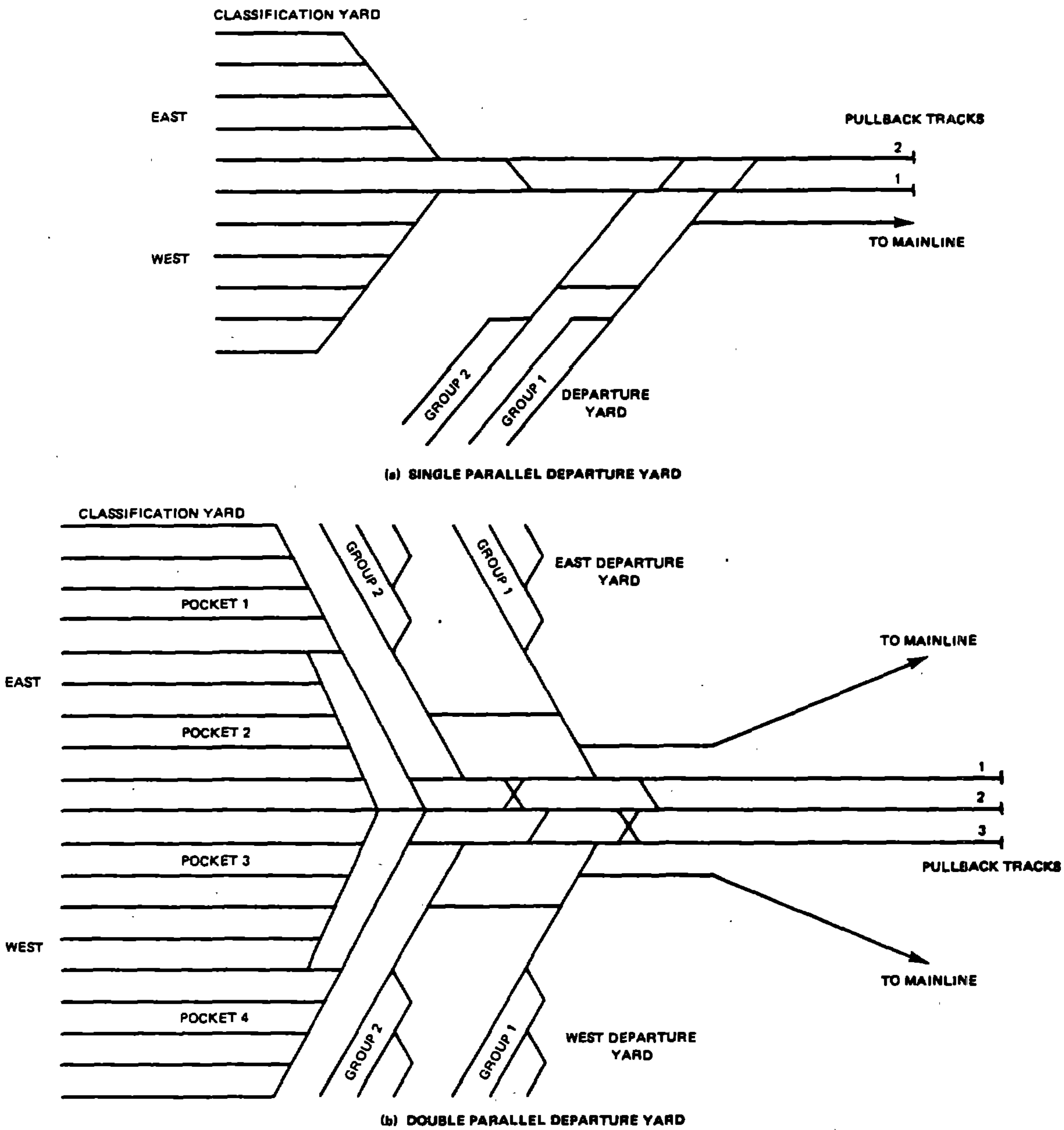

FIGURE 10-11. THROAT DESIGN FOR PARALLEL DEPARTURE YARDS

Figure 10-13 shows two pullback hump leads from a parallel receiving yard to the hump crest. The configuration is designed to allow two hump engines to pull from any receiving track to any pulling lead with minimum conflict. Note that the bottom lead is shortened 50% with a crossover to the rear of the top lead. A hump engine pulling into the bottom lead can use the rear of the top lead after the engine in the top lead has cleared the crossover. This simple "trick" allows the elimination of 50% of one lead.

Figure 10-14 shows the two hump leads from an inline receiving yard to the hump crest. The configuration minimizes the conflict for two hump engines and any hump lead can be reached from any receiving track. Generally, an inline receiving yard configuration requires excess engine travel from the hump to the rear of the receiving yard. The design in Figure 10-14 attempts to minimize hump engine travel for shoving short trains. The two outside tracks are running tracks; short trains are yarded in the pockets on the two tracks adjacent to the outside running tracks. Because of the crossovers indicated, a hump engine need not travel all the way to the mouth of the receiving yard to get behind a short train; it can short-circuit its travel via the crossovers.

In either the parallel or inline receiving yard configuration, consideration must be given to escape tracks which allow the hump engine to proceed down the hump after the last car is humped and return to the receiving yard. Provision must be made for the light hump engine to get to any receiving track regardless of which hump lead is occupied by another hump engine and cut of cars. Often a tunnel under the hump can facilitate escape routes.

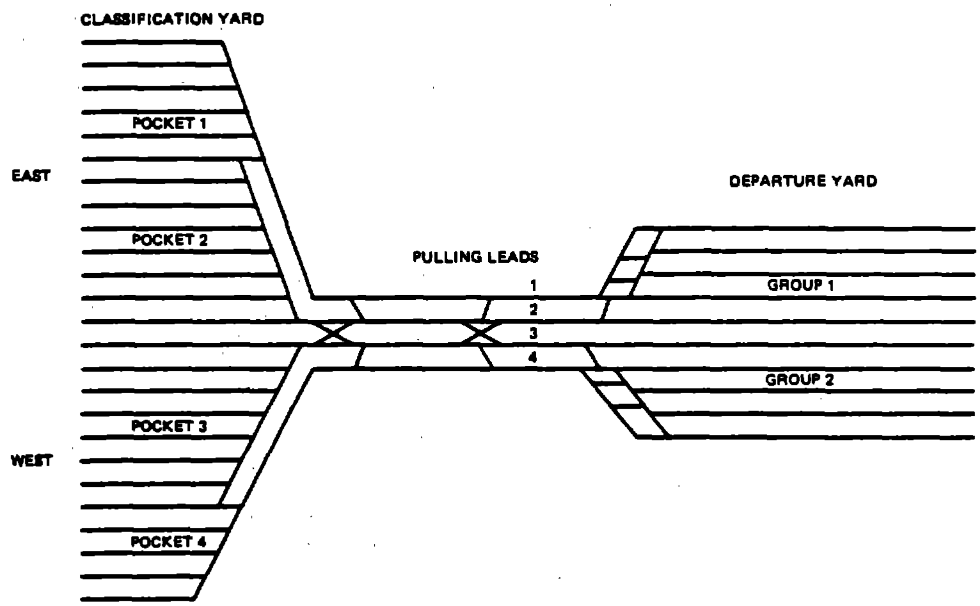

FIGURE 10-12. THROAT DESIGN FOR INLINE DEPARTURE YARD

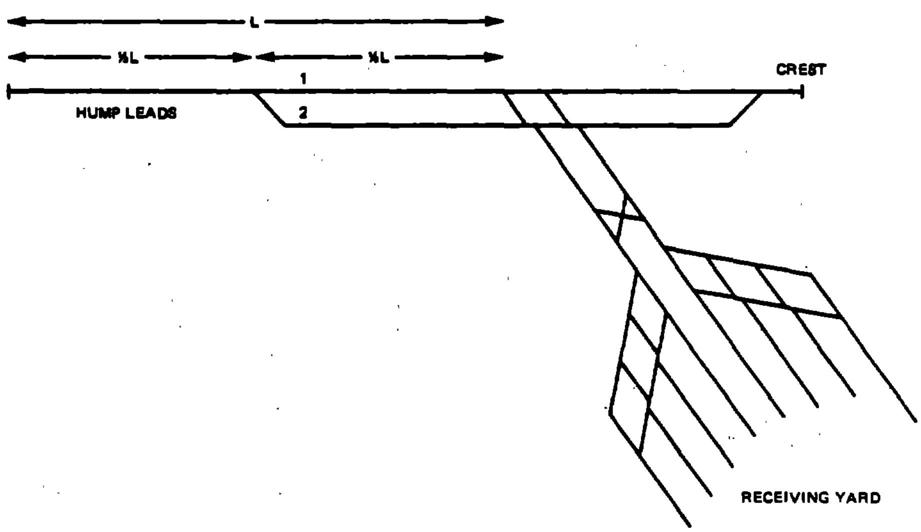

FIGURE 10-13. HUMP LEADS AND PARALLEL RECEIVING YARD

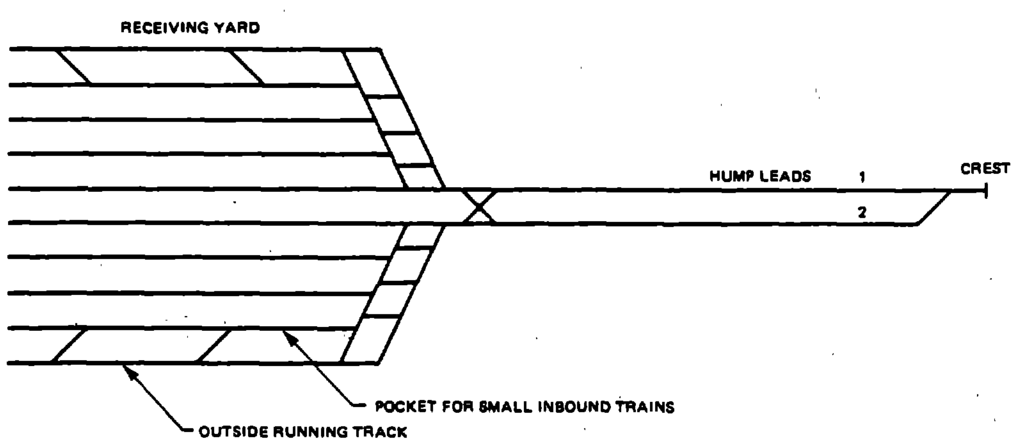

FIGURE 10-14. HUMP LEADS AND INLINE RECEIVING YARD

10.4 GUIDELINES FOR SUPPORT FACILITIES

In earlier sections, we discussed rules and guidelines regarding the location and configuration of the receiving, classification, and departure yards. However, in order to have an efficient and fluid yard operation, the location and placement of service facilities, running tracks, and roadways are equally important. Guidelines are presented below; generally it is not possible to satisfy simultaneously all of the guidelines. In this case, the guidelines state what is desirable so that tradeoffs can be properly evaluated.

10.4.1 Diesel Service Facilities

Locomotives from inbound trains go to the diesel facilities from the receiving yards for servicing (e.g., cleaning, sanding, fueling, minor repairs). Locomotives for outbound trains go the head-end of a train in the departure yard from the diesel facilities. Thus, it is logical that the optimum location of the diesel facilities be between the receiving and departure yards. Furthermore, if possible, the diesel facilities should be near that end of the departure yard which has the preponderance of outbound train departures.

10.4.2 Car Repair Facilities

Cars needing repairs are humped to a bad-order class track. Car repair facilities or tracks (also called rip tracks) should be located, if possible, so that:

- It is easy for a trim engine to pull cars from the bowl end of a bad-order class track and move them to the repair tracks.
- It is easy for the hump engine to go to the repair tracks and rehump the repaired cars.
- Repair tracks are near the receiving tracks, so that the hump engine can "double" from a receiving track into the repair track to fetch repaired cars.

Based on the above items, the optimum location of the repair facilities would be alongside (parallel to) the classification yard and between the departure yard and receiving yard. If a tradeoff is required between the repair facilities being nearer the departure yard or the receiving yard, one should opt for placing them closer to the departure yard to facilitate removal of bad-order cars discovered in the departure yard during outbound inspection.

10.4.3 Caboose Facilities

Cabooses are normally humped into a specifically designated classification track, and from there they are moved to a caboose facility for servicing (e.g., cleaning and minor repairs). They are removed from the caboose service facility and placed on the tail end of a departing train in the departure yard. Thus, it is logical that the caboose facility be placed between the classification and departure yards. Furthermore, the caboose facility should be closer to that end of the departure yard in which there is a preponderance of the rear ends of trains being made up.

10.4.4 Towers and Yard Offices

If there is only one tower, then it should be near the hump and situated so that it can simultaneously have clear line-of-sight down the classification track and observe as much as possible of the receiving and departure activities.

For a large yard, there is often a bowl office or tower in addition to a hump tower. The bowl office or tower should be situated so that it can observe activities in the yard throat.

It is desirable that the crest office be located on the right side of the hump lead as one looks down the hump grade. The reasons for this are technical. In particular, we want the pinpuller and conductor to stand on the right side of the cars to open the "leading" knuckle of cars as they are shoved over the hump. If he opens the "trailing" knuckle (i.e., stands on left side), then there is a high probability that the trailing knuckle will close when the car impacts another car on the class track. If this occurs, the next car into the class track will not couple and the impact may break a coupler. Uncoupled cars and broken couplers will cause more trim effort and delays in making up outbound trains. Consequently, if the pinpuller and conductor stand on the right side, then the crest office should be on that side so that they can easily obtain hump lists, instructions, etc.

10.4.5 Running Tracks and Roadways

The placement of subyards and service facilities cannot be done independently of a support network of running tracks and roadways to move trains, engines, and carmen around the yard. This support infrastructure must be carefully laid out to avoid conflict and minimize travel distances.

Careful attention is usually spent on the movements of trains and heavy engine movements. However, attention must also be spent on insuring the efficiency of light engine movements around the yard, and in particular, the light return portion of the hump and makeup engine movement cycle. If the hump and makeup engines cannot return to the proper receiving or classification tracks respectively, then hump and train makeup activities are adversely affected. Furthermore, carmen must be able to move around effectively on the road network; otherwise, the delay of inbound and outbound inspections may delay humping and train departure.

The two most critical operations are humping cars and making up trains. These operations must be facilitated and not obstructed with unnecessary conflicting traffic. Consequently, it is a general rule of thumb to avoid all roads and any unnecessary running tracks through the two most critical areas of a yard, namely

- The yard throat, where train makeup activities are performed.
- The receiving yard to hump crest, where humping activities are performed.

However, it is virtually impossible to design a conflict-free yard which does not require excess travel by engines or carmen without the use of either a tunnel or bridge (flyover) at an appropriate location. The basic design consideration is the question of cost versus benefit, i.e., more initial capital costs for tunnels or bridges which will save future operating costs. The following three cases are instances where tunnels and bridges should be considered.

<u>Tunnel Under the Hump</u>

A tunnel (or tunnels) under the hump for use by both engine and motor vehicles has proven useful in facilitating the following movements without interference of the humping operation.

- Inbound train movements to either side of the receiving yard.
- Escape routes for the light return of the hump engine to either side of the receiving yard.
- Movement of carmen and yard personnel from one side of the classification yard to the other.

Santa Fe's Barstow Yard is an example in which a tunnel under the hump is used.

Bridge or Tunnel To Facilitate Mainline Arrivals and Departures

The conflict-free movement of train arrivals and departures is not only critical for yard performance, but also for the entire rail system operation. It is often desirable to ensure conflict-free train arrivals or departures via a bridge or tunnel which grade-separates entrance and exit routes to the mainline. Santa Fe's Barstow yard is an example in which there is a grade separation, i.e., an inbound route passes under the mainline.

Flyover the Departure Yard into Receiving Yard

If the receiving yard is inline and the departure yard is in parallel (see designs 2 and 6 of Figure 10-1), it may be desirable to build a bridge over the departure yard to allow a mainline entrance into the receiving yard and keep the departure yard in proper alignment with the classification yard (see discussion in Chapter 10.3.2.1 on alignment of parallel receiving and departure yards). The extra capital costs may be offset by the improved operating efficiency of the makeup engine effort. CONRAIL's Selkirk Yard is an example in which a flyover to the departure yard is used.

10.5 EVALUATION OF YARD DESIGN ALTERNATIVES

Planning the layout and configuration of a yard is as much an art as a science. Even within the given constraints of the site, there are likely to be many alternatives in the location of the subyards and support facilities. Ultimately, the design process involves laying out several alternative configurations using the principles and guidelines discussed in this chapter and evaluating the pros and cons of each alternative.

To assist in the overall evaluation of alternative designs, a yard evaluation matrix similar to that shown in Figure 10-15 is useful. The matrix is designed to display which moves are conflicting, the pulling/shoving distances for each move, and whether the move is with a light or heavy engine. The use and construction of the matrix is described in the following steps:

Step 1: Define all movements of importance through the yard by origin and destination. Table 10-1 provides an example in which movements are described, numbered, and an abbreviation is chosen.

Step 2: The movements should be priority ranked in terms of importance, either by individual moves or perhaps by groups. The more important moves are placed first on the list.

Step 3: Form a matrix as shown in Figure 10-15, where the priority ranked moves are listed along the top and sides. In addition, the top of the matrix is enlarged to contain desired information concerning each move, such as pull or shove move, heavy or light engine move, and travel distance.

Step 4: For each move listed along the side, a particular design is analyzed by: (1) Placing an "X" in the appropriate box of a move which is conflicting, and (2) noting the characteristics of the move such as pull or shove, heavy or light engine, and travel distance.

When the matrix is developed for each alternative design, the information is presented in a concise manner for the evaluation of alternative designs. In particular, it is desirable that the high-priority moves have minimum conflict and short travel distances. The matrix is also likely to be useful during the design process. In particular, the process of developing the matrix will show the weakness of any specific design, which will likely lead to improvements and modifications. In this manner the matrix can be a key element in an interactive design process in which design improvements are suggested by the matrix. Also, the matrix serves as a "checklist" to insure that all potential moves and conflicts be duly considered.

10.6 AN EXAMPLE YARD CONFIGURATION: "T" DESIGN

Although there are no perfect yards, Figure 10-16 displays a "symbolic" yard configuration (called a "T" design) which has a lot of desirable characteristics. This design is presented as a point of reference to consolidate a number of ideas discussed in this chapter. The yard is a symbolic representation in the sense that it is not to scale, and only major flows or movements are indicated. The track layout would be too complex to represent in a simple diagram.

The basic attribute of the yard is that it lies "perpendicular" to the mainline. Because of this, there is minimum conflict between train arrivals and departures, humping operations, and train makeup operations. These characteristics are summarized as follows:

- The departure yard is designed so that shoving cars for train makeup is from one end, and all of the mainline departures are from the opposite end. Consequently, there is no interference between train makeup and mainline departures.
- The receiving yard is designed so that mainline arrivals are at one end and cars are pushed to the hump at the other end. Consequently, there is no interference between humping cars and mainline arrivals.
- There is a tunnel under the hump for both engines and motor vehicles. This tunnel allows mainline locomotives to go to the diesel service facilities without interference from the humping operation. Also, the light return of the hump engine to either side of the receiving yard without interference from the humping operation is facilitated by the tunnel. The tunnel also facilitates the movement of carmen and other yard personnel from one side of the classification yard to the other.
- There is a bridge (flyover) separating east arriving trains from west departing trains. Thus the design allows mainline departures and arrivals simultaneously from all directions without interference.

YARD MOVEMENTS (columns) / YARD MOVEMENTS (rows)	1 WEST ARRIVAL	2 EAST ARRIVAL	3 WEST DEPART	4 EAST DEPART	5 RECV TO HUMP	6 HUMP TO RECV	7 W CLASS TO W DEPART	8 W DEPART TO W CLASS	9 E CLASS TO E DEPART	10 E DEPART TO E CLASS	11 W CLASS TO E DEPART	12 E DEPART TO W CLASS	13 E CLASS TO W DEPART	14 W DEPART TO E CLASS	15 RECV TO DIESEL	16 DIESEL TO DEPART	17 CARMEN: RECV TO DEPART	18 CARMEN: DEPART TO RECV	19 B.O. TRK TO REPAIR	20 REPAIR TO RECV	21 DEPART TO REPAIR	22 CAB TRK TO CAB SEV	23 CAB SEV TO DEPART	MOVEMENT CHARACTERISTICS	PULL OR SHOVE MOVE	HEAVY OR LIGHT MOVE	TRAVEL DISTANCE
1 WEST ARRIVAL																											
2 EAST ARRIVAL																											
3 WEST DEPART																											
4 EAST DEPART																											
5 RECV TO HUMP																											
6 HUMP TO RECV																											
7 W CLASS TO W DEPART																											
8 W DEPART TO W CLASS																											
9 E CLASS TO E DEPART																											
10 E DEPART TO E CLASS																											
11 W CLASS TO E DEPART																											
12 E DEPART TO W CLASS																											
13 E CLASS TO W DEPART																											
14 W DEPART TO E CLASS																											
15 RECV TO DIESEL																											
16 DIESEL TO DEPART																											
17 CARMEN: RECV TO DEPART																											
18 CARMEN: DEPART TO RECV																											
19 B.O. TRK TO REPAIR																											
20 REPAIR TO RECV																											
21 DEPART TO REPAIR																											
22 CAB TRK TO CAB SEV																											
23 CAB SEV TO DEPART																											

FIGURE 10-15. YARD EVALUATION MATRIX

- The diesel service facilities are conveniently located so that a mainline locomotive can easily get there from any receiving track, and so that mainline locomotives can get to the head-end of a departure track.
- The repair facilities are located so that it is easy to get to and from either the bad-order classification track or from the departure yard, and repaired cars can easily be placed in the receiving yard.
- The caboose service facilities are situated so as to be accessible from the caboose classification track, so a caboose can easily be placed on the rear end of a departure track.

TABLE 10-1.-EXAMPLE LIST OF YARD MOVEMENTS

Movement Number and Description	Abbreviation
Mainline Trains	
1 - West Arrival	(West Arrival)
2 - East Arrival	(East Arrival)
3 - West Departure	(West Depart)
4 - East Departure	(East Depart)
Hump Engine	
5 - Receiving Yard to Hump	(Recv to Hump)
6 - Hump to Receiving Yard	(Hump to Recv)
Makeup Engine	
7 - West Class Yard to West Departure Yard	(W Class to W Depart)
8 - West Departure Yard to West Class Yard	(W Depart to W Class)
9 - East Class Yard to East Departure Yard	(E Class to E Depart)
10 - East Departure Yard to East Class Yard	(E Depart to E Class)
11 - West Class Yard to East Departure Yard	(W Class to E Depart)
12 - East Departure Yard to West Class Yard	(E Depart to W Class)
13 - East Class Yard to West Departure Yard	(E Class to W Depart)
14 - West Departure Yard to East Class Yard	(W Depart to E Class)
Mainline Locomotives	
15 - Receiving Yard to Diesel Service	(Recv to Diesel)
16 - Diesel Service to Departure Yard	(Diesel to Depart)
Carmen	
17 - Receiving Yard to Departure Yard	(Carmen: Recv to Depart)
18 - Departure Yard to Receiving Yard	(Carmen: Depart to Recv)
Utility Work	
19 - Bad Order Track to Repair Facility	(B.O. Trk to Repair)
20 - Repair Facility to Receiving Yard	(Repair to Recv)
21 - Departure Yard to Repair Facility	(Depart to Repair)
22 - Caboose Track to Caboose Facility	(Cab Trk to Cab Sev)
23 - Caboose Facility to Departure Yard	(Cab Sev to Depart)

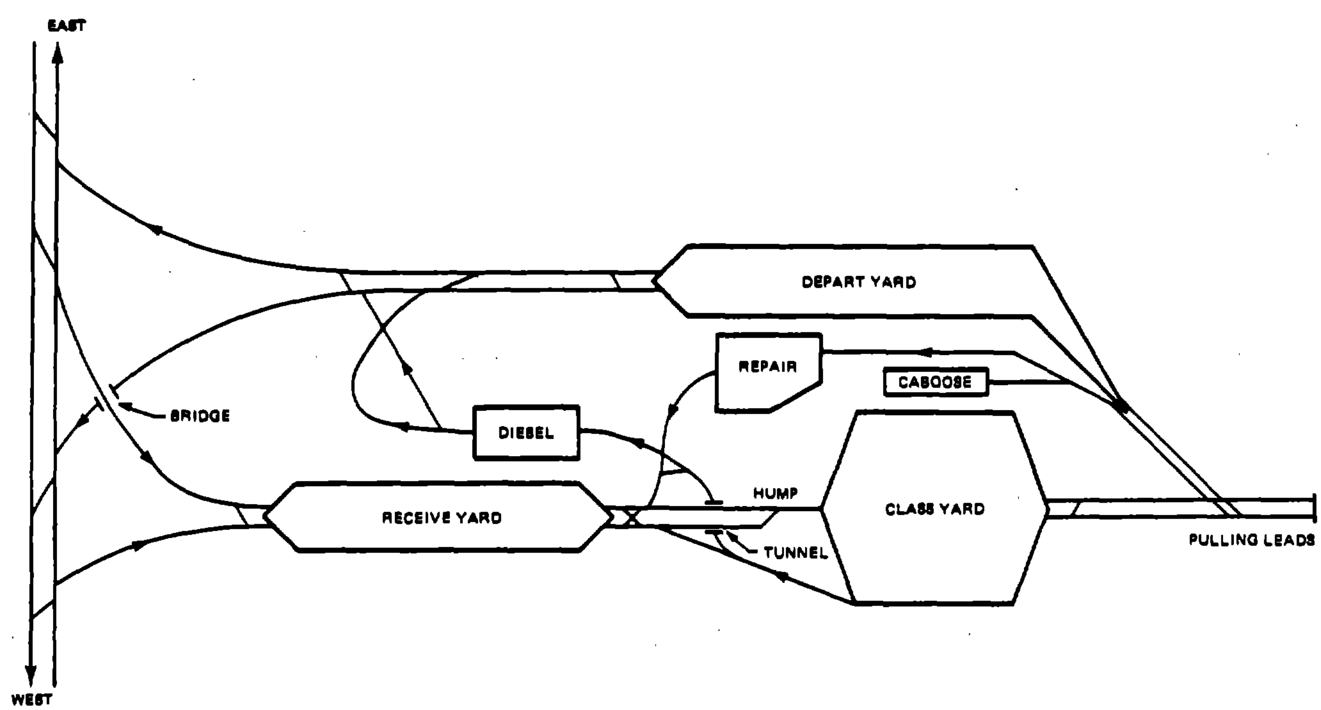

FIGURE 10-16. EXAMPLE "T" DESIGN YARD CONFIGURATION

CHAPTER 11: HUMP YARD TRACK AND SWITCH LAYOUT CONSIDERATIONS

11.0 GENERAL

This chapter describes yard design and track layout considerations. The topics covered in this chapter are:

- Key Design Elements
- Hump and Trim-End Geometries
- Design Guidelines
- Yard Trackwork and Hardware
- Special Considerations.

The first topic, Key Design Elements, contains the basic description of horizontal and vertical curves, turnouts, and retarder characteristics. In the second topic, Hump and Trim-End Geometries, various track layouts for the hump end of the classification yard are described and two types of ladder geometries used at the trim-end of the classification yard are presented. The third topic, Design Guidelines, describes guidelines for the design of horizontal curves, turnouts, and grades in each subyard. The fourth topic, Yard Trackwork and Hardware, describes specifications and applications of various trackwork and hardware. The evaluation criteria to use when selecting trackwork and hardware are also described in this section.

11.1 KEY DESIGN ELEMENTS

The key elements of yard design are described in this section, comprising horizontal curves, turnouts, grades and vertical curves, and retarders.

11.1.1 Horizontal Curves

There are various types of curves commonly used to connect two straight segments of a track which are not horizontally tangent to each other. Among these curves are: simple circular curves, compound curves, reverse curves, curves with spiral transition segments, etc.

The curvature of a circular arc is often defined by a parameter that is called the degree of curve. Though there are several definitions for the degree of curve, the most commonly used definition in the railroad industry is the so-called chord definition of the degree of curve; i.e., the degree of curve is the central angel subtended by a 100-ft chord. The relationship between the degree of curve, D_c, and the radius, R, is expressed as

$$R = \frac{50}{\sin \frac{D_c}{2}} \quad . \qquad (11.1)$$

The degree of curve D_c can be approximated as

$$D_c \approx \frac{5730}{R} \quad . \qquad (11.2)$$

*This material was developed with the generous cooperation of C. Yespelkis (CONRAIL), M. Anderson (Union Pacific), B. Gallacher (Southern Pacific) and J. Wetzel (CONRAIL). Much of the text in descriptions of switches and crossings was extracted from the AREA manual for Railway Engineering.

The determination of radius or the degree of curve of a curve segment is usually done by evaluating the lateral acceleration rate experienced by a car on the curve segment. The lateral acceleration rate, a, at the curve segment with radius R can be expressed as a function of the speed of a car, v, as

$$a = \frac{v^2}{R} \quad . \qquad (11.3)$$

If the permissible (or tolerable) lateral acceleration rate and the car speed at the curve section are known, then the radius of a curve can be computed from the above formula.

In yard design practice the maximum degree of curve recommended is about 12° 30', independent of the car speed. This value translates to a 459-ft radius curve.

Spirals are not usually used in yard track alignments except at receiving and departure yard approaches. The main reasons for this are that: (1) the spirals require extra track length and consequently would make the yard size much larger, and (2) the car speeds in yards are usually less than 15 mph, which is considered sufficiently low to make spirals unnecessary.

11.1.2 Turnouts

A turnout consists of a switch and a frog with closure rails. There are two types of turnouts:

- Equilateral Turnout--A turnout in which the diversion due to the angle of turnout is divided equally between the two tracks.
- Lateral Turnout--A turnout in which the diversion due to the angle of turnout is entirely on one side of the track from which the turnout is made.

For design information, the most critical data are frog angle, length of turnout (actual lead), theoretical point of curve through the turnout, location of joint behind the point of switch (where bent stock rail begins), distance from point of frog to heel of frog, and distance from point of switch to end of switch ties. This information allows the designer to designate the proper turnout and make the necessary calculations to construct the trackage for its particular use.

The turnout data specified in the AREA manual for straight and curved switch points are presented in Tables 11-1 and 11-2. It should be noted that turnouts with a straight switch point are usually used in yards.

The split switch used in a turnout is generally of such length that the operating speed through the switch is comparable to the operating speed in the closure curve between the switch and frog. AREA recommended practice determines this speed in a straight turnout by taking the switch to represent a curve with a tangent length equal to the length of the switch and an internal angle equal to the arc sine of the heel spread divided by the length of point. For a curved point, the radius (or degree of curve) formed by the curved point controls the allowable speed according to the speed/curve tables published by AREA.

The AREA table is presented in Table 11-3. The table shows that turnouts with curved switch points have higher speed limits than those with straight switch

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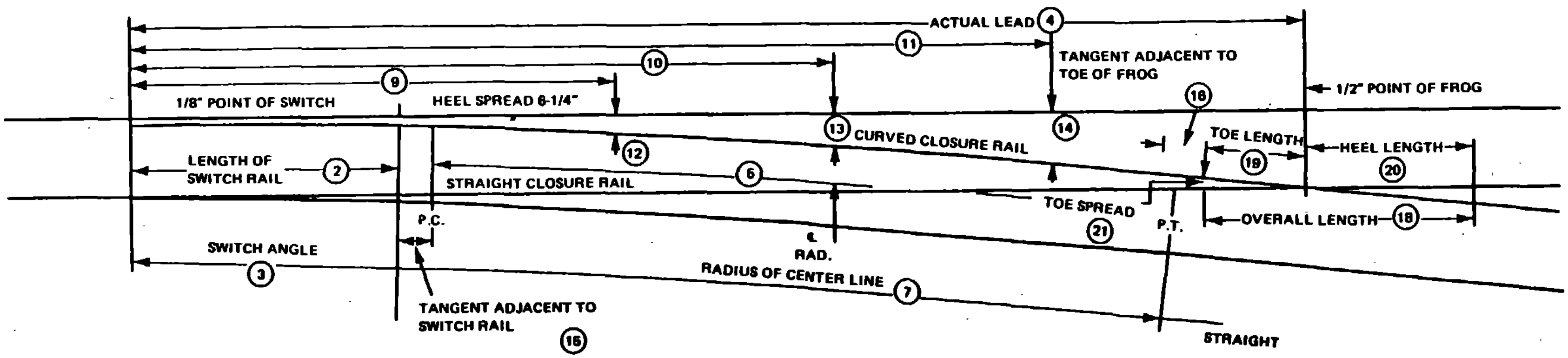
TABLE 11-1.-TURNOUT DATA (Straight Switch)

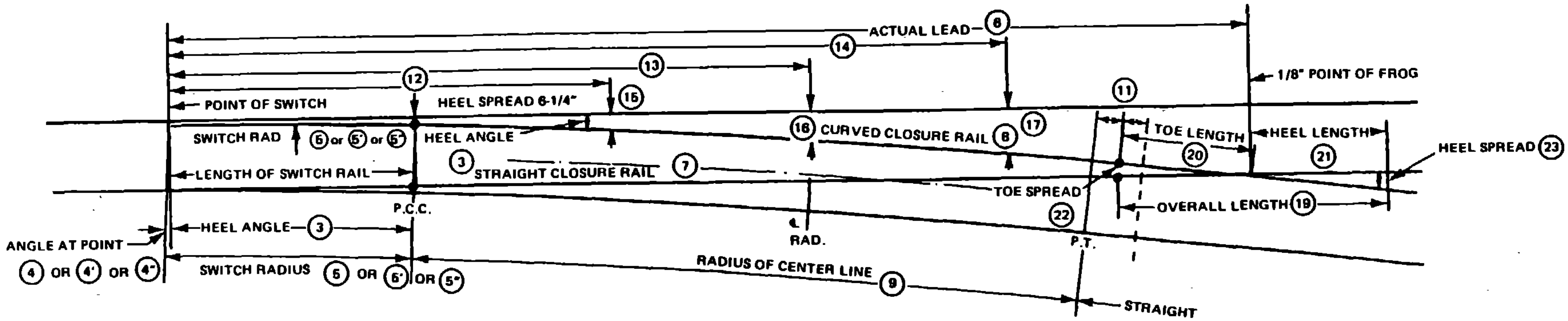


TURNOUT DATA

	Properties of Switches			Closure Distance		Lead Curve		Gage Line Offsets								Properties of Frogs						
Col. (1) Frog Number	Col. (2) Length of Switch Rail	Col. (3) Switch Angle	Col. (4) Actual Lead	Col. (5) Straight Closure Rail	Col. (6) Curved Closure Rail	Col. (7) Radius of Center Line	Col. (8) Degree of Curve	Col. (9)	Col. (10)	Col. (11)	Col. (12)	Col. (13)	Col. (14)	Col. (15) Tangent Adjacent to Switch Rail	Col. (16) Tangent Adjacent to Toe of Frog	Col. (1) Frog Number	Col. (17) Frog Angle	Col. (18) Overall Length	Col. (19) Toe Length	Col. (20) Heel Length	Col. (21) Toe Spread	Col. (22) Heel Spread
	Ft. In.	Deg.Min.Sec.	Ft. In.	Ft. In.	Ft. In.	Feet	Deg.Min.Sec.	Ft. In.	Ft. In.	Ft. In.	Inches	Inches	Ft. In.	Feet	Feet		Deg.Min.Sec.	Ft. In.	Ft. In.	Ft. In.	Inches	Inches
5	11-0	2-39-34	42-6-1/2	28-0	28-4	177.80	32-39-56	18-0	25-0	32-0	11-13/16	20-5/8	2-8-7/8	0.00	0.78	5	11-25-16	9-0	3-6-1/2	5-6-1/2	7-15/16	13-9/16
6	11-0	2-39-34	47-6	32-9	33-0	258.57	22-17-58	19-2-1/4	27-4-1/2	35-6-3/4	12-3/8	21-5/8	2-10	0.00	1.78	6	9-31-38	10-0	3-9	6-3	7	13
7	16-6	1-46-22	62-1	40-10-1/2	41-1-1/4	365.59	15-43-16	26-2-1/4	35-10-1/2	45-6-3/4	11-3/8	19-9/16	2-6-7/8	0.01	0.00	7	8-10-16	12-0	4-8-1/2	7-3-1/2	7-9/16	13
8	16-6	1-46-22	68-0	46-6	46-7-1/2	487.28	11-46-44	27-7-1/4	38-8-1/2	49-9-3/4	11-7/8	20-9/16	2-8-5/16	0.04	0.00	8	7-09-10	13-0	5-1	7-11	7-1/8	12-3/8
9	16-6	1-46-22	72-3-1/2	49-5	49-7-1/4	615.12	9-19-30	28-10-1/4	41-2-1/2	53-6-3/4	12-5/16	21-3/8	2-9-7/16	0.00	0.17	9	6-21-35	15-0	6-4-1/2	9-7-1/2	8	13-5/16
10	16-6	1-46-22	78-9	55-10	56-0	779.39	7-21-24	29-11-3/4	43-6-1/2	56-11-1/4	12-1/4	21	2-8-5/8	2.08	0.00	10	5-43-29	16-6	6-6	10-1	7-3/16	12-5/8
11	22-0	1-19-46	91-10-1/4	62-10-1/4	63-0	927.27	6-10-56	37-8-1/2	53-5	69-1-1/2	12-1/4	21-3/8	2-9-3/4	0.00	0.13	11	5-12-18	18-6-1/2	7-0	11-8-1/2	7-1/8	13-1/4
12	22-0	1-19-46	96-8	66-10-1/2	67-0	1104.63	5-11-20	38-8-1/2	55-5	72-1-1/2	12-7/16	21-5/8	2-9-7/8	0.00	0.50	12	4-46-19	20-4	7-9-1/2	12-6-1/2	7-5/16	13-1/16
14	22-0	1-19-46	107-0-3/4	76-5-1/4	76-6-3/4	1581.20	3-37-28	41-1-1/4	60-2-1/2	78-3-3/4	12-7/8	22-5/16	2-10-1/2	0.24	0.00	14	4-05-27	23-7	8-7-1/2	14-11-1/2	6-7/8	13-5/16
15	30-0	0-58-30	126-4-1/2	86-11-1/2	87-0-3/4	1720.77	3-19-48	51-0	73-6	95-3	12-1/8	21-1/4	2-9-3/4	1.86	0.00	15	3-49-06	24-4-1/2	9-5	14-11-1/2	7	12-7/16
16	30-0	0-58-30	131-4	91-11	92-0	2007.12	2-51-18	53-0	76-0	99-0	12-7/16	21-13/16	2-10-5/16	0.86	0.00	16	3-34-47	26-0	9-6	16-7	6-9/16	12-15/16
18	30-0	0-58-30	140-11-1/2	99-11	100-0	2578.79	2-13-20	55-0	80-0	105-0	12-3/4	22-1/8	2-10-7/16	0.57	0.00	18	3-10-56	29-3	11-0-1/2	18-2-1/2	6-7/8	12-5/8
20	30-0	0-58-30	151-11-1/2	110-11	111-0	3289.29	1-44-32	57-9	86-6	113-3	13-1/16	22-11/16	2-11-3/16	2.47	0.00	20	2-51-51	30-10-1/2	11-0-1/2	19-10	6-1/8	12-3/8

Source: AREA Manual for Railway Engineering

TABLE 11-2.-TURNOUT DATA (Curved Switch)



TURNOUT DATA

	PROPERTIES OF SWITCHES			CLOSURE DISTANCE		LEAD CURVE		GAGE LINE OFFSETS								PROPERTIES OF FROGS						
Col ①	Col ②	Col ③	Col ④	Col ⑤	Col ⑥	Col ⑦	Col ⑧	Col ⑨	Col ⑩	Col ⑪	Col ⑫	Col ⑬	Col ⑭	Col ⑮	Col ⑯	Col ①	Col ⑰	Col ⑱	Col ⑲	Col ⑳	Col ㉑	Col ㉒
FROG NUMBER	LENGTH OF SWITCH RAIL	SWITCH ANGLE	ACTUAL LEAD	STRAIGHT CLOSURE RAIL	CURVED CLOSURE RAIL	RADIUS OF CENTER LINE	DEGREE OF CURVE							TANGENT ADJACENT TO SWITCH RAIL	TANGENT ADJACENT TO TOE OF FROG	FROG NUMBER	FROG ANGLE	OVERALL LENGTH	TOE LENGTH	HEEL LENGTH	TOE SPREAD	HEEL SPREAD
	Ft In.	Deg Min Sec	Ft In	Ft. In.	Ft In	Feet	Deg Min Sec.	Ft. In.	Ft. In.	Ft In.	Inches	Inches	Ft In.	Feet	Feet		Deg Min Sec.	Ft. In.	Ft. In	Ft. In.	Inches	Inches
5	11–0	2–39–34	42–6-1/2	28–0	28–4	177 80	32–39–58	18–0	25–0	32–0	11-13/16	20 6/8	2–8-7/8	0 00	0 78	5	11–25–18	9–0	3–6-1/2	5–6 1/2	7-15/16	13 9/16
6	11–0	2–39–34	47–6	32–9	33–0	258.57	22–17–58	19–2-1/4	27–4-1/2	36–8-3/4	12-3/8	21-6/8	2–10	0 00	1 76	6	9–31–38	10–0	3–8	6–3	7	13
7	16–6	1–46–22	62–1	40–10-1/2	41–1-1/4	365 59	15–43–16	26–2-1/4	35–10-1/2	45–8-3/4	11-3/8	19-9/16	2–6-7/8	0 01	0 00	7	8–10–16	12–0	4–8-1/2	7–3-1/2	7-9/16	13
8	16–6	1–46–22	68–0	46–5	46–7-1/2	487 28	11–46–44	27–7-1/4	38–8-1/2	49–9-3/4	11-7/8	20-9/16	2–8-5/16	0 84	0.00	8	7–09–10	13–0	5–1	7–11	7-1/8	12-3/8
9	16–6	1–46–22	72–3-1/2	49–5	49–7-1/4	615 12	9–18–30	28–10-1/4	41–2-1/2	53–6-3/4	12-5/16	21-3/8	2–9-7/16	0 00	0.17	9	6–21–35	16–0	6–4-1/2	9–7-1/2	8	13-5/16
10	16–6	1–46–22	78–9	55–10	56–0	778 39	7–21–24	29–11-3/4	43–5-1/2	56–11-1/4	12 1/4	21	2–8 5/8	2 08	0.00	10	6–43–29	18–6	6–5	10–1	7-3/16	12 5/8
11	22–0	1–19–46	91–10-1/4	62–10-1/4	63–0	927 27	6–10–56	37–8-1/2	53–6	69–1-1/2	12 1/4	21-3/8	2–9-3/4	0.00	0 13	11	5–12–18	18–8-1/2	7–0	11–8 1/2	7 1/8	13 1/4
12	22–0	1–19–46	96–8	66–10 1/2	67–0	1104 83	5–11–20	38–8-1/2	55–5	72–1-1/2	12-7/16	21-6/8	2–9-7/8	0 00	0 50	12	4–46–19	20–4	7–9-1/2	12–6-1/2	7-5/16	13 1/16
14	22–0	1–19–46	107–0 3/4	76–5-1/4	76–8-3/4	1581 20	3–37–28	41–1-1/4	60–2-1/2	79–3-3/4	12-7/8	22-5/16	2–10-1/2	0 24	0 00	14	4–05–27	23–7	8–7-1/2	14–11-1/2	6-7/8	13 5/16
15	30–0	0–58–30	126–4-1/2	86–11-1/2	87–0 3/4	1720 77	3–19–48	51–9	73–6	95–3	12-1/8	21-1/4	2–9 3/4	1 66	0 00	15	3–49–06	24–4-1/2	9–5	14–11-1/2	7	12 7/16
16	30–0	0–58–30	131–4	91–11	92–0	2007.12	2–51–18	53–0	78–0	99–0	12-7/16	21-13/16	2–10-5/16	0 68	0 00	16	3–34–47	26–0	9–5	18–7	6 9/16	12 15/16
18	30–0	0–58–30	140–11 1/2	99–11	100–0	2578 79	2–13–20	55–0	80–0	105–0	12-3/4	22-1/8	2–10 7/15	0 57	0 00	18	3–10–56	29–3	11–0-1/2	18–2-1/2	6 7/8	12 5/8
20	30–0	0–58–30	151–11 1/2	110–11	111–0	3289 29	1–44–32	57–9	85–8	113–3	13-1/16	22 11/16	2–11-3/16	2 47	0 00	20	2–51–51	30–10 1/2	11–0-1/2	19–10	6 1/8	12–3/8

Source AREA Manual for Railway Engineering

TABLE 11-3.-SPEEDS OF TRAINS THROUGH LEVEL TURNOUTS

Turnouts with Straight Switch Points (AREA)

Turnout number	Length of switch points	Speed in miles per hour	
		Lateral turnouts	Equilateral turnouts
5	11'-0"	12	16
6	11'-0"	13	19
7	16'-6"	17	23
8	16'-6"	19	27
9	16'-6"	20	28
10	16'-6"	20	28
11	22'-0"	26	37
12	22'-0"	27	38
14	22'-0"	27	38
15	30'-0"	36	51
16	30'-0"	36	52
18	30'-0"	36	52
20	30'-0"	36	52

Turnouts with Curved Switch Points (AREA)

Turnout number	Length of switch points	Speed in miles per hour	
		Lateral turnouts	Equilateral turnouts
5	13'-0"	12	17
6	13'-0"	15	21
7	13'-0"	18	25
8	13'-0"	20	28
9	19'-6"	22	30
10	19'-6"	25	35
11	19'-6"	28	39
12	19'-6"	29	40
14	26'-0"	34	49
15	26'-0"	38	53
16	26'-0"	40	57
18	39'-0"	44	63
20	39'-0"	50	70

For passenger trains completely equipped with cars in which the lean tests show a roll angle of less than 1° 30', trains may operate comfortably through turnouts at 12 percent higher speeds than those indicated in the foregoing.

points, and that equilateral turnouts have higher speed limits than lateral turnouts for the same turnout numbers.

11.1.3 Vertical Curves and Grades*

For vertical transitions, parabolic curves are most commonly used. A detailed description of parabolic vertical curves may be found in the literature. Here, we will describe relationships of some of the major variables used in vertical curve design without going through explanations of how these relationships are derived. The schematic layout of vertical curve sections for a summit and a sag are shown in Figure 11-1.

*Source: Southern Pacific Transportation Company.

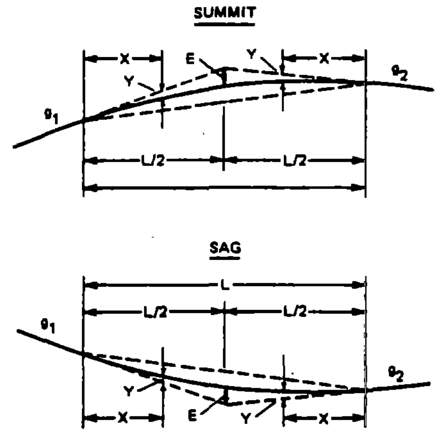


FIGURE 11-1. VERTICAL CURVES

Recommended minimum length of curve in feet (L),

$$L = A \cdot C \quad , \qquad (11.4)$$

external distance in feet (E),

$$E = \frac{A \cdot L}{800} \quad , \qquad (11.5)$$

vertical distance between grade line and vertical curve in feet (Y),

$$Y = \left(\frac{X}{L/2}\right)^2 E \quad , \qquad (11.6)$$

where g_1, g_2 = gradients in percent,

$A = |g_1 - g_2|$ = algebraic difference in percent,

C = 15 (for hump crest),

= 40 (for summits),

= 60 (for sags), and

X = vertical distance between grade line and vertical curve in feet.

11.2 HUMP AND TRIM-END GEOMETRIES

11.2.1 Track Geometric Configuration at Hump End of Classification Yard

The track geometry at the hump end of the classification yard is one of the critical design problems of any hump yard. The hump profile design problem is discussed in Chapter 12. In this section the horizontal track configurations between the hump crest and the tangent point are discussed. The types of switches, possible number of classification tracks, and application examples are also described for each geometry. In this discussion, the track arrangements are broken down into two parts. The first part covers the track arrangements between the hump crest and the group retarders, and the second part covers the track arrangements between the group retarders and the tangent point.

11.2.1.1 Track Geometry Between the Hump Crest and the Group Retarders. A total of ten different schematics of track geometries ranging from a two-group arrangement to an eight-group arrangement are shown in Table 11-4. The schematic drawing of each track

TABLE 11-4.-HUMP GROUP RETARDER GEOMETRIES

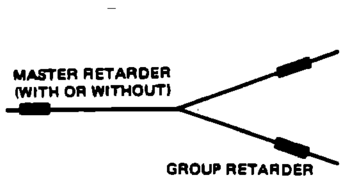
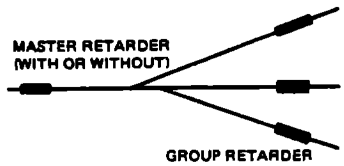
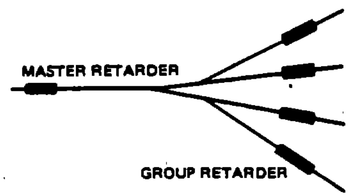
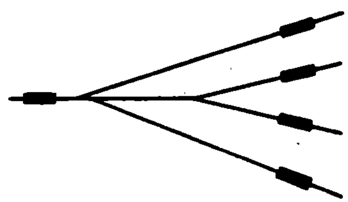
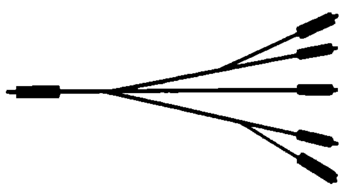
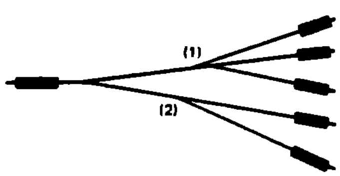
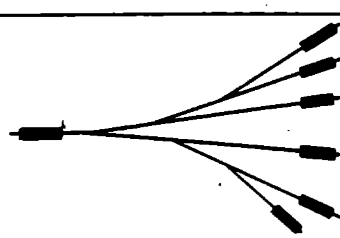
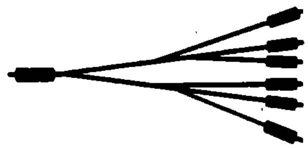
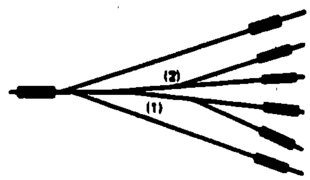
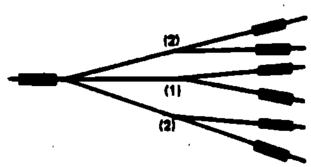
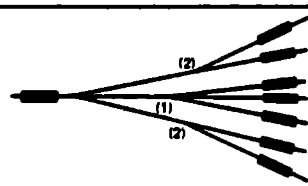
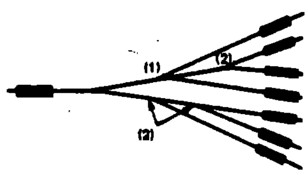
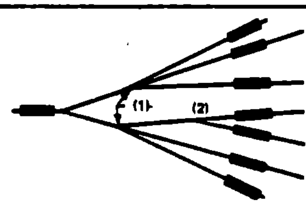
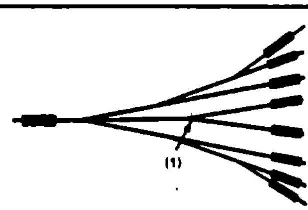
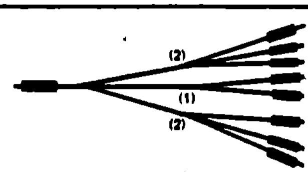
No.	Title	Schematic drawing	King switch type	Secondary switch type	No. of class tracks	Application examples
1	Two-Track Group		Equilateral	N.A.	12 ~ 20 tracks	
2	Three-Track Group		Lap	N.A.	18 ~ 30 tracks	
3	Four-Track Group (A)		Equilateral	Lateral or equilateral	24 ~ 40 tracks	Columbus Yard (CONRAIL): 40 tracks
4	Four-Track Group (B)		Lap	Equilateral	24 ~ 40 tracks	
5	Five-Track Group (A)		Lap	Lateral or equilateral	30 ~ 50 tracks	
6	Five-Track Group (B)		Equilateral	(1) Lap (2) Lateral or equilateral	30 ~ 50 tracks	
7	Six-Track Group (A)		Equilateral	Lateral or equilateral	36 ~ 60 tracks	West Colton Yard (SP): 48 tracks Expansion plan of Columbus Yard (CONRAIL): 60 tracks

TABLE 11-4.-CONCLUDED

No.	Title	Schematic drawing	King switch type	Secondary switch-type	No. of class tracks	Application examples
8	Six-Track Group (B)		Equilateral	Lap	36 ~ 60 tracks	
9	Six-Track Group (C)		Lap	(1) Equilateral (2) Lateral or equilateral	32 ~ 60 tracks	Sheffield Yard (Southern): 32 tracks
10	Six-Track Group (D)		Lap	(1) Equilateral (2) Lateral or equilateral	36 ~ 60 tracks	Big Four Yard (CONRAIL): 55 tracks
11	Seven-Track Group (A)		Lap	(1) Lap (2) Lateral or equilateral	42 ~ 70 tracks	East Buffalo Yard (CONRAIL): 63 tracks
12	Seven-Track Group (B)		Equilateral	(1) Lap (2) Lateral or equilateral	42 ~ 70 tracks	Selkirk Yard (CONRAIL)
13	Seven-Track Group (C)		Equilateral	(1) Lap (2) Lateral or equilateral	42 ~ 70 tracks	
14	Eight-Track Group (A)		Lap	(1) Equilateral Others: lateral or equilateral	48 ~ 80 tracks	Elkhart Yard (CONRAIL): 72 tracks
15	Eight-Track Group (B)		Lap	(1) Equilateral (2) Lap	48 ~ 80 tracks	

arrangement is followed by a brief characterization of the geometry by such items as type of switches used, number of classification tracks handled by the scheme, and application examples.

11.2.1.2 Track Geometry Between the Group Retarder and the Tangent Point. Four types of track groups are covered here, ranging from six- to ten-track groups. Their schematics are presented in Table 11-5.

11.2.2 Trim End Ladder Geometry

Considering Single Ladder versus Tandem Ladder, it is believed by some that the single ladder is suitable for manual operation of switches because all of the switch machines can be installed on a straight line, thus facilitating the switchman's work. On the other hand, some designers believe that the tandem design makes the job easier for a switchman, because the walking distance is shorter.

An example tandem-ladder layout is shown in Figure 11-2a and an example single-ladder layout is shown in Figure 11-2b. In both cases, the distance between track centers is 14 feet. However, it is shown in the figure that the angle of the ladder to the track group in the tandem ladder is much sharper than that in the single ladder case (14° 18' 20" in the tandem ladder, and 10° 02' 10" in the single ladder). Note that the angle between tangents is identical, 7° 9' 10", for all switches shown in both the tandem-ladder and single-ladder layouts (turnout number 8).

11.3 DESIGN GUIDELINES

11.3.1 General Guidelines

11.3.1.1 Switch Distance. The switch-to-switch distance is determined simply from the center-to-center distance between adjacent tracks. The relationship between the distance between switches, K, and the distance between adjacent tracks, P, and the switch angle, a, is given as (see Figure 11-3):

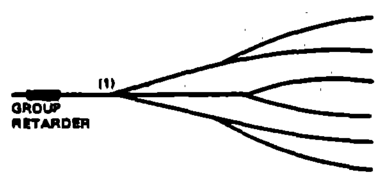
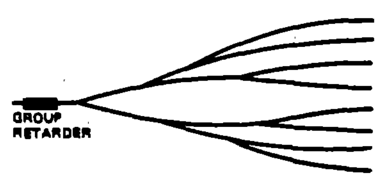
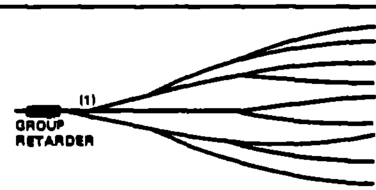
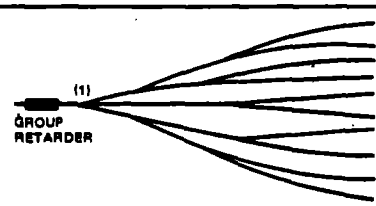
$$K = P/\sin a \qquad (11.7)$$

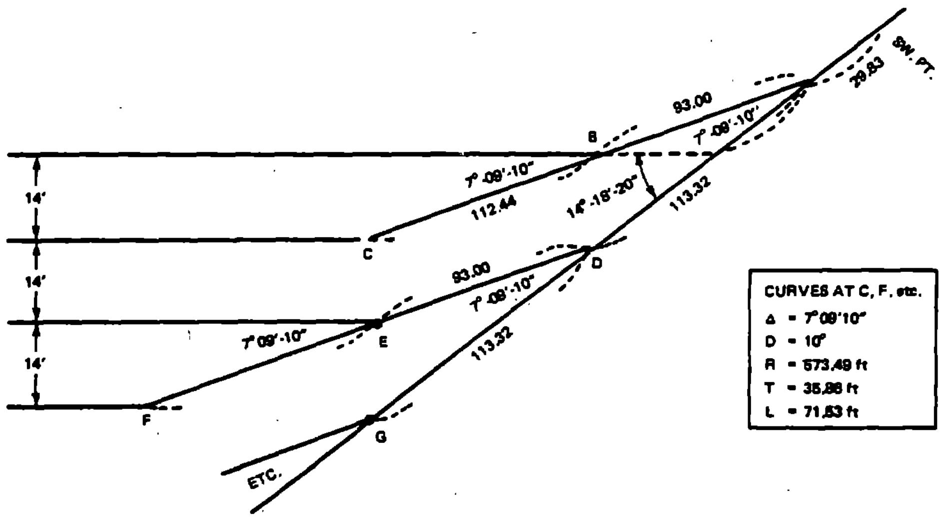
The distance between tracks, P, varies from yard to yard at the receiving and departure yards. This spacing is required for inspectors to travel along the yard tracks using a small vehicle, which also carries necessary spare parts for repairs.

11.3.1.2 Location of the Yard Relative to the Mainline. The preferred location of the yard relative to the mainline is shown in Figure 11-4. The yard should be located close to the mainline and should be perpendicular to the mainline connected by grade-separated tracks. This geometric configuration allows the most conflict-free operations between yard traffic and incoming and outgoing traffic.

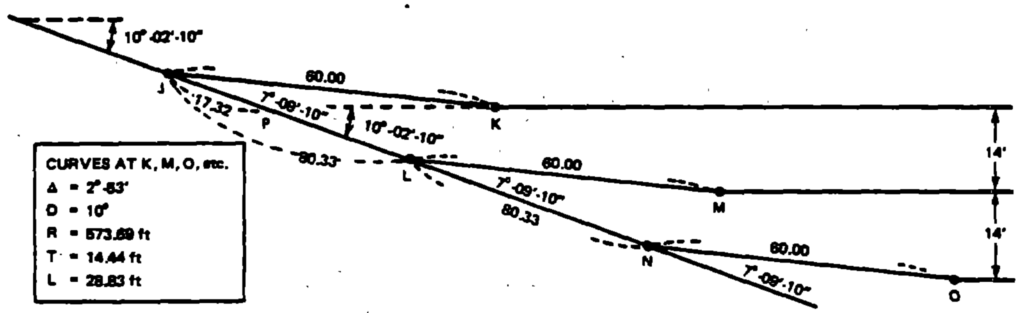
If the yard is located adjacent and parallel to the mainline, then conflicting movements of traffic can be avoided by installing tunnels or bridges. It is not recommended that the mainline or any other track cross through either the receiving or departure yards. It is often suitable to construct a tunnel under the hump.

TABLE 11-5.-GROUP RETARDER - TANGENT POINT GEOMETRIES

No.	Title	Schematic drawing	Switch type	Application example
16	Six-Track Group		Lap (1), equilateral and/or lateral	Sheffield Yard (Southern): inside groups
17	Eight-Track Group		Equilateral or lateral	West Colton Yard (SP): has a tangent point retarder on each track
18	Nine-Track Group		Lap (1), lateral and/or equilateral	Elkhart Yard (CONRAIL) East Buffalo Yard (CONRAIL)
19	Ten-Track Group		Lap (1), lateral and/or equilateral	Selkirk Yard (CONRAIL) Columbus Yard (CONRAIL) Proprosed Yermo Yard (UP)



(a) EXAMPLE TANDEM CONFIGURATION LADDER LAYOUT



(b) EXAMPLE SINGLE CONFIGURATION LADDER LAYOUT

FIGURE 11-2. EXAMPLE LAYOUTS OF CLASS TRACK LADDERS

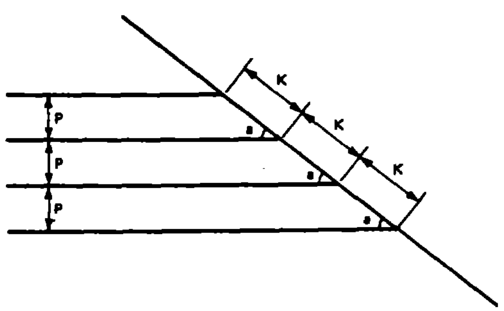


FIGURE 11-3. SCHEMATIC LADDER LAYOUT

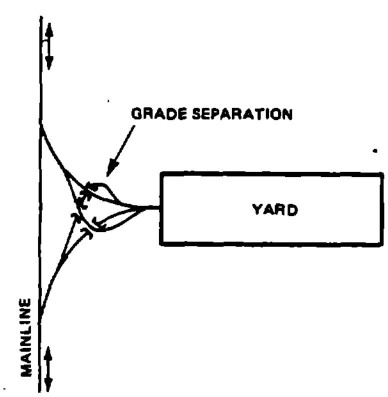


FIGURE 11-4. PREFERRED YARD LOCATION

The grade separation of incoming traffic from the yard traffic can otherwise be done by use of a bridge. A tunnel or the bridge can also be utilized for auto traffic that crosses the yard.

11.3.1.3 Use of Templates. To assist the designer in laying out his yard, it is recommended that templates be made of the throats and ladder designs with the number of tracks that each yard will require. These should be drawn on a scale of 1 inch = 100 feet and with the proper track centers that are to be utilized. It is recommended that 14-foot track centers be used in classification yards and 22- to 25-foot track centers be used in receiving and departure yards for inspection roads.

11.3.2 Receiving and Departure Yard

11.3.2.1 Turnouts. The turnout numbers usually used are No. 10 or No. 14. In receiving or departure leads, where crossovers or connections are to mainline and are power operated, No. 20 turnouts are recommended.

11.3.2.2 Grades. The preferred grade in the receiving and departure yards is 0%. However, yards may reach a grade of approximately 0.15% before consideration should be given to installing inert retarders to prevent rollouts without having to set air brakes in some of the cars.

Both ends of receiving and departure yards should have 300 feet of 0.3% to 0.4% grade to prevent rollouts.

11.3.3 Hump Pullout Lead

In the pullback style yard, a positive grade of 0.1 to 0.6% is preferred in the pull direction. This allows the slack to run out of the cars as the switch engine changes directions to push to hump. This grade should be maintained as low as possible to allow quick and high speeds in the pullback operation.

11.3.4 Classification Yard

11.3.4.1 Horizontal Curves. While there are many yards designed with 14° curves on the outside tracks and even some with as high as 16° curves, it is best to limit the entrance curves to 12° 30' if possible. There should be no curves in the body tracks if at all possible.

11.3.4.2 Turnouts. The most commonly used turnout numbers are No. 7's and 8's at the hump end and No. 8's and 10's at the trim end of the classification yard.

11.3.4.3 Grades. Classification yards are generally designed with 0.08 to 0.11% of grade descending away from the hump. These are considered nonaccelerating grades and generally 0.08% grade is used unless humping is done into the prevailing winds or the traffic is primarily empties, in which case these grades may be increased to 0.10 or 0.11%.

At the trim end of the classificaton yard a grade to prevent rollouts should be installed 300 feet from the clearance point. This is generally 300 feet of 0.4% grade. An inert retarder is installed at the beginning of this grade change to assist in the stoppage of cars.

11.3.5 Trim-End Design

The throat design splits a group of tracks generally with one-half the frog angle on each side. It is started most frequently by an equilateral turnout and the second turnout on each side is equilateral, which generates a standard ladder from that point on. However, a throat design may also start with a lap turnout, and this is most common in the design of groups of bowl tracks. The other locations for this design would be the hump end of the receiving yard or the trim end of an inline departure yard.

11.3.6 Trim-End Pullout Lead

The preferred grade is between 0 and 0.2%. This grade should be positive toward the spur end of the drill track. Its purpose is the same as on the hump pullout track in that it allows the slack to run out of the cars as the switch engine starts toward the departure yard.

11.4 SWITCHES AND CROSSINGS

This section first describes specifications of major trackwork elements, such as split switches and frogs. The information here can be used when ordering the yard hardwares described. Also described are various types of switches, crossings, and their applications.

11.4.1 Switches and Crossings Specifications

11.4.1.1 Split Switch. The specifications of a split switch include (see schematics in Tables 11-1 and 11-2):

- Type of split switch.
- Straight or curved--For a curved switch it is required to know whether the curved rail is on the left-hand or right-hand side, and the curve alignment is also required.
- Gauge of track.
- Switch point--Specified by length, thickness of point, single reinforced or double reinforced, and spacing of holes for the switch clips.
- Heel spread.
- Design of switch rods, plates, braces and other special requirements.
- Weight and section of rail together with the details of joint drillings.

11.4.1.2 Frog. A sample layout of a standard frog is shown in Figure 11-5. The specifications of a frog include information essential for specifying a frog:

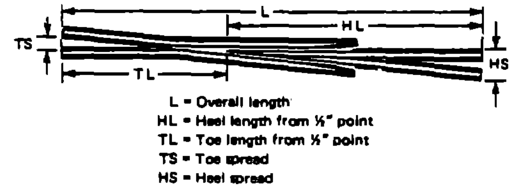


FIGURE 11-5. STANDARD FROG LAYOUT

- Type of frog.
- Frog number or angle—found by dividing the frog length (L) by the sum of the gauge line spreads at the heel (HS) and to the toe (TS).
- Weight and section of rail of which a frog is to be made, together with the details of all joint drillings.

Important information, in addition to the foregoing, can also be found in:

- Width and depth of flangeways.
- For standard rigid frog, important measurements such as overall length and heel length from 1/2" point (see Figure 11-5).
- For special frogs, important measurements such as overall length of each side and the length of each leg from 1/2" point (see Figure 11-5).
- For a curved frog, diagram showing direction of curvature and radius or sufficient data to determine the curvature and radius; i.e., the heel spread (HS), toe spread (TS), heel offset (HO) and toe offset (TO) (see Figure 11-6).
- If special tie plates are wanted, a sketch showing the location of ties on which the tie plates are to be located must be given.

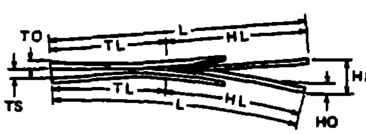
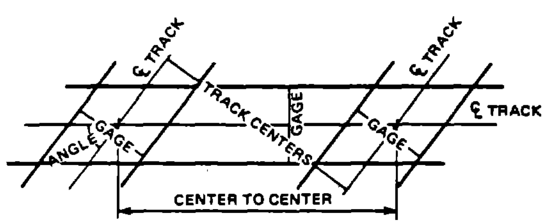
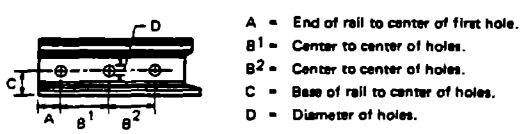


FIGURE 11-6. CURVED FROG LAYOUT

11.4.1.3 Crossing. A sample layout of two crossings is shown in Figure 11-7. The specification of a crossing includes:



(a) SCHEMATIC LAYOUT



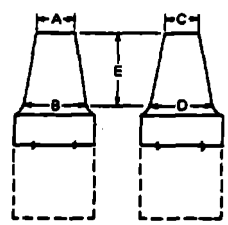
(b) END DRILLING FOR SPLICES

FIGURE 11-7. SAMPLE CROSSING LAYOUT

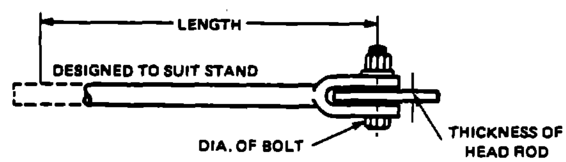
- The angle of crossing between center lines of tracks.
- In the case of a curved crossing, the direction and radius (or degree of curves).
- Distance between crossings, if more than one. When the tracks are parallel, this is given as the perpendicular of the track centers. When the tracks are not parallel, this is given as the distance from center to center of the crossings.
- Gauge of track and width of flangeways.
- Section number of rail and rail drilling, connecting rail sections and corresponding drilling.
- Type of construction, if there is a preference.
- Tie spacing and plating arrangement, if other than AREA.

11.4.1.4 Switch Stand. The dimensions of a switch stand are given in Figure 11-8. The specifications of a switch stand include:

- Type of stand.
- Description of target or sketch giving complete information.
- Lamp tip: Give dimensions as shown in sketch.
- Connecting rod: Give length center to center of holes, thickness of head rod, and diameter of bolt as shown in sketch.



(a) DIMENSIONS FOR LAMP TIP



(b) DIMENSIONS FOR CONNECTING ROD

FIGURE 11-8. SWITCH STAND

11.4.2 Various Track Work Types and Their Uses

11.4.2.1 Switches. There is a wide variety of switches, and a brief description of each switch type is given below:

- Straight Split Switch—A split switch having straight switch points. Straight split switches are almost universally used in the U.S.
- Curved Split Switch—A split switch having a curved switch point. For a left-hand switch, the curved switch point is the right-hand switch point, and for a right-hand switch, the curved switch point is the left-hand switch

point. Curved split switches are more expensive and are usually used only in special situations, such as high-speed turnouts. They have been used in a few locations in yards where space is limited. The advantage of curved split switches is that they will allow slightly higher speeds for the same length of switch.

- Insulated Split Switch--A switch in which the fixtures, principally the gauge plates and switch rods connecting or reaching from one rail to the opposite rail, are provided with insulation so that the electric track circuit will not be shunted. Insulated switches must be used in signalized territory (Automatic Block Signals, Centralized Traffic Control, Interlocking).

- Split Switch with Uniform Risers--A split switch in which the switch rails have a uniform elevation or riser plates for the entire length of the switch, and therefore do not have a heel slope, the point rail rise being run off back of the switch in the closure rails.

- Split Switch with Graduated Risers--A split switch in which the switch rails are gradually elevated by means of graduated riser plates until they reach the required height above the stock rail, and therefore have a heel slope. Most U.S. railroads use graduated risers. This permits all switch plates beyond the heel of the switch point to be of uniform thickness.

- Spring Switch--A switch with a spring device so arranged as to automatically return the points to their original or normal position after they have been thrown over by the flanges of trailing wheels passing along the other track from that for which the points are set for facing movements. (A spring switch is also classified as a switch throwing mechanism. See Section 11.4.2.5.) Spring switches are used where it is desired to trail through in one direction without stopping to throw the switch. Heavily used spring switches are commonly equipped with a device known as a "mechanical switchman." These are hydraulic buffers which hold the switch from returning to the original position for 10 to 15 seconds. Without this device, the points will return to their original position after each set of wheels. This creates considerable wear on the points.

- Hub-Safety (or Flip) Switch--A trailable switch, but after the switch is thrown by the wheels it stays in the new position. For facing-point moves it may be hand thrown or power thrown.

- Single-Slip Switch--A combination of a crossing with one right-hand switch and a curve between them within the limits of the crossing connecting the two intersecting tracks without the use of separate turnout frogs. A schematic representation of a single-slip switch is given in Figure 11-9.

- Double-Slip Switch--A combination of a crossing with two right-hand and two left-hand switches and curves between them within the limits of the crossing connecting the two intersecting tracks on both sides of the crossing without the use of separate turnout frogs. A schematic representation of a double-slip switch layout is given in Figure 11-10.

For slip switches, virtually without exception, a slip switch will require a slightly higher (and irregular) curvature and provide a rougher ride than a simple turnout with the same number frog.

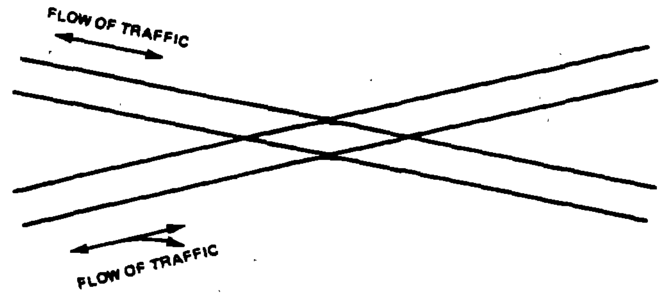


FIGURE 11-9. SCHEMATIC LAYOUT OF A SINGLE SLIP SWITCH

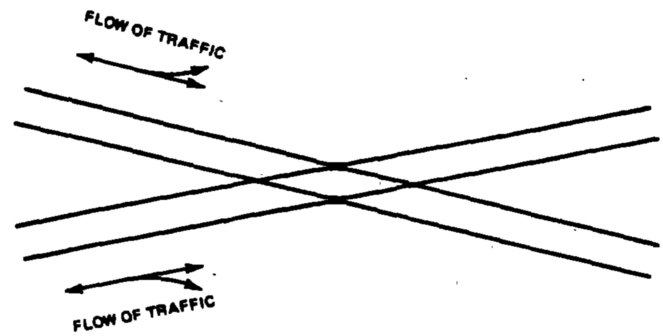


FIGURE 11-10. SCHEMATIC LAYOUT OF A DOUBLE SLIP SWITCH

- Lap Switch--A compound switch in which two split switches are in close proximity. It allows one track to fan out into three tracks within a shorter distance than two independent split switches would. A schematic diagram of a lap switch is shown in Figure 11-11.

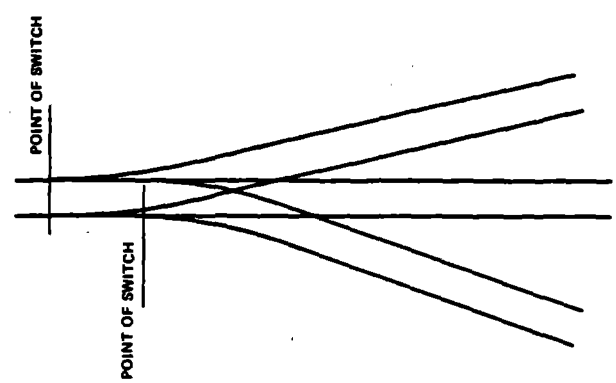


FIGURE 11-11. LAP SWITCH

- Double Turnout (Three-Throw Point)--A type of switch that has a similar geometric configuration to a lap switch. In a double switch the two switch points are so closely located that the two turning flows fan out to these tracks at virtually the same point. A double turnout is used to accomplish a fan-out of car flows into three tracks at one point. A double switch is more difficult to insulate because of its complexity.

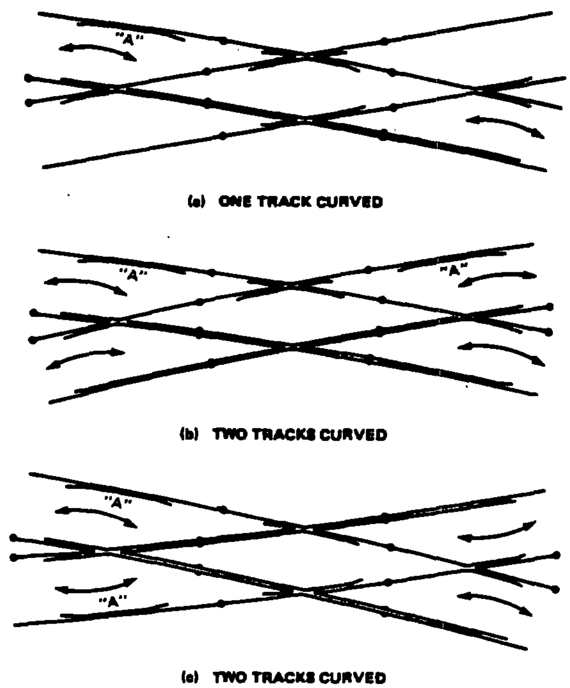
11.4.2.2 Frogs. There is a variety of frog types. A brief description and the proper usage of each frog type are given below:

- Spring-Rail Frog--A frog having a movable wing rail which is normally held against the point rail by springs, thus making an unbroken running surface for wheels using one track, whereas the flanges of wheels on the other track force the movable wing rail away from the point rail to provide a passageway. A spring-rail frog may be used in main tracks, where traffic is predominantly on the main track side of the frog, and in yard tracks, but only when rigid frogs are not available. Spring frogs should only be used when one can insure that the supporting tie condition will be well maintained. A poor tie condition may result in movements and deflections in the frog which can cause derailments.
- Railbound Manganese Steel Frog--A frog consisting essentially of a manganese steel body casting fitted into and between rolled rails and held together with bolts. Railbound manganese steel frogs should be used only on heavy traffic lines.
- Solid Manganese Steel Frog--A frog consisting essentially of a single manganese steel casting. A solid manganese steel frog may be used as an alternate to a railbound manganese steel frog. The solid frog will require less maintenance in severe applications because it has fewer joints to work loose, but it has a consequentially higher initial cost.
- Bolted Rigid Frog--A frog built essentially of rolled rails, with fillers between the rails and held together with bolts. Bolted rigid frogs may be used in yard and industry tracks where traffic is light on both sides of the frog, but only when self-guarded frogs are not available or when it is desirable to utilize available second-hand frogs.
- Self-Guarded Frog (Flange Frog)--A frog provided with guides on flanges above its running surface which contact the tread rims of wheels for the purpose of safely guiding their flanges past the point of frog. Self-guarded frogs can be used in yard tracks, and they may be used in main tracks where speed does not exceed 30 mph. (Note: Guard rails may be used with self-guarded frogs when conditions justify.) Self-guarded frogs (which may be manganese steel) by their nature do not adapt themselves to any but low-speed uses because the necessarily short guard flange produces an abrupt directing action. This results in a rougher ride than other types with separate guard rails. generally, a speed below 20 mph is much preferable to the 30 mph limit cited above. For the general nature of this discussion, note should be made that self-guarded frogs may only be used where the wheel tread width is uniform. The outside of the wheel strikes the guard flange of the frog to provide the guarding action. Equipment, such as maintenance equipment, not fitted with A.A.R. standard wheels may have difficulty negotiating self-guarded frogs. They may not, therefore, adapt themselves to street or industrial (non-common-carriers) use.

11.4.2.3 Guard Rail. Guarding becomes important for crossings with smaller angles, and crossing on curved tracks. The AREA manual for Railway Engineering specifies the guidelines for guarding at crossings as:

- The points of end frogs of angles below 50 degrees shall be guarded, and the same requirement shall apply to greater angles if the track is curved in excess of a 6-degree curve. The points of end frogs shall also be guarded on an electric railway track for all angles.
- If a track is curved through a crossing in excess of a 6-degree curve, the inside rail of such curve shall be equipped with a guard rail throughout.
- Special guard rails shall be furnished with crossings. It is recommended that standard guard rails be used when space permits, but they shall not be furnished with every crossing unless specifically called for.

A diagram showing the typical guarding arrangements when guarding is required because of track curvature is given in Figure 11-12.

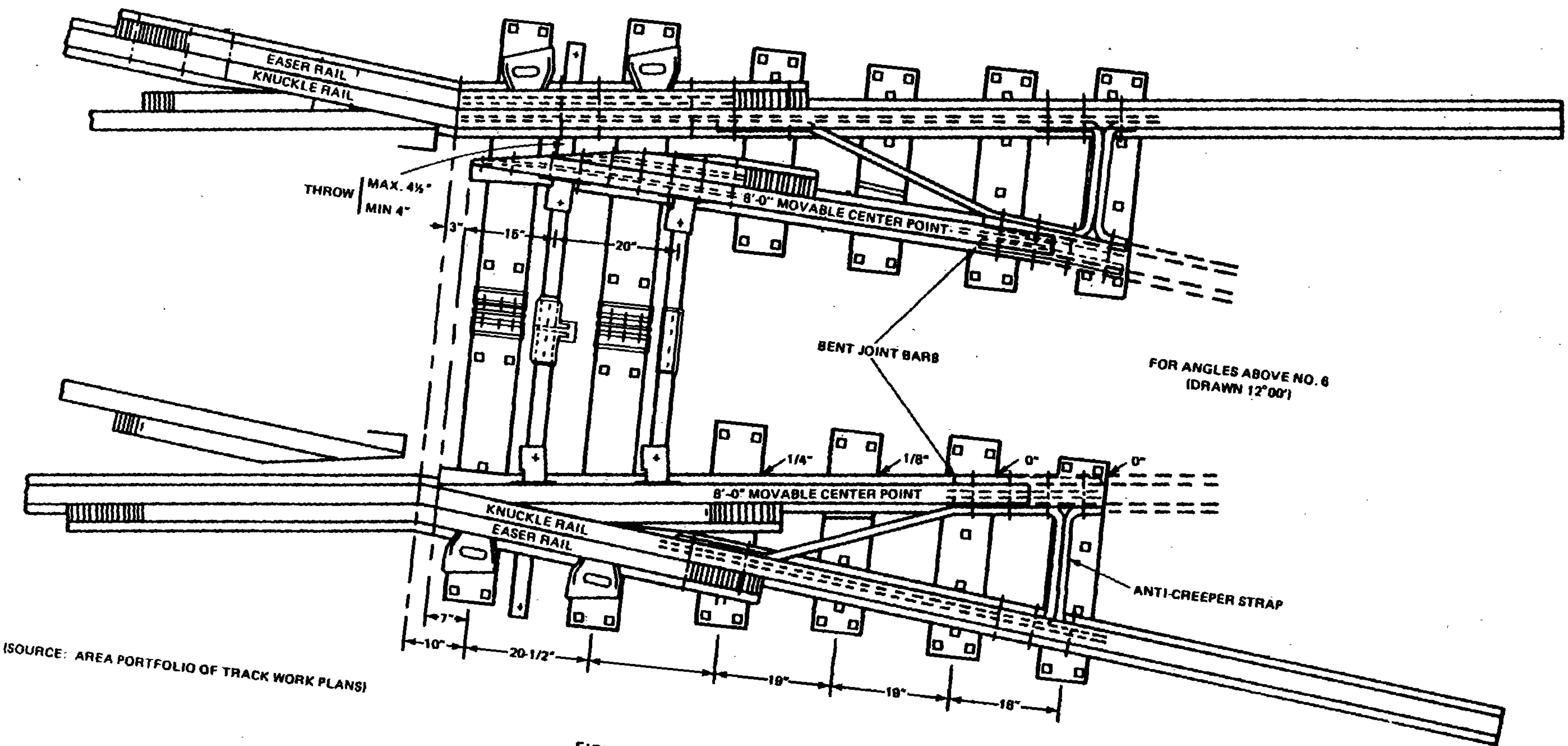


Guard rails marked "A" should have widened flangeways when required by curvature and should be furnished with crossing when specified.

Source: AREA Portfolio of Trackwork Plans

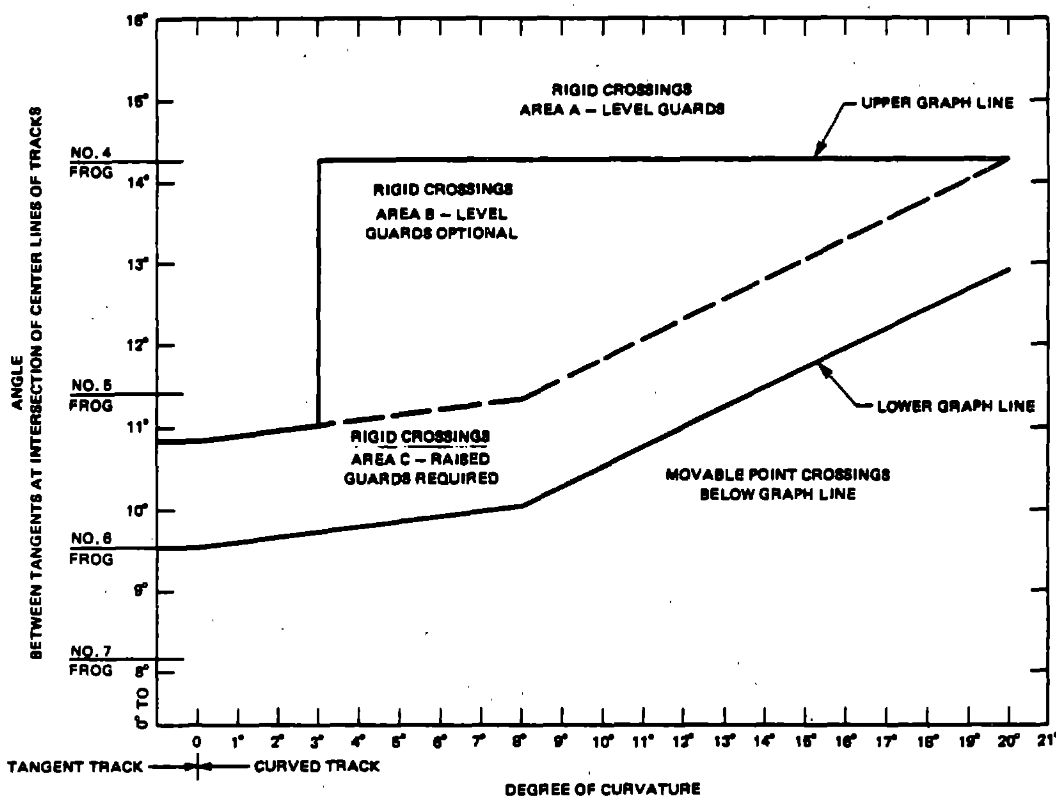
FIGURE 11-12. DIAGRAMS SHOWING TYPICAL GUARDING ARRANGEMENTS REQUIRED BECAUSE OF TRACK CURVATURE

11.4.2.4 Movable-Point Crossing. A movable-point crossing is a type of crossing for small angles in which each of two center frogs consists essentially of a knuckle rail and two opposed movable center points with the necessary fixtures (see Figure 11-13). Movable-point crossings are recommended by AREA under certain conditions for intersection angles below 14° 15'. Information on the recommended limitations for crossings with rigid center frogs is given in Figure 11-14.



(SOURCE: AREA PORTFOLIO OF TRACK WORK PLANS)

FIGURE 11-13 MOVABLE POINT CROSSING



NOTES:

1. The graph shows minimum angles between tangents at intersection of center lines of track for which rigid center frogs may be used as referred to on Plan Basic No. 700.
2. For curved track the center line of track having the greater degree of curvature within the limits of the diamond of the crossing shall apply.
3. For crossings in the Area C between the lower solid graph line and the dash graph line raised guards are required to provide effective guarding. For crossings in the Area B between the dash graph line and the upper solid graph line, level guards will provide sufficient guarding, but raised guards are recommended to protect the frog points from flange wear. For crossings in the Area A above the upper solid graph line, level guards are recommended.
4. Where raised guards are specified, the inside guarding face shall be 1" higher than the top surface of the frog.

Source: AREA Portfolio of Track Work Plans

FIGURE 11-14. GRAPH SHOWING LIMITATIONS FOR THE USE OF CROSSINGS WITH RIGID CENTER FROGS

11.4.2.5 Switch-Throwing Mechanisms. Various methods are available to throw switches. Switch-throwing mechanisms may be classified as follows:

- Switch stand manual method
- Spring switch
- Power switch machine
  - Electric machine
  - Hydraulic machine
  - Pneumatic machine.

The power switch can be thrown by one of the following methods:

- Hand thrown (if necessary)
- Remote control from the ground
- Remote control from a moving train.

11.4.3 Evaluation Criteria

One major problem engineers will face in the yard design process will be to select the hardware type to be used at the new yard from among the many available hardware types. The major criteria in the selection process of the hardware should be:

- Performance of the system
- Lifespan of the system
- Operation and maintenance costs
- Weather capability
- Availability of power
- Installation cost, including the capital cost of the equipment.

These selection criteria do not necessarily have the same weight. One criterion can dominate the others in certain cases.

CHAPTER 12: HUMP GRADE DESIGN AND RETARDER PLACEMENT

12.0 GENERAL

Hump profile design is one of the major tasks in the overall design of a hump yard. A poorly designed hump profile can yield various types of undesirable phenomena, such as a bottleneck at the hump or a high rate of car and cargo damages. Also, the retarder system is one of the most expensive items in the hump yard. Thus, a careful design is essential.

This chapter is intended to present the basic theory and methodology required in the design of the hump profile and the placement of retarders. The first topic, Basic Theory, deals with the basic physics of motion of a car along the track. This topic also deals with the concept of velocity head, velocity head adjustment factors, and other fundamental rules used in profile design. The second topic, Car Rollability Distributions, describes the characteristics of rolling resistance and various types of factors that affect the rolling resistance of a car. The third topic, Retarders and Retarder Configurations, describes various retarder and retarder configurations most commonly used in hump yards. The fourth topic, General Approach to Profile Design, describes the conceptual flow of work and the rules of thumb used in profile design. The fifth topic, Manual Profile Design Procedure, describes a step-by-step method of designing a hump profile using a manual method. The sixth topic, Computer-Assisted Profile Design Procedure, describes a step-by-step method of designing a hump profile using the PROFILE program.

12.1 BASIC THEORY

12.1.1 Problems in Designing a Hump Profile

The classification of cars in the hump yard is accomplished by pushing a string of cars single-file over a hump and switching cars to various classification tracks. Cars are uncoupled right after the center of gravity of the car passes the hump crest. From that point on each cut of cars is a free moving body whose energy of motion is due to the downward grade along the hump track. (A schematic representation of the hump area is shown in Figure 12-1.) Essentially each car has different rollability (or rolling resistance) and thus, without controlling the cars' speeds at certain points along the track, collisions are inevitable. The cars' spacings and speeds along the route from the hump crest to the classification track are controlled by retarders. Here cuts can be single or multiple, but the subsequent discussion assumes single-car cuts.

In the switching area, a minimum separation of approximately 60 feet is generally required for cars being switched to different tracks. If this separation is not achieved, the switch cannot be thrown for the trailing car and the trailing car is switched to the wrong

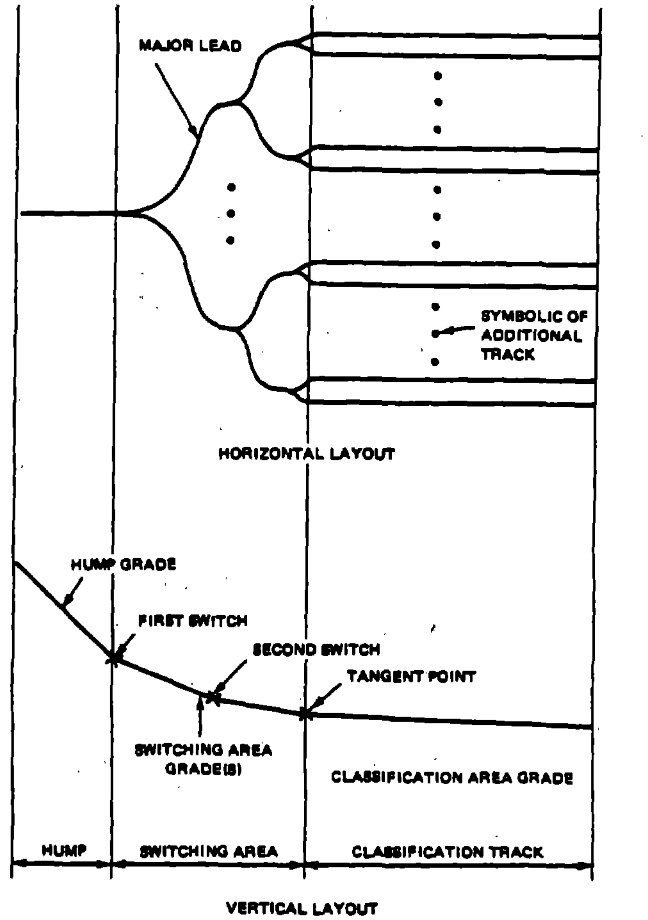


FIGURE 12-1. HORIZONTAL AND VERTICAL LAYOUTS OF A HUMP YARD

classification track.[†] This problem of maintaining sufficient car separation (to avoid misswitching cars) is compounded by the fact that cars have widely different values of rolling resistance; consequently, the easy rolling cars tend to overtake the hard rolling cars. By properly monitoring the behavior of each car and decelerating the easy rolling cars, cars can be guided through as many as a half-dozen switches to their proper classification tracks.

When a car has reached the beginning of a classification track (a tangent point) it may be required to roll as far as 3,000 feet or as little as 100 feet, depending on the number of cars already on the classification track to which it is being switched. Because of this great disparity of distances and the different rolling behavior of cars, the velocity of each car must be adjusted so that severe impacts do not occur on the classification tracks. At the same time, cars must have sufficient energy to couple with other cars already on the classification tracks.

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[*] This chapter was developed with the generous cooperation and inputs from Messrs. B. Gallacher (Southern Pacific), J. Wetzel (CONRAIL), M. Anderson (Union Pacific), and Vinay Mudholkar (Boston and Maine).

[†] The assumption that a 60-foot separation is required for effective switching is an approximation. Actually this distance separation should be a function of the switch length, the time required to move the switch, the velocity of cars over the switch, plus a safety factor.

The objectives in designing a hump profile and corresponding retarder system are three fold:

1. The hump system must have a sufficiently high hump speed.

2. The impact of cars during coupling on the classification tracks should be minimal.

3. The probability of misswitching must be small.

The set of objectives above can be interpreted as: (1) to create and maintain sufficient separation between consecutive cars in the switching area to permit satisfactory switching operation and (2) to minimize impacts between cars. Both (1) and (2) must be satisfied under a specified hump speed.

12.1.2 Motion of a Car Along the Track

The motion of a car rolling under gravity from the hump crest to the classification tracks is quite complex. Most of this complexity is due to the non-uniform, variable nature of the resistances tending to impede a car's motion.

A number of methods exist by which the car's motion may be modeled. Here we will describe a simplified model that is concise enough to show the basic theory of a car's movement along the track.

Let us consider a case where a car is rolling down the track between two points, point 1 and point 2 as shown in Figure 12-2. We assume that the inclined track has a constant grade between these two points. If we denote the weight of the car by W (i.e., mg), then the force F_t accelerating the car which is a component of the weight, works parallel to the direction of motion.

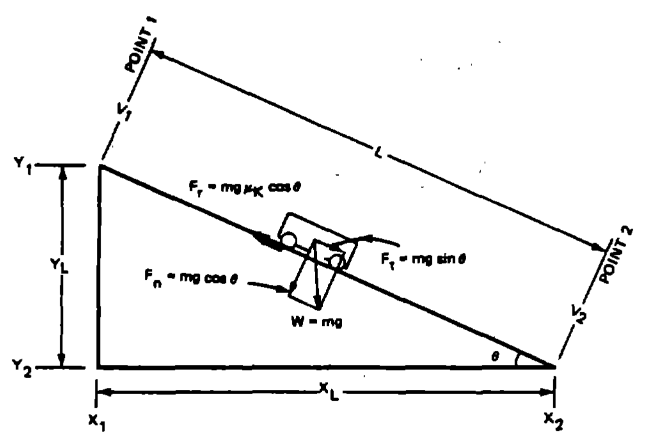


FIGURE 12-2. FORCES WORKING ON A CAR

F_t is expressed as

$$F_t = W \cdot \sin\theta \; . \qquad (12.1)$$

Also, the force which the car exerts normal to the track surface over which it moves, F_n, is expressed as

$$F_n = W \cos\theta \; . \qquad (12.2)$$

Experience shows that the functional force, F_r, is proportional to the force F_n, or

$$F_r = \mu_k \cdot W \cos\theta \; . \qquad (12.3)$$

If we denote the acceleration of the car by a, then the resultant force of F_t and F_r, F, expressed as

$$\begin{aligned} F &= ma \; , \\ &= F_t - F_r \; , \\ &= W \sin\theta - \mu_k W \cos\theta \; , \end{aligned} \qquad (12.4)$$

where m = mass of the car.

Since we know that the weight of the car W = mg, we obtain

$$a = g(\sin\theta - \mu_k \cos\theta) \; , \qquad (12.5)$$

where μ_k = functional coefficient or rolling resistance of the car, and

θ = angle between the track surface and the horizontal plane.

The car will accelerate if a > o, travel with a constant speed if a = o, and decelerate if a < o. From Eq. (12.5) if a = o (or the car travels with a constant speed), we have

$$\mu_k = \tan\theta \; . \qquad (12.6)$$

Equation (12.6) says that the rolling resistance of a car is expressed as the tangent of the angle of the grade (i.e., the slope of the grade) on which the car is moving with a constant speed. We know that the slope of a 100% gradient is equivalent to $\tan\theta = 1$, and also that 2000 lbs = 1 ton. In addition, we know that μ_k is defined as the ratio of two forces. So, using these facts we come up with the relationship that

$$\begin{aligned} 100\% \text{ grade} &<=> 1 \text{ ton/ton} \; , \\ &<=> 2000 \text{ lbs/ton} \; , \end{aligned} \qquad (12.7)$$

therefore,

$$1\% \text{ grade} <=> 20 \text{ lbs/ton} \; .$$

Let us assume that the speed of the car at point 1 is V_1, then the speed of the car at point 2, V_2, is expressed as

$$V_2 = V_1 + a \cdot t \; , \qquad (12.8)$$

where t = time required for the car to travel between points 1 and 2. The distance between points 1 and 2 is L, which is expressed as

$$L = V_1 t + \frac{1}{2} a t^2 \qquad (12.9)$$

Eliminating t from Eqs. (12.8) and (12.9) we obtain the acceleration of the car, a, expressed as a function of the initial speed, V_1, the final speed, V_2, and the distance between the two points, L

$$a = \frac{V_2^2 - V_1^2}{2L} \; . \qquad (12.10)$$

From Eqs. (12.5) and (12.10), we obtain

$$\frac{V_2^2 - V_1^2}{2L} = g(\sin\theta - \mu_k \cos\theta) \; . \qquad (12.11)$$

Equation (12.11) can be rewritten as

$$\begin{aligned} \frac{V_2^2}{2g} &= \frac{V_1^2}{2g} + L \sin\theta - \mu_k \cdot L \cos\theta \; , \\ &= \frac{V_1^2}{2g} + Y_L - \mu_k X_L \end{aligned} \qquad (12.12)$$

or

$$\frac{WV_2^2}{2g} = \frac{WV_1^2}{2g} + WY_L - W\mu_k X_L , \qquad (12.13)$$

where Y_L = elevation difference between points 1 and 2,
X_L = horizontal distance between points 1 and 2.

Equation (12.13) expresses that the kinetic energy at point 2 is equal to the sum of the kinetic energy at point 1 and the potential energy due to the elevation difference between points 1 and 2 minus the energy loss due to rolling resistance between the two points.

In Eq. (12.12) the V^2 term is called the energy head, or

$$H_e = \frac{V^2}{2g} , \qquad (12.14)$$

where H_e = energy head, in feet.

Using the energy head concept, Eq. (12.12) can be rewritten as

$$H_{e,2} = H_{e,1} + Y_L - \mu_k \cdot X_L . \qquad (12.15)$$

This equation can be plotted graphically as shown in Figure 12-3.

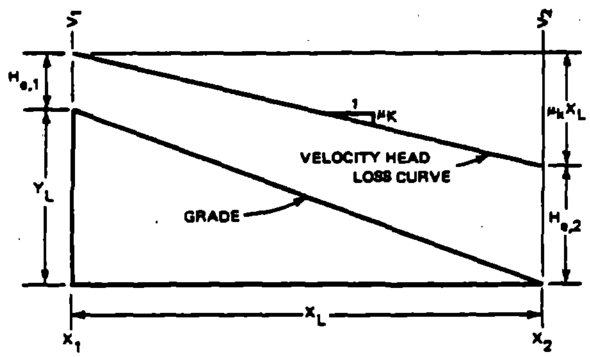


FIGURE 12-3. ENERGY HEAD PLOT

To derive Eq. (12.15), the car rollability, μ_k, was considered a constant, not a velocity-dependent parameter. It should be noted that under the assumption of a velocity-dependent rolling resistance, Eq. (12.15) no longer applies; however, a similar but more complex equation can be derived for this case. This will not be done here.

12.1.3 Adjustments to the Basic Equation

A number of adjustments to the basic Eq. (12.15) are usually required to achieve a more realistic portrayal of the car's motion. The emphasis in this section will be to discuss the basic nature of these adjustments. Each of these adjustments will be discussed in turn.

12.1.3.1 Rotational Energy in Wheels and Axles. The first adjustment is a correction due to the rotational energy stored in the car's wheels and axles. The AREA Manual for Railway Engineering (1976) recommends that this be taken account of by reducing the energy head computed as per Eq. (12.14) by employing the reduction factor

$$H = \frac{1}{1 + \frac{4wr^2}{D^2W}} H_e = \frac{W}{W+I} H_e = kH_e , \qquad (12.16)$$

or

$$H_e = \frac{H}{k}$$

where H = velocity head (translational head) in feet,
W = gross weight of cars, in lb,
w = weight of car's wheels and axles, in lb,
r = radius of gyration of the car's wheels and axles with respect to their axis of rotation, inches,
D = car wheel diameter at tread, inches,
I = additional weight reflecting the rotational energy of the car's wheels and axles.

The AREA recommended values of k are given in Table 12-1. More detailed information can be found in the AREA Manual.

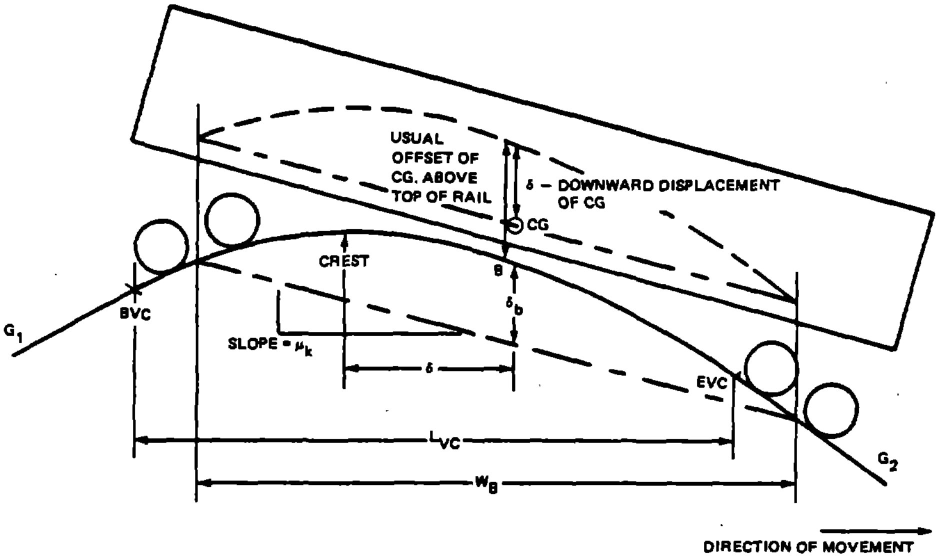
TABLE 12-1.-AREA RECOMMENDED VALUES OF k FACTOR

Design assumption	k factor
Mixed Empty Cars	0.92
Mixed Loaded Cars	0.98
Effect of Rotating Wheels and Axles neglected	1.00

12.1.3.2 Center of Gravity at Hump Crest and Breakaway Point Corrections. An adjustment should be made due to the vertical position of the car's center of gravity at the hump crest. Closely related to the center of gravity, an adjustment should also be considered due to the fact that the car generally must overcome a resistance and thus will not break free precisely at the hump crest. These two corrections will be discussed together here, with the discussion of the center of gravity correction leading naturally into a discussion of the "breakaway point."

The profile one normally works with plots the top of the rail as a function of distance. Usually it is sufficient to take the car's center of gravity as being at the top of the rail, since this just offsets the car's center of gravity downward by an approximately fixed amount. However, at the top of the hump the vertical curve is usually short enough that this approximation is poor (see Figure 12-4). The offset of the center of gravity, δ, can be approximated as the quantity δ_b shown in the figure. δ_b depends upon a number of factors: G_1 = approach grade, G_2 = departing grade, L_{VC} = length of the vertical curve, S_L = separation between the trucks of the car, and μ_k = unitless resistance at the hump.

The quantity μ_b can be found graphically as follows:



G_1 = Approach grade
G_2 = Departing grade
L_{VC} = Length of the vertical curve
W_B = Wheelbase of the car
U_k = Unitless rolling resistance at hump

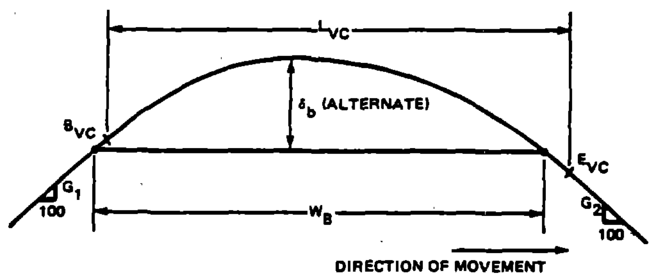
FIGURE 12-4. CENTER OF GRAVITY AND BREAKAWAY POINT CORRECTIONS

1. Find the horizontal chord of length S_L* and slope μ_k† (being sure to adjust for the vertical scale exaggeration) that cuts off the hump crest.

2. Take the vertical distance from the track profile to the midpoint of the chord as δ_b.

Note that this analysis also implies that the separation of the car from its string does not occur at the top of the hump, but rather at the "breakaway point," point B. Best accuracy also demands that this be accounted for in the calculation.

However, these procedures are rather cumbersome to work with. Therefore, most users will probably prefer to sacrifice some accuracy and make the further approximation the δ_b can be measured at the hump crest, referenced from a horizontal chord, as shown in Figure 12-5. This is equivalent to assuming that μ_k is zero. These users probably will also wish to assume that the breakaway point coincides precisely with the hump crest. Obviously, the largest errors in this alternate approach will occur when the car is unusually long or the vertical curve at the hump is unusually short. When the user has experience handling these calculations at the hump, it will be apparent that usually the added refinement of the more accurate representation of δ_b and the breakaway point makes little difference to the car's overall motion. It is left to the user's discretion to choose between the accurate approach in which both δ_b and a breakaway point are considered, or the



G_1 : Approach grade
G_2 : Departing grade
L_{VC} : Length of the vertical curve
S_L : Separation between the trucks of the car

FIGURE 12-5. SIMPLIFIED VERSION OF CENTER OF GRAVITY CORRECTION AT THE HUMP CREST

slightly less accurate but considerably more convenient alternate which considers only (a more approximate) δ_b.

Once δ_b is obtained, by whichever method, it is then subtracted from the initial energy head at the hump crest or at the breakaway point, whichever is consistent with the method being used. This approach is equivalent to reducing the height of the hump crest (or breakaway point) by an amount δ_b.

For the actual design of the vertical curve at the hump crest see Section 12.4.2.3, Vertical Layout Design.

12.1.3.3 Switch Losses. A correction should also be made for each switch the car traverses. Each switch has a retarding effect on a car. The total switch resistance, S_w, is usually expressed in feet of energy head extracted per switch. It is recommended that this total resistance be spread over the length of the switch by converting to the switch resistance per foot of switch, s_w, using the conversion

*Strictly speaking, the length of the chord should be adjusted for the vertical exaggeration. However, even with the exaggeration this adjustment would be negligible for the small slope considered here, and so can be ignored.

†For greater accuracy, the other losses (to be discussed later) should be added to μ_k if applicable.

$$s_w = \frac{S_w}{L_s} , \qquad (12.17)$$

where s_w = switch resistance, feet of energy head lost/feet of switch,

S_w = total feet of energy head lost at the switch, and

L_s = length of the switch, feet.

Expressing the switch loss in this manner permits the car's energy head and thereby the car's motion to be calculated at intermediate points within the switch, if desired. This is done by calculating the switch loss between points 1 and 2 within the switch as

$$s_w(X_2 - X_1) = s_w X_L , \qquad (12.18)$$

and then subtracting this additional term from the basic energy head Eq. (12.15).

No recommendation is made for a value of S_w; this is left to the user's discretion. However, typical values of S_w would be in the range of 0.02 to 0.06 feet of head per switch.

12.1.3.4 Curve Resistance. Each horizontal curve the car traverses creates additional resistance to be overcome by gravity. Horizontal curve resistance is usually expressed in feet of energy head lost per degree of central angle, i.e.,

$$C_R = c_a \Delta , \qquad (12.19)$$

where C_R = total feet of energy head lost for the horizontal curve,

c_a = feet of energy head lost per degree of central angle, and

Δ = central angle, degrees.

No recommendation is made for a value of c_a; however, AREA recommends that curves be compensated at 0.025 ft/degree of central angle. Sometimes curve resistance is also made a function of the degree of curvature. One major railroad recommends the curve compensations shown in Table 12-2. In either case, note that recommended curve compensation values are not necessarily the same as curve resistances, unless the compensation is designed to precisely cancel out the resistance.

TABLE 12-2.-CURVE COMPENSATION

Degree of curve	Compensation,* ft/degree of central angle
0°00' - 3°00'	0.035
3°01' - 6°00'	0.040
6°01' - 8°30'	0.045
8°31' - 10°00'	0.050

*For unlubricated curves. For lubricated curves, values are approximately half of those tabled.

Once a value for c_a is selected, C_R can be computed as per Eq. (12.19). As with switch losses, it is recommended that the curve losses be spread over the length of the curve as an extra resistance. Again, this is done by dividing the total resistance C_R by the length of the curve,

$$c_r = \frac{C_R}{L_{HC}} = \frac{c_a \Delta}{L_{HC}} , \qquad (12.20)$$

where c_r = curve loss, feet of energy head/feet of horizontal curve,

L_{HC} = length of the horizontal curve, feet.

Expressing the curve resistance in this manner permits the car's energy head and thereby the car's motion to be calculated at intermediate points within the curve. This is done by calculating the energy head loss between points 1 and 2 as

$$c_r(X_2 - X_1) = c_r X_L . \qquad (12.21)$$

12.1.3.5 Wind Resistance. Wind resistance can have a considerable impact on a car's motion. It is well known that resistance of static air to the motion of a car is proportional to the square of the speed of the car.

The emphasis here will be to account for the prevailing wind in the design of the yard. This phenomenon is assumed to be represented as a uniformly increased resistance over some portion of or over the entire length of the yard. This effect is simply quantified as an additional resistance term expressed as an equivalent grade. Thus, the additional resistance term

$$w_r(X_2 - X_1) = w_r S_L , \qquad (12.22)$$

where w_r = prevailing wind resistance, feet of velocity head lost/feet

of grade is simply subtracted from the basic Eq. (12.15).

No recommendation is made for w_r. At the user's discretion it can be set to zero or to some positive quantity.

12.1.3.6 Effect of Retardation. Retarders are required so that the user can exert a degree of control over a car during the course of its roll. Each retarder is capable of extracting up to a specified maximum energy head from each car. These maximum values are specified by the manufacturer for each retarder. The retarder is also capable of extracting any smaller amount of energy head from the car. The amount of retardation selected by the user is called the "retarder control policy."

The effect of retardation on the movement of the car could conceptually require quite a complex model. Suppose the total energy head to be extracted by the retarder is E_R. One way the retarder could extract E_R would be to close to maximum retardation, holding it until E_R is achieved, and then open up, allowing the car to roll freely through the remainder of the retarder. An additional complication is that one axle of the car enters the retarder at a time. Therefore any retardation will be applied incrementally until all axles are in the retarder. If the retardation is applied throughout the entire length of the car's roll through the retarder, the retardation will also end incrementally. To simplify the calculations for the retarder, usually it is assumed that retardation starts when the car's center of gravity enters the retarder and ends when the center of gravity leaves the retarder, with a total energy head of E_R extracted uniformly along the entire length of the retarder.

When modeled in this manner, the retardation is mathematically no different from a controlled resistance applied to the car while the center of gravity is within the retarder. Therefore, the total energy head extracted, E_R, can be expressed as an equivalent energy head extracted per foot

$$e_r = \frac{E_R}{L_R} , \tag{12.23}$$

where e_r = energy head extracted per foot of retarder,

L_R = length of the retarder.

This looks just like a resistance, and also like a resistance is handled as a total energy head loss applying between two points, 1 and 2, within the retarder

$$e_r(X_2 - X_1) = e_r X_L . \tag{12.24}$$

Thus, this term simply becomes another energy head loss term to be subtracted from the basic Eq. (12.15).

12.1.3.7 Energy Head Equation with Adjustments. It is useful to rewrite Eq. (12.15) in light of all of the adjustments made in this section.

$$H_{e,2} = H_{e,1} + Y_L - \mu_k X_L - S_W - C_R - W_R - E_R , \tag{12.25}$$

where $H_{e,1} = V_1^2/2gk$ = energy head at point 2 (ft),

$H_{e,2} = V_2^2/2gk$ = energy head at point 1 (ft),

k = rotational head correction factor,

$Y_L = y_2 - y_1$ = drop from 1 to 2 (ft),

$= y_2 - y_1 - \delta_b$ in the first segment, where δ_b indicates the center of gravity adjustment at the hump crest,

μ_k = static car rolling resistance (lbs/lbs),

S_W = switch loss (ft),

C_R = curve loss (ft),

W_R = wind loss (ft),

E_R = retarder extraction (ft),

$X_L = X_2 - X_1$ = horizontal distance between 1 and 2,

$= X_2 - X_1 - \delta$ in the first segment, where δ indicates the adjustment of breakaway point.

Although Eq. (12.25) looks complex, it can be summarized conveniently in a graphical form. Let M represent the sum of the energy losses (ft)

$$M = \mu_k X_L + S_W + C_R + W_R + E_R , \tag{12.26}$$

then Eq. (12.25) can be written as

$$H_{e,2} = H_{e,1} + Y_L - M . \tag{12.27}$$

The relationship expressed by Eq. (12.27) is shown graphically in Figure 12-6. In Figure 12-6, the loss line is drawn straight. However, the loss line will become a nonstraight line when the length X_L contains track segments with different velocity head loss characteristics, such as switches, curves, etc.

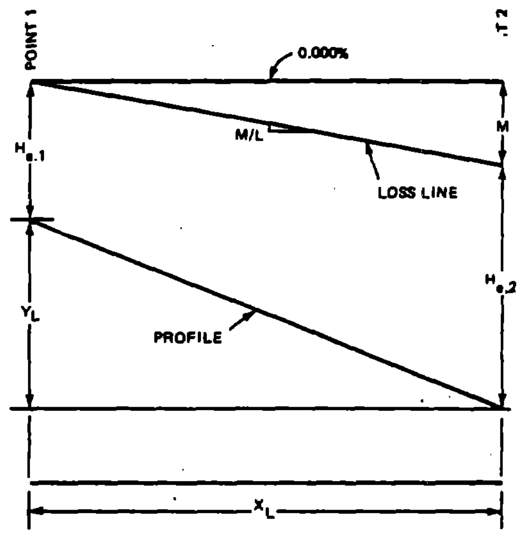


FIGURE 12-6. ENERGY HEAD PROFILE PLOT

12.1.4 Fundamental Rules

There are various basic physical rules which relate to the hump profile design. Some of the key rules are introduced in this section.

12.1.4.1 A Fundamental Velocity Relationship. Here, we will consider a case when two cars with identical rollability are rolling down the hump in sequence. At the hump crest the two cars are moving coupler-to-coupler (i.e., there is no gap between the cars). If we assume that both cars have the identical length, L_c, and also assume that they are humped with the hump speed of V_h, then the hump throughput T_h (number of cars processed per unit time) is expressed as

$$T_h = \frac{V_h}{L_c} . \tag{12.28}$$

This hump throughput, T_h, must be equal to the switching area throughput, T_s. In the switching area the two cars are no longer moving coupler-to-coupler, but are separated by a gap. If we assume the length of the gap is expressed as H, then the throughput at the switch area T_s can be expressed in terms of the speed of the cars in the switch area, V_s, the gap between the two cars, H, and the car length, L_c, such that

$$T_s = \frac{V_s}{L_c + H} . \tag{12.29}$$

As stated before, the throughput at the hump crest must be identical to the throughput at the switch area; therefore equating (12.28) with (12.29) yields

$$V_s = \frac{L_c + H}{L_c} V_h . \tag{12.30}$$

The minimum gap between two cars in order to throw a switch is assumed to be about 60 feet, and the car length is assumed to be about 60 feet. Thus, substituting these values in Eq. (12.30) gives

$$V_s \geq 2V_h . \tag{12.31}$$

The implication of inequality (12.31) for the proper design of a hump yard is simple yet far reaching. If a high-throughput yard with a hump velocity V_h is desired, then the grades, switches, and retarders must be such that the velocity of the slowest-rolling car expected in the switching area be at least $2V_h$. On the other hand, for a yard already in existence, the minimum velocity in the switching area is a controlling restriction on hump throughput because the hump velocity is restricted to being approximately one-half the velocity of the slowest-rolling car expected in the switching area.

12.1.4.2 Location of the First Switch. The location of the first switch (or master retarder, if a master retarder is placed before the first switch) is an important factor in designing a hump system.

The determining factors for the location of the first switch are the desired hump velocity and the hump grade. For a given desired hump velocity and hump grade, there is an optimum location for the first switch in terms of obtaining the maximum headway separation at that point. Locating the first switch either too close or too far from the hump crest will restrict the hump speed. Also, for a given location of the first switch, any increase in hump velocity requires that the hump grade be made steeper for cars to clear the first switch; or if the first switch location is moved away from the optimum location--either toward or away from the hump crest--the hump grade may have to be steepened to achieve a desired hump velocity. For a particular case, the tradeoffs involved in designing the hump grade can be conveniently studied by a plot similar to Figure 12-7, where the maximum hump velocity is plotted as a function of the optimum distance to the first switch with the hump grade as a parameter. Plots similar to Figure 12-7 can be conveniently generated in a digital computer by assuming that the slowest-rolling car is followed by the fastest-rolling car and that there must be a 60-foot headway between the cars at the first switch to allow the cars to be switched to different tracks.

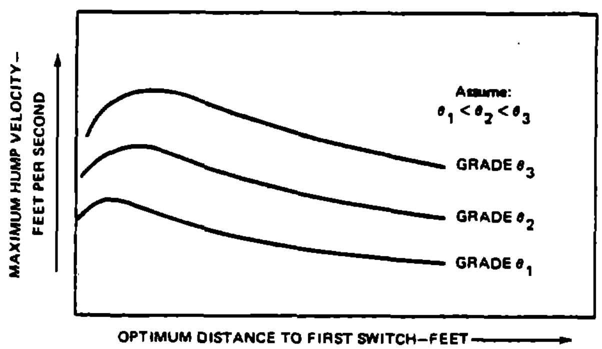


FIGURE 12-7. RELATIONSHIP BETWEEN MAXIMUM HUMP VELOCITY, FIRST SWITCH LOCATION AND HUMP GRADE

12.1.4.3 Location of Retarders. The retarders must be placed in such a manner that cars have sufficient separation at switches and retarders downstream within the given speed limits. Retarder placement studies can be done by studying velocity and distance profiles of a special sequence: a hard-rolling car followed by an easy-rolling car, which in turn is followed by another hard-rolling car. This represents the worst case as far as closing up the headway is concerned.

If the easy-rolling car is allowed to roll freely, it will tend to catch up with the hard-rolling car within a short distance. The first retarder should be placed before the headway is first indicated to be getting smaller than the desired value. The velocity of the easy-rolling car at the exit point of the retarder should be reduced below that of a hard-rolling car through retarder action. The necessary size and location of the second, third, etc., retarder can similarly be established through further computation of distance and velocity profiles. The resulting controlled velocity profile of the easy-rolling car should intertwine the profile of the hard-rolling car, as shown in Figure 12-8.

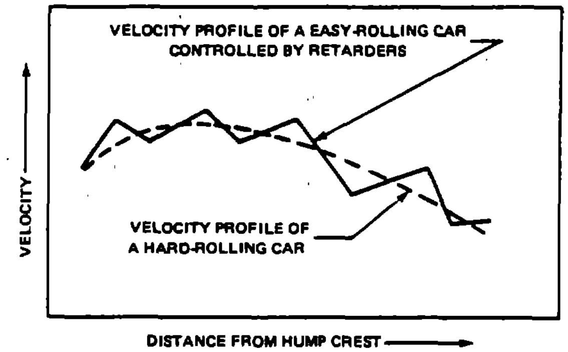


FIGURE 12-8. RETARDER-CONTROLLED VELOCITY PROFILE OF AN EASY ROLLING CAR COMPARED TO THE VELOCITY PROFILE OF A HARD ROLLING CAR

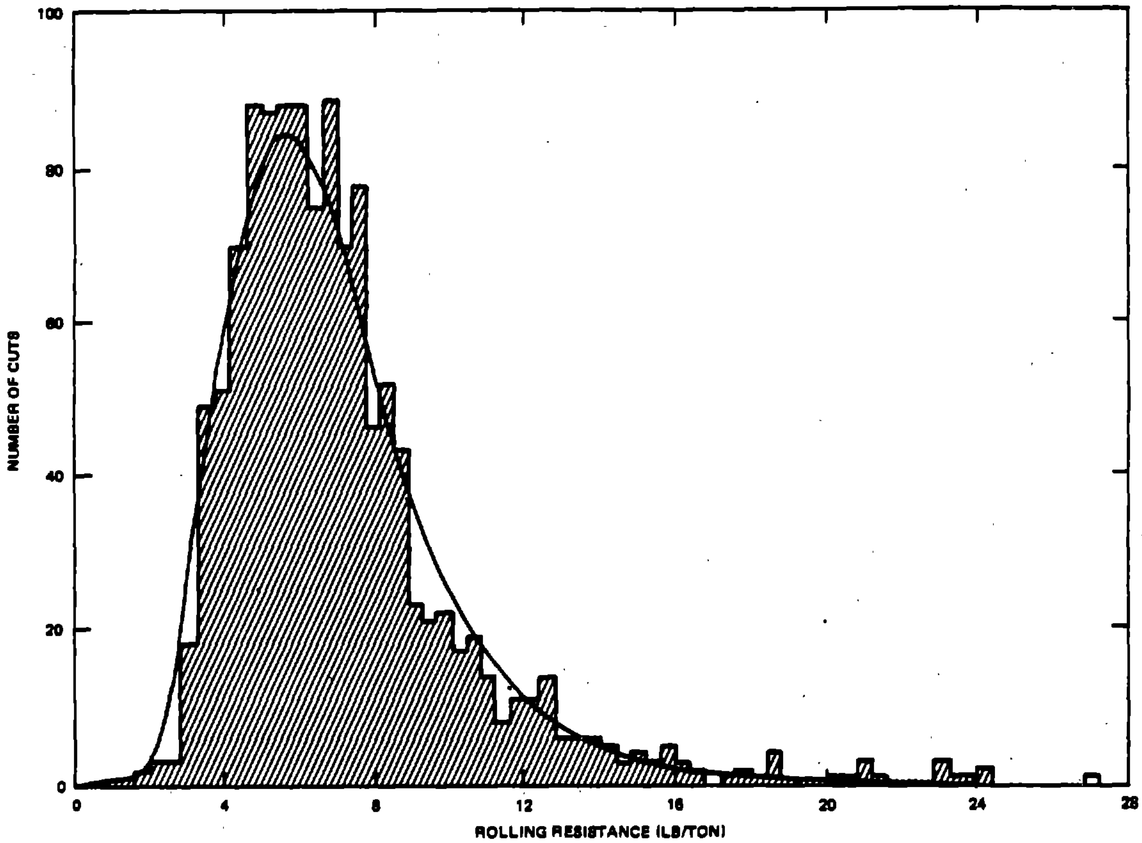
12.2 CAR ROLLABILITY DISTRIBUTIONS

If all the cars humped had identical rollability characteristics, the design of a hump profile would be a simple matter. However, in reality every single car has its own rollability characteristics, and moreover the characteristics of the same car can change while moving along the track depending on factors such as ambient temperature, weather, distance from the hump, speed of the car, etc. Obviously, estimating the rollability characteristics is one of the most difficult but important tasks in profile design. In particular, the knowledge of the car rollability distribution is important, because from this rollability distribution the designer can determine the rollability values for design cars. However, in reality not much is known about the characteristics of car rollability.

Using the data measured in the field and the practical knowledge acquired through experience by operating hump yards, designers have been estimating the rollability values to be used in yard design. Figure 12-9 shows a histogram of rolling resistance data at CONRAIL's Elkhart yard taken in 1957. The data were obtained on the bowl track. The figure shows that the rolling resistance distribution varies widely from 3 lbs/ton to 27 lbs/ton, with a mode at about 6 lbs/ton.

Figure 12-10 shows a scattergram of rolling resistance as a function of speed obtained at the Houston yard of Southern Pacific Transportation Company. From the figure it appears that the location of the car along the track as well as the speed of the car has a considerable effect on the rollability distribution.

Those two figures are presented here only to show how the rollability distribution might look; they are not for use in real profile design.



Plot of Tangent Classification Track Rolling Resistance in Groups 4, 5, 6, 7, and 8 – 1,225 Cuts Total
Statistical Fit of Log Normal Distribution:
μ – 1.86
σ – 0.0394

FIGURE 12-9 HISTOGRAM OF ROLLING RESISTANCE DATA SUPPLIED BY CONRAIL (ELKHART YARD)

12.3 RETARDERS AND RETARDER CONFIGURATIONS

Here we will describe various retarder types and retarder configurations most commonly used in hump yards.

12.3.1 Clasp-Type Retarders

Clasp-type retarders consist of two long steel beams or rails that flank the track rails and rely on friction to dissipate the kinetic energy of a rolling car. As a car rolls down the track, the steel beams are forced toward each other to compress the lower portion of each wheel. The friction between the contacting surfaces of the wheel and the beams causes retardation. Three types of clasp-type retarders are described below.

12.3.1.1 Heavy-Duty Retarder. The heavy-duty type of retarder is the standard retarder for use as a master or group retarder. They can apply variable pressures (i.e., braking forces) depending on car weight to insure that a light car is not lifted off the track.*

The retarder can accomplish multiple openings and closings to insure that a car leaves the end of the retarder at approximately the desired exit speed. To conserve space, the retarder beams sit astride both rails.

Although the retarder characteristics of each manufacturer may vary slightly, the general characteristics of this retarder type can be summarized as:

- Able to remove 0.105 foot of velocity head per foot of retarder length.
- Capable of handling up to 160-ton cars.
- Capable of ±0.1 mph accuracy on exit velocity.
- Total life of retarder is approximately 15 years, assuming one million car passages per year. Brake shoes/beams must be replaced periodically; no frequency data are available.

12.3.1.2 Weight-Responsive Hydraulic Retarder. The weight-responsive hydraulic retarder is a relatively cheap retarder that can be used in small/medium yards as either master, group, tangent-point, or end-of-class track retarders. The hydraulic action merely cocks the retarder in the open "active" position; the weight of the car on the running rail forces the retarder beams into a squeezing position. For this reason, the retardation force is proportional to the weight of the car. Once the car is in the retarder, the retarder

*The weight sensing is accomplished by a weigh-rail preceding the retarder which classifies cars. Typical categories might be: light, medium, heavy, and extra heavy.

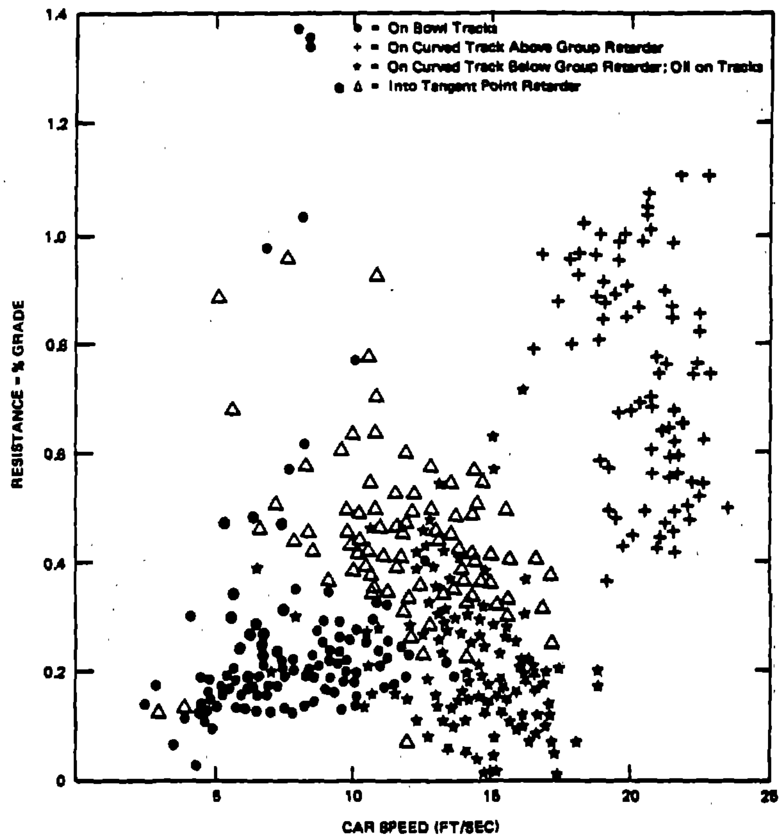


FIGURE 12-10 SCATTERGRAM OF ROLLING RESISTANCE VERSUS SPEED FROM HOUSTON YARD (SOUTHERN PACIFIC)

can open to an "inactive" position, but cannot reclose itself again.* This single closure property has disadvantages, since if the car reaches the specified exit velocity midway through the retarder, the retarder will open, allowing the car to accelerate out of the end of the retarder at higher than the specified exit velocity. To overcome these difficulties it is recommended that the retarder be ordered in 16-foot independent sections with each section independently having the ability to close once. Also, the retarders are generally placed on a shallow grade (i.e., 0.5%) to minimize the acceleration of cars that have been released midway through the retarder.

Presently, all manufacturers allow the retarder beam to sit astride only one rail. It would be desirable to have the retarder beams sit astride both rails to double the braking force accomplished in a specified distance. However, it appears that all current models have the danger of squeezing wheels off cars (i.e., car wheels are press-fit) if the retarder beams sit astride both rails. The engineering design changes necessary to have these retarders sit astride both rails are unknown.

The retarder characteristics are roughly summarized as:

- Able to remove 0.067 foot of velocity head per linear foot of retarder.
- Capable of handling a 160-ton car.
- Capable of ±0.25 mph accuracy on exit velocity.
- No data on life expectancy and maintenance are available.

12.3.1.3 Inert Retarder. An inert retarder is placed at the end-of-class track to keep cars from rolling out the end of the class track onto the trimming leads. This function was previously accomplished by having personnel place skates at the end of the class track. This was both costly and dangerous. These retarders are weight responsive and are always in the closed position. Consequently, a makeup engine would have to pull a cut of cars through a closed inert retarder to take the cut to the departure track. This causes a wheel squeal noise problem.

Inert retarders remove approximately 1.0 foot of velocity head per retarder unit.

12.3.2 Non-Clasp-Type Retarders

Two non-clasp-type speed-control devices are described below.

12.3.2.1 Dowty System. This is a non-clasp-type device, which is called an "oil pressure" retarder. It was designed by Dowty of England. It consists of a series of hydraulic cylinders bolted to the gauge side of the rail. A sliding piston in each cylinder contacts the approaching wheel flange. As the piston is depressed by the moving flange, oil is forced to flow from one chamber to another within the cylinder unit, resembling the action of a shock absorber.

*To cock the retarder into the open "active" position for reclosure would require forces powerful enough to lift the weight of a car.

A unique feature of this device is that it has a speed-sensing capability that allows presetting of an adjustable threshold. If the car speed is below this threshold, the piston will depress with virtually no resistance; otherwise, an internal valve is automatically closed and oil is forced to flow through small orifices, thereby creating resistance to motion. These two operations are illustrated in Figure 12-11, which is a simplifed drawing of the cylinder to the cavity in the piston via the speed-control valve openings. These openings are large enough so that there is virtually no resistance to the oil flow. If the piston is depressed at a speed above the threshold, which is determined by the loading of the calibrated spring and the openings of the speed-control valve, these openings will be closed. Further depression of the piston increases the oil pressure in the cylinder, which raises the pressure-relief valve. Exposure of the orifices allows oil to flow again to the cavity in the piston but with increased resistance.

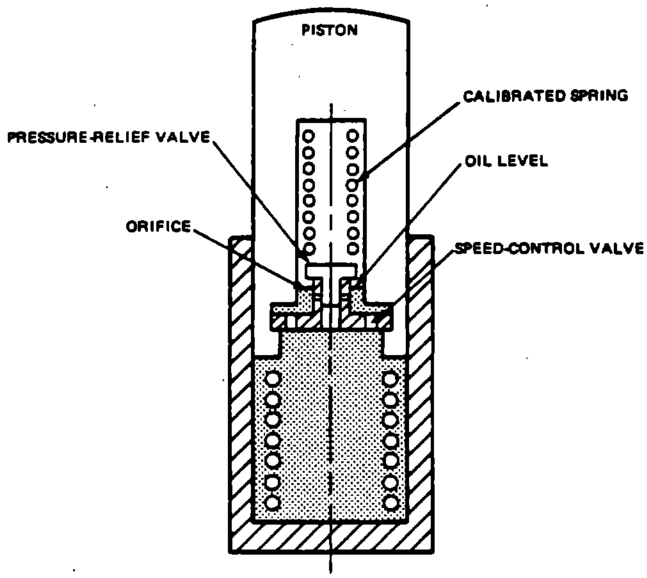


FIGURE 12-11. SIMPLIFIED DRAWING OF DOWTY CYLINDER

The Dowty unit illustrated in Figure 12-11 acts only as a retarder. With a modified unit called a "booster" retarder, cars can be propelled as well as retarded, and such a system has full control over car speed. A high-pressure hydraulic pump is required.

12.3.2.2 Hydraulic Retarder. This retarder, shown in Figure 12-12, was designed by ASEA of Sweden. It employs a rotating cylinder with a spiral cam along its periphery, which engages the passing wheel flange. Like the Dowty unit, this retarder measures the car speed at the beginning of its operating cycle. If the speed is below a threshold, little resistance is developed; otherwise, rotation of the cylinder forces internal oil to flow through the restricting orifices, thereby converting the kinetic energy of the car into heat.

In the hydraulic retarder the cylinder is forced to rotate one revolution for each wheel passage. The rated capacity is 7240 ft-lb per wheel, roughly ten times that of a Dowty unit.

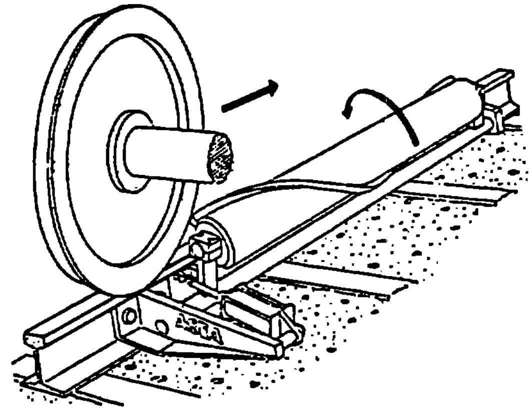


FIGURE 12-12. ASEA SPIRAL RETARDER

12.3.3 Retarder Configurations

Here we will discuss retarder configurations for conventional clasp-type retarders. Basically the clasp-type retarders can be placed in one or more of the following track segments:

- Between the hump crest and the first switch (master retarder)
- On the lead track of each track group (group retarder)
- On the tangent point of each classification track (tangent-point retarder).

Theoretically all combinations of the above retarder locations are possible (see Figure 12-13). They are:

1. Master retarder only
2. Group retarders only
3. Tangent-point retarders only
4. Master retarder and group retarders
5. Master retarder and tangent-point retarders
6. Group retarders and tangent-point retarders
7. Master retarder, group retarders, and tangent-point retarders.

The selection of the retarder combination is usually done based on the performance and the cost of the retardation system. Usually as the number of retarders along the track increases the performance of the system improves, but the cost also increases.

It also must be noted that the performance and cost of retardation systems are very much influenced directly and indirectly by the number of classification tracks. The number of classification tracks influence the cost of the system directly because the total number of retarder segments required increases as the number of classification tracks increases. At the same time, the distance between the hump crest and the tangent point generally increases as the number of classification tracks increases; this may require more and longer retarder sections to obtain the same performance characteristics.

Retarder configurations which are recommended from a cost/effectiveness point of view are the single-control-point systems (master retarder only, group retarder

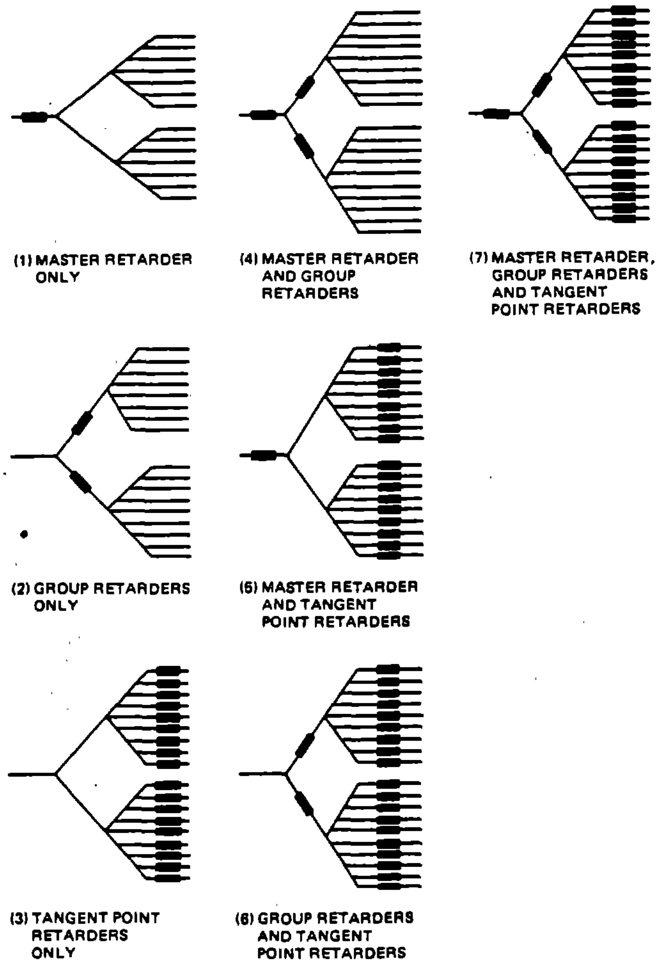


FIGURE 12-13. POSSIBLE RETARDER CONFIGURATIONS

only, and tangent-point retarder only) for small yards,* the two-control-point systems (master retarder and group retarders, master retarder and tangent-point retarder) for intermediate size yards, and the three-control-point system (master retarder, group retarders, and tangent-point retarders) for large yards. The type of clasp retarders used also becomes an important part of the retarder configuration selection. For example, in small yards the retarder types normally installed would be the less expensive weight-responsive hydraulic retarders, while in larger yards heavy-duty retarders would normally be installed.

12.4 GENERAL APPROACH TO PROFILE DESIGN

Various requirements must be satisfied in designing a hump profile and retarder placement. A retarder system must be able to accomplish its purpose, which is to help hump cars with a sufficient speed, with a reasonable misswitching rate, and without damaging cargos and cars. At the same time the retardation system, including the civil engineering design and electrical systems, must cost as little as possible and be easy and inexpensive to operate and maintain. This section describes how to design a hump profile and a retarder system which satisfy (or try to satisfy) the above objectives.

12.4.1 Flow of Work

The exact flow of work will vary depending on whether the designer uses a manual approach or a computer-assisted approach. However, both methods share much in common. The general flow of the hump profile design process is presented in Figure 12-14.

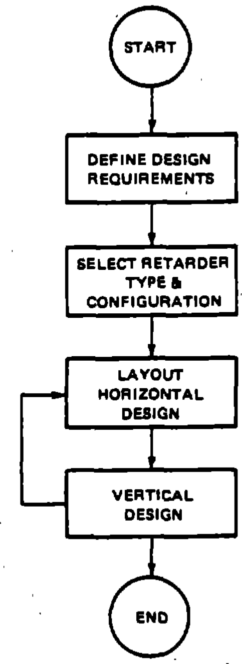


FIGURE 12-14. GENERAL WORK FLOW CHART OF HUMP PROFILE DESIGN

The first task of hump profile design is to define the requirements, which include both the performance requirements and the cost constraints. The performance requirements would include such items as:

- The net hump speed in terms of cars per minute (or miles per hour): If the number of cars to be humped per day is given, then the net hump speed must be estimated based on that number.
- The impact speed requirements: The range of allowable impact speed can be defined in terms of the maximum allowable impact speed for both hard- and easy-rolling cars, and the hard-rolling car's stalling point.
- An alternative to the impact speed requirements would be to define a range of speeds at the tangent point for both hard- and easy-rolling cars.
- The percentage of misswitchings: This can be estimated from the proportion of cars which are outside the rollability boundaries of the design cars.
- The budget allocated for the retardation system.

Based on the above requirements, the designer will then select the retarder configuration(s) to be designed. This process not only determines the physical

*See Chapter 5 for retarder configurations in small yards.

configuration of the retarder arrangement, but also determines the types of retarders to be used. The retarder characteristics to be specified in the process will include:

- Retarder Configuration
  - Master and group retarder system
  - Master, group, and tangent-point retarder system
  - Group retarder system
  - Tangent-point retarder system
  - Master and tangent-point retarder system, etc.
- Type of Retarder
  - Weight-responsive hydraulic retarder
  - Electropneumatic retarder
  - Electrohydraulic retarder
  - Electric retarder
  - Dowty retarder
  - Hydraulic retarder, etc.
- Hump Control Method
  - Manual control of retarders and route selection
  - Manual control of retarders and automatic route selection
  - Automatic control of retarders and manual route selection
  - Automatic control of retarders and route selection.

A dominant factor in selecting the retarder configuration and the retarder type is the number of classification tracks in the yard. This is because for any number of classification tracks there are only a few possible configurations, and often a specific track configuration requires certain retarder capacity (see Tables 11-4 and 11-5 in Chapter 11). There may be a little more flexibility in the selection of the hump control method, though usually as the number of classification tracks increases the more automated the hump control method becomes.

Having determined the retarder configuration, the retarder type, and the hump control method, the next task is to lay out the preliminary horizontal design of track alignment between the hump crest and the tangent points of the classification tracks. The initial horizontal layout includes retarder segments alongside other design elements, where the location and the lengths of the retarders are determined based on the designer's experience and judgment. Here, the objective of the designer should be to attain the shortest distance possible between the hump crest and the tangent point within the constraints, since the shortest distance between the hump crest and the tangent point implies the shortest retarder length along the track and therefore the least cost.

The last step is to design the vertical layout of the hump. The vertical profile is designed to correspond to the base horizontal design prepared in the previous step. In this profile design stage the designer can either use a computer-assisted approach or a manual approach. The horizontal design and the profile design must be completed in an iterative manner. Usually it takes several iterations to find a satisfactory profile design.

12.4.2 Design Method

There are various types of design factors to be considered in profile design. This section describes design methods, which can be applied in the design process.

12.4.2.1 Selection of Retarder Configuration and Retarder Type. The retarder configuration and retarder type are determined based on the combination of various factors such as the number of classification tracks, desired performance level, and allowable capital and operational costs. The information related to retarder configuration is given in Section 11.2, where various geometries between the hump crest and the tangent points are described. The characteristics of various retarder types are described in Section 12.3. These two sections can be used to generate alternative retarder configurations and the retarder type to be used. A very rough cost estimation may be possible using the cost data of the most recent installations at other locations. However, to obtain reliable cost figures, one has to go through a bidding process and obtain data from hardware suppliers.

12.4.2.2 Horizontal Layout Design. The layout prepared is used as the initial layout, which becomes the "seed" of the trial-and-error type profile design process. The initial horizontal layout is a complete design of the track layout between the hump crest and the tangent points, including the switches, curves and retarder segments. Here, the retarder lengths are estimated based on the designer's experience. The required total retarder length along the track, e.g., the total retarder length between the hump crest and the tangent point, can be estimated using the two constraints as described in following calculations.

The speed of a hard-rolling car at the tangent point is faster than the specified speed level. This can be expressed as

$$\left(\begin{array}{l}\text{adjusted}\\ \text{hump}\\ \text{height}\end{array}\right) - \left(\begin{array}{l}\text{rolling}\\ \text{resistance of}\\ \text{a hard-roller}\end{array}\right) \times \left(\begin{array}{l}\text{the distance between}\\ \text{the hump crest and}\\ \text{the tangent point}\end{array}\right) - \left(\begin{array}{l}\text{velocity head}\\ \text{loss due to curves}\\ \text{and switches}\end{array}\right) \geq \left(\begin{array}{l}\text{the velocity head of}\\ \text{the specified speed}\\ \text{at the tangent point}\end{array}\right) \qquad (12.32)$$

The speed of an easy-rolling car at the tangent point is slower than the specified speed level. This can be expressed as:

$$\left(\begin{array}{l}\text{adjusted}\\ \text{hump}\\ \text{height}\end{array}\right) - \left(\begin{array}{l}\text{rolling}\\ \text{resistance of}\\ \text{an easy-roller}\end{array}\right) \times \left(\begin{array}{l}\text{the distance between}\\ \text{the hump crest and}\\ \text{the tangent point}\end{array}\right) - \left(\begin{array}{l}\text{velocity head}\\ \text{loss due to curves}\\ \text{and switches}\end{array}\right) - \left(\begin{array}{l}\text{total}\\ \text{retardation}\\ \text{by retarders}\end{array}\right) \leq \left(\begin{array}{l}\text{the velocity head of}\\ \text{the specified speed}\\ \text{at the tangent point}\end{array}\right) \qquad (12.33)$$

In constraints (12.32) and (12.33), the initial velocity head is the velocity head computed from the humping speed and adjustment for the center of gravity of a car at the hump crest, which are included in the first term, adjusted hump height. The hump height, which is also unknown before designing the geometry, is estimated from the two inequalities. Here, the hump height is the elevation difference between the hump crest and the tangent point.

Constraints (12.32) and (12.33) must be met for each classification track. However, in this state of the design process the estimation of the hump height and the total retarder lengths can be done using the most critical track, which is either the track with the most or least total deflections at curves. If the design philosophy is to compensate the velocity head loss due to curves by varying the elevation of each classification track, the track that has the most total deflection angle (usually the outermost track) becomes most critical. If the design philosophy is to compensate the velocity head loss due to curves by varying the retardation amount of each classification track, then two tracks become critical. These are: (1) the track which has the most total deflection angle and (2) the track with the least total deflection angle. The schematic representations of these two cases are shown in Figures 12-15 and 12-16, respectively.

This method of estimating the hump height and the total retarder length assumes a constant static rollability value for the easy-rolling car. If different static rollability values are assumed for different sections of the hump track, the velocity head loss due to a car's rolling resistance (the second term in both inequalities) must be revised so that it can satisfy this assumption. In this situation, the second term of constraints (12.32) and (12.33) should be replaced by

$$\sum_{\text{for all i's}} \begin{pmatrix}\text{rolling resistance}\\ \text{of a hard-roller}\\ \text{for segment i}\end{pmatrix} \times \begin{pmatrix}\text{the length}\\ \text{of}\\ \text{segment i}\end{pmatrix} \qquad (12.34)$$

If speed-dependent rollability values are assumed, then the estimated average rollability values throughout the hump section (hump crest to tangent point) must be used in the inequalities. This will cause results to be more approximate.

The reference point used here is the tangent point of the classification track. However, any other point along the track can be used as a reference point. For example, a point above 1000 feet downstream from the tangent point could be a reference point.

At the initial design stage of the horizontal layout, the designer must go through various types of estimation such as defining section lengths and assuming the speeds of cars. However, some of the rules developed by engineers who actually designed many hump systems over the years are valuable and can be integrated into this work process. Some of these rules are described below:

- At the hump crest, the vertical curve length is determined based on the ascending and descending grades. The vertical grades will not yet have been designed at this point. This implies that a rough estimate must be used for horizontal design purposes.
- The recommended minimum distance between the hump crest and the entrance point to the master retarder is 70 feet. This is an empirically established value.
- The scale is usually placed between the hump crest and the first switch.
- The minimum effective length of retarders is considered to be approximately 20 feet. There is no maximum limit. However, it should be noted that the retarder section can be shortened by one-half if retarders are installed on both sides of the track. This type of application is possible with pneumatic and electropneumatic retarders, but not with weight-responsive hydraulic retarders.

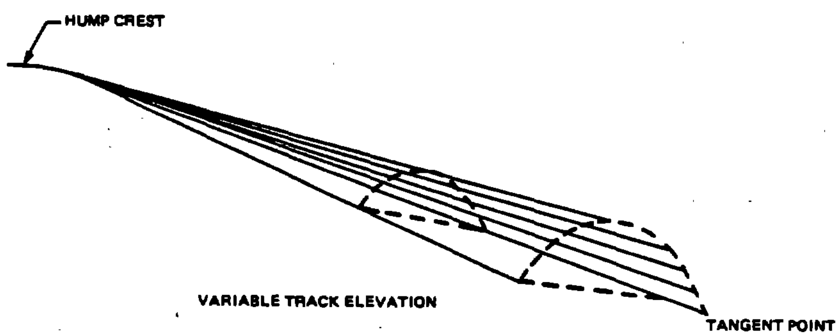


FIGURE 12-15. SCHEMATIC REPRESENTATION OF THE VARIABLE TRACK ELEVATION PHILOSOPHY

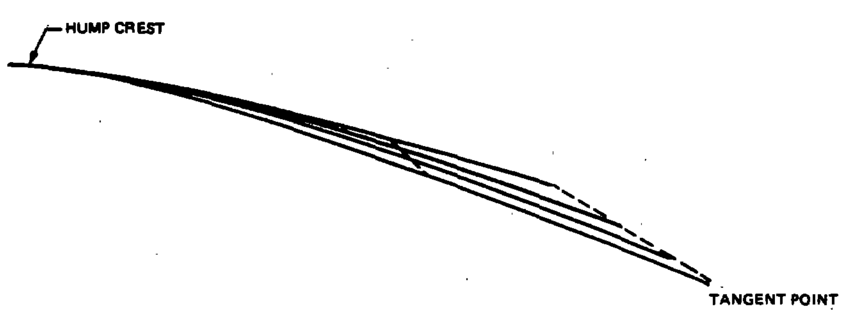


FIGURE 12-16. SCHEMATIC REPRESENTATION OF THE FIXED TRACK ELEVATION DESIGN PHILOSOPHY

- The recommended vertical curve length at the sag is calculated using Eq. (11.4) of Chapter 11. It should be noted that points of switches should not be on the vertical curves.
- The turnout number of each switch is determined based on the expected maximum car speed traveling through the switch. The maximum allowable speed of cars through turnouts are given in Table 11-3 of Chapter 11.
- Turnouts with straight switch points are universally used in the United States.
- The length of the switch lead and the degree of central angle differ depending on the turnout numbers used. See Tables 11-1 and 11-2 of Chapter 11.
- The recommended minimum distance between the end of a horizontal curve and the beginning of another horizontal curve is about 20 feet.
- The required curve length is determined from the central angle, the design speed, and the permissible lateral acceleration in the curve segment as

$$\text{Curve length (ft)} = \frac{\theta\pi}{180} (1.47 \cdot V^2) \frac{1}{A} , \quad (12.35)$$

where θ = central angle (degrees),

V = design speed (mph), and

A = lateral acceleration rate (mph/s).

It is considered reasonable to use $A = 1$ (mph/s) in the above equation.

- The recommended minimum distance between the end of a horizontal curve to the beginning of a retarder is approximately 20 feet.
- The recommended minimum distance between the point of frog to the point of switch of another switch is approximately 20 feet.
- The maximum degree of curve to be used in horizontal layout design is 12.5 degrees, which translates to 459 feet of radius.
- Escape tracks can be placed on the outermost tracks.

12.4.2.3 Vertical Layout Design. The basic principle in designing a hump profile is to select a sequence of grades and retardation amounts in such a manner that:

1. Cars do not violate the maximum speed limits for switches and curves.
2. Cars maintain sufficient spacing at switches and retarders.
3. Cars do not catch up to other cars prior to the tangent point.
4. The speed requirements at the reference points, such as the tangent point, are met.
5. Cars do not violate the minimum speed limit set up by the designer.

The usual approach to this problem is to select a sequence of grades, starting with the steepest grade immediately after the hump crest vertical curve and followed by successively less steep grades into the bowl.

Figure 12-17 shows a schematic velocity head loss plot of both the hard and easy rolling cars from the hump crest to the tangent point for given retardation amounts at the two retarders. The velocity heads of the two types of cars can be defined by assigning the grades along the track. It is important to note that this velocity head loss plot is uniquely defined without having defined the hump profile grades (for the easy-rolling car the amount of retardation at each retarder must be known, however).

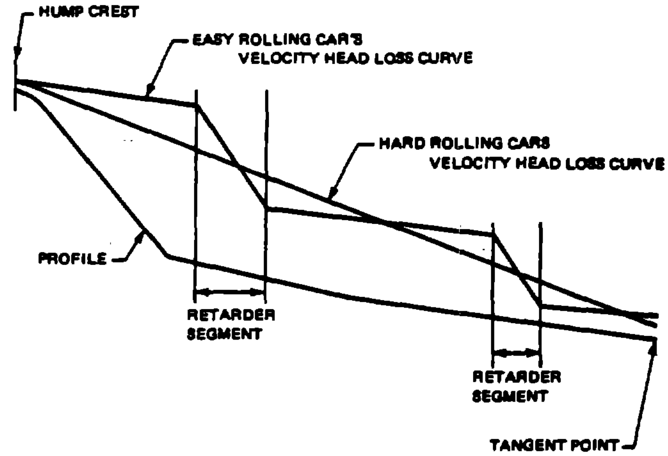


FIGURE 12-17. SCHEMATIC VELOCITY HEAD LOSS DIAGRAM

The retarder lengths are sometimes kept significantly longer than the minimum required lengths for various reasons, such as for fine-tuning of the retardation amount, as a safety reserve in case the car is unusually heavy or has grease on its wheels, and to insure the capability of stopping any car. The retardation amount at each retarder is determined in such a manner that the velocity head loss curve of the easy-roller intertwines the velocity head loss curve of the hard-roller along the track. This attempts to yield sufficient separation between any two consecutive cars.

Some of the design guidelines applicable to the selection of grades along the hump track are:

- The grade the track segment on which the scale is placed should not exceed the given maximum limit. (Usually the recommended maximum grade for the scale section is about 3%.)
- Sometimes the grades in the retarder and switch segments are designed so that they are greater than or equal to the grade equivalent of the hard-roller, so no cars stall in the retarder and switch segments.

The vertical design is thus laid out. The vertical design is checked either by a manual method or by a computerized method. If the design is found satisfactory, then the hump profile design is completed. However, if the design is found unsatisfactory, first examine if changes in grade selection can solve the problem. If not, the horizontal design must be modified and the grade design must be iterated again.

The general design approach described here applies to both the manual and computer-assisted design methods. The only difference of the two methods appears in the vertical design process. Vertical design by these two methods is described in the following two sections.

12.5 MANUAL DESIGN PROCEDURE

The limiting situation in the design of a hump yard occurs when a hard-rolling car is followed by an easy-rolling car, which in turn is followed by another hard-rolling car. The grade must be designed so that the cars satisfy all the requirements given in the previous section (see 12.4.2.3). In this section, we will first present a description of the manual design procedure and will then illustrate the procedure by working through an example.

12.5.1 Description of the Procedure

Some simplifications are inevitable in the manual design of profile grades. The major simplification adopted for this manual design method is that only static car rollability be considered.

The manual technique involves splitting the profile into a series of segments, using Eq. (12.25) and the profile drawing to plot an energy head profile for the car. The beginning and ending points of each segment are considered as points 1 and 2. Note that each point (except the hump crest and very last point) is first considered as point 2 for its upstream segment, and next considered as point 1 for its downstream segment. In this manner, starting from the known initial condition (as computed from the humping speed at the crest), the car's entire energy head profile, and therefore velocity profile, can be obtained. The segments need not be of equal length. Indeed, the plot should be constructed so that segment boundaries fall at natural points of discontinuity, such as the beginning of a retarder. This will generally result in unequal segment lengths. The segment length can be as long as the track section in which the velocity head loss characteristics remain the same, or where cars move with uniformly accelerated motion. For example, a curve segment of track could become one section.

Once the speeds at each end of the segment, V_1 and V_2, are obtained, the average speed in the segment, $\overline{V}$, can be computed as

$$\overline{V} = \frac{V_1 + V_2}{2} . \qquad (12.36)$$

The average speed can then be used to compute the time spent in traversing the segment, Δt, as

$$\Delta t = \frac{X_L}{\overline{V}} . \qquad (12.37)$$

It should also be noted that these computations for $\overline{V}$ and Δt are exact for uniformly accelerated motion.

Let t_1 represent the entry time of the car's center of gravity to the segment and t_2 represent the exit time of the car's center of gravity from the segment. Then,

$$t_2 = t_1 + \Delta t , \qquad (12.38)$$

and, as with distance, the times can be accumulated from one segment to the next, obtaining the total time to any point referenced to the time the first car passed over the hump. The time separation of cars at the hump is

$$T_H = \frac{L_C}{V_H} , \qquad (12.39)$$

where T_H = time separation of cars at the hump (s),

L_C = length of each car (assumed all are equal) (ft),

V_H = velocity of humping (ft/s).

Therefore, the time over the hump of the i^{th} car should be taken as

$$t_{1,i} = (i - 1)T_H \text{ for } i = 1,2,\ldots . \qquad (12.40)$$

$t_{1,i}$ is then used as the t_1 value in the first segment after the hump when computing car i's motion.

The manual examination involves calculating the speed and separation of a special sequence of cars. The conventional method is to examine three cars that start to roll at the hump crest in a sequence of hard-easy-hard (HEH). This conventional method is recommended.

When computing the motion of two identical cars (such as the two H cars in the HEH group), the motion of the second H car, j, is identical to that of the first H car, i.* The only difference between the two cars will be that the t_1 times of the second car will be offset by an amount given as

$$t_{1,j} = t_{1,i} + (j - i)T_H . \qquad (12.41)$$

All the foregoing information may be conveniently arranged into a tabular computation format. A blank computation table, to be filled out for the user's specific problem, is given as Table 12-3. Of course, this table must be worked in conjunction with the energy head plot on the profile.

The only additional information required is the spacing between cars during their roll. This can be most conveniently obtained by plotting a time-space diagram. Each car whose motion is calculated in Table 12-3 should be plotted on the same diagram. All the information required to plot the time-space trajectory of each car is contained in the completed Table 12-3 information for that car. The coordinates of each point to be plotted for each car are the (t_2, X_2) values from Table 12-3 for that car. Figure 12-18 shows a hypothetical sketch of a time-space diagram. The separation (headway) between any two cars can then be scaled directly off the diagram as the difference between the car's distance coordinates at any fixed point in time. The separation can be referenced to distance by reading the corresponding distance coordinate of either the lead or following car, as desired. Note the separations thus obtained are center of gravity to center of gravity.

12.5.2 Application of Manual Design Procedure

The example design using the manual method shown here is taken from the design work done for the East Deerfield Yard of the Boston and Maine Railroad. The proposed East Deerfield Yard has a total of 18 classification tracks. Several alternative retarder configurations were proposed for this yard. The example design shown here is one of the candidate designs considered. The candidate design has a short master retarder and six group retarders (see Figure 12-19). The tangent point location varies from one track to another.

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*So long as they each also receive the same amount of retardation.

TABLE 12-3.—CAR MOTION CALCULATION SHEET

(Easy Rolling Car: Car 2)

Segment no.	No.
Segment length	X_L (1)
Distance from the hump crest to pt. 2	X_2 (2)
Elevation difference	Y_L (3)
Elevation of pt. 2	Y_2 (4)
Speed at pt. 1	V_1 (5)
Velocity head at pt. 1	He,1 (6)
Car rollability loss	$\mu_1 X_L$ (7)
Switch loss	S_w (8)
Curve loss	C_R (9)
Wind loss	W_R (10)
Retarded extraction	E_R (11)
(8) + (9) + (10) + (11)	M (12)
Velocity head at pt. 2	He,2 (13)
Speed at pt. 2 $V_2 = \sqrt{2g k' \cdot He,2}$	V_2 (14)
Average speed ((5) + (14))/2	$\bar{V}$ (15)
Travel time (1)/(15)	Δt (16)
Time car 2 passes pt. 2	t_1 (17)
	t_2 (18)

(Hard Rolling Car: Car 1 and Car 3)

Segment no.	No.
Segment length	X_L (1)
Distance from the hump crest to pt. 2	X_2 (2)
Elevation difference	Y_L (3)
Elevation of pt. 2	Y_2 (4)
Speed at pt. 1	V_1 (5)
Velocity head at pt. 1	He,1 (6)
Car rollability loss	$\mu_1 X_L$ (7)
Switch loss	S_w (8)
Curve loss	C_R (9)
Wind loss	W_R (10)
Retarded extraction	E_R (11)
(8) + (9) + (10) + (11)	M (12)
Velocity head at pt. 2	He,2 (13)
Speed at pt. 2 $V_2 = \sqrt{2g k' \cdot He,2}$	V_2 (14)
Average speed ((5) + (14))/2	$\bar{V}$ (15)
Travel time (1)/(15)	Δt (16)
Time car 1 passes pt. 2	t_1 (17)
Time car 3 passes pt. 2	t_2 (18)

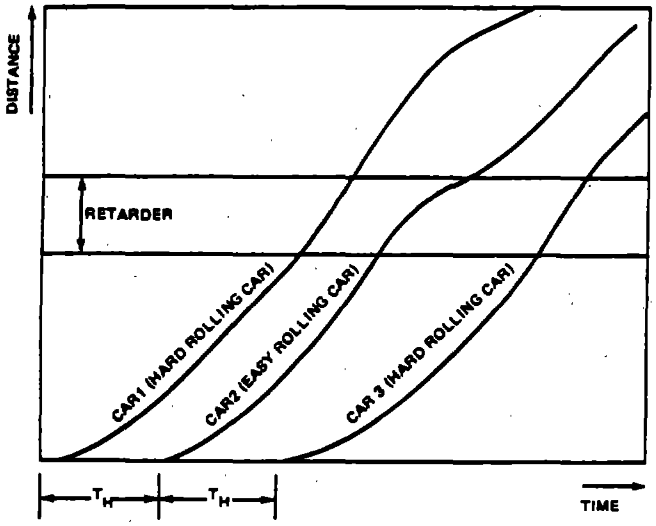

FIGURE 12-18. SCHEMATIC TIME-SPACE DIAGRAM PLOT

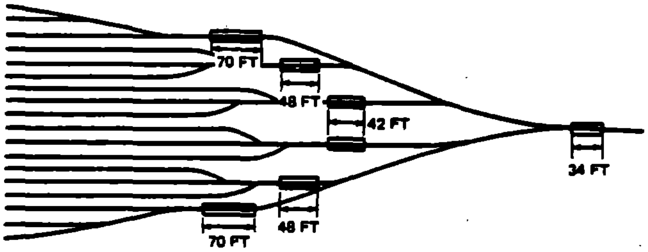

FIGURE 12-19. MASTER AND SIX-GROUP RETARDERS: SCHEMATIC LAYOUT

The hump design objective was to satisfy the following conditions:

- The speed of the hard-rolling car at the tangent point is approximately 4 mph or higher.
- The easy-rolling car's speed at the tangent point is approximately 6 mph or lower.
- There should be no catch-ups before the clearance point of each track.

The major assumptions used in the design process were:

- The hard-rolling car has a rolling resistance of 18 lbs/ton between the hump crest and the entrance to the group retarders, and 12 lbs/ton thereafter.
- The easy-rolling car has a rolling resistance of 2 lbs/ton at all points along the track.
- The velocity head loss due to each switch is 0.06 feet when the car travels along the curved track. The velocity head loss is assumed to be zero if a car travels on the straight track. The value 0.06 is constant for all turnout numbers. The velocity head loss is 0.03 feet for equilateral turnouts.
- The velocity head loss due to a curved section of the track is 0.045 per degree of deflection angle.
- The adjustment factors for the car's center of gravity for the vertical curve at the hump crest are 0.125 feet for the combination of 2.5% ascending and 2.5% descending grades, and 0.133 feet when both ascending and descending grades are 3.0%. The curve lengths are 80 feet for the former and 90 feet for the latter.
- The breakaway point is the hump crest.
- The minimum vertical curve length is 30 times the absolute difference of the two grades expressed in percent. No switch points or retarder segments should be located in a vertical curve section.
- The average car length is 55 feet and the average car weight is 64 tons.
- The extra weight of the car due to wheel rotation is 3.061 tons, which translates to a 5% lower value for gravitational acceleration.
- The wind resistance is zero.

The manual design method is iterative with the trial horizontal and vertical designs being laid out and examined in sequence. The steps in this procedure are to:

1. Determine the car speed constraints at the tangent point and other points along the track.
2. Design a trial horizontal layout.
3. Determine the hump height from Steps 1 and 2.
4. Select the trial grades incrementally, starting from the hump crest.
5. Perform manual calculations and plot the velocity head diagram.
6. Examine the output. If the result is satisfactory, then design the next increment along the track and go to Step 4; if the segment currently being examined is the last segment of the track, go to Step 7. If the result contains catch-up problems, first go to Step 4; if the catch-up problems cannot be solved by changing grades, go to Step 2.
7. Examine if all the segments along the track are properly designed; if so, the design is completed. Otherwise, go to either Step 2 or 4.

The velocity head plot is done for both hard- and easy-rolling cars. The example velocity head plot from the East Deerfield study is given in Figure 12-20. A numerical example of the car motion calculation is given in Table 12-4, and the resultant time-space diagram is given in Figure 12-21. The set of figures and the table show that the hump profile design was performed satisfactorily.

12.6 COMPUTER-ASSISTED PROCEDURE

As a part of the yard design methodology study sponsored by the Federal Railroad Administration, a computerization of the manual procedure with additional enhancements was developed. This computer model is called PROFILE. The purpose of the PROFILE model is to provide the yard designer with an iterative and interactive computer design tool to perform an analysis as described

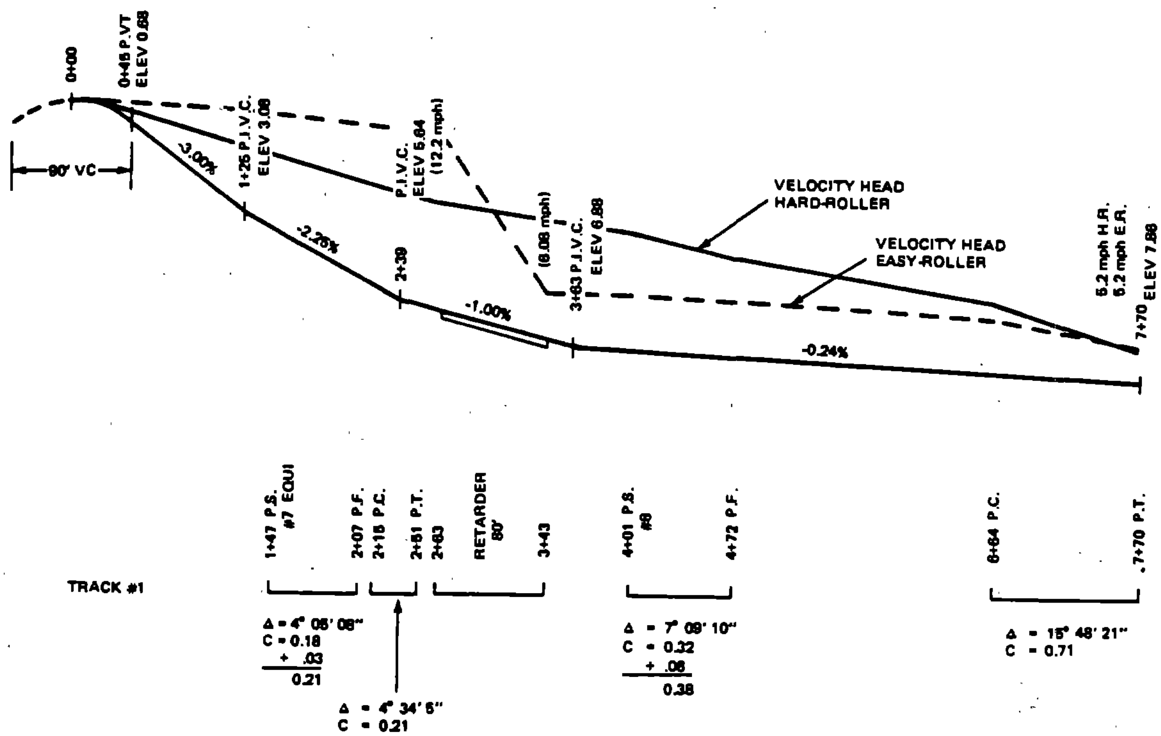

FIGURE 12-20. EXAMPLE OF VELOCITY HEAD PLOT

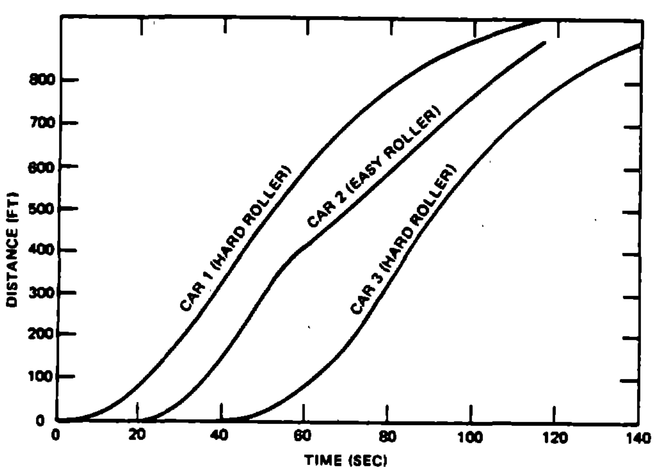

FIGURE 12-21. EXAMPLE TIME-SPACE DIAGRAM

above and to ensure that the design constraints are satisfied. The need for some automation of the hump design procedure has long been recognized. The labor and hours involved in plotting velocity head diagrams and converting them to car velocity, in integrating velocity of cars to obtain time-distance plots, and finally in comparing time-distance plots of cars to obtain headway have severely restricted the number of design alternatives that the yard designer could consider. The PROFILE simulation model is intended to automate this process, and automation also offers the designer the option of selecting a more advanced car rollability model (over the usual static rolling resistance formulation) if desired. PROFILE does not automate the entire yard design process or replace the designer; rather it extends the abilities of the designer by permitting him or her to evaluate many more design alternatives in a shorter time than is possible by the manual process. (See Appendix B for further details.)

12.6.1 Overview of the PROFILE Model

PROFILE is a one-track simulation; that is, the user selects one route from the crest to the bowl and simulates only that route in a run. With repeated runs, all routes to the bowl can be simulated, if necessary. The profile gradient along this route is represented as a series of track sections in the manner previously discussed. All parameters are assumed to be constant within a given track section.

Only single-car cuts are modeled, although longer cuts can be approximated as a single car of unusual length. Within each track section, each car is treated for the purpose of its dynamics as a point mass, the motion of which is assumed to be governed by the following differential equation

$$\frac{d^2X}{dt^2} = \frac{dV}{dt}\alpha + \beta V , \qquad (12.42)$$

$$\alpha = g_e(\tan\theta - \mu_k - c_r - w_r - s_r - e_r) , \qquad (12.43)$$

$$\beta = g_e(-\mu_v - W_V) , \qquad (12.44)$$

TABLE 12-4.-NUMERICAL EXAMPLE OF THE CAR MOTION CALCULATION

Car No. 1 and Car No. 3 (Hard-rolling car)

Seg. No.	X_L	X_Z	Y_L	Y_Z	V_1	He,1	$\mu_X X_L$	S_W	C_R	W_R	E_R	M	He,2	V_2	$\bar{V}$	Δt	t_1	t_3
1	45.0	45.0	0.68 (0.54)	0.68	2.75	0.123	0.405						0.258	3.98	3.37	13.37	13.37	53.37
2	80.0	125.0	2.40	3.08			0.72						1.938	10.91	7.45	10.75	24.12	64.12
3	22.0	147.0	0.50	3.58			0.198						2.240	11.73	11.32	1.94	26.06	66.06
4	1.0	148.0	0.02	3.60			0.009	0.03	0.003			0.033	2.248	11.75	11.74	0.09	26.15	66.15
5	59.0	207.0	1.33	4.93			0.531		0.181			0.181	2.866	13.27	12.51	4.72	30.87	70.87
6	8.0	215.0	0.18	5.11			0.072						2.974	13.52	13.40	0.60	31.47	71.47
7	24.0	239.0	0.54	5.64			0.216		0.137			0.137	3.151	13.92	13.72	1.75	33.22	73.22
8	12.0	251.0	0.12	5.77			0.108		0.069			0.069	3.094	13.79	13.86	0.87	34.09	74.09
9	12.0	263.0	0.12	5.89			0.108						3.106	13.82	13.81	0.87	34.96	74.96
10	80.0	343.0	0.80	6.69			0.480						3.420	14.50	14.16	5.65	40.61	80.61
11	20.0	363.0	0.20	6.89			0.120						3.506	14.68	14.59	1.37	41.98	81.98
12	38.0	401.0	0.09	6.98			0.220						3.376	14.40	14.54	2.61	44.59	84.59
13	1.0	402.0	0.00	6.98			0.006	0.06	0.004			0.064	3.306	14.25	14.33	0.07	44.66	84.66
14	70.0	472.0	0.17	7.15			0.420		0.317			0.317	2.739	12.97	13.61	5.14	49.80	89.80
15	192.0	664.0	0.46	7.61			1.152						2.047	11.22	12.10	15.87	65.67	105.67
16	106.0	770.0	0.25	7.86			0.636		0.711			0.711	0.950	7.64	9.43	11.24	76.91	116.91

Car No. 2 (Easy-rolling car)

Seg. No.	X_L	X_Z	Y_L	Y_Z	V_1	He,1	$\mu_X X_L$	S_W	C_R	W_R	E_R	M	He,2	V_2	$\bar{V}$	Δt	t_2
1	45.0	45.0	0.68 (0.54)	0.68	2.75	0.123	0.045						0.618	6.16	4.46	10.09	30.09
2	80.0	125.0	2.40	3.08			0.080						2.938	13.44	9.80	8.16	38.25
3	22.0	147.0	0.50	3.58			0.022						3.416	14.49	13.97	1.57	39.82
4	1.0	148.0	0.02	3.60			0.001	0.03	0.003			0.033	3.402	14.46	14.48	0.07	39.89
5	59.0	207.0	1.33	4.93			0.059		0.181			0.181	4.492	16.62	15.54	3.80	43.69
6	8.0	215.0	0.18	5.11			0.008						4.664	16.93	16.78	0.48	44.17
7	24.0	239.0	0.54	5.64			0.024		0.137			0.137	5.043	17.05	16.99	1.41	45.58
8	12.0	251.0	0.12	5.77			0.012		0.069			0.069	5.082	17.67	17.36	0.69	46.27
9	12.0	263.0	0.12	5.89			0.012						5.190	17.86	17.77	0.68	46.95
10	80.0	343.0	0.80	6.69			0.080				4.610	4.610	1.300	8.94	13.40	5.97	52.92
11	20.0	363.0	0.20	6.89			0.020						1.480	9.54	9.24	2.16	55.08
12	38.0	401.0	0.09	6.98			0.038						1.532	9.70	9.62	3.95	59.03
13	1.0	402.0	0.00	6.98			0.001	0.06	0.004			0.064	1.467	9.50	9.60	0.10	59.13
14	70.0	472.0	0.17	7.15			0.070		0.317			0.317	1.250	8.77	9.13	7.66	66.79
15	192.0	664.0	0.46	7.61			0.192						1.518	9.66	9.22	20.82	87.61
16	106.0	770.0	0.25	7.86			0.106		0.711			0.711	0.951	7.65	8.66	12.24	99.85

$$g_e = \left(\frac{W}{W + I}\right) G \; , \qquad (12.45)$$

where X = distance from an arbitrary origin, (ft),

V = velocity of the car, (ft/s),

t = time, (s),

α = sum of all static terms contributing to the car's acceleration, (ft/s^2),

β = sum of all velocity-dependent terms contributing to the car's acceleration, (s^{-1}),

g_e = effective acceleration of gravity used to account for energy stored in the rotating wheels of the car, (ft/s^2),

g = acceleration of gravity, (ft/s^2),

θ = angle of the grade below horizontal,

$\tan\theta$ = grade (downgrades taken positive), (ft/ft),

μ_k = static rolling resistance, (lb/lb),

c_r = curve resistance (if the track section is on a curve), (lb/lb),

w_r = wind resistance, (lb/lb),

s_r = velocity head lost in switch (if the track section is a switch), (ft),

e_r = velocity head extracted by retarder (if the track section is a retarder), (ft),

x_L = length of track section, (ft),

μ_V = velocity-dependent resistance coefficient, (lb/lb per ft/s),

w_v = velocity-dependent wind resistance coefficient, (lb/lb per ft/s),

W = weight of the car, (lb), and

I = additional weight of the car to account for the rotation of the wheels, (lb).

Obviously, in any given track section, not all the terms will be applicable. For example, a conventional retarder and a switch would never be found in the same track section. The various parameters are assumed to be constant within each track section; whenever any parameters change, a new track section must be specified. This happens, for example, when specifying the beginning and end of a retarder. Specification of a new track section is also required whenever the grade changes.

The $\beta = 0$ case is the usual static rolling resistance formulation for which computational techniques based on $F = ma$ were developed earlier. However, although this relationship can be easily applied to obtain velocity, integrating the velocities over a varying grade to obtain distance-time plots and hence headways between cars can become tedious. Even when the static rolling resistance formulation is being used, PROFILE has great utility as a quick means of calculation.

Although wind resistance would usually be handled by a V^2 term, in PROFILE only a V term is used. At the low speeds in a hump yard, the curvature of a V^2 relation should be sufficiently slight that it can be satisfactorily approximated by a linear term.

Some critical portions of the model require further elaboration. These points are discussed below.

12.6.1.1 Modeling of Retarders. The retarders treated in the present version of PROFILE are the conventional clasp-type, usually controlled by a process-control computer. PROFILE does not consider the distributed types of retarders offering quasi-continuous control through purely mechanical/hydraulic analog logic systems (as offered by certain European vendors). The conventional retarder system is quite complex, with the process-control computer controlling both the overall amount of retardation as well as the detailed dynamics of the car-retarder interactions while the car is within the retarder. Several algorithms are in use to decelerate the car within the retarder. They are all based on achieving a desired exit speed from the retarder. The algorithms can be roughly categorized into three types, as shown in Figure 12-22 and discussed as follows:

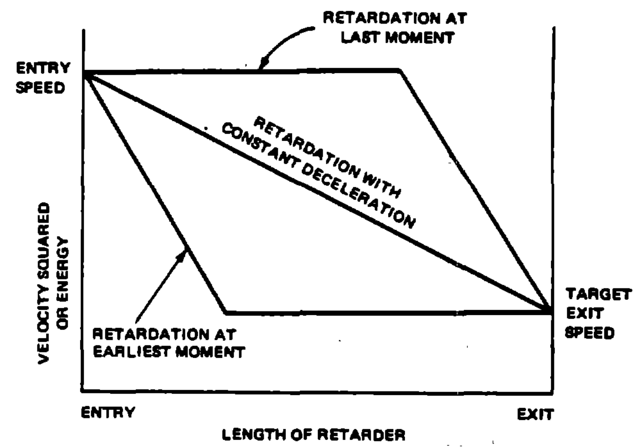

FIGURE 12-22. SCHEMATIC DIAGRAM OF RETARDER DECELERATION ALGORITHMS

Retardation at the Earliest Moment--Retardation at the earliest moment is probably the most common retarder control algorithm (König, 1969; Berti, 1966; Budway and McGlumphy, 1976). The retarder closes as soon as the car enters; when the car reaches the exit velocity, either the retarder opens and the car rolls freely for the rest of the length of the retarder or the retarder opens and closes in an attempt to maintain the car at approximately the desired exit speed. This scheme tends to restrict hump throughput because the car travels at minimum average speed for the length of the retarder. It also causes a disproportionate amount of retarder wear to occur near the front.

Retardation at the Last Moment--This algorithm is based on a prediction of the rollability of the car and the power of the retarder (König, 1969). The retarder initially remains open when the car enters it. Using the predicted parameters, the retarder is then closed just at the time expected to produce deceleration of the car to the desired exit velocity. This scheme generally permits a high throughput because the car moves at maximum speed through the retarder. However, this algorithm lacks a safety margin for cases where the car rolls faster than predicted because of rollability prediction errors, grease on the wheels or rails, or the like. This algorithm also causes a disproportionate amount of retarder wear to occur near the rear of the retarder.

Retardation with Constant Deceleration--Under this algorithm, the retarder either is commanded to open and close several times (Wong and Ratner, 1973) or to exert a constant retardation force (Berti, 1966); in either case, the aim is to achieve the desired exit speed with approximately constant deceleration. Some modern commercial retarder systems achieve this ideal at least approximately (Westinghouse Air Brake Service Manual, 1977). This scheme maintains better throughput than algorithm 1, and it also maintains a safety reserve of retarder power lacking in algorithm 2. It also causes the retarder to wear approximately uniformly throughout.

Consequently, in the PROFILE model, the third type of deceleration scheme, constant deceleration, is assumed to apply. Under constant deceleration, energy (i.e., velocity head) is extracted at a uniform rate during the car's transit of the retarder, and the total amount of velocity head extracted within the retarder, when divided by the retarder length, acts simply as an additional resistance term; hence its appearance in Eq. (12.44). The retardation is assumed to commence when the point mass representing the car enters the retarder; the retardation ends when the point mass exits the retarder.

12.6.1.2 Vertical Curves. The model is capable of handling vertical curves in an approximate manner.[*] A parabolic vertical curve is assumed, which is in keeping with most designs. The method employed utilizes the facts that (1) the slope (i.e., grade) at any point on a parabola is a linear function of distance X, and (2) the slope of the straight line (i.e., the chord) joining any two points on a parabola is equal to the arithmetic mean of the slopes of the parabola at those points. With these facts, the calculations to approximate the car's motion on a vertical curve proceed as follows:

1. Estimate average grade during the next time step Δt as the grade on the parabola at the current point (i.e., at car's position at time t).
2. Calculate position of car at time $t + \Delta t$ using latest grade estimate.
3. Compute grade at car's new position and average grade traversed during time interval Δt.
4. Is new estimate of average grade within 10^{-6} (i.e., 0.0001% grade) of the old estimate of average grade? If yes, the calculation is complete; otherwise go back to Step 2.

To prevent infinite looping should this procedure ever fail to converge, a limit of 10 iterations is placed on the above process.[†] Obviously, the smaller the simulation time step Δt, the more accurate the above procedure.

12.6.1.3 Breakaway at Hump Crest. PROFILE is capable of optionally modeling each car's breakaway process as discussed in Section 12.1.3.2. The more exact method discussed there is used. Depending upon the crest geometry and car length, neither, either, or both trucks of the car can be positioned on the crest vertical curve proper, or on the approach or departure grades. While a direct solution for the breakaway point would be possible, it would require numerous special cases depending upon the above crest and car geometric factors. To avoid these special cases, a simple iterative procedure has been adopted to locate the breakaway point. This procedure uses a simple convergent iterative technique[‡] to locate that chord to the crest grade line whose length equals the car's wheelbase,[§] and whose slope equals the total resistances[**] (see Figure 12-23). The car's breakaway point location (B) and the effective depression of the car's center of gravity at breakaway (δ_c) are given in the program output, both relative to the hump crest.

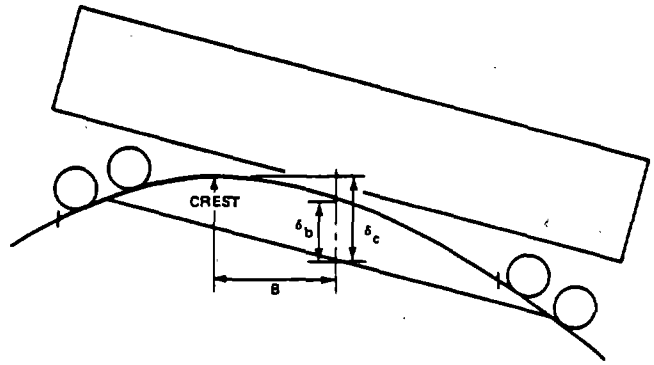

FIGURE 12-23. BREAKAWAY POINT PARAMETERS REPORTED BY PROFILE

The point mass representing the car is assumed to traverse an effective vertical curve grade line from the depressed center of gravity at the breakaway point [(X_{mid}, Y_{mid}) in Figure 12-24] to a point called the "runout point" [(X_r, Y_r) in Figure 12-24]. The runout point is that point where the car's center of gravity may be assumed to become coincident with the top of the rail. It is taken as a half-wheelbase past the end of vertical curve (EVC). This effective vertical curve is constructed to exactly pass through the two points (X_{mid}, Y_{mid}) and (X_r, Y_r), and to have a slope equal to the total resistances at the former point.[††] Having the car traverse this effective grade line insures conservation in energy in the drop traversed by the car's center of gravity. The car's motion on the effective vertical curve is modeled in the same manner as for any other vertical curve, in the manner which was discussed above.

[*] Handling vertical curves in an exact manner would require that the grade (i.e., $\tan\theta$) term be expressed as a function of X in Eq. (12.43). Although a solution to the resulting equation can theoretically be found, it would, in practice, be cumersome to handle.

[†] Using instrumented test versions of PROFILE, convergence was observed in all cases within a maximum of three iterations.

[‡] Interval halving.

[§] Truck center-to-center.

[**] The hump speed is used to compute speed-dependent resistances.

[††] Note that the slope, in general, will not equal the grade at (X_r, Y_r). A cubic rather than parabolic grade line would be required to satisfy the grade line at (X_r, Y_r). However, in practice, the difference between the slope of the vertical curve and the actual grade line at point (X_r, Y_r) is not great. In instrumented PROFILE runs, the largest difference in grades observed was about 1%.

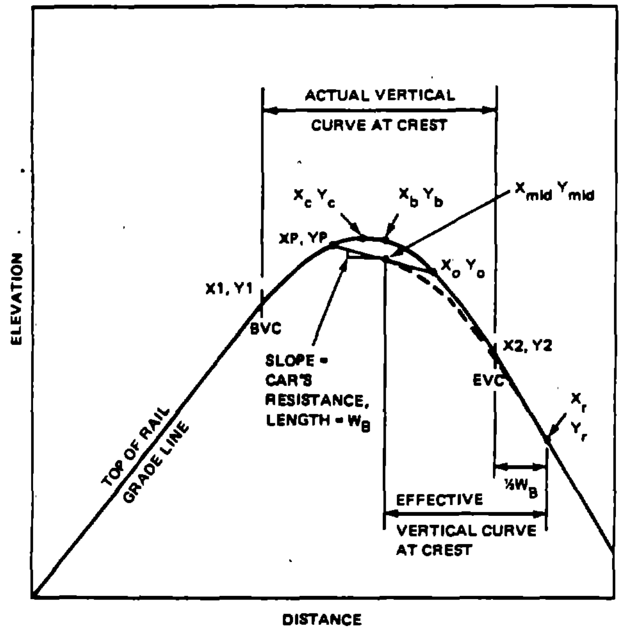

FIGURE 12-24. EFFECTIVE VERTICAL CURVE TRAVERSED BY POINT MASS REPRESENTING CAR'S CENTER OF GRAVITY AT CREST

12.6.2 Program Description

PROFILE is a time-step simulation written in ANSI standard FORTRAN. Events are assumed to occur either at integral multiples of a predetermined time step, Δt, or within the time step for certain easily calculated events (such as a car's entry into a new track section). The time-step method has been selected because of the ease it affords calculating transcendental solutions to differential equations.

The simulation starts by humping the first car at simulation clock time zero. From the length of the cars involved and the hump speed, the hump time for the second car is computed and stored until the simulation clock is equal to that hump time. At the calculated hump time, the second car is humped and put into the system. The hump time for each car is so computed until all cars that the user wishes to put into the system are humped.

Once a car has been humped, movement of cars along the track is accomplished by advancing the simulation clock in increments of Δt. At each time step, the differential Eq. (12.42) is solved for the instantaneous velocities and the distances of cars along the track. Each time a car enters a new track station, the program solves an initial-value problem based on the general solution to the differential equation and the specified configurations of the new track segment. These coefficients are used in subsequent calculations for this car on the track at steps of Δt until the car leaves the track section.

At each time step, the coupler-to-coupler headways between the cars in the system are checked to maintain a safe operating distance between the cars and to avoid misswitching, catch-up in retarders, and collisions. If headway is insufficient, the program writes a warning message to the output file. If a collision occurs or if a car stalls, the program stops and writes a message to the output file. These messages show the stimulation clock time when the catch-up occurred, the distance along the track for each car, and the velocities of the cars at that time. The user may then analyze the output and change retarder placements, the length of the retarder, or any other parameter and start a new computer iteration.

Data on each car are collected at each print interval as specified by the user. For each car the simulation clock time, the instantaneous velocity, the velocity head, the distance from the hump crest, and the distance and time headways from the preceding car are written to and stored in a print buffer. Data in the buffer are written to the output file whenever the simulation stops. If no collision or stall occurs, the simulation stops when the last car has come to the end of the last track section. Figure 12-25 and Tables 12-5 and 12-6 are sample partial outputs.

12.6.3 Description of Input

The first input variables are general: the time step (Δt), the hump speed (mph), the data print interval, switches controlling printing of tables and plots, and the printer width (in characters). To model event occurrences accurately, the time step chosen should be sufficiently small but not too small as to cause an inordinate increase in running time (1 second is usually satisfactory). Data output frequency is controlled by the data print interval variable, which should be chosen in integral multiples of the time step but should never be less than the time step.

Next, the following data for the track sections are specified:

- Length of track section (ft)
- Grade of track (%)
- Rolling resistance, static, easy-rolling car (lb/ton)
- Rolling resistance, static, hard-rolling car (lb/ton)
- Rolling resistance, velocity, easy-rolling car (lb/ton per ft/s)
- Rolling resistance, velocity, hard-rolling car (lb/ton per ft/s)
- If the section is a switch, switch loss, in velocity head (ft)
- If the section is a retarder, amount of retardation to be given easy-rolling car, in velocity head (ft)
- If the section is a retarder, amount of retardation to be given hard-rolling car, in velocity head (ft)
- If the section is a retarder, maximum retardation of the retarder, in velocity head (ft)
- Track section alphanumeric identification.

The static and velocity resistances can be specified separately for each track section for the two types of cars, easy-rolling or hard-rolling. Specify rolling resistances in this manner allows them to vary along the simulated track. If the track segment is a switch or retarder section, additional parameters are required as shown.

Additional data for the cars constitute the final set of information specified to the program. First, the type of car must be specified (easy- or hard-rolling).

Then the car length (feet), the weight (tons) of the car, and an equivalent rotational weight (tons) for the wheels must be given. Each car is associated with static (lb/ton) and velocity-dependent (lb/ton per ft/s) wind-resistance terms. These values may vary depending on the type of car (box car, flat car, gondola, etc.).

12.6.4 Description of Output

The output from PROFILE consists of four parts. The first part is an "echo-back" of the input data (Table 12-5), simply a listing of the user's input given for documentation and verification. The second part, immediately following the car data "echo-back," lists any special events that might have occurred during the simulation, such as a catch-up of two cars within a retarder, a collision between two cars, or a car stalling. Note that if no special events occurred, this portion of the output is omitted.

The third part is the numerical output from the simulation proper. This consists of a series of tables, one table for each car. Table 12-6 is an example of a portion of such a table. Each line in a table gives a number of variables defining the status of that particular car at a point in time. The lines are generally printed at uniform increments of simulated time, although whenever a car enters a new track section an additional line is printed. The print increment is specified by the user and is usually on the order of 1 second.

The fourth output section gives optional line-printer plots of selected variables. These plots, which include relevant annotation, consist of:

- A plot of the yard profile versus distance.
- A plot of speeds of all cars versus distance.
- A plot of distance headways between all cars versus distance (Figure 12-25).

12.6.5 Application of the Computer-Assisted Design Procedure

The sample application problem described in this section is based on a modified specification for the Union Pacific Railroad's Yermo Yard in Southern California. The hump profile design requires several levels of decision making on cost- and performance-related matters as discussed previously. After having determined the type of retarder and retarder configuration to be adopted, the designer must iteratively examine both the horizontal and vertical design to arrive at the final design that satisfies the specified goal.

The application problem discussed here is only one stage of the hump profile design process in which a given profile design is evaluated and modified to a better design through iterations of PROFILE runs.

The design as used in Trial Run 1 (not shown) in this example has a master retarder of 93 feet and three group retarders of 100 feet. Each group retarder leads to 10 classification tracks. The distance between the hump crest and the tangent point of the outermost track is 1061 feet.

The runs for this design were based on the simulation of a conventional hard-easy-hard rolling triplet of cars. A worst-case condition was assumed: The easy-rolling car is going to a nearly full class track so that it must be retarded to a low target speed by the tangent point (6 mph) while the hard-rolling car must penetrate an adjacent empty class track as far as possible so that its retardation is minimal.

The objective of the study was to test the feasibility of the design by examining the following design requirements:

- The hump speed be at least 2.6 mph (3.67 cars/min).
- The hard-roller must not stall before the tangent point.
- The maximum speed of the easy-roller at the tangent point be 6 mph.
- The maximum speed of a car in the switch segments be 15 mph.
- The coupler-to-coupler headway be at least 50 feet at each switch.
- There never be more than one car in the same retarder at any time.
- No catch-ups should occur before the clearance point of each track.

The major assumptions used in the design process were:

- Only static rolling resistances apply.
- The hard-roller has a rolling resistance of 18 lbs/ton between the hump crest and the exit from the group retarders and 10 lb/ton thereafter.
- The easy-roller has a rolling resistance of 4 lbs/ton between the hump crest and the exit from the group retarders and 2 lb/ton thereafter.
- The velocity head loss due to each switch is 0.06 feet when the car travels along the curved track. The velocity head loss is assumed to be zero if a car travels on the straight track. This value is constant for all turnout numbers.
- The velocity head loss due to a curved section of track is 0.04 feet per degree of deflection angle.
- The average car length is 60 feet.
- The average car weight is 64 tons for the hard-roller and 135 tons for the easy-roller.
- The extra weight of the car due to wheel rotation is 1.00 tons.
- The wind resistance is zero.

A general interactive and iterative design procedure was used here to select an example design. The steps in this procedure are to:

1. Determine the car speed constraints at the tangent point and other points along the track.
2. Design a trial horizontal layout.
3. Determine the hump height from Steps 1 and 2.
4. Select the trial grades along the track.
5. Run PROFILE.
6. Examine the output. If the result is satisfactory, go to Step 7. If the result has speed violations, go back to Step 2. If the result contains catch-up problems, go first to Step 4; if the catch-up problem cannot be solved by changing grades, go to Step 2.

TABLE 12-5.-ECHO BACK AND COLLISION INFORMATION FOR TRIAL RUN 2 OF YERMO YARD

SRI HUMP PROFILE SIMULATION - YERMO NO. 5 FILE - TRIAL RUN 2 - ELIMINATE MASTER RETARDER

SIMULATION TIME STEP, DELTA T, SEC	1.0000
HUMP SPEED, MILES PER HOUR	2.5000
DATA PRINT INTERVAL, SEC	1.00
TABLE SWITCH	1
PLOT SWITCH	1
PRINTER WIDTH (CHARACTERS)	132

T R A C K   D A T A

TRK SEC NO.	LENG (FT)	CUM. LENG (FT)	GRADE (PCT)	RESISTANCES: ROLLING: STATIC (LB/TON) EASY	STATIC (LB/TON) HARD	VELOCITY (LB/TON)/(FT/SEC) EASY	VELOCITY (LB/TON)/(FT/SEC) HARD	HORIZ. CURVE (LB/T)	SWITCH LOSS (FT OF VELOC. HEAD)	RETARDATION (FT. OF VEL. HEAD) CAR 1	CAR 2	CAR 3	MAX. RETARDATION (FT OF VELOC. HEAD)	DESCRIPTION
1	50.0	0.0	3.00	4.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	CREST TO EVC
2	71.0	50.0	4.23	4.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	EVC TO FORMER M. RET.
3	72.0	121.0	3.99	4.00	18.00	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00	6.72	FORMER MASTER RET.
4	24.0	193.0	1.44	4.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	FORMER M. RET. TO KING SW.
5	1.0	217.0	1.44	4.00	18.00	-0.00	-0.00	-0.00	.06	-0.00	-0.00	-0.00	-0.00	KING SW
6	25.0	218.0	.50	4.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	KING SW TO LAP
7	1.0	243.0	.50	4.00	18.00	-0.00	-0.00	-0.00	.06	-0.00	-0.00	-0.00	-0.00	LAP SW
8	100.0	244.0	.50	4.00	18.00	-0.00	-0.00	11.30	-0.00	-0.00	-0.00	-0.00	-0.00	LAP SW TO PT
9	95.0	344.0	.50	4.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	PT TO GR. RET.
10	100.0	439.0	1.20	4.00	18.00	-0.00	-0.00	-0.00	-0.00	0.00	5.24	0.00	6.72	GR. RET.
11	17.0	539.0	.10	2.00	10.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	GR TO LAP 2
12	1.0	556.0	.10	2.00	10.00	-0.00	-0.00	-0.00	.06	-0.00	-0.00	-0.00	-0.00	LAP 2
13	70.0	557.0	.10	2.00	10.00	-0.00	-0.00	5.25	-0.00	-0.00	-0.00	-0.00	-0.00	LAP 2 TO HF 2
14	28.0	627.0	.10	2.00	10.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	HF 2 TO SW 3
15	1.0	655.0	.10	2.00	10.00	-0.00	-0.00	-0.00	.06	-0.00	-0.00	-0.00	-0.00	SW 3
16	70.0	656.0	.10	2.00	10.00	-0.00	-0.00	5.25	-0.00	-0.00	-0.00	-0.00	-0.00	SW 3 TO HF 3
17	30.0	726.0	.10	2.00	10.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	HF 3 TO SW 4
18	1.0	756.0	.10	2.00	10.00	-0.00	-0.00	-0.00	.06	-0.00	-0.00	-0.00	-0.00	SW 4
19	70.0	757.0	.10	2.00	10.00	-0.00	-0.00	5.25	-0.00	-0.00	-0.00	-0.00	-0.00	SW 4 TO HF 4
20	68.0	827.0	.10	2.00	10.00	-0.00	-0.00	12.25	-0.00	-0.00	-0.00	-0.00	-0.00	HF 4 TO CLEAR
21	145.0	895.0	.10	2.00	10.00	-0.00	-0.00	12.25	-0.00	-0.00	-0.00	-0.00	-0.00	CLEAR TO PCT
22	15.0	1040.0	.10	2.00	10.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	PCT TO PTT
23	300.0	1055.0	.08	2.00	10.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	PTT TO END

C A R   D A T A

TYPE OF ROLLER, 1 = EASY, 2 = HARD

CAR NO.	TYPE ROLLER	CAR LENGTH (FT)	WEIGHT OF CAR (TONS)	EXTRA WEIGHT WHEEL ROTATION (TONS)	WIND RESIS STAT (LB/T)	WIND RESIS VELOC (LB/T)/(FPS)
1	2	60.00	64.00	1.00	-0.00	-0.00
2	1	60.00	135.00	1.00	-0.00	-0.00
3	2	60.00	64.00	1.00	-0.00	-0.00

A COLLISION OCCURRED AT TIME 116.40 SEC. BETWEEN
CAR 1 - VEL = 2.27 MPH, DIST = 1336.30 FT., TIME ON TRACK = 116.40 SEC.
CAR 2 - VEL = 5.59 MPH, DIST = 1276.30 FT., TIME ON TRACK = 100.04 SEC.

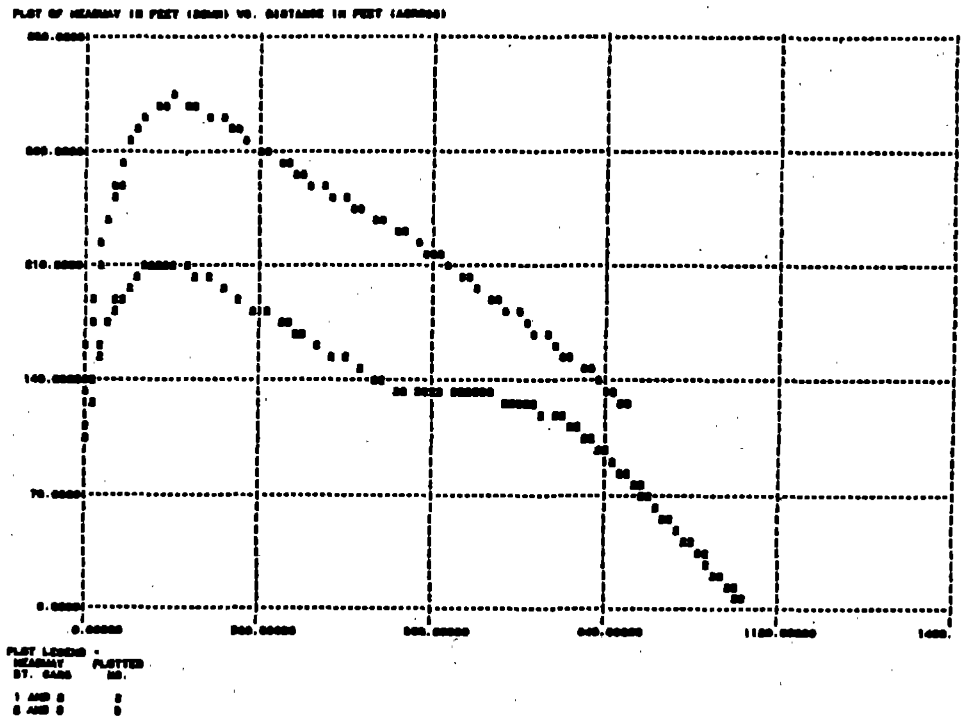

FIGURE 12-25. PLOT OF DISTANCE HEADWAY AS A FUNCTION OF DISTANCE FOR TRIAL RUN 2 OF YERMO YARD

TABLE 12-6.-EXAMPLE OF CAR HISTORY TABLE--PARTIAL OUTPUT FOR CAR NO. 2 (EASY-ROLLER) FOR TRIAL RUN 2 OF YERMO YARD

CAR TRAVEL TIME (SEC)	SYSTEM TIME (SEC)	DISTANCE ALONG TRACK (FT)	DISTANCE HEADWAY BETWEEN PREC CAR (FT)	TIME HEADWAY BETWEEN PREC CAR (SEC)	INSTANTANEOUS VELOCITY (FT/SEC)	INSTANTANEOUS VELOCITY (MPH)	VELOCITY HEAD (FT)	TRACK SECTION NUMBER	TRACK SECTION DESCRIPTION
0.000	16.984	0.000	108.770	7.008	0.007	2.000	.010	0/ 1	****TRACK SECTION BOUNDARY****
.400	17.000	2.016	111.001	7.772	4.230	2.900	.001	1	CREST TO EVG
1.000	18.000	7.184	120.770	8.380	6.181	3.480	.418	1	CREST TO EVG
2.000	19.000	13.777	130.047	8.683	6.086	4.100	.808	1	CREST TO EVG
3.000	20.000	18.250	158.447	8.280	6.881	4.710	.740	1	CREST TO EVG
4.000	21.000	26.610	164.201	8.863	7.610	5.820	.800	1	CREST TO EVG
5.000	22.000	34.000	174.000	10.020	8.711	6.000	1.167	1	CREST TO EVG
6.000	23.000	44.041	184.286	10.047	8.000	6.000	1.448	1	CREST TO EVG
7.000	23.000	50.000	186.022	10.080	10.146	6.910	1.618	1/ 2	****TRACK SECTION BOUNDARY****
7.000	24.000	54.120	188.004	10.042	10.667	7.280	1.777	2	EVG TO FORMER M. RET.
8.000	25.000	66.427	190.020	10.008	11.840	8.148	2.280	2	EVG TO FORMER M. RET.
9.000	26.000	78.610	204.007	11.007	12.204	9.020	2.740	2	EVG TO FORMER M. RET.
10.000	27.000	91.004	207.000	11.000	14.022	9.001	3.290	2	EVG TO FORMER M. RET.
11.000	28.000	107.000	200.000	11.000	15.010	10.770	3.010	2	EVG TO FORMER M. RET.
12.400	28.082	121.000	210.004	11.464	16.000	11.000	4.478	2/ 3	****TRACK SECTION BOUNDARY****
12.000	29.000	123.018	216.000	11.490	17.007	11.061	4.087	3	FORMER MASTER RET.
13.000	30.000	141.000	280.000	11.574	18.250	12.477	5.290	3	FORMER MASTER RET.
14.000	31.000	160.111	287.000	11.590	19.510	13.000	6.090	3	FORMER MASTER RET.
15.000	32.000	180.227	204.034	11.007	20.782	14.120	6.717	3	FORMER MASTER RET.
15.240	32.000	188.000	201.780	11.404	21.400	14.620	7.001	3/ 4	****TRACK SECTION BOUNDARY****
16.000	33.000	201.401	190.077	11.490	21.618	14.780	7.000	4	FORMER M. RET. TO KIND SW.
17.040	33.718	217.000	196.410	11.620	21.500	14.800	7.490	4/ 5	****TRACK SECTION BOUNDARY****
17.090	33.790	218.000	196.180	11.218	21.480	14.861	7.481	5/ 6	****TRACK SECTION BOUNDARY****
17.000	34.000	220.250	196.010	11.272	21.640	14.880	7.487	6	KIND SW TO LAP
18.000	34.081	240.000	190.006	11.000	21.080	14.850	7.500	6/ 7	****TRACK SECTION BOUNDARY****
18.020	34.047	244.000	190.041	11.005	21.061	14.900	7.490	7/ 8	****TRACK SECTION BOUNDARY****
18.000	35.000	248.180	190.187	11.075	21.647	14.985	7.408	8	LAP SW TO PT
19.000	36.000	280.048	185.484	10.800	21.702	14.830	7.480	8	LAP SW TO PT
20.000	37.000	290.048	180.901	10.833	21.677	14.790	7.381	8	LAP SW TO PT
21.000	38.000	310.017	176.830	10.878	21.500	14.782	7.290	8	LAP SW TO PT
22.000	39.000	331.400	172.184	10.116	21.500	14.685	7.295	8	LAP SW TO PT
23.201	39.944	344.000	180.020	8.071	21.400	14.652	7.004	8/ 9	****TRACK SECTION BOUNDARY****
23.000	40.000	353.001	157.403	8.909	21.003	14.640	7.282	9	PT TO GR. RET.
24.000	41.000	374.000	162.046	8.678	21.400	14.728	7.297	9	PT TO GR. RET.
25.000	42.000	396.540	157.341	8.896	21.564	14.701	7.062	9	PT TO GR. RET.
26.000	43.000	418.860	151.078	8.000	21.700	14.867	7.487	9	PT TO GR. RET.
27.000	43.949	428.000	146.418	8.701	21.441	14.816	7.490	9/10	****TRACK SECTION BOUNDARY****
27.000	44.000	440.184	146.118	8.717	21.011	14.871	7.448	10	GR. RET.
28.000	45.000	461.257	140.878	8.404	20.480	13.947	6.846	10	GR. RET.
29.000	46.000	481.000	136.704	8.837	19.180	13.088	5.707	10	GR. RET.
30.000	47.000	499.468	135.758	8.296	17.748	12.090	4.886	10	GR. RET.
31.000	48.000	516.685	131.076	8.237	16.308	11.175	4.684	10	GR. RET.
32.000	49.000	532.587	131.160	8.617	15.000	10.251	3.800	10	GR. RET.
33.095	49.490	540.000	131.230	8.944	14.418	9.827	3.240	10/11	****TRACK SECTION BOUNDARY****
33.096	50.000	548.703	131.438	8.495	14.418	9.827	3.240	11	GR TO LAP 2
34.275	50.650	556.000	131.627	8.018	14.418	9.827	3.240	11/12	****TRACK SECTION BOUNDARY****
34.045	50.790	557.000	131.840	8.320	14.279	9.784	3.150	12/13	****TRACK SECTION BOUNDARY****
34.000	51.000	561.160	131.700	8.800	14.290	9.710	3.170	13	LAP 2 TO HF 2

7. Determine whether any segment (especially the retarder segment) is excessively long; if so, go to Step 2. Otherwise, the design is complete.

The example shown here illustrates one step of the interactive and iterative design procedure presented above. The objective in Trial Run 2, the partial output of which is shown in Figure 12-25 and Tables 12-5 and 12-6, was to try to eliminate the master retarder. This change necessitated shortening the distance between the hump crest and the first switch by 21 feet, which shortened the distance to the tangent point to 1040 feet. Comparing the collision-related output for Trial Run 1 (not shown) with the same information for Trial Run 2 (Table 12-5) revealed that the collision point decreased from 1306 feet to 1099 feet from the hump crest. Since the latter value is still well past the clearance point (in fact, past the tangent point), the Trial Run 2 design satisfies the design requirements. Examination of other performance measures output by the model, as shown partially in Figure 12-25 and Tables 12-5 and 12-6, reveals that all other design requirements are also met by the design of Trial Run 2.

Under the assumptions used in this example, the design changes effected between Trial Runs 1 and 2 demonstrate a considerable cost reduction and point out the advantage of having the PROFILE model available to try such "what if" experiments.

Table 12-6 shows a part of the output for Car No. 2 (the easy-rolling car). All the necessary data related to the movements of Car No. 2 are included in this table.

From the plot of speeds of the cars as a function of distance (not shown) or data as in Table 12-6, it has been determined that the easy-rolling car in Trial Run 2 attains a maximum speed slightly less than 15 mph. This satisfies the maximum speed constraint in the switching area. It can also be verified that the easy-rolling car satisfies the 15 mph speed constraint at the tangent point and that the unretarded hard-rolling car satisfies both speed constraints.

Figure 12-25 is a plot of distance headway between successive cars. The number 2 indicates the headway between Car No. 1 and Car No. 2, and 3 indicates the headway between Car No. 2 and Car No. 3. Table 12-6 and Figure 12-25 indicate that sufficient headway exists between cars to detect individual cars and to throw the switch in all switch segments.

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CHAPTER 13: TRIM END DESIGN AND CONFLICT EVALUATION

13.0 GENERAL

One of the most important functions of a classification yard is to make up departing trains by coupling cars in the classification yard and pulling them to the departure yard. This necessitates many back-and-forth trips by the trim engines between the classification and departure yards. The engines travel heavy with a string of cars from the classification yard to the departure yard and travel light on the return movement. These trim engine movements conflict at the throat, creating a bottleneck in the yard operations. The conflicts of engine movement may be caused by several factors, such as geometric conditions, yard traffic characteristics, and the trim engine operations. These factors are interrelated; often it is not clear which factor contributes most to the engine movement conflicts. There may be several approaches to solve the throat capacity problems: If the yard already exists and there are no means of changing the trim-end geometry, then the yard operator may have to devise a better trimming operation, or the transportation department of the railroad may have to reschedule the network operations to avoid the problem. However, if the yard is to be newly designed and built, then the designer must design the trim end of the yard so that the possibilities of engine movement conflicts are minimized.

The ideal situation occurs when the trim engines do not have to make frequent moves between the classification yard and the departure yard, and the required travel time between the two subyards is short. This can be translated to the basic rules of trim-end design:

- Make the classification tracks sufficiently long that doubling of blocks is unnecessary.
- Make the distance of travel between the classification yard and the departure yard as short as possible.
- Implement as many independent routes as possible between the two subyards.

However, understanding the basic rules is one thing; designing a real-world facility is another. Often the real-world problem does not allow the designer to adhere to the theoretical ideal. The reasons the designer cannot implement an idealistic trim-end design for a yard may vary from budgetary constraints to geographical constraints. Thus, it is frequently unavoidable for a good designer to deal with "not so good" trim-end design.

The purpose of this chapter is to describe several methods for evaluating trim-end designs. The evaluation methods dealt with in this chapter include a macroscopic manual method, a microscopic manual method, and a computer-assisted method. The designer can choose the most appropriate evaluation method from the three. The macroscopic manual method is very convenient when the designer must select a proper design in a short time. If the designer has sufficient time to work on the design and has access to a computer, then the computer-assisted method is the best method. If a computer is unavailable, but sufficient time exists, then the microscopic manual evaluation should be selected.

The trim-end analysis is one of many tasks to be conducted in the process of designing a new yard. Trim-end analysis is strongly related to the yard capacity and operations analysis, and is difficult to conduct if the capacity analysis is not completed beforehand. This is because the trim-end analysis uses many of the results produced in the yard capacity analysis.

This chapter contains five major sections. The first section describes various trim-end designs, ranging from the inline yard to the parallel yard, and from one departure yard to double departure yards. The second section describes trim-end operational alternatives, which are described for each inline and parallel type yards. The third section describes the measures of effectiveness that can be used in analyzing the trim-end. The fourth section describes a manual evaluation method and its application to a real-world problem. The fifth section describes a computer-assisted evaluation method. Here, the computer simulation model CONFLICT is introduced, and a method or trim and evaluation using the model is described. An application of the computer-assisted method to a real-world problem is also described.

13.1 TRIM-END DESIGN ALTERNATIVES

The design of the trim-end geometry strongly affects the trim engine operations. Therefore, the engine operations and engine productivity must be carefully studied at the design stage of the trim end. There are two primary types of yard designs: the parallel departure yard and the inline departure yard. For each of these yard designs there are various trim-end designs. This section describes briefly the types of trim-end designs available and the particular engine operations methods usually practiced in these trim-end geometries.

13.1.1 Parallel Departure Yard

In this design the trim engine must pull car blocks from the classification track to the pullout lead, then shove the blocks back from the pullout lead to the departure yard. Repeated movements of this type make up the outbound trains on the departure tracks. The productivity, which may be expressed in terms of the number of cars carried per unit time, is affected by the length of a block pulled in one pull, the distance to be traveled between the classification yard and the departure yard, and the amount of delay experienced by an engine due to conflicting movements. From an engine productivity point of view, the best trim-end designs will be those having long classification tracks, short distances between the classification yard and the departure yard, and satisfactory track geometry designs to facilitate movements of multiple engines without conflict.

The trim-end design layout is determined based on the amount of traffic to be handled at the yard of interest. For example, if the traffic level is rather low, say 600 cars/day, probably one engine will be sufficient to handle the traffic. Under such circumstances, one pullout lead with efficient track geometry is desirable for trimming. On the other hand, if the traffic level is very high, say 3000 cars/day, the designer may have to do his best to eliminate possible conflict movements in the trim-end design. In real-world applications another factor to be kept in mind is the geometric constraints due to site-specific problems, such as availability of land for the second pullout lead or the conflict of movements with mainline traffic.

Basically five types of trim-end designs are possible for the parallel departure yard. These trim-end types are generated in concordance with certain combinations of the number of pullout leads and the number of departure yards. Schematic diagrams of these five trim-end types are given in Table 13-1. The table also shows the yard sizes where these trim-end designs are applicable; there yard sizes are expressed in terms of the number of classification tracks and the traffic level.

The trim-end Types 1 through 4 in the table are often found in U.S. yards. Trim-end Type 1 is applicable to small yards where only one engine is required to do the trimming. Trim-end Type 2 is applicable to medium-size yards where multiple engines are required to do the trimming. Trim-end Type 3 is applicable to medium to large yards where only one engine is required in one departure yard, but multiple engines are required in the other departure yard. Trim-end Type 4 is applicable for large-scale yards which require multiple numbers of engines in both of the departure yards.

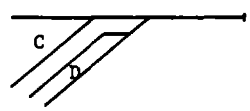
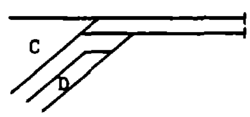
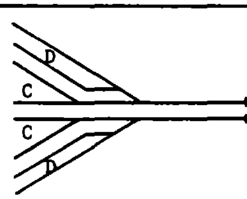
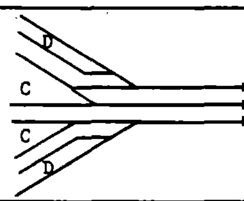
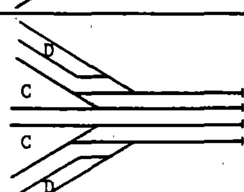
One of the major problems in dual departure yard systems is cross-traffic between the two sides of the yard. Often this cross-traffic is unavoidable because the traffic patterns vary from time to time, thus, creating oversaturated conditions in one yard. It is especially important to consider this cross-traffic handling in the larger yards with two directional departure yards.

13.1.2 Inline Departure Yard

In this type of yard, the trim engines usually perform many doubling maneuvers and make up trains by moving back and forth in the throat of the yard. For example, if a departure train consists of two blocks, first the trim engine will pull a block from one classification track and then shove that block onto another classification track, doubling the blocks while making up a train. After doubling the two blocks, the engine will pull the two blocks together to an assigned departure track.

In this type of design it is especially important that the trim engines operate without conflicting movements because the blockage time for this type of design, when it occurs, is much longer than the blockage time for the parallel departure yard.

TABLE 13-1.-PARALLEL DEPARTURE YARD TYPES

Type	No. of pullout leads	No. of departure yards	Schematic Diagram	No. of class tracks	Traffic level cars/day	Application examples
1	1	1		8 ~ 20	500 ~ 1000	Existing E. Deerfield (B&M)
2	2	1		15 ~ 60	800 ~ 1500	
3	1 + 1	2		40 ~ 60	1000 ~ 2000	
4	2 or more + 1	2		50 ~ 70	1500 ~ 3000	Existing Elkhart (CONRAIL)
5	2 or more + 2 or more	2		50 ~ 80	2000 ~ 4000	

The number of independent routes in the inline departure yard can vary from one to as many as four. A typical trim-end design for an inline departure yard, designed for four trim engines, is given in Figure 13-1. Possible arrangements for three independent route combinations are also shown in the figure.

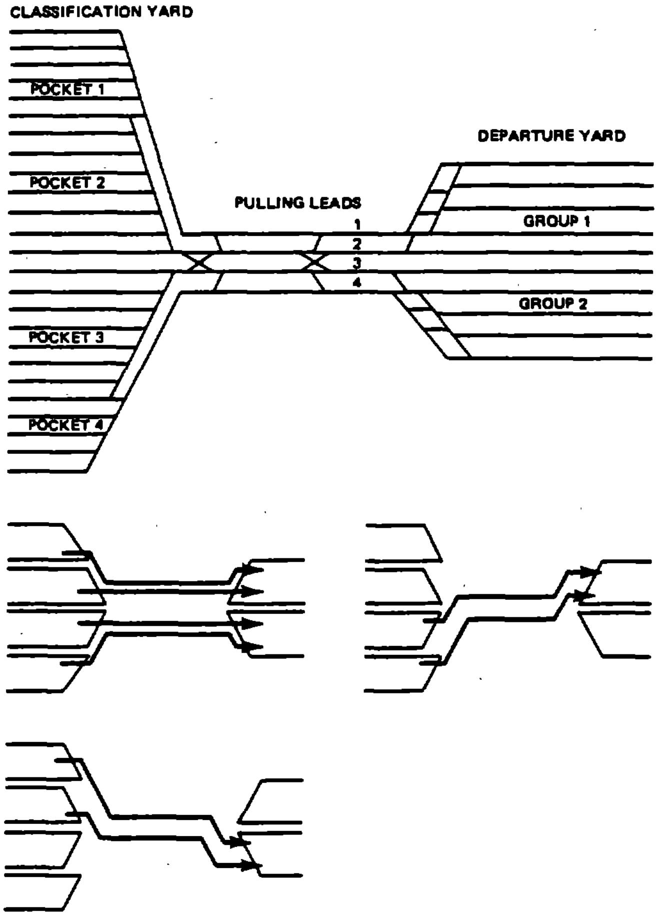
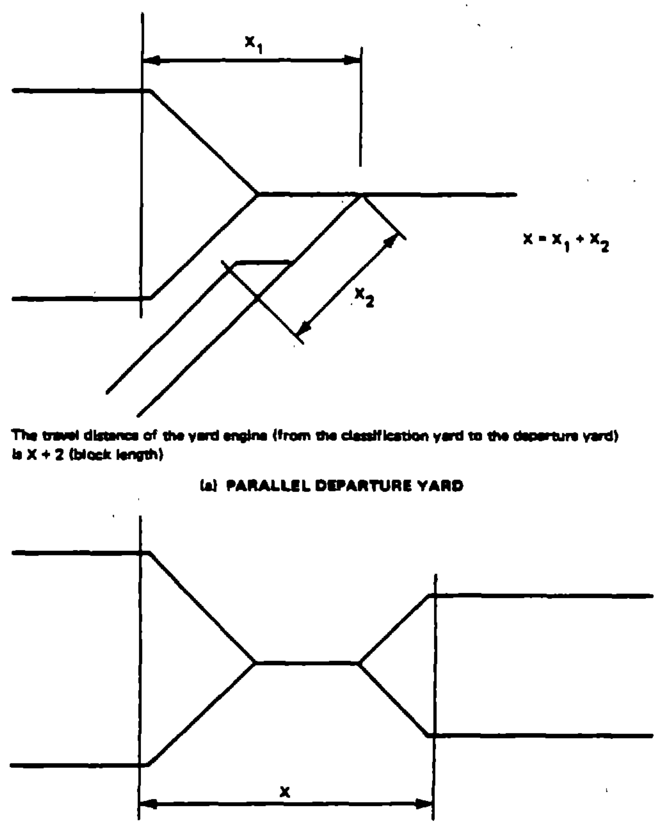


FIGURE 13-1. INLINE DEPARTURE TRACK SCHEMATIC DESIGN AND INDEPENDENT ROUTE COMBINATIONS

The ultimate goal of any trim-end design is to make the trim-end capacity sufficiently large to handle the given workload. The trim-end capacity may be expressed in terms of the number of cars pulled per unit time period. The trim-end capacity is determined by three factors:

- Average Length of Cuts--The average length of cuts is determined by the classification track lengths and the frequency of pulls. Longer classification tracks naturally contribute to a large capacity at the trim end. However, longer tracks will also be more costly than shorter classification tracks. Studying the trade-offs between the cost and capacity (or productivity) of the length of classification tracks is especially important, since a small difference in track length per track could result in a significant cost difference for the whole yard.
- Average Travel Distance Between the Classification Yard and the Departure Yard--The maximum efficiency of a trim-end operation under a no-conflict situation is obtained by minimizing the travel distance between the classification yard and the departure yard. Especially important is the distance from the locations of the inert retarders in the classification yard to the throat-side tangent point of the departure tracks. The key elements of the travel distance between the classification yard and the departure yards are shown in Figure 13-2.



The travel distance of the yard engine (from the classification yard to the departure yard) is X + 2 (block length)

(a) PARALLEL DEPARTURE YARD

The travel distance of the yard engine (from the classification yard to the departure yard) is X + block length

(b) INLINE DEPARTURE YARD

FIGURE 13-2. KEY ELEMENTS OF TRAVEL DISTANCES BETWEEN THE CLASSIFICATION YARD AND THE DEPARTURE YARD

- Number of Independently Operated Routes Between the Classification Yard and the Departure Yard--The possibility of delayed engine movements due to conflicting engine movements can be reduced by designing the trim end with many nonconflicting routes between the classification yard and the departure yard. Obviously, because of the cost and geometry involved, the number of nonconflicting routes to be designed is limited. For example, it is rare to find a yard with more than two pullout leads between a classification yard and a departure yard. The conflict of engine movements should be minimized in all subyards; however, it is especially important to minimize conflict in the classification yard. This is because the trim engines spend a signficant amount of time here coupling cars. Minimization of conflict in the classification yard is attained by installing as many classification track ladders as the geometry allows. Figure 13-3 illustrates that only one engine can engage in coupling activities in Case 1, which has one

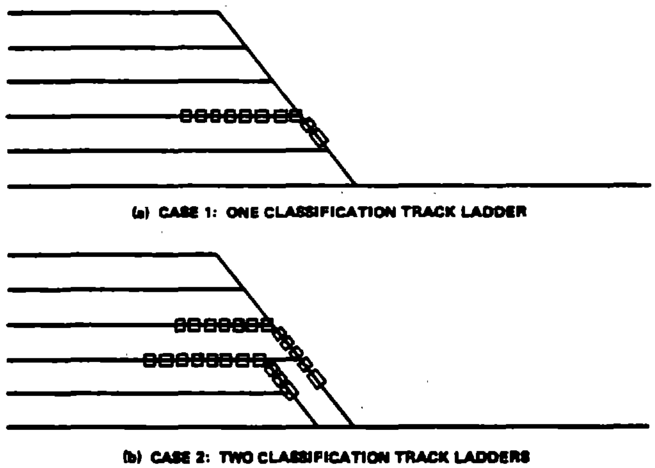


FIGURE 13-3. EXAMPLE GEOMETRIES OF CLASSIFICATION TRACK LADDERS

classification track ladder, whereas two engines can work simultaneously in Case 2, which has two classification track ladders.

13.2 TRIM-END OPERATIONAL ALTERNATIVES

Methods of trim-end operations are closely related to trim-end designs. However, in each trim-end design there are different ways to operating yard engines. Some of the most typical trim-end operations for both parallel and inline departure yards are briefly described below.

13.2.1 Parallel Departure Yard

Two major activities performed by engines at the trim end of the parallel yard are coupling cars on the classification tracks and pulling cars from the classification yard to the departure yard. In larger yards where more than one engine is used, it is possible to assign engines especially to one of the two job types. The decision of the job assignments to each engine can be made based on the expected efficiency.

It is entirely possible that one engine assignment method that works for one geometric condition will not function well in other geometric conditions.

One of the operational characteristics to be considered, especially in the parallel departure yard, is the method of making up trains at the departure yard. There are two ways of doing this task when simultaneously making up trains involving more than one pull each from the classification yard. One method is to make up one departing train at a time; i.e., a train is made up by multiple engines. The other method is to make up the departing trains simultaneously; i.e., each engine makes up one train.

13.2.2 Inline Departure Yard

In the inline departure yard the coupling and the pulling activities can also be done by different engines. However, the making up of a train is usually done by one engine. The engine usually pulls one block from a classification track, then without pulling that block all the way to the departure track, shoves back to the next classification track with the first block still intact, and then doubles the blocks. In this manner the engine doubles all the blocks and makes up a train by doubling blocks in the trim-end area. After finishing a complete train, the engine then pulls the entire train to the departure yard. The trim engine travels back to the classification yard via an empty departure track.

In theory the trim work in the inline departure yard can be performed in a different manner. The trim engine could pull each block separately to a departure track and then double the blocks on the track and make up a train. However, to make this operation possible, the departure yard would need numerous escape tracks. A compromise method would be to make up a train in two separate doubling-and-pulling movements. To make this operational procedure possible, the departure yard would have to be equipped with crossovers in the middle of the tracks so that the trim engine could escape from the track and return to the classification yard.

13.3 MEASURES OF EFFECTIVENESS AND EVALUATION OF DESIGNS

Numerous measures of effectiveness can be considered. Some are related to the total trim-end performance, and others are related to a partial trim-end performance. Some of the measures of effectiveness related to the total trim-end performance are:

- Total delay of the cars pulled per day
- Average delay of cars pulled
- Total number of blocks pulled per day
- Total number of cars pulled per day
- Total number of trains departed per day
- Total delay per train departed per day
- Total delay of the cars departed per day
- Average delay per departed car (train).

Some of the measures of effectiveness related to a partial trim-end performance are:

- Total delay of the cars passed through a track segment per day
- Average delay of the cars passed through a track segment
- Total delay of the cars using a route per day
- Average delay of the cars using a route.

The measures of effectiveness used in evaluating trim-end designs will be different case by case. If the purpose of the study is to evaluate the capacity of the trim-end design, then the most appropriate measure of effectiveness would be the total number of cars (or blocks) pulled in one day. The capacity is obtained through a series of evaluation trials by changing the demand. The demand in the study may be varied from an extremely low volume to an extremely high volume, so that the capacity which is expressed in terms of volume per unit time is covered by the two extreme demand points. For example, if the capacity of a trim-end design is expected to lie between 1000 cars/day to 2000 cars/day, then the designer must use demand levels varying from 1000 cars/day to 2000 cars/day and evaluate the trim-end operations. The capacity of the trim end is the highest traffic volume it can handle between 1000 cars/day and 2000 cars/day.

If the purpose of the study is to evaluate the possible operational effects to a given traffic demand, then one of the delay measures, such as the average delay per trains departed, would be appropriate. If the purpose of evaluation is to find bottlenecks and possible design improvements, then delay information on each route or track segment becomes essential. Improved designs can also be evaluated using these same type of measures of effectiveness, and can be examined to determine whether the new design actually improves the performance of the system.

13.4 MANUAL EVALUATION METHOD

Two types of manual evaluation methods are discussed in this section. One is a macroscopic method and the other is a microscopic method. The measures of effectiveness used in these two evaluation processes are not necessarily the same. The macroscopic manual evaluation method approaches the problem at an aggregated level, and because of this the measures of effectiveness that can be estimated are limited. The measures of effectiveness considered in the macroscopic manual analysis are a conflict index, a route availability index, an expected wait time due to engine movements, conflicts, and an expected capacity at the trim end. The microscopic method is essentially a manual simulation with pencil and paper. Therefore, most measures of effectiveness discussed in Section 13.3 can be obtained.

13.4.1 Macroscopic Manual Evaluation

The trim-end operations can be improved in three ways: by lengthening the classification yard tracks, by shortening the engine's travel distances between the classification yard and the departure yard, and by increasing the number of mutually nonconflicting routes between the classification yard and the departure yard. The macroscopic manual evaluation is performed in two stages. The first step is to evaluate the engine movement conflicts, and the second step is to evaluate the trim-end productivity (or trim-end capacity).

13.4.1.1 Input to the Macroscopic Manual Evaluation. The macroscopic trim-end design and conflict evaluation method requires a high-level aggregated type of input. The inputs required for the study are:

- Traffic-Related Inputs
  - The demand level in terms of the number of cars per day.
  - The expected number of pulls to be made: this can be estimated from the expected outbound train schedule and the blocks to be carried by each outbound train.
  - The expected number of doubling maneuvers made at the classification yards (for parallel departure yards).
- Trim-End Operations-Related Inputs
  - The number of engines.
  - Travel time from the classification yard to the departure yard.
  - Travel time from the departure yard to the classification yard.
  - Travel time from one classification track to another.
  - The coupling rate.
  - The productive crew time/engine/day in minutes.
- Trim-End Geometry-Related Inputs
  - A rough sketch of trim-end design that enables the designer to identify routes and potential conflict points.

13.4.1.2 Engine Movement Conflict. First, all possible combinations of the origin and destination of trips taken by the trim engines between the classification yard and the departure yard are identified. In this process, track groups instead of individual tracks are treated as either origins or destinations of the trips. Sample track layouts and their origin and destination track groups are shown in Figures 13-4 and 13-5. In the sample layouts given in the figures, both the classification yard and the departure yard are divided into two track groups. Each of the track groups can be an origin or a destination of a trip.

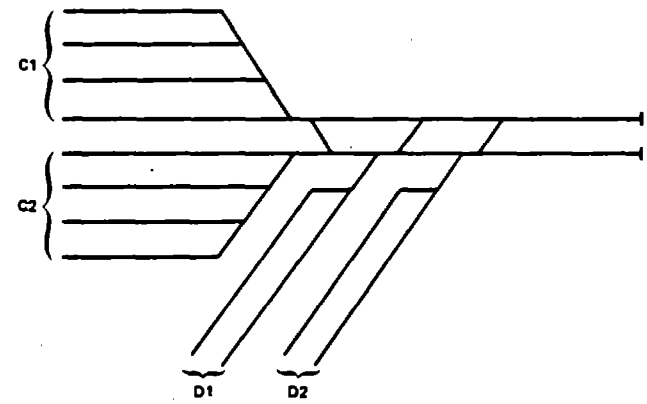


FIGURE 13-4. SAMPLE GEOMETRY FOR MACROSCOPIC EVALUATION: CONFIGURATION 1

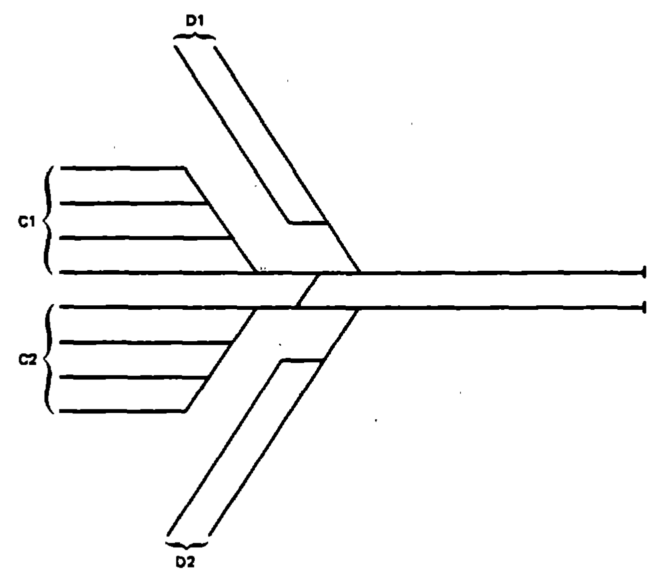


FIGURE 13-5. SAMPLE GEOMETRY FOR MACROSCOPIC EVALUATION: CONFIGURATION 2

Second, all possible combinations of origin and destination trips are identified. Then a matrix showing the level of conflict between a pair of origin/destination trips is prepared. The matrices prepared for the sample layouts are given in Tables 13-2 and 13-3; one for Configuration 1 and the other for Configuration 2.

Each cell in the matrices indicates the possible amount of delay that may be experienced by the engine on the origin destination trips shown on the far left-side

TABLE 13-2.-CONFLICT INDEX MATRIX: CONFIGURATION 1

Route Engine 2 is on / Route Engine 1 is on	C1 - D1	C1 - D2	C2 - D1	C2 - D2	D1 - C1	D1 - C2	D2 - C1	D2 - C2
C1 - D1	1.0	0.5	0.5	0.0	0.5	0.5	0.5	0.5
C1 - D2	0.5	1.0	0.5	0.5	0.5	0.5	0.5	0.5
C2 - D1	0.5	0.5	1.0	0.5	0.5	1.0	0.5	0.5
C2 - D2	0.0	0.5	0.5	1.0	0.5	0.5	0.5	0.5
D1 - C1	0.5	0.5	0.5	0.5	1.0	0.5	0.5	0.0
D1 - C2	0.5	0.5	1.0	0.5	0.5	1.0	0.5	0.5
D2 - C1	0.5	0.5	0.5	0.5	0.5	0.5	1.0	0.5
D2 - C2	0.5	0.5	0.5	0.5	0.0	0.5	0.5	1.0

Conflict index for 2 engines $C_F' = \frac{35}{64} = 0.55$

Route availability index $= 1.0$

TABLE 13-3.-CONFLICT INDEX MATRIX: CONFIGURATION 2

Route Engine 2 is on / Route Engine 1 is on	C1 - D1	C1 - D2	C2 - D1	C2 - D2	D1 - C1	D1 - C2	D2 - C1	D2 - C2
C1 - D1	1.0		1.0	0.0	1.0	1.0		0.0
C1 - D2								
C2 - D1	1.0		1.0	0.5	1.0	1.0		0.0
C2 - D2	0.0		0.5	1.0	0.0	0.0		1.0
D1 - C1	1.0		1.0	0.0	1.0	1.0		0.0
D1 - C2	1.0		1.0	0.0	1.0	1.0		0.5
D2 - C1								
D2 - C2	0.0		0.0	1.0	0.0	0.5		1.0

Conflict index for 2 engines $C_F' = \frac{22}{36} = 0.61$

Route availability index $= \frac{36}{64} = 0.43$

column of the matrix. The amounts of delay indicated in the matrices are expressed in terms of fractions of travel times of the engine on the origin-destination trip given on the far-left column of the matrix. If no routes are available to make an origin-destination trip given in the matrix, the cells associating the origin-destination trip must be indicated by an X.

For example, in Table 13-1 a pull from track group C1 to track group D1 and another pull from track group C2 to track group D2 can be operated without any conflict, and the conflict index for this trip pair is zero. An illustration of the pull movements is given in Figure 13-6a. In the figure, Phase 1 shows a pair of pull movements in which the two engines simultaneously pull blocks to the pullout leads out of the classification tracks. Then in Phase 2 the blocks are pushed back to the departure tracks simultaneously. The figure shows that in both phases the engines can operate simultaneously without any conflict of movements.

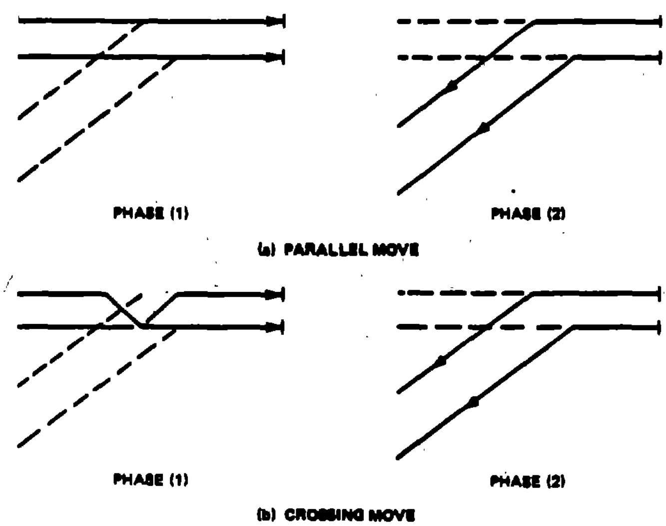


FIGURE 13-6. SCHEMATIC REPRESENTATION OF ENGINE CONFLICT ANALYSIS

If a pull is made from classification track Group C1 to departure track Group D2, and another pull is made simultaneously from classification track Group C2 to departure track Group D1, these engine movements conflict each other. It is assumed that one engine must wait approximately half the travel time between the classification yard to the departure yard (see Figure 13-6b), and thus the conflict index for this origin-destination combination is 0.5.

In this manner the conflict index for each combination of any two origin-destination pairs, C_{ij}, is estimated. The value given to each combination can vary from 0 to 1.0. However, in practice it is considered difficult to identify the exact conflict index for each combination of any two origin-destination pairs. Because of this it is suggested that the designer assign either 0, 0.5, or 1.0 as the conflict index, C_{ij}.

The conflict coefficient when two engines are engaged in trimming operation C_F' is computed as

$$C_F' = \sum C_{ij}/N , \qquad (13.1)$$

where C_{ij} = the i, j entry in cell (i,j), and

N = the total number of cells minus the number of cells with an X mark.

The conflict coefficient, C_F', may be interpreted as the average delay expected due to conflict of engine movements, expressed in terms of fraction of travel time between the classification yard and the departure yard.

The conflict coefficient, C_F', indicates the effect of trim-end geometry on conflict between a pair of engine trips. If the trim-end operation requires more than two engines, then the conflict coefficient is approximated as

$$C_F = C_F' + N_E - N_P , \qquad (13.2)$$

where C_F = the conflict coefficient when N_E engines are used,

N_E = the number of trim engines at work,

N_P = the number of nonconflicting routes between the classification yard and the departure yard.

Equation (13.2) was derived on the assumption that the number of nonconflicting routes between the classification yard and the departure yard is either one or two, and implies that every additional engine (i.e., the third and fourth engines...) put to work at the trim end will cause an increase in the conflict coefficient by 1.0.

The computed conflict coefficients for different numbers of engines in two configurations given Figure 13-5 are listed in Table 13-4.

TABLE 13-4.-CONFLICT COEFFICIENTS AND ROUTE AVAILABILITY INDEX

No. of engines	Conflict coefficient	Route availability index
Configuration 1		
1	0.0	1.0
2	0.55	1.0
3	1.55	1.0
4	2.55	1.0
Configuration 2		
1	0.0	0.43
2	0.61	0.43
3	1.61	0.43
4	2.61	0.43

The route availability index is the ratio of the number of origin-destination combinations which have one or more routes to the number of total origin-destination combinations (whether used or not). The route availability index 1.0 indicates that a route (or routes) is available from any track to any other tracks. Route availability index 0 on the other hand indicates that no routes are available for any origin and destination combinations. Obviously the higher the route availability index, the better the design. The example configurations have different route availability indexes: Configuration 1 in Figure 13-5 has a 1.0 route availability index and Configuration 2 in Figure 13-5 has 0.43.

13.4.1.3 Trim-End Capacity. The methods of trim-end operations are different in the parallel departure yard and in the inline departure yard. Therefore, the method of capacity estimation reflects the difference in operation. In the parallel departure yard the trim-end capacity is estimated from the formula

$$\begin{Bmatrix}\text{Trim-end}\\\text{capacity}\end{Bmatrix} = \begin{Bmatrix}\text{Average number}\\\text{of trims made}\\\text{in a day}\end{Bmatrix} \times \begin{Bmatrix}\text{Average number}\\\text{of cars in a}\\\text{block}\end{Bmatrix}$$

$$= \left[\begin{Bmatrix}\text{Productive}\\\text{crew time}\end{Bmatrix} \times \begin{Bmatrix}\text{Number of}\\\text{trim engines}\end{Bmatrix} \Big/ \begin{Bmatrix}\text{Time for an engine}\\\text{to do a full cycle}\\\text{of a pull}\end{Bmatrix}\right] \times \begin{Bmatrix}\text{Average number}\\\text{of cars in a}\\\text{block}\end{Bmatrix} \quad (13.3)$$

Equation (13.3) can be rewritten as

$$C_P = \frac{T_M \cdot N_E \cdot N_C}{(T_H + T_L + N_D \cdot T_D)(1.0 + C_F) + T_C}, \quad (13.4)$$

where C_P = Capacity of the trim-end (cars/day),

T_M = Productive crew time (min),

N_E = Number of trim engines (engines),

N_C = Average number of cars in a cut of a block (cars),

T_H = Average travel time from the classification yard to the departure yard (min),

T_C = Average travel time from the departure yard to the classification yard (min),

T_D = Time required to do a doubling manuever,

N_D = Average number of doubling manuevers to be made per pull,

C_F = Conflict coefficient, and

T_C = Average coupling time to couple an average size block (min).

In Eq. (13.4) all the parameters must be estimated by the designer. The productive crew time, T_M, is the time that the trim engine crew is actually doing productive work. The maximum possible productive crew time per day is 1440 minutes minus the total minutes for meals and breaks. The average number of cars per block, N_C, may be estimated from the outbound train consist data if available. The travel times, T_H and T_L, are both net travel time and do not include waiting time due to conflict of movement. The conflict coefficient, C_F, is obtained from the conflict matrix. (The method of preparing the conflict matrix was explained in the previous section.) The coupling time, T_C, is the average time to couple a cut of a block expressed in minutes.

A sample problem that reflects the sample geometric configurations given in Figure 13-5 is presented here. If we assume the parameter values are identical in both configurations such that T_M = 1200 (min), N_E = 2 (engines), N_C = 20 (cars), T_H = 10 (min), T_L = 5 (min), C_F = 0.55 or 0.61 (given from Table 13-4) and T_C = 10 (min), then the capacity of the trim-end for Configuraion 1 is 1444 cars/day, and for Configuration 2 is 1406 cars/day.

13.4.2 Microscopic Evaluation

Microscopic evaluation of the yard trim-end design is basically a manual method of simulating every trim-end engine movement. The manual simulation is conducted using a pencil and paper for a given set of traffic variables using a set of rules and assumptions. This method will be most effective if conducted at the same time with the yard capacity analysis (see Chapter 7). When this microscopic evaluation method is applied independently from the capacity analysis, it requires a set of input variables specified in an explicit manner. The required inputs for an independent trim-end evaluation are given in the following.

13.4.2.1 Input to Microscopic Evaluation. There are eight input types for the trim-end conflict analysis:

- Outbound train information, including the scheduled departure time, the block types carried by each departing train, and the departure track used, if possible.
- Work assignment and trim-end operational policy, including the cut-off time, block type, the number of cars in the block, classification track the block is on, the number of trim engines used, and the trim engine assigned to pull the block.
- Yard engine activity information, including the average speed of the trim engine for each direction and the time required to perform each activity, such as set-off activity on the departure track or the movement change of direction activity on the pullout lead.
- Engine crew break information, including the starting time and the duration of each crew break period throughout the day.
- Departure yard crew information, including the rate of inspection and starting time and duration of each break.
- Trim-end geometric information, essentially a layout of the trim-end, including the precise distances traversed.
- Trim-engine operations policy, describing how trains are made up; e.g., a train is made up by an engine or by several engines.
- Departure yard inspection crew information, including the time to walk from one track to another and rate of inspection.

13.4.2.2 Time-Space Diagram. The microscopic manual simulation is performed on a large rectangularly gridded worksheet. Prior to describing the step-by-step method of the manual procedure, a simplified discussion on the time-space diagram is given.

The time-space diagram is essentially the tool used in the manual analysis. It is frequently used to analyze flows of traffic in other types of transportation systems. In highway traffic analysis it is used in the theoretical analysis of highway traffic flow characteristics and for coordinating signals at multiple intersections along a street. In the railroad and transit fields the time-space diagram is usually called a train graph. Use of the train graph varies from train scheduling to evaluation of train delays on single-track segments of a railroad's mainline.

To illustrate how the time-space diagram works, a sample time-space diagram was prepared (see Figure 13-7). In this figure an engine travels back and forth between two points A and B. The physical layout of the sample track is shown on the left-hand side of the time-space diagram. In this diagram the vertical axis represents space and the horizontal axis time. The key events of engine movement are identified from the time-space diagram in Figure 13-7. Here, the engine leaves point A at time T_0 and reaches point B at time T_1. Then, the

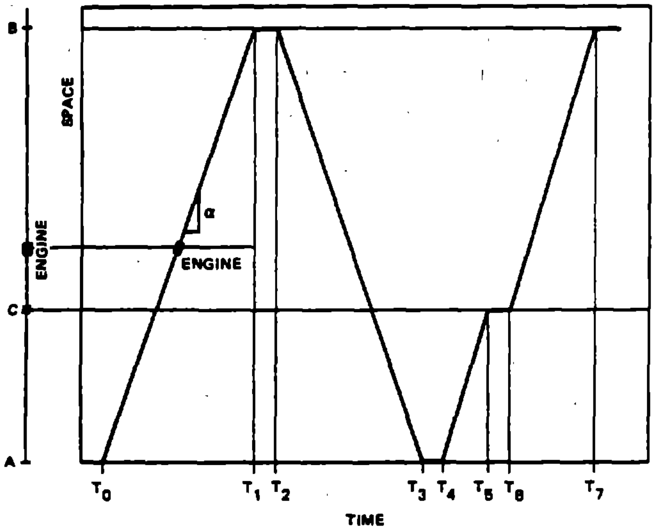


FIGURE 13-7. SAMPLE TIME-SPACE DIAGRAM (ONE TRACK)

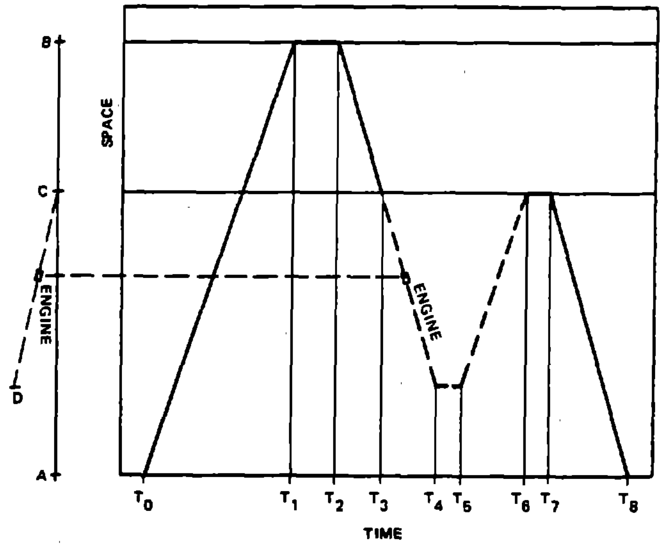


FIGURE 13-8. SAMPLE TIME-SPACE DIAGRAM (A TRACK WITH A SPUR)

engine stays at point B until time T_2, and leaves point B at that time. The motion of the engine is depicted in the time-space diagram by a line, which abruptly changes its slope as the time goes by. The slope of the line indicates the speed of the engine at that point. For example, between time T_0 and T_1 the speed of the engine is given as

$$V = (B - A)/(T_1 - T_0) \quad . \qquad (13.5)$$

A zero slope of the trajectory naturally indicates that the engine is stopped. A negative slope indicates that the engine is travelling in the opposite direction relative to increasing in distance. In this manner, the location of the engine at any time point is specifically identified. The time-space diagram also indicates the speed of the engine by the slope of the line.

When the track configuration is not a single track as in the above case, the time-space diagram must be somewhat modified. In this case the time-space diagram should be able to indicate not only the time and the location of the engine along the track, but also the track that is used by the engine. An example is again shown to illustrate this. The example shown in Figure 13-8 illustrates a case in which the track segment has a switch in the middle and the engine has a choice of travelling either on the straight track leading to point A or on the curved track leading to point D. For illustrative purposes the track segment between points C and D is indicated by a broken line. The time-space diagram shows a series of trips made by an engine starting from point A to point D via point B, and then coming back to point A via point C. In this figure the engine is on the track segment between points C and D in the time interval between T_3 and T_6. This is indicated by the broken line in the time-space diagram.

In the time-space diagram shown in Figure 13-8 the length of the engine is not considered. This can be justified so long as the engine is not too long relative to the distance of travel. However, when a train's movement instead of a single engine's movement is shown in the time-space diagram, the length of the train must be indicated in the diagram. When this is done, the time-space diagram will consist of wide bands instead of lines. The width of the band indicates the length of the train.

13.4.2.3 Microscopic Evaluation Procedure. The step-by-step procedure of the manual microscopic evaluation method is described in this section in the following manner.

Step 1: Prepare Engine Work Assignments--The engine work is specified by the following information types:

- Outbound train No.
- Engine No. to be used
- Block type
- Earliest time to start coupling the block
- Classification track where the pull originates
- Departure track where the train is made up
- Number of cars to be pulled.

The engine work assignment is prepared from the outbound train schedule, cut-off time, classification track inflow information, and yard operational policy. Specifically, the earliest time to start pulling the block is calculated as the scheduled departure time minus the cut-off time. The departure track is assigned so that the train can be made up on the shortest available track. The number of cars to be pulled is identical to the number of cars that have flowed into the classification track since the last pull from the track. Some of the work assignment information listed above may be difficult to estimate at the beginning of the simulation. Therefore, an optimum engine work assignment can be selected as the manual simulation proceeds. This is much more conveniently done and the trim-end conflict analysis becomes more efficient and meaningful if conducted simultaneously with the yard capacity analysis.

Step 2: Prepare the Worksheet on Which the Time-Space Diagram will be Drawn--This includes the following tasks:

- Draw a schematic layout of the trim-end geometry to be analyzed on one side of the graph sheet as shown in Figure 13-9.
- For each classification and departure track group, define the approximate point from which either the head or the tail of the cut of the block originates (or terminates) its trips.

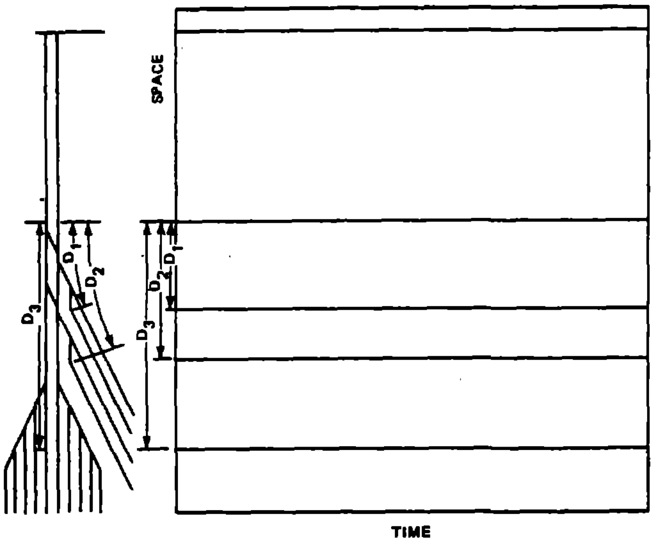


FIGURE 13-9. TIME-SPACE DIAGRAM PREPARATION SHEET

- For pullout lead-type trim-end configurations, identify how far the tail end of the cut should travel on the pullout leads.
- Prepare the two-dimensional time-space diagram in which the X-axis indicates time and the Y-axis indicates space as shown in Figure 13-9.
- Identify on the time-space diagram the critical points for trimming maneuvers.

Step 3: Construct a Time-Space Diagram Based on the Engine Work Assignment Prepared in Step 1—The work involved in constructing the time-space diagram may be represented as a sequence of calculations, drawing, and checking. One cycle of the sequence of work is described in the following:

- Find the next activity link (pullout lead, classification track, departure track, or any other track where a trim engine can stop in order to select the next route).
- Select the best route available.
- If no routes are available, then the engine waits until a route becomes available.
- Calculate the travel time from the current location to the next activity link (pullout lead, departure track, or any other track where the trim engine can stop in order to select the next route).
- Draw a train trajectory on the time-space diagram.

A sample time-space diagram for a parallel departure yard trim end is given in Figure 13-10. The figure includes not only the information related to engine movement, such as starting time or waiting time, but also the information type related to the block carried by the engine.

In the example, Engine No. 1 leaves classification track 10 at 7:10 pulling 30 cars of block type 10, and arrives at pullout lead No. 2. The engine stays at the pullout lead for 1 minute for evaluating the

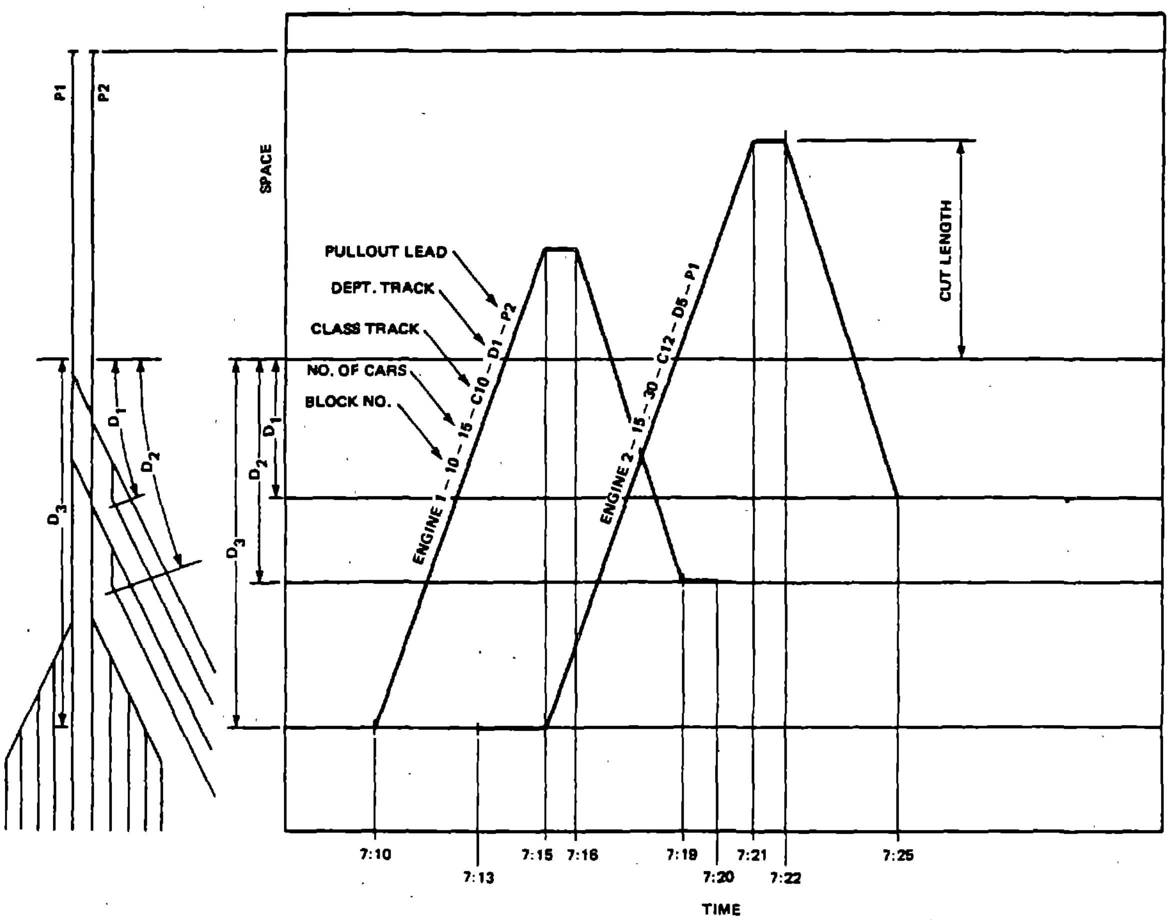


FIGURE 13-10. SAMPLE TIME-SPACE DIAGRAM (PARALLEL DEPARTURE YARD)

switch status and reversing the direction of movements, then leaves pullout lead No. 2 for departure track No. 1, and arrives at departure track No. 1 at 7:19.

The second engine (or Engine No. 2) is ready to leave classification track No. 15 at 7:13. However, it must wait until 7:15 to leave that track because that is the time the route becomes clear for the engine. The engine arrives at pullout lead No. 1 at 7:21. This describes one cycle of the manual simulation process. This process is then iterated until an entire day can be simulated.

Step 4: Compile the Trim-End Operations-Related Information--Key information contained in the time-space diagram may be summarized in a systematic manner. The type of information most useful for the analysis may be:

- Engine information
  - Total number of cars carried by each engine
  - Total number of trips made by each engine
  - Total time period in which each engine was idle
- Delay information
  - Total delay due to conflict of engine movements
  - Total outbound train delay.

13.4.3 Application of the Manual Evaluation Methods

13.4.3.1 Application of the Macroscopic Evaluation Method. The sample problem discussed here deals with the trim end of the newly proposed East Deerfield yard of the Boston and Maine Railroad. The proposed yard has 18 classification tracks averaging 68 cars in length and 8 receiving and departure tracks ranging from 65 to 94 cars in length. The trim end of the yard has only one pullout lead. Naturally, the yard was designed for a single trim-engine operation. A schematic layout of the proposed East Deerfield yard geometry is given in Figure 13-11.

The objective of this macroscopic manual evaluation is to find the trim-end capacity (or the maximum throughput that can be handled at the trim end) under two trim-engine operations. To do this, an extremely high traffic demand was artificially created based on the existing traffic pattern. Then, using the yard simulation model CAPACITY, the yard operation was simulated assuming a fixed travel time between the classification yard and the departure yard. The inputs to the trim-end evaluation work can be prepared either by the computer-simulation model CAPACITY or by the manual-simulation method described in Chapter 7.

The inputs used in the analysis are:

- Demand level at the trim end = 1504 cars/day.
- Expected number of pulls = 34 times/day.
- Expected number of doubling moves = 20 times/day.
- The number of engines = 2.
- Travel time from the classification yard to the departure yard = 15 min.
- Travel time from the departure yard to the classification yard = 5 min.
- Travel time from one classification track to another = 5 min.
- Coupling rate = 0.50 min/car.

In this case, the conflict coefficient, C_F, is 1.0, because the engines will have conflicting movements every time they travel. The capacity of the trim end is estimated at

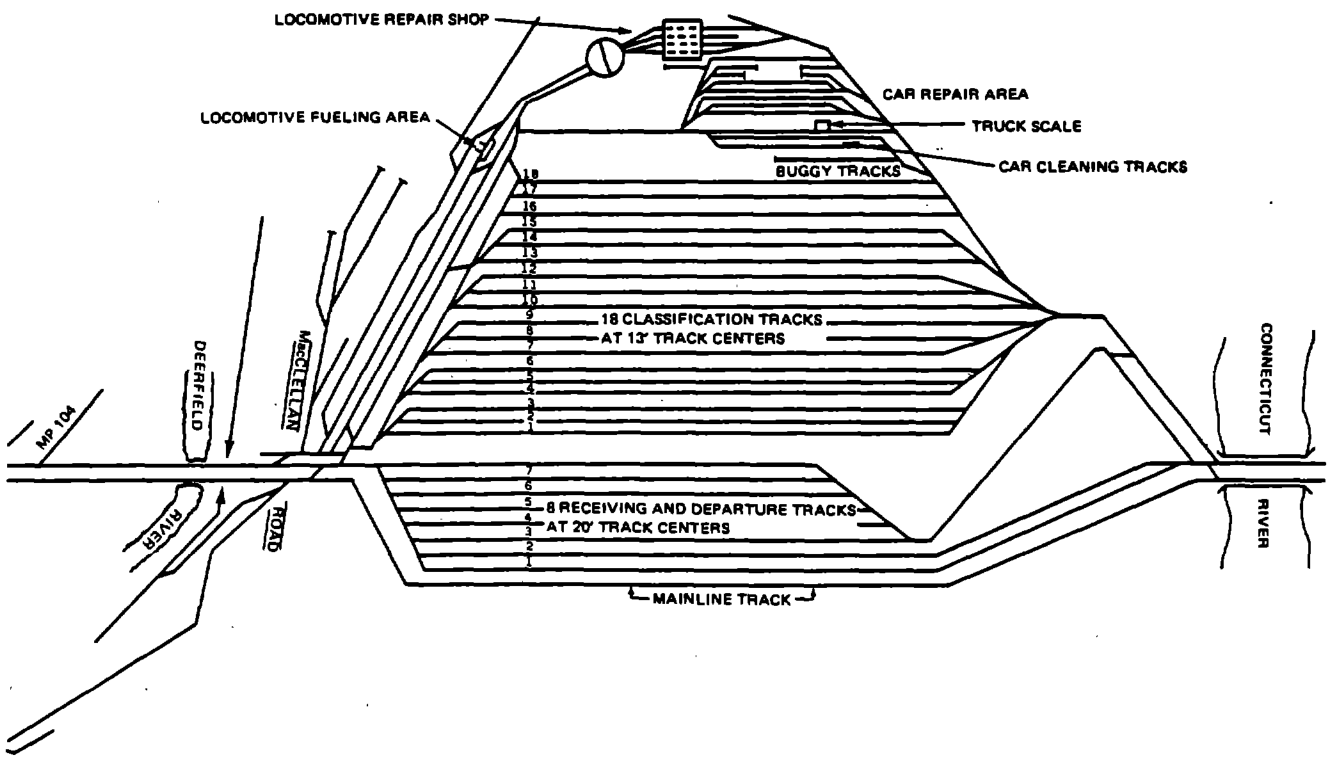


FIGURE 13-11. PROPOSED SCHEMATIC LAYOUT OF EAST DEERFIELD YARD

$$C_P = \frac{1325 \cdot 2 \cdot (1504/34)}{(15 + 5 + .5 \cdot 20/34)(1.0 + 1.0) + .5\ (1504/34) + 1} ,$$

$$= 1699 \text{ cars/day} > 1504 \text{ cars/day} . \quad (13.6)$$

The analysis shows that the capacity of the trim end is larger than the fictitious demand, and thus the demand can be handled at the trim end. However, it should be noted that the difference between the capacity and the demand is not large, i.e., the yard trim end utilizes 88.5% of its capacity with the given constant demand rate. In reality, because of the peaking effect of traffic, it is estimated that the departing trains will experience much delay.

If the total number of pulls to be made in a day is N_P, the time required for an engine to perform one rounding pulling maneuver (which includes coupling, doubling if applicable, pulling the block to the departure yard, and returning back to the classification yard) is P, and the number of trim engines N_E, then by assuming that exactly one-half of the work is done by each engine and also that the cut-off times of blocks occur at random in the yard, the waiting time of a block to be pulled, W_q, is expressed as

$$W_q = \frac{P^2}{2(1/\lambda - P)} , \quad (13.7)$$

where λ = rate of pulls to be made by an engine per minute,

$P = (T_H + T_L + N_P T_D)(1.0 + C_P) + T_C$ in Eq. (13.4).

Equation (13.7) is a conventional queueing equation, which assumes a random arrival pattern and a constant service time. The arrival pattern in this case implies the pull ready time, and the service time comprises the coupling and round-trip time of the engine.

In this example, λ = 0.0128 pulls/minute and P = 69.0 minutes. Then, the mean waiting time for blocks to be pulled is

$$W_q = \frac{69.0^2}{2(1/.0128 - 69.0)} = 260 \text{ minutes} . \quad (13.8)$$

The result in Eq. (13.8) shows that on the average blocks must wait for about 260 minutes or 4.33 hours under the given assumptions.

Looking at the same problem from a different aspect, one might ask what would be the capacity of the trim end if all the operational parameters, such as the coupling time, the travel times, and the average block length stay the same, but the mean waiting time is restricted to 60 minutes. Using Eq. (13.7), one obtains λ = 0.0092 or approximately 24 pulls a day. This converts to 1012 cars/day or λ/μ = 0.63. This can be interpreted that the degree of saturation at the trim-end is 0.63, or that the crew is engaging in pull work 63% of the assigned work hours.

13.4.3.2 Application of the Microscopic Evaluation Method. The sample problem deals with the trim end of the existing Elkhart Yard of Consolidated Railroad Corporation. A schematic geometry of the trim end is given in Figure 13-12. The existing westbound yard has 33 classification tracks ranging from 24 to 50 cars in length. There are five departure tracks of varied lengths ranging from 107 to 112 cars long. Figure 13-12 shows that the westbound trim end has one pullput lead of full length and another short pullout lead.

The work proceeds as described in Section 13.4.2.3, Microscopic Evaluation Procedure. The engine work assignment was obtained from the computer output CAPACITY.

Step 1: Prepare the Engine Work Assignment--The engine work assignment of the Elkhart Yard west trim end is given in Table 13-5. The engine work assignments are taken from the yard simulation model CAPACITY. Neither a specific engine No. to be used for each pull nor a departure track to be used to make up a train are specified in the table. The designer, in this case, must find which engine is available for each pull and select the departure track on which the train is made up.

Step 2: Prepare a Worksheet on Which the Time-Space Diagram Will Be Drawn--The prepared worksheet is given in Figure 13-13. The key points of the trim-end are identified on the graph for illustrative purposes.

Step 3: Construct a Time-Space Diagram on the Worksheet Using the Engine Work Assignment Prepared in Step 1 and Input Information Defined in Section 13.5.2.1--The input information used in the analysis is as follows:

- Outbound train schedule (see Table 13-6).
- Number of trim engines: 2 engines.
- Trim-end operational policy: A train is made up by two engines simultaneously.
- Average speed: 6 mph for pulling activities and 4 mph for pushing activities. Set-off and changing directions both take 1 minute. The assumed speed for a light engine is 6 mph for both directions.

FIGURE 13-12. EXISTING TRIM-END DESIGN

TABLE 13-5.-ENGINE WORK ASSIGNMENTS OF EXISTING ELKHART YARD WEST TRIM END

Depart. train	Train E/W	Block No.	Track No.	Block E/W	No. of cars	Total cars	Start couple	Engine used	Depart track No.	Cut-off time
LS21	W	22	61	W	38		(To Be Assigned in Simulation Process)	(To Be Assigned in Simulation Process)	(To Be Assigned in Simulation Process)	0015
LS21	W	22		W	36	74				
KDC7	W	39	66	W	35					0200
KDC7	W	39	66	W	19					
KDC7	W	62	72	W	29	83				
XBRC7	W	5	54	W	53					0200
XBRC7	W	5		W	53	106				
DTVS	W	78	70	W	26	26				0200
CJ1	W	13	59	W	21					0300
CJ1	W	19	60	W	17					
CJ1	W	52	68	W	39					
CJ1	W	10	58	W	1					
CJ1	W	24	62	W	2	70				
IHB1	W	8	56	W	6					0500
IHB1	W	28	63	W	21					
IHB1	W	29	64	W	27	54				
IC7	W	34	65	W	51					0530
IC7	W	54	69	W	51	102				
BM1	W	9	57	W	1					0600
BM1	W	7	55	W	20					
BM1	W	49	67	W	23	44				
CJ1A	W	13	59	W	6	6				0700
SF3	W	1	52	W	33					0730
SF3	W	1	52	W	33					
SF3	W	1	52	W	33					
SF3	W	1	52	W	33	132				
ABN1	W	85	71	W	43					0800
ABNL	W	4	53	W	55					
ABN1	W	4	53	W	12	110				
BRC7	W	5	54	W	53					1000
BRC7	W	5	54	W	47	100				
XBN1A	W	85	71	W	9					1500
XBN1A	W	4	53	W	4	13				
PIHB5	W	28	63	W	57					1700
PIHB5	W	28	63	W	6	63				
SF1	W	1	52	W	33					2130
SF1	W	1	52	W	33					
SF1	W	1	52	W	21	87				
BN1	W	85	71	W	39					0000
BN1	W	4	53	W	26	65				

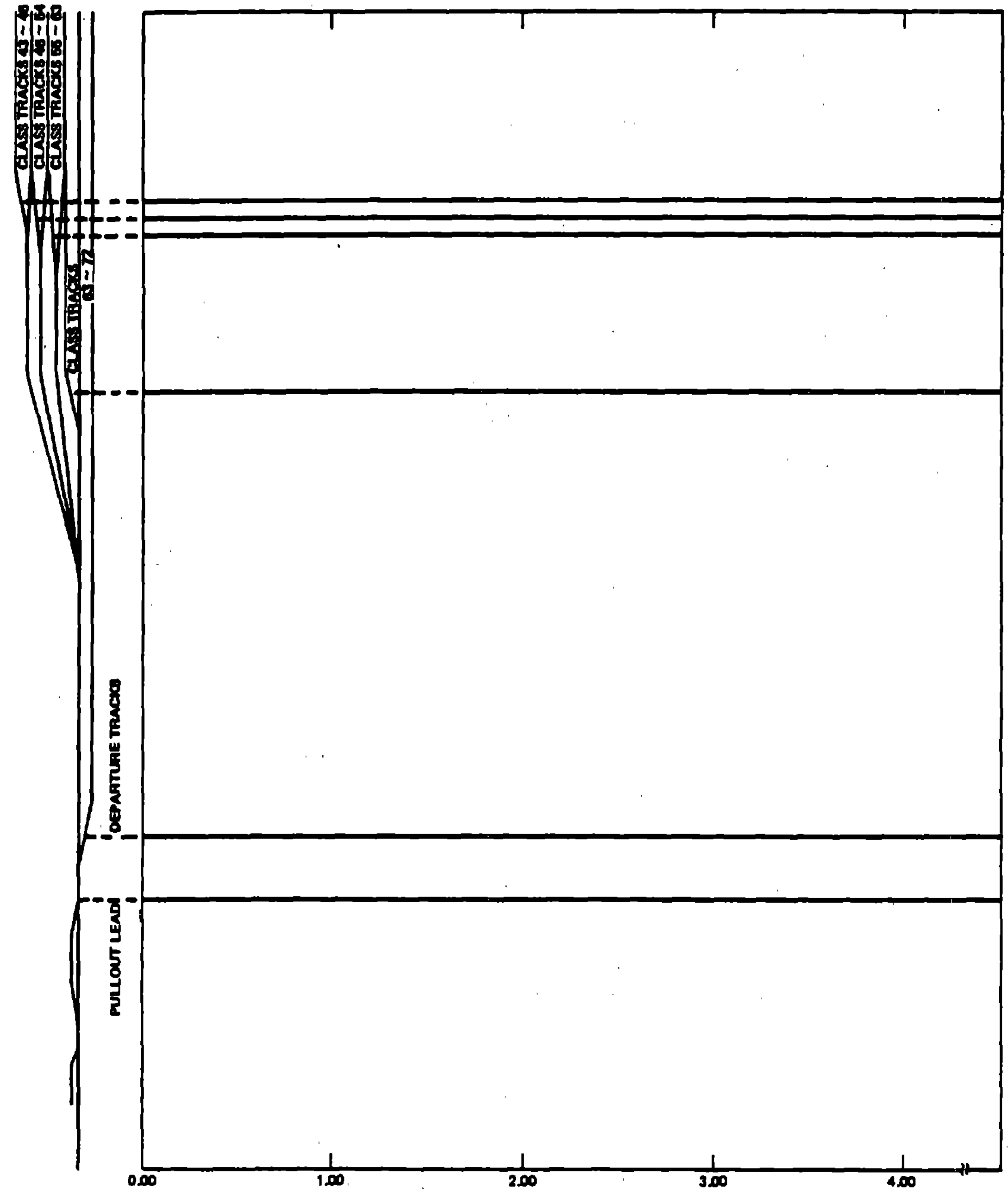


FIGURE 13-13. PREPARED WORKSHEET

TABLE 13-6.-OUTBOUND TRAIN SCHEDULE

Departing train no.	E/W	Scheduled departure time	Blocks pulled for this train
SF1	W	30	1
BN1	W	300	85, 4
LS21	W	315	22
KDC7	W	500	39, 62
XBRC7	W	500	5
DTVS	W	500	78
CJ1	W	600	13, 19, 52, 10, 24
IHB1	W	800	8, 28, 29
IC7	W	830	34, 54
EM1	W	900	9, 7, 49
CJ1A	W	1000	13, 19
SF3	W	1030	1
ABN1	W	1100	85, 4
BRC7	W	1300	5, 88
XBN1A	W	1800	85, 4
PIHB5	W	2000	87, 28

- The same crew breaks for the engine crew and the departure yard inspection crew are assumed. The crew break information is listed in Table 13-7.
- Number of departure yard inspection crews: 2.
- The outbound inspection rate: 0.66 min/car plus 18 minutes for each train.
- The coupling rate: 0.41 min/car plus 2 minutes for each block.

Using the above information, the manual simulation was conducted. The resultant time-space diagram is given in Figure 13-14.

TABLE 13-7.-CREW BREAK INFORMATION

Break period	Start	Duration (min)
1	0300	30
2	0650	5
3	1000	5
4	1200	30
5	1450	5
6	1630	5
7	1830	30
8	2240	5

Step 4: Compile the Trim-End Operations-Related Information from the Time-Space Diagram Constructed in Step 3—Sample information is given below:

- Engine information
  - Total number of cars carried by
    - Engine 1 = cars/day
    - Engine 2 = cars/day
    - Total = cars/day
  - Total number of round trips made by
    - Engine 1 = trips/day
    - Engine 2 = trips/day
    - Total = trips/day
  - Total time period in which engine was idle
    - Engine 1 = min/day
    - Engine 2 = min/day
    - Total = min/day
- Delay information
  - Total delay due to conflict of engine movements
    - Engine 1 = min/day
    - Engine 2 = min/day
    - Total = min/day
  - Total outbound train delay min/day

13.5 COMPUTER-ASSISTED EVALUATION METHOD

A computer simulation program that can simulate these classification yard-departure yard vehicle movement operations was developed to analyze the yard conflict problems. This program, called CONFLICT, is used to evaluate yard design in the throat. CONFLICT has been successfully used in a design evaluation study for Elkhart Yard (Elliott, et al., 1979).

The aim was to create a simulation model that is as simple as possible, but at the same time is flexible and precise enough to be useful for the yard analyst. The model is able to simulate most geometry and operation types, and is designed to be capable of simulating 400 links (100 classification tracks, 30 departure tracks, 170 other links), 100 routes, and 8 engines.

Many assumptions were adopted to make the simulation model feasible. The assumed items or rules include:

- Travel time calculation rule
- Route decision rule
- Operational strategy (input)
- Outgoing and incoming train delay
- Classification cuts rules (input).

The measure of effectiveness used in evaluating yard geometry is the throughput of cars in the conflict region per unit time period of operation. (See Appendix C for further details.)

13.5.1 Model Description

CONFLICT is an event-step simulation model in which the advancement of clock time is determined by the occurrence of events to be simulated in the model. The events to be simulated are:

- Time when the head of the engine/cut enters a link
- Time when the tail of the engine/cut exits a link
- Time when a train is scheduled to depart the departure yard
- Time when an engine selects a route.

A flowchart that shows the overall structure of the simulation model is presented in Figure 13-15. A brief rundown of the overall simulation process is given here.

The simulation process starts by reading in input variables and setting certain initial values to the rest of variables. This process is indicated by box (1) in the flowchart. Among many other input variables, the train departure schedule and the cut-off time of a car block are input variables.

The simulation program keeps track of each engine movement in terms of event occurrence times. Whenever the

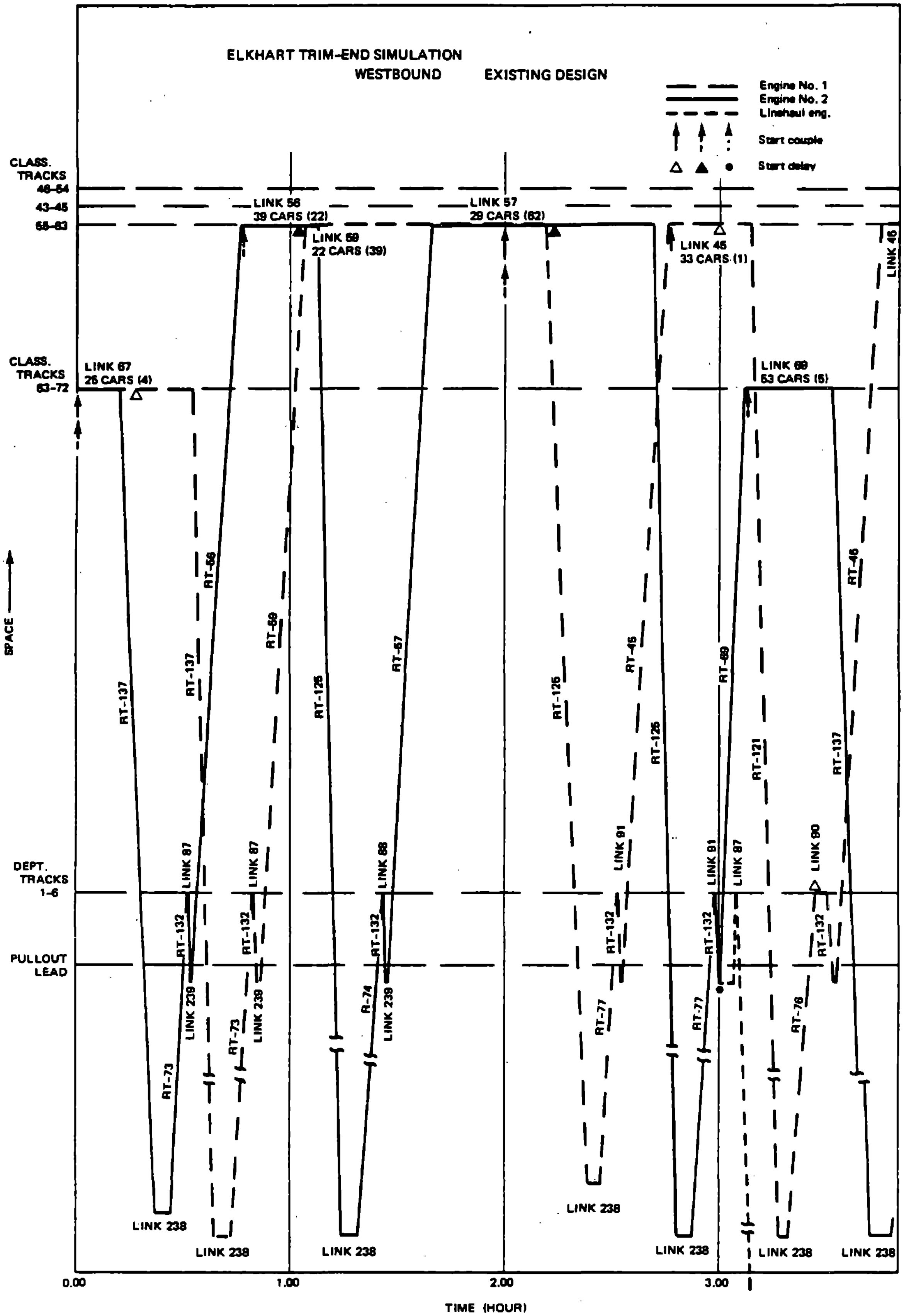


FIGURE 13-14. TIME-SPACE DIAGRAM (EXISTING ELKHART YARD)

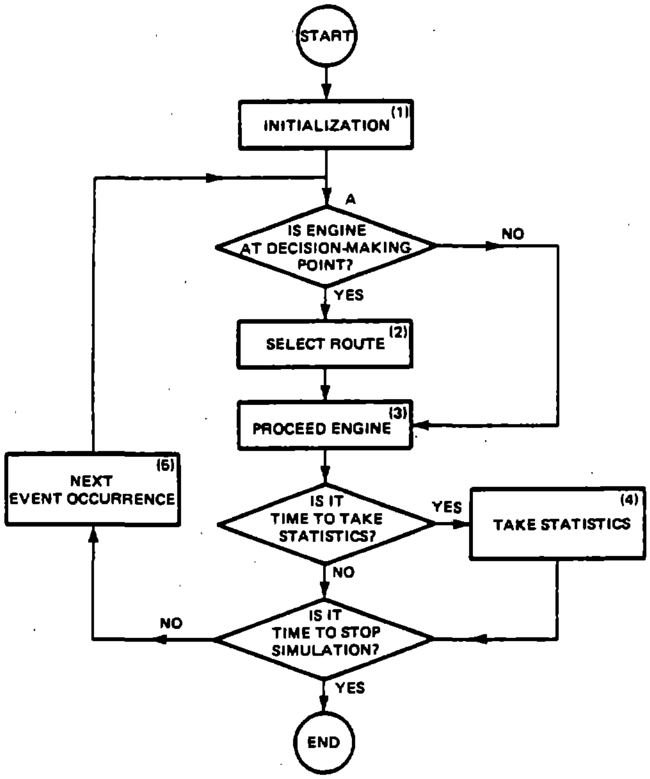


FIGURE 13-15. OVERALL STRUCTURE OF THE CONFLICT MODEL

clock time is updated, a new series of decisions and computations start in the program. This point is indicated in the flowchart by A.

If the engine is in the classification yard, the program must first find the departure track to which the engine is sent. Then the route to the departure track is determined. The departure track number is an input variable specified by the model user. The route (or a series of links) to be taken to the departure track is determined based on the conditions of conflict with other engine movements at the time of decision making. Then the travel time to that departure track is calculated and the engine's arrival time there is added to the list of future events.

If the engine is in the departure yard, the program must first find the classification yard track to which the engine is sent. Next, the route to be taken by the engine is chosen based on the current conflict information, i.e., a route is chosen that avoids conflict and is most preferred. The immediate destination of the engine (or a classification track to which the engine is sent) is determined from a look-up table which indicates the sequence of the work assigned to the engine by the model user. This process is shown in the flowchart by box (2). The route selection for the line-haul engine is also performed in this subroutine.

If the event does not involve any decision making, then the engine can be advanced to the next event point. This is shown by box (3) in the flowchart.

If it is time to take statistics on yard operations, then this must be done. Unless it is the end of simulation time, update the next time event and proceed with the simulation (see boxes 4 and 5 in the flowchart).

13.5.2 Input to the Model

The inputs to CONFLICT are divided into six categories:

- General simulation information
- Yard geometry
- Engine and engine schedule-related information
- Class track inflow information
- Outbound train schedule
- Initialization of tracks.

Each input category is briefly described in the following sections.

13.5.2.1 General Simulation Information. This input type deals with general information, such as the simulation program options, the simulation time period, and operation parameters.

13.5.2.2 Yard Geometry-Related Information. This input type describes the yard geometry. This information includes individual link data, individual route data, and origin-destination (OD) route matrix data. Brief descriptions of yard geometry-related terminologies follow.

Link--A section of track between switches. It is assumed that only one engine can occupy a link at one time. Two types of links are considered: activity links, and enroute links. An activity link is one on which an engine may stop or a link located at the simulation boundary. The links considered to be activity links are departure tracks, classification tracks, pullout leads, outbound tracks to the mainline, inbound tracks from the mainline, repair tracks, and diesel/caboose service tracks. The other links are classified as enroute links which function as route segments for movements in the yard.

Route--A route is a sequence of links between two activity links. If an engine travels from a class track to a departure track via a pullout lead, then the engine travels on two routes in that sequence. First, it travels from the class track to the pullout lead on a route, then it travels from the pullout lead to the departure track on a different route. A route usually consists of two partial routes: a ladder and a lead. A ladder is a set of links that connects either a classification track and a classification track lead, or a departure track and a departure track lead. A lead is a set of links that connects a classification track lead and pullout lead, or a departure track lead and pullout lead, or a classification track lead and departure track lead.

OD Route Matrix--An OD route matrix is one that indicates a set of common routes which connect the origin and the next activity link. The entries of each cell are the route numbers (to the next activity link) in the order of preference. The origin in the matrix indicates the activity link that the engine occupies at the decision-making point, and the destination indicates the final activity (not the intermediate stop) link or collector link to which the engine is traveling. Here, a collector link is one that joins a common route and collector-distributor route. In the link classification this collector link is classified as an enroute link.

13.5.2.3 Engine and Engine Schedule-Related Information. Two types of information are included in this category. One type is information related to the engine itself, and the other type is information related to the engine schedule. The engine information data consisting of engine type and speeds are rather simple and self-explanatory. However, the data related to the engine schedule require further explanation.

The schedule of each engine is specified by the user, who can specify the engine schedule in the order-of-time sequence of the jobs to be done. The engine activity types that can be simulated in the model are line-haul engine assignment, train departure, departure track starting, doubling operations, and coupling operations.

The model is capable of simulating different engine assignment methods. For example, if there are eight activities to be conducted at the yard and two engines are available, and if the user wants to let each activity be done by the first available engine, then the user can specify each activity as one assignment in the data setting. Under the same condition, if the user wants to let one engine do a series of activities in a given sequence, then those activities are collectively coded as one assignment.

13.5.2.4 Classification Track Inflow Information. Cars are considered to be flowing into classification tracks in batches. The classification track inflow information defines the block types, the number of cars, and the time of each batch arrival to each classification track.

13.5.2.5 Outbound Train Schedule. The outbound train schedule contains relevant information on outbound trains that depart from the departure yard.

13.5.2.6 Initialization Tracks. The initialization of each track is not critical to running the program. If no classification track initialization is made, the program assumes zero cars on each classification track at the simulated starting time.

13.5.3 Output of the Model

The outputs of the model are classified into the six categories listed below:

- Echo-back input data
- Conflict-related data
  - Engine movement history.
  - Delay time of engines caused by conflict for each route and origin/destination combination.
  - Delay of engines classified by each engine.
- Traffic-related data
  - Traffic flows at each link and route in terms of the number of cars and engines.
  - Number of trips made by each engine and the the number of cars carried by each engine.
- Yard inventory-related data
  - Classification yard car build-up information expressed in terms of the number of cars per track at the beginning of each hour.
  - Departure yard occupancy diagram showing the time duration tracks are occupied by trains.
- Engine activity-related data
  - Engine activity diagram showing the activity type each engine is engaged in every minute.
- Departure train-related data
  - Scheduled and actual departure time of each departing train.

Samples of key output types are given in Figures 13-16 to 13-20. Figure 13-16 shows the Engine Activity Report, which records all the moves made by each engine. The information types contained in the report include the engine number, block number, outbound train number, start-pull time, origin track number, end-pull time, destination track number, and amount of delay and route number on which the engine was when the delay occurred. The designer can pinpoint the route numbers and the origin-destination track combinations that suffer delays due to engine conflicts.

Figure 13-17 shows a classification yard car build-up matrix. The figure shows not only the number of cars sitting on each track at the beginning of each hour, but also shows the maximum number of cars observed on each classification track in a day. Note that every time a pull is made at a classification track, all of the cars on that track are taken. This assumption can be seen in the matrix. A sudden drop in the number of cars stored on a track indicates that a pull was made between the two time points.

Figure 13-19 shows the train departure report, which includes the scheduled and actual train departure times, and delays of trains in terms of both train-minutes and car-minutes. If the train delay becomes progressively larger as time passes, then the capacity of the modeled trim end is less than the demand used. The capacity of the modeled yard trim end is about equal to the demand level when the delays of the departure trains can barely be kept cyclical every day.

Figure 13-20 shows the engine work-activity diagram, which indicates the engine activity each train is engaged in for every one-minute interval. Each letter in the strip chart signifies an activity done in that one minute. Each band of the strip chart is made up of a series of three letters. The time sequence starts from the three letters on the far left and ends at the three letters on the far right. Among the three letters in the same column, the top letter indicates the engine activity in the first minute, the middle letter indicates the engine activity at the next minute, and the bottom letter indicates the engine activity in the third minute. The engine activity in the fourth minute is indicated by the top letter in the next column, and so on.

13.5.4 Application of the Model

The sample problem described in this paper is based on a study conducted on CONRAIL's Elkhart Yard.

Elkhart Yard, built by the former New York Central in 1957, is a first-generation computerized hump-yard with an inline receiving yard, a hump with electronic retarder controls, a classification yard with a fish-tail configuration, and two parallel departure yards. Figure 13-21 is a sketch of the present facility.

Approximately 1100 to 1200 cars are currently pulled daily from the classification yard to the departure yard at the westbound trim end of the Elkhart Yard. The existing geometry of the yard's westbound trim end

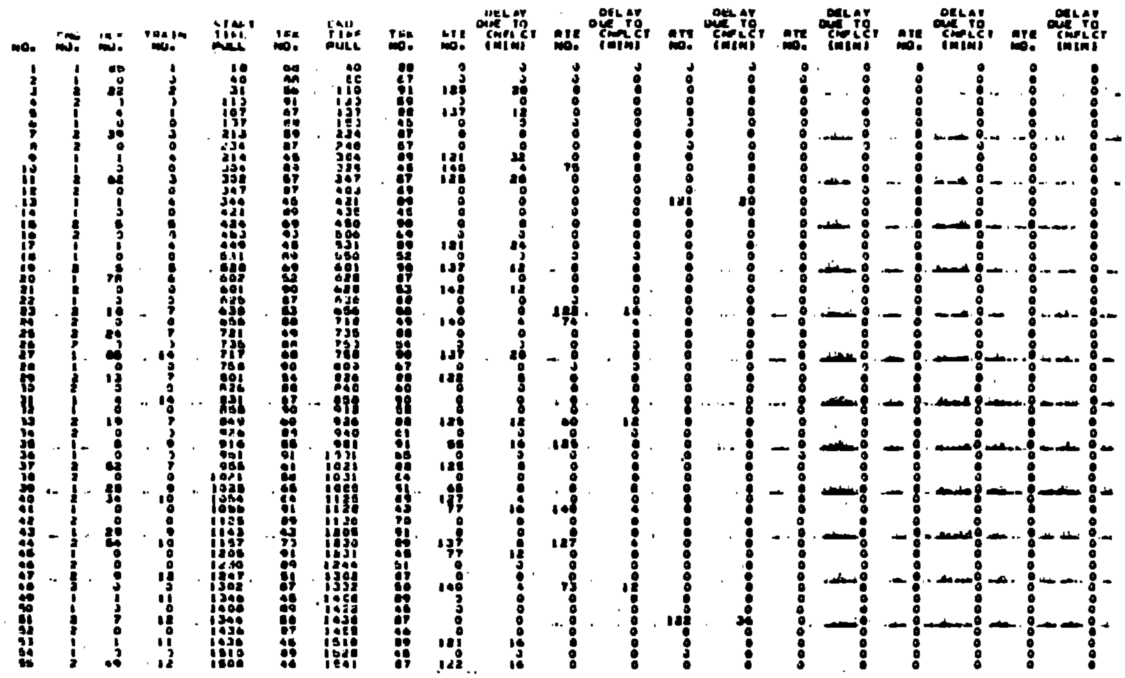


FIGURE 13-16. ENGINE ACTIVITY REPORT

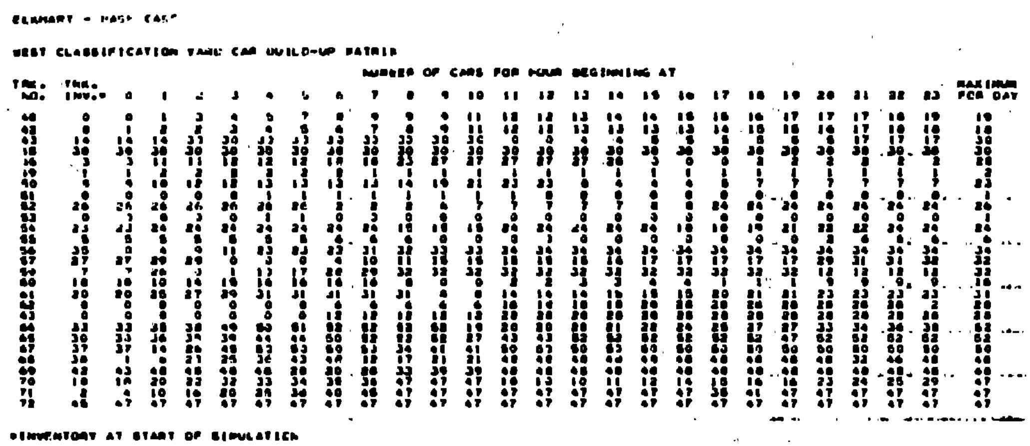


FIGURE 13-17. CLASSIFICATION TRACK CAR BUILD-UP MATRIX

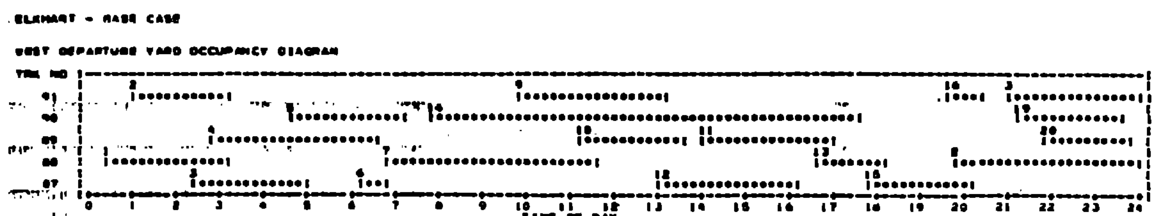


FIGURE 13-18. DEPARTURE YARD OCCUPANCY DIAGRAM

ELKHART - BASE CASE

TRAIN DEPARTURE REPORT

TRAIN NO.	SCHEDULED DEPARTURE TIME	ACTUAL DEPARTURE TIME	TRAIN DELAY TIME (MIN)	NUMBER OF CARS ON TRAIN	TOTAL DELAY TIME OF CARS ON DEPT. TRAINS (MIN)
1	300	305	5	75	375
2	315	316	1	35	35
3	600	601	1	65	65
4	500	633	90	90	8100
5	500	657	117	26	3042
6	503	703	120	96	11520
7	400	1118	318	76	23088
9	800	1305	305	88	26840
10	830	1331	301	99	29799
12	905	1616	436	53	23108
11	900	1700	480	90	43200
14	1100	1712	372	116	43152
13	1000	1758	478	28	13384
15	1300	2005	425	76	32300
16	1330	2021	411	52	21372
19	1800	2333	333	98	32340
20	1830	2341	311	60	18660
TOTAL 17			4498	1211	330378

AVERAGE DELAY TIME PER TRAIN IS 264 MINUTES
AVERAGE DELAY TIME PER CAR IS 272 MINUTES.

FIGURE 13-19. TRAIN DEPARTURE REPORT

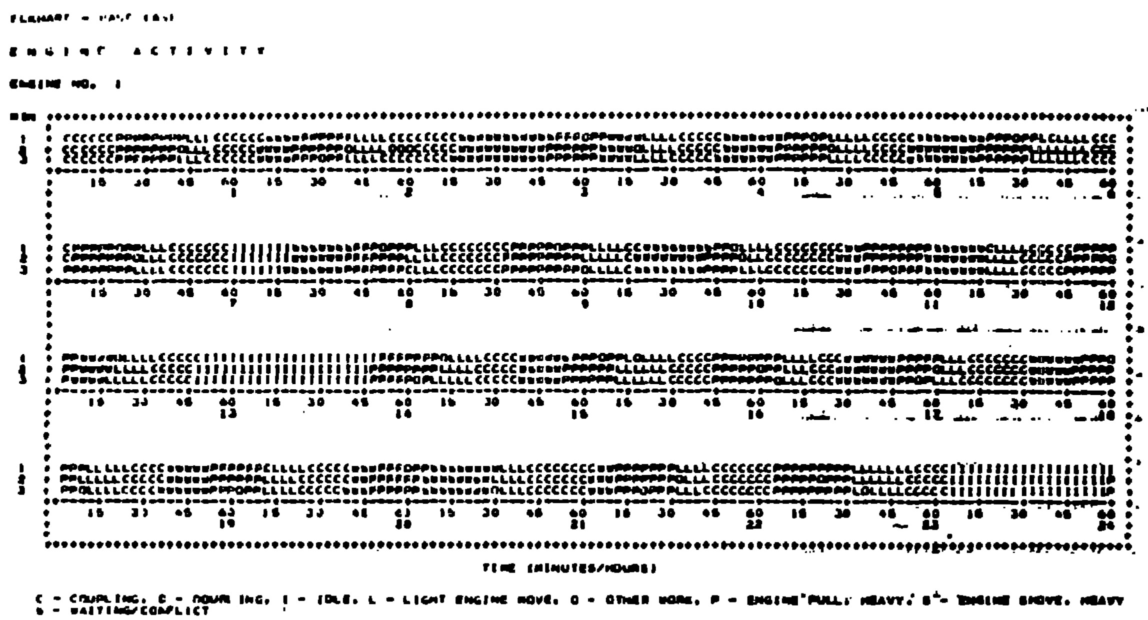


FIGURE 13-20. ENGINE WORK-ACTIVITY DIAGRAM

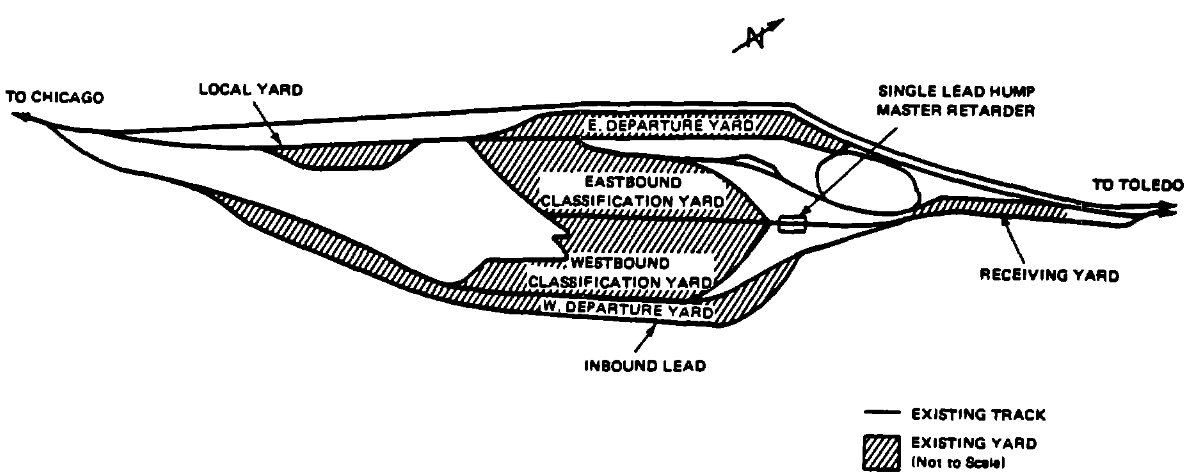


FIGURE 13-21. PRESENT CONFIGURATION OF ELKHART YARD
(Capacity at 2,600 Cars/Day)

contains yard capacity for moving over 1200 cars per day through the westbound departure yard. This capacity, however, is insufficient, and is caused by factors such as (1) the long travel distance for the trim engines between the classification yard and the departure yard, (2) short classification tracks ranging from 24 to 50 cars, and (3) the insufficient length of the single pullout lead for the longest class track.

Three alternative designs have been proposed to alleviate the problems with the existing geometry. The alternatives are:

1. Extended classification tracks with dual pullout leads.
2. Extended classification tracks with crossover in the departure yard.
3. Extended classification tracks with dual pullout leads and relocation of the departure yard.

Computer simulations using the CONFLICT model were performed for the trim-end geometries of the existing design and Alternatives 1 and 2. Alternative 3 was not evaluated using the simulation model because the design was considered too costly, i.e., it exceeds the budget constraints put on capital improvement. The objective of the simulation was to determine which of the two alternatives (1 and 2) would perform better under higher traffic demand.

13.5.4.1 Trim-End Design Alternatives—The trim-end designs of the existing yard and the three alternatives are briefly described below.

Existing Yard--The existing westbound yard has 33 classification tracks ranging from 24 to 50 cars in length. There are five departure tracks of varied lengths ranging from 107 to 112 cars. A schematic layout of the trim end is given in Figure 13-22. The existing geometry of the westbound trim end will limit the yard capacity with increased traffic demand.

Alternative 1: Extended Classification Tracks with Dual Pullout Leads--In this alternative, shown in Figure 13-22, the classification tracks in the middle of the yard are extended by 1000 to 1500 feet. The westbound classification yard under this design will hold 41 to 50 cars on each track. A pullout lead is added to the existing lead and the track layout around the trim end is modified. The yard engines still travel an extra distance from the convergence point of the classification track (Point A in Figure 13-22) to the pullout leads. However, the extra distance involved is much shorter than that under the existing configuration.

Improvements are made in the departure yard also, which has five tracks ranging from 108 to 112 cars long. Two additional tracks 112 cars long are adjacent to the existing yard. Dead access ladders with parallel leads will provide capacity for making trains simultaneously.

Alternative 2: Extended Classification Tracks with Crossovers in the Departure Yard--In this alternative, shown in Figure 13-23, the westbound class tracks in the middle of the yard are extended to 1500 feet and the class track leads merge into the middle of the departure track. The westbound class track lengths under this design vary from 41 to 50 cars. From where the merging point of the classification track leads to the departure track, a series of crossovers are installed to the outermost departure track. The tracks on the west side of the crossover can be used as the pullout leads as well as departure tracks. This configuration shortens travel distances of the trim engines as long as each outbound train is sufficiently short to avoid blocking the crossover.

Seven departure tracks are proposed in this design with a capacity of 107 to 142 cars each if east side and west side are combined. When a train exceeds the length of the east side section of track, the train sections must be stored on both sides of the crossover. Just prior to departing, the cuts will be coupled. During this time a completed train is blocking a crossover. The trim engine building a train on the far track will need to use the pullout lead in order to reach the far track, or wait for the departure of the train blocking its route.

Alternative 3: Extended Classification Tracks with Dual Pullout Leads and Relocation of Departure Tracks--In this design, shown in Figure 13-24, westbound classification tracks in the middle of the yard are extended by 1000 to 1500 feet. The westbound classification tracks under this design hold 41 to 50 cars per track. A pullout lead is added to the existing lead. In addition, sections of track at the west end of the departure yard are shortened. Corresponding lengths of departure track are added to the east end of the departure yard. The westbound departure yard has seven tracks ranging from 130 to 140 cars.

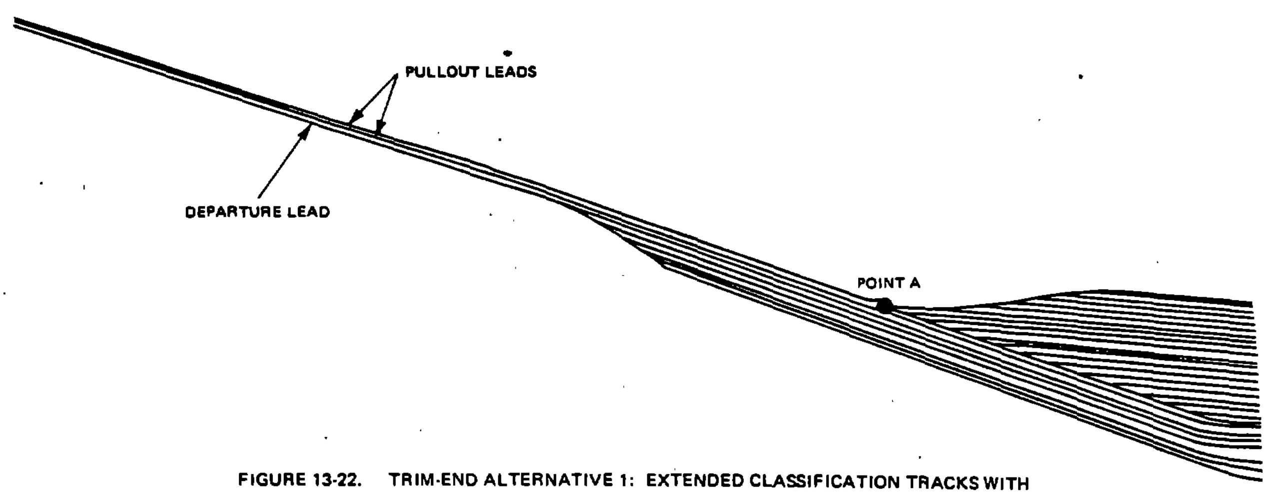


FIGURE 13-22. TRIM-END ALTERNATIVE 1: EXTENDED CLASSIFICATION TRACKS WITH DUAL PULLOUT LEADS

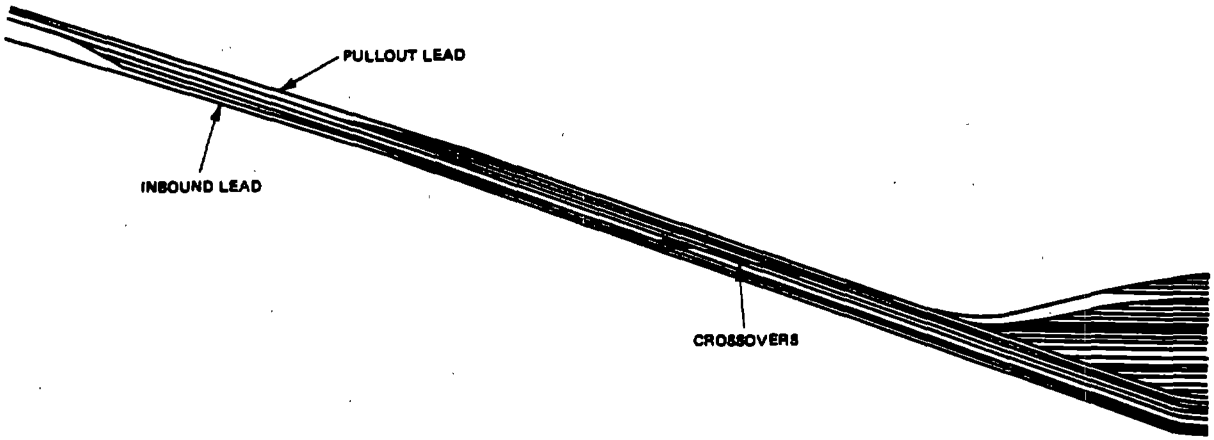


FIGURE 13-23. TRIM-END ALTERNATIVE 2: EXTENDED CLASSIFICATION TRACKS WITH CROSSOVERS IN THE DEPARTURE YARD

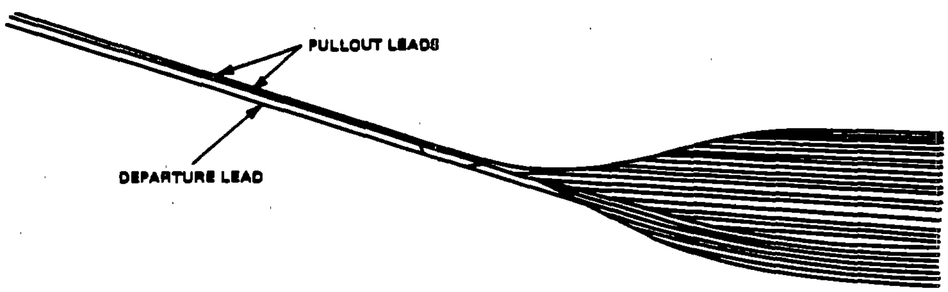


FIGURE 13-24. TRIM-END ALTERNATIVE 3: EXTENDED CLASSIFICATION TRACKS WITH DUAL PULLOUT LEADS AND RELOCATED DEPARTURE TRACKS

This scheme combines the advantages of all the desirable design features: large classification track capacity, dual pullout leads, short trim engine travel distance, and large departure track capacity.

13.5.4.2 Operational Parameters and Assumptions Used for the Simulation--To achieve uniformity in the yard design computer simulations, most operational procedures are held constant for the three simulated design plans. In general, the yard design simulations are based on the following operations parameters and assumptions:

- The input traffic level is set at an inflow of 1800 cars per day to the westbound yard.
- A 24-hour period of trim-end operations starting at midnight is simulated.
- Two trim engines are assigned to do the work in the westbound yard.
- The pull speed of the trim engines is a constant 6 miles per hour and the shove speed is 4 miles per hour.
- The engine work schedule remains the same for each simulated plan.
- The schedule allows simultaneous train make-up; a train is built by one engine only.
- Track overflows on classification tracks are prevented by limiting the flow of cars to the track's capacity.
- The departure track assignment is done manually by assigning the shortest departure track that is long enough to perform a train make-up.
- No constraints on line-haul engine availability are assumed.
- In Alternative 2, the duration of crossover blocking due to extra trimming work and train departure preparation is assumed to be 20 minutes if the train is built on both sides of a split departure track and is to occur prior to the train departure.

13.5.4.3 Input Preparation. Three types of inputs are required to run the CONFLICT model. These are operations-related, geometry-related, and traffic-related. A set of sample inputs is given in Figures 13-25 through 13-32. The sample inputs shown here are the echo-back printouts of a computer run for the base Elkhart Yard design.

Figure 13-25 shows sample inputs of yard operations-related parameters used for the evaluation of the existing design of Elkhart Yard. The values of the input parameters are different from yard to yard. The values used in the input for the specific case must reflect the operations for that yard properly.

Figure 13-26 is a sample layout of a part of the existing Elkhart trim-end design. This layout identifies link numbers and link lengths of this part of the trim end. To obtain the desired quantities, it is recommended that the designer prepare a trim-end geometric layout with a scale of roughly 1 inch = 100 feet. The links numbered and measured from the layout become the input to the computer model. A sample echo-back of the link inputs is given in Figure 13-27.

ELKHART - BASE CASE

MISCELLANEOUS SIMULATION AND CONTROL VARIABLES

TYPE OF YARD	PULL-BACK
SIMULATION START TIME (MILITARY TIME)	)
SIMULATION START DAY	0
SIMULATION END TIME (MILITARY TIME)	2400
SIMULATION END DAY	0
TIME AFTER WHICH ENGINE AGAIN TRIES TO CAPTURE A CLASSIFICATION TRACK TO COUPLE CARS (MIN)	5.00
TIME AFTER WHICH ENGINE AGAIN TRIES TO CAPTURE A CLASSIFICATION TRACK TO DOUBLE CARS (MIN)	5.00
PULL-OUT LEAD DELAY (MIN)	1.00
TIME AFTER A CONFLICT SITUATION AT WHICH ENGINE WILL ATTEMPT ANOTHER ROUTE SELECTION (MIN)	4.00
DELAY AFTER A ROUTE SELECTION BEFORE ENGINE STARTS TO MOVE OR PULL CARS (MIN)	5.00
LINE-HAUL ENGINE DELAY TO ENSURE THAT TRIP ENGINE VACATES TRACK (MIN)	2.00
TIME AFTER WHICH ENGINE CHECKS AGAIN ON THE AVAILABILITY OF A DEPARTURE TRACK FOR BLOCK SETOUT (MIA)	5.00
INSPECTION DELAY TIME (MIN)	5.00
RATE OF INSPECTION (MIN/CAR)	.56
COUPLING DELAY TIME (MIN)	2.00
RATE OF COUPLING (MIN/CAR)	.41
BLOCK SETOUT TIME (MIN)	0.00
TRAFFIC INFLOW MULTIPLIER	1.20

FIGURE 13-25. SAMPLE INPUT-YARD OPERATIONAL PARAMETERS

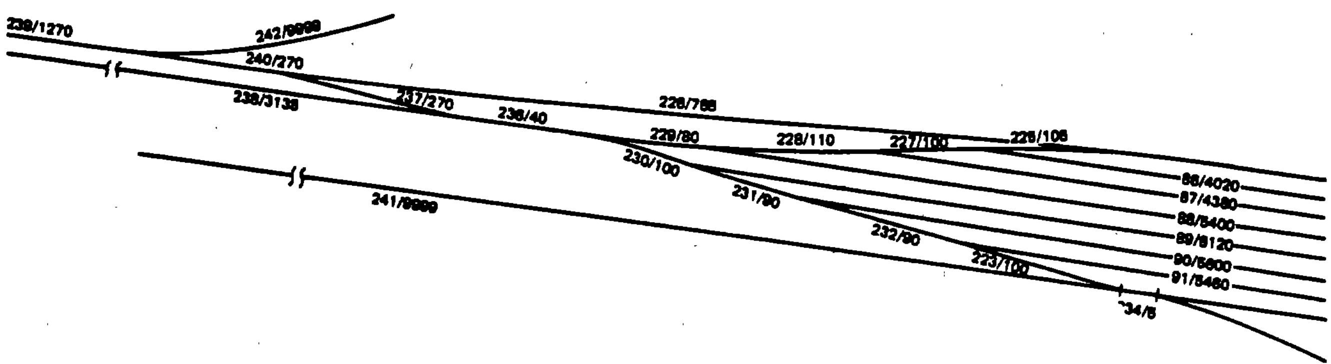


FIGURE 13-26. IDENTIFYING LINKS ON THE LAYOUT (EXISTING ELKHART YARD)

ELKHART - BASE CASE

LINKS

LINK NUMBER	LINK LENGTH (FT)	LINK TYPE	YARD SECTION	LINK NUMBER	LINK LENGTH (FT)	LINK TYPE	YARD SECTION	LINK NUMBER	LINK LENGTH (FT)	LINK TYPE	YARD SECTION	LINK NUMBER	LINK LENGTH (FT)	LINK TYPE	YARD SECTION
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FIGURE 13-27. SAMPLE INPUT LINKS

ELKHART - BASE CASE

ROUTES

NUMBER	ROUTE NUMBER	ROUTE TYPE	NO. OF LINKS	LINK NUMBERS						
1	1	-0	3	1	101	108				
2	2	-0	3	2	101	108				
3	3	-0	4	3	103	102	108			
4	4	-0	4	4	103	102	108			
5	5	-0	5	5	105	104	102	108		
6	6	-0	5	6	105	104	102	108		
7	7	-0	6	7	107	106	104	102	108	
8	8	-0	6	8	107	106	104	102	108	
9	9	-0	5	9	106	104	102	108		
10	10	-0	3	10	112	111				
11	11	-0	3	11	112	111				
12	12	-0	4	12	114	113	111			
13	13	-0	4	13	114	113	111			
14	14	-0	5	14	115	128	113	111		
15	15	-0	5	15	115	128	113	111		
16	16	-0	6	16	117	116	128	113	111	
17	17	-0	6	17	117	116	128	113	111	
18	18	-0	5	18	116	128	113	111		
19	19	-0	3	19	121	120				
20	20	-0	3	20	121	120				
21	21	-0	4	21	123	122	120			
22	22	-0	4	22	123	122	120			
23	23	-0	5	23	125	124	122	120		
24	24	-0	5	24	125	124	122	120		
25	25	-0	6	25	127	126	124	122	120	
26	26	-0	6	26	127	126	124	122	120	
27	27	-0	5	27	126	124	122	120		
28	28	-0	4	28	132	131	130			
29	29	-0	4	29	132	131	130			
30	30	-0	5	30	134	133	131	130		
31	31	-0	5	31	134	133	131	130		
32	32	-0	6	32	136	135	133	131	130	
33	33	-0	6	33	136	135	133	131	130	
34	34	-0	7	34	138	137	135	133	131	130
35	35	-0	7	35	138	137	135	133	131	130
36	36	-0	6	36	137	135	133	131	130	
37	37	-0	4	37	140	139	130			
38	38	-0	4	38	140	139	130			
39	39	-0	3	39	139	130				
40	40	-0	2	40	179					
41	41	-0	3	41	180	179				
42	42	-0	3	42	180	179				
43	43	-0	2	43	186					
44	44	-0	3	44	187	186				
45	45	-0	3	45	187	186				

FIGURE 13-28. SAMPLE INPUT ROUTES

ELKHART - BASE CASE

O/D ROUTE MATRIX

I	95	108	111	120	130	164	179	186	189	195	201	217	235	236	238	246	247	248	249
95I	0	0	158	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
108I	0	0	0	0	0	86	0	0	0	0	0	0	0	166	0	0	0	0	0
I	0	0	0	0	0	88	0	0	0	0	0	0	0	-0	0	0	0	0	0
111I	164	0	0	0	0	90	0	0	0	0	0	0	0	164	0	0	0	0	0
I	-0	0	0	0	0	92	0	0	0	0	0	0	0	-0	0	0	0	0	0
120I	0	0	0	0	0	249	0	0	0	0	0	0	0	156	0	0	0	0	0
I	0	0	0	0	0	96	0	0	0	0	0	0	0	-0	0	0	0	0	0
130I	0	0	0	0	0	98	0	0	0	0	0	0	0	158	0	0	0	0	0
I	0	0	0	0	0	100	0	0	0	0	0	0	0	-0	0	0	0	0	0
150I	0	0	0	0	0	139	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0
157I	0	87	91	95	99	102	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0	-0	-0	-0	-0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0
158I	0	89	93	96	101	106	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0	-0	-0	-0	-0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0
164I	0	103	109	109	109	0	0	0	0	160	0	160	0	160	0	0	0	0	0
I	0	109	103	103	103	0	0	0	0	-0	0	-0	0	-0	0	0	0	0	0
179I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119	115
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	-0
186I	0	0	0	0	0	0	0	0	0	0	0	0	0	121	0	0	0	117	0
I	0	0	0	0	0	0	0	0	0	0	0	0	0	123	0	0	0	-0	0
195I	0	0	0	0	0	167	0	0	0	0	0	0	0	122	0	0	0	0	0
I	0	0	0	0	0	-0	0	0	0	0	0	0	0	124	0	0	0	0	0
201I	0	0	0	0	0	162	0	0	0	0	0	0	137	137	137	0	0	0	0
I	0	0	0	0	0	-0	0	0	0	0	0	0	138	138	138	0	0	0	0
217I	0	0	0	0	0	168	0	0	0	0	0	0	0	125	0	0	0	0	0
I	0	0	0	0	0	-0	0	0	0	0	0	0	0	126	0	0	0	0	0
235I	0	0	0	0	0	0	0	129	0	129	129	129	0	0	129	0	0	0	0
I	0	0	0	0	0	0	0	-0	0	-0	-0	-0	0	0	-0	0	0	0	0
236I	0	140	140	140	140	140	0	143	0	140	140	140	0	0	0	145	0	0	0
I	0	132	132	132	132	132	0	-0	0	-0	-0	-0	0	0	0	-0	0	0	0
238I	0	0	0	0	0	0	0	133	0	135	172	170	128	127	0	0	0	0	0
I	0	0	0	0	0	0	0	134	0	136	173	171	-0	-0	0	0	0	0	0
239I	0	165	163	157	159	161	0	141	0	142	144	143	0	131	0	0	0	0	0
I	0	-0	-0	-0	-0	-0	0	-0	0	-0	-0	-0	0	-0	0	0	0	0	0
242I	0	0	0	0	0	0	0	0	0	0	0	0	0	130	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0
246I	0	0	0	0	0	0	0	0	0	0	0	0	0	146	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0
247I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	153	0	0
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0
248I	0	0	0	0	0	0	120	0	118	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	-0	0	-0	0	0	0	0	0	0	0	0	0	0
249I	0	0	0	0	0	0	116	0	0	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0

FIGURE 13-29. SAMPLE INPUT ORIGIN-DESTINATION ROUTE MATRIX

```
ELKHART - BASE CASE

E N G I N E   W O R K   S C H E D U L E
---------------------------------------

ASSIGNMENT     1
ASSIGNED ENGINE(S) -      1    2
      LINK   68
             COUPLE CARS AT TIME      0 OR LATER
                  COUPLE  63 CARS OF BLOCK 86
                  ENGINE IS ALLOWED TC OCCUPY LINK(S)     68
      LINK   68
             MOVE  63 CARS OF BLOCK      86 TO LINK    88 FOR TRAIN     1
                  CUTOFF TIME FOR PULL        0
      LINK   88
             SET OUT CARS
      LINK   67
             COUPLE CARS AT TIME      0 OR LATER
                  COUPLE  55 CARS OF BLOCK   4
                  ENGINE IS ALLOWED TC CCCUPY LINK(S)     67
      LINK   67
             MOVE  55 CARS OF BLOCK       4 TO LINK    88 FOR TRAIN     1
                  CUTOFF TIME FOR PULL        0
      LINK   88
             SET OUT CARS
      LINK  242
             MOVE LINE-HAUL ENGINE    21 TO LINK    88 TO PULL TRAIN     1
      LINK   88
             DEPART TRAIN FOR LINK   245

ASSIGNMENT     2
ASSIGNED ENGINE(S) -      1    2
      LINK   56
             COUPLE CARS AT TIME     15 OR LATER
                  COUPLE ALL CARS OF BLOCK   22
                  ENGINE IS ALLOWED TO CCCUPY LINK(S)     56
      LINK   56
             MCVE ALL CARS OF BLOCK      22 TC LINK    91 FCR TRAIN     2
                  CUTOFF TIME FOR PULL       15
      LINK   91
             SET OUT CARS
      LINK  242
             MOVE LINE-HAUL ENGINE    22 TO LINK    91 TO PULL TRAIN     2
      LINK   91
             DEPART TRAIN FOR LINK   246

ASSIGNMENT     3
ASSIGNED ENGINE(S) -      1    2
      LINK   59
             COUPLE CARS AT TIME    200 OR LATER
                  COUPLE  39 CARS CF BLCCK 39
                  ENGINE IS ALLOWED TO CCCUPY LINK(S)     59
      LINK   59
             MOVE  39 CARS OF BLOCK      39 TC LINK    87 FOR TRAIN     3
                  CUTOFF TIME FOR PULL      200
      LINK   87
             SET OUT CARS
      LINK   57
             COUPLE CARS AT TIME    200 CR LATER
```

FIGURE 13-30. SAMPLE INPUT ENGINE WORK SCHEDULE

Figure 13-28 shows a sample input of the routes for the Elkhart Yard existing design. A route is structured in the CONFLICT model as an ordered series of links. The path in the opposite direction is considered a different route.

Figure 13-29 shows a sample input of the origin-destination route matrix taken from the echo-back printout of this same computer run. Note that two alternate routes are given for each origin-destination (O-D) combination when two routes are available for that O-D combination.

Figure 13-30 shows a sample input of engine work schedules taken from the echo-back output of this computer run. Each assignment specifies the classification and departure tracks where the pull originates and ends, the number of cars carried, block types carried, outbound train number, and the cut-off time. The work assignment is usually the most time consuming and complex input to prepare. The preparation of this input is almost impossible without conducting a yard capacity analysis, since only by this means will the designer have a clear idea as to when and how blocks will be pulled from the classification yard to the departure yard.

Figure 13-31 shows a sample input of the outbound train schedule. This is again an echo-back given in the computer output. Figure 13-32 shows the classification track inflow information presented in an aggregated fashion. The raw input data for the classification track inflow requires that the user specify the time and number of cars flowing into each classification track.

13.5.4.4 Analysis of Simulation Results. To examine the performance of each simulated yard design, reports of the conflict simulation output for the train activity and link occupancy were analyzed with the following results:

Existing Yard--The simulation for the existing yard covered a time period from 0 to 24:00 hours (military time). During this period, 17 out of 19 trains scheduled were built, carrying a total of 1211 cars (Table 13-8). The trim engines moved a total of 1370 cars during this period. The number of trains processed in a 24-hour period was fewer than the total number of trains planned for departure and fewer than the total input flow to the yard. This implies that the yard was oversaturated. Therefore, the amount of delay for both trains and cars will increase indefinitely as simulation time increases. The total train departure delay time was 4487 minutes. This amounted to 264 minutes per train. The average delay time per car on departed trains was 272 minutes. During the simulated period, conflict (adverse events) caused a total delay of 620 minutes, or an average of 36 minutes per train. Most of the conflicts were caused by the heavy occupancy of the pullout lead.

At the traffic level of 1800 cars per day and any higher level, trim-end operations in the existing yard will be severely hampered because of the lack of an extra pullout lead. In addition, the long travel time of the trim engines from the classification yard to the departure yard causes train delays, which compound as the daily operations proceed.

ELKHART - BASE CASE

T R A I N   S C H E D U L E

```
TRAIN   1  DEPARTURE DAY/TIME    0   300
           NUMBER OF BLOCKS      2
           BLOCK NUMBER(S)      85     4

TRAIN   2  DEPARTURE DAY/TIME    0   315
           NUMBER OF BLOCKS      1
           BLOCK NUMBER(S)      22

TRAIN   3  DEPARTURE DAY/TIME    0   500
           NUMBER OF BLOCKS      2
           BLOCK NUMBER(S)      39    62

TRAIN   4  DEPARTURE DAY/TIME    0   500
           NUMBER OF BLOCKS      1
           BLOCK NUMBER(S)       1

TRAIN   5  DEPARTURE DAY/TIME    0   500
           NUMBER OF BLOCKS      1
           BLOCK NUMBER(S)       5

TRAIN   6  DEPARTURE DAY/TIME    0   500
           NUMBER OF BLOCKS      1
           BLOCK NUMBER(S)      78

TRAIN   7  DEPARTURE DAY/TIME    0   600
           NUMBER OF BLOCKS      5
           BLOCK NUMBER(S)      10    24    13    19    52

TRAIN   8  DEPARTURE DAY/TIME    0   800
           NUMBER OF BLOCKS      2
           BLOCK NUMBER(S)      85     4

TRAIN   9  DEPARTURE DAY/TIME    0   800
           NUMBER OF BLOCKS      3
           BLOCK NUMBER(S)       8    28    29

TRAIN  10  DEPARTURE DAY/TIME    0   830
           NUMBER OF BLOCKS      2
           BLOCK NUMBER(S)      34    54

TRAIN  11  DEPARTURE DAY/TIME    0   900
           NUMBER OF BLOCKS      1
           BLOCK NUMBER(S)       1

TRAIN  12  DEPARTURE DAY/TIME    0   900
           NUMBER OF BLOCKS      3
           BLOCK NUMBER(S)       9     7    49

TRAIN  13  DEPARTURE DAY/TIME    0  1000
           NUMBER OF BLOCKS      2
           BLOCK NUMBER(S)      13    19

TRAIN  14  DEPARTURE DAY/TIME    0  1100
           NUMBER OF BLOCKS      2
           BLOCK NUMBER(S)      85     4

TRAIN  15  DEPARTURE DAY/TIME    0  1300
           NUMBER OF BLOCKS      2
           BLOCK NUMBER(S)       5    88

TRAIN  16  DEPARTURE DAY/TIME    0  1330
           NUMBER OF BLOCKS      1
           BLOCK NUMBER(S)      28

TRAIN  17  DEPARTURE DAY/TIME    0  1700
           NUMBER OF BLOCKS      1
           BLOCK NUMBER(S)      22

TRAIN  18  DEPARTURE DAY/TIME    0  1800
           NUMBER OF BLOCKS      1
           BLOCK NUMBER(S)      39

TRAIN  19  DEPARTURE DAY/TIME    0  1800
           NUMBER OF BLOCKS      2
           BLOCK NUMBER(S)      85     4

TRAIN  20  DEPARTURE DAY/TIME    0  1830
           NUMBER OF BLOCKS      1
```

FIGURE 13-31. SAMPLE INPUT-OUTPUT TRAIN SCHEDULE

TABLE 13-8.-TRAIN DEPARTURE REPORT FOR THE EXISTING YARD

Train no.	Scheduled Departure time	Actual departure time	Delay time (min)	No. of cars on train	Total delay time for cars on departure tracks* (min)
1	300	305	4	75	300
2	315	316	0	35	—
3	500	501	0	55	—
4	500	630	89	90	8,010
6	500	657	117	26	3,042
5	500	700	120	96	11,520
7	600	1112	311	74	23,014
9	800	1305	305	88	26,840
10	830	1331	301	99	29,799
12	900	1616	436	53	23,108
11	900	1700	479	90	43,110
14	1100	1712	372	116	43,152
13	1000	1758	478	28	13,384
15	1300	2005	425	76	32,300
16	1330	2021	410	52	21,320
19	1800	2330	329	98	32,242
20	1830	2341	311	60	18,660
Total			4,487	1,211	329,801

*Average departure delay time per car is 272 minutes.

Alternative 1: Extended Classification Tracks with Dual Pullout Leads--With two trim engines at work, the work schedule of the simulation was completed earlier. Within 24 hours, 19 trains were built. The total train departure delay time amounted to 3780 minutes (Table 13-9). The delay time per train was 199 minutes. There were a total of 1456 cars on the 19 trains. The average delay time per car caused by delayed departure was 205 minutes. In comparison with the existing yard, conflict delay time was substantially reduced. The total conflict delay time amounted to 380 minutes or an average of 20 minutes per train.

The train delay time decreased substantially toward the end of the 24-hour period. The last two trains built in the simulated time period were delayed by 122 minutes and 117 minutes, respectively. These were well below the maximum delay of 369 minutes for this design. With appropriate trim engine assignment scheduling, this configuration seems to be able to handle a throughput level of 1,800 cars per day. Two factors substantiate this analysis: (1) the number of cars moved

ELKHART - BASE CASE

WEST CLASSIFICATION YARD INFLOW PER HOUR

NUMBER OF CARS ADDED DURING HOUR BEGINNING AT

TRK. NO.	TRK. INV.*	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MAXIMUM FOR DAY
40	3	0	1	2	1	1	8	1	1	0	0	2	1	0	1	1	0	1	0	1	1	0	0	1	1	2
42	0	1	1	0	1	1	1	1	1	1	1	2	1	0	1	0	0	0	1	1	0	1	1	1	0	2
43	14	0	0	16	0	0	0	0	0	0	1	3	3	3	4	3	1	0	0	3	0	3	12	0	0	16
45	30	0	24	28	28	26	4	21	26	0	2	8	20	0	8	6	20	13	18	4	0	13	29	13	14	28
46	3	0	8	0	1	0	0	6	0	8	4	0	0	0	8	1	0	0	0	2	0	0	0	0	0	8
49	1	0	1	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
50	9	0	1	2	0	1	0	0	0	1	5	2	2	0	1	4	0	0	1	2	0	0	0	0	0	5
51	3	0	0	0	4	1	0	0	0	0	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	1
52	26	0	0	0	0	0	0	8	0	0	4	1	0	0	0	0	1	0	17	0	0	6	0	0	0	17
53	0	0	0	0	0	1	0	0	8	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1
54	23	0	1	0	0	0	0	4	7	4	0	0	2	0	0	1	0	1	0	9	2	1	0	4	1	9
55	8	0	0	0	8	0	0	1	0	8	0	0	0	0	0	0	0	0	0	0	0	8	4	0	0	4
56	35	0	4	8	2	12	0	7	0	1	1	3	7	0	0	1	1	10	6	10	0	2	2	0	7	12
57	27	0	2	0	0	0	0	4	6	1	4	0	0	0	8	1	1	0	0	0	9	12	2	0	1	12
59	7	0	19	0	1	9	7	11	1	6	3	1	0	3	0	2	1	3	0	3	5	2	0	0	0	19
60	10	0	0	4	1	1	0	0	0	0	0	0	8	0	1	0	1	0	1	0	0	8	0	0	0	8
61	20	0	8	2	2	2	0	0	2	5	1	0	6	0	0	1	0	0	5	1	0	2	0	0	0	6
62	7	0	0	0	0	0	0	6	0	0	0	0	12	0	0	0	12	0	0	0	0	0	0	0	0	12
63	0	0	0	0	0	0	0	12	0	0	0	3	24	0	0	0	26	0	0	0	0	0	0	0	0	24
64	33	0	2	3	11	1	1	1	1	14	1	1	1	0	0	1	1	2	1	2	0	6	1	2	2	16
65	30	0	6	2	1	5	0	6	4	8	11	0	16	3	30	1	13	11	0	0	1	6	0	2	1	30
67	37	0	14	12	19	0	0	12	18	1	7	0	24	3	3	2	26	0	1	1	0	6	6	6	11	26
68	39	1	5	17	2	11	7	12	5	6	4	0	20	0	0	1	26	2	6	2	0	6	4	14	8	20
69	42	1	28	11	11	18	3	0	8	5	6	0	19	0	66	3	8	8	4	11	0	7	0	23	18	66
70	18	0	2	2	10	1	1	1	1	18	2	3	1	3	0	1	1	2	1	1	0	7	1	1	4	18
71	2	2	6	6	4	8	10	2	8	4	6	5	7	0	4	2	1	4	4	6	7	8	4	4	6	10
72	45	0	0	4	0	1	2	0	1	0	0	3	1	3	0	2	0	1	5	3	4	3	0	0	0	6

*INVENTORY AT START OF SIMULATION

FIGURE 13-32. SAMPLE INPUTS: CLASSIFICATION YARD INFLOW INFORMATION

TABLE 13-9.-TRAIN DEPARTURE REPORT
FOR ALTERNATIVE 1: EXTENDED CLASSIFICATION
TRACKS WITH DUAL PULLOUT LEADS

Train no.	Scheduled Departure time	Actual departure time	Delay time (min)	No. of cars on train	Total delay time for cars on departure tracks* (min)
1	300	306	5	75	375
2	315	317	1	39	39
3	500	526	25	55	1,375
6	500	612	71	26	1,846
5	500	621	80	96	7,680
4	500	640	100	153	15,300
7	600	1112	312	85	26,520
9	800	1159	238	88	20,944
10	830	1320	290	99	28,710
11	900	1444	343	79	27,097
12	900	1509	369	51	18,819
13	1000	1535	335	23	7,705
14	1100	1538	278	141	39,198
16	1330	1837	307	52	15,964
15	1300	1902	361	102	36,822
20	1830	2144	193	67	12,931
19	1800	2154	233	93	21,669
21	2000	2203	122	30	3,660
22	2200	2358	117	102	11,934
Total			3,780	1,456	298,588

*Average departure delay time per car is 205 minutes.

TABLE 13-10.-TRAIN DEPARTURE REPORT
FOR ALTERNATIVE 2: EXTENDED CLASSIFICATION
TRACKS WITH CROSSOVERS IN DEPARTURE YARD

Train no.	Scheduled Departure time	Actual departure time	Delay time (min)	No. of cars on train	Total delay time for cars on departure tracks* (min)
1	300	320	19	75	1,425
2	315	330	15	39	585
3	500	515	15	55	825
5	500	705	125	100	12,500
4	500	734	153	111	16,983
6	500	804	184	28	5,152
7	600	939	219	80	17,520
9	800	1143	222	86	19,092
10	830	1359	329	97	31,913
11	900	1426	325	102	33,150
13	1000	1437	277	23	6,371
14	1100	1528	268	147	39,396
12	900	1611	431	53	22,843
16	1330	1758	268	50	13,400
15	1300	1900	359	102	36,618
20	1830	2146	196	67	13,132
21	2000	2150	110	30	3,300
19	1800	2157	236	87	20,532
Total			3,751	1,332	294,737

*Average departure delay time per car is 221 minutes.

by the two trim engines was 1597 cars within 24 hours; (2) one trim engine was left idle from 21:30 hours to the end of the simulation at 24:00 hours. This means that more cars could have been moved by making additional pull assignments.

Alternative 2: Extended Classification Tracks with Crossovers in the Departure Yard--The simulation of the second alternative ended at 24:00 hours. During the simulated time frame, 18 scheduled trains were built. Total departure delay time was 3751 minutes (Table 13-10) with an average departure delay time of 208 minutes per train. The 18 trains moved 1332 cars. The average delay time per car caused by delayed departure was 221 minutes. The total conflict delay time amounted to 684 minutes or a 38-minute delay per train. This 38-minute delay per train was 90 percent higher than the low of 20 minutes per train seen with the first alternative. It was also slightly higher than the 36 minutes per train with the existing yard. The bottleneck in this alternative, causing considerable difficulty for the trim engines, was the point where the classification leads merge at the crossover to the departure tracks.

More conflict delay is certain to arise if both sides of the departure yard are used. The west side of the departure yard was not modeled in the simulated design. With both sides in use, crossover tracks will be blocked for certain lengths of time by trains being readied for departure (i.e., coupled and air-tested) and during departure.

Split train make-ups were predicted to occur. This observation was substantiated by a display in the activity log of the computer-simulated design that shows overflows at several one-side-only departure tracks and the need for additional track space.

In this design the trim engines move 1567 cars from the classification tracks to the departure tracks. As in Alternative 1, more cars could have been moved if additional assignments had been made to the trim engine left idle from 21:15 hours to the end of the simulation.

13.5.4.5 Evaluation of Alternatives. The results of the simulation of the existing design and the two alternatives (1 and 2) are summarized for comparison in Table 13-11. Alternative 3, which is considered to have the largest capacity (in terms of number of cars handled in a time unit), was not considered for evaluation because it exceeded the target budget of capital improvement for this yard.

Table 13-11 indicates that the existing design can handle the least number of trains in a day (17 trains), and creates the longest delay (264 min/train). Clearly, the existing design is the poorest among the three. Extended class tracks with dual pullout leads (Alternative 1) show the best performance results among the three designs, handling 19 trains with the least delay (199 min/train). The two trim engines move the largest number of cars (1597 versus 1567 cars) in Alternative 2. Departing trains leave with a total of 1456 cars in Alternative 1; this exceeds the number of cars on departing trains by 124 cars in Alternative 2 and by 245 cars for the existing yard.

In general, the difference between the extended class tracks design (Alternative 1), and the crossover design (Alternative 2) is not significantly large under the given traffic demand. It is conceivable that under higher traffic demand levels the extended class tracks design (Alternative 1) would perform significantly better than the crossover design (Alternative 2) because the crossover tracks may frequently be blocked, causing delay for trimming operations.

13.5.4.6 Conclusions. The simulation model CONFLICT was developed and applied to a real-world problem. The model was proven to be an extremely powerful tool

TABLE 13-11.-SUMMARY TABLE FOR CONFLICT EVALUATION

Description	Existing design	Extended classification tracks design	Crossover design
Number of trains built	17	19	18
Total train departure delay time (min)	4,487*	3,780	3,751*
Average train departure delay time (min)	264*	199	208*
Average delay time per car (min)	272*	205	221*
Total number of cars on departed trains	1,211	1,456	1,332
Total conflict delay time (min)	620	380	684
Average conflict delay time per train (min)	36	20	38
Number of trim engine trips	85	90	90
Number of cars moved by trim engines	1,370	1,597	1,567
Simulation end time (military time)	24:00	24:00	24:00

*These numbers do not reflect the delays associated with the trains that were not built during the 24-hour period.

to evaluate trim-end designs. The use of the CONFLICT is not limited to design evaluation. The model is considered to be a useful tool to evaluate operational methods at the trim end or to evaluate outbound schedules.

REFERENCES

Elliott, C. V., M. Sakasita, W. A. Stock, P. J. Wong, and J. Wetzel. "Elkhart Yard Rehabilitation: A Case Study," Proceedings, Classification Yard Technology Workshop, Office of Research and Development, Federal Railroad Administration, Chicago, October 1979.

APPENDIX A: INPUT, OUTPUT, AND PROGRAM DOCUMENTATION FOR CAPACITY

This appendix describes the input, output, and program structure of the CAPACITY model. The reader should refer to Chapter 7 for a discussion of the model itself. This appendix has been written assuming that the reader is familiar with the material in Chapter 7 pertaining to the model.

A.1 PROGRAM INPUT REQUIREMENTS

CAPACITY inputs are divided into six groups of cards:*

- General yard parameter cards
- Crew description cards
- Arriving train specification cards
- Arriving train consist mix ID specification cards
- Block to class yard assignment cards
- Departing train specification cards.

Each group of cards is ended by a terminator card containing "99999" punched in columns 1 through 5. Essentially all counting is done by the program, so the user need not have to specify such counts. Further, no redundant information† is required to be input by the user. All fields on all cards, except the title card, are 5-columns wide. This greatly simplifies preparation of input. A listing of a sample input deck is given in Exhibit A-1, attached at the end of this appendix.

CAPACITY optionally allows the user to specify dual receiving yards, dual lead humps, dual class yards, and dual departure yards. These are nominally designated to and within the model as east and west (E and W); however, it should be realized that these designations are entirely arbitrary. When the user has only a single rather than dual facility, the user enters all references to that facility as "E" (or "W," so long as he is consistent).

All times of day and time durations are input to the model, unless specified otherwise, in the form of hours and minutes with no separation or punctuation between hours and minutes. Times of day are specified on a 24-hour clock basis. For example, 1:30 p.m. would be specified on input as 1330; a time duration of 1 1/2 hours would be specified as 0130.

In CAPACITY, crews are treated as a single entity throughout the day. The change of shift is ignored in the program, although the user might wish to code an optional crew break to accommodate the change of shift. Each crew that mans an engine is not considered as being distinct from its engine, and is referred to herein as an "engine," "engine crew," or simply "crew," whichever is more convenient to the context.

*In this discussion, the input data will be referred to as if it were on cards. Of course it is realized that in most modern time-sharing computer environments such input would be maintained on a card image disk file.

†Due to the wide availability of options in CAPACITY, some input requirements may appear redundant when not all options are being used.

A.1.1 General Yard Parameter Cards

The formats for these cards are shown in Table A-1. To aid user input, any or all of these values may be defaulted to the values indicated in Table A-1 by leaving the appropriate fields blank. All the cards, however, must be present, even if they are entirely blank.

The information in Table A-1 is largely self-explanatory; discussion will be given below only where warranted.

A.1.1.1. Card No. 2. The parameter IOFLG should be set to 0. Setting it to 1 will produce a voluminous output on the file designated as unit 1—an output most users will have little interest in.

The simulation runs to the end of the day specified by NDAYS; the printed output starts with the beginning of the day specified by NDSTPR. Trains currently being processed at the beginning and ending of the printing period are also listed, even if their arrival or departure times are outside of the printing period.

A.1.1.2 Card No. 3. CAPACITY tracks the movement of various crew types through the yard. A necessary part of the information to perform this tracking are the travel times for various crew types between various points. The parameters on these cards provide the necessary information to the program. If any of the movements between different subyard directions (e.g., receiving yard E to receiving yard W) specified by these travel times are undesirable for the particular yard being analyzed, these moves can be prohibited crew-by-crew in the "crew description cards." If there is only one receiving yard (say "E"), then all references referring to travel times for the "W" yard, and for travel between "E" and "W" may be left blank.

A.1.1.3 Card No. 4. The model allows for two types of receiving yards: Inline and pull-out lead. The parameter IRCTYP specifies the yard type as follows:

IRCTYP = 1, Inline

IRCTYP = 2, Pull-out lead

If the field is blank, or if any other numbers are coded, IRCTYP is defaulted to 2. When a train goes to humping in a pull-out lead geometry yard, the train quickly clears the receiving yard. On the other hand, in an inline geometry yard, the train continues to occupy the receiving track until nearly the end of humping. In CAPACITY, when IRCTYP = 2, the train is assumed to clear the receiving yard at the start of travel to the hump. When IRCTYP = 1, the train is assumed to clear the receiving yard generally much later; namely at the hump end time minus the travel time to the hump. Thus selection of this parameter has an important impact on the model's calculation of receiving yard track requirements. Selection of this parameter in no way affects the humping process itself; however, it is up to the user to see that the travel time to the hump is appropriate to the yard geometry at hand.

The inbound pre-inspection delay constant ICINS is a fixed start-up time for the inspection crew to start its work. It is assumed to be independent of the size of the train to be inspected (this is handled by the inspection rate parameter RINS).

TABLE A-1.-INPUT FORMATS
FOR GENERAL YARD PARAMETER CARDS

Cols.	Variable	Type	Description	Default Value*
Card No. 1: Title Card				
1-80	TITLE	A	Any alphanumeric information to appear in title	"blank"
Card No. 2: Simulation Control Parameters				
1-5	IOFLG	I	Output flag for CAPCON/CONFLICT: 0 = No output 1 = Produce output data on unit 1	0
6-10	NDAYS	I	Total number of days to be simulated (including warm-up days)	3
11-15	NDSTPR	I	Simulated day to start printing yard operations outputs	3
Card No. 3: Front End of Yard Travel Time Parameters				
1-5	ITTHMP(1)	I	Travel time from receiving yard E to hump	10
6-10	ITTHMP(2)	I	Travel time from receiving yard W to hump	10
11-15	TTHR(1)	I	Travel time from hump to receiving yard E	5
16-20	TTHR(2)	I	Travel time from hump to receiving yard W	5
21-25	TTRR(1)	I	Travel time for an inspection crew to go from E to W receiving yard	10
26-30	TTRR(2)	I	Travel time for an inspection crew to go from W to E receiving yard	10
31-35	ITTRD	I	Travel time for bypass blocks from receiving to departure yards, hours:minutes	30
Card No. 4: Front End of Yard Miscellaneous Parameters				
1-5	IRCTYP	I	Code for receiving yard type: 1 = Inline 2 = Pull-out lead	2
6-10	ICINS	I	Inbound pre-inspection delay constant, hours:minutes	10
11-15	RINS	F	Inbound rate of inspection, min/car	0.5
16-20	IHMPBR	I	Hump break constant, hours:minutes	10
21-25	RHUMP	F	Humping rate, min/car	0.3
26-30	NHMPS	I	Number of hump leads	1

TABLE A-1.-CONTINUED

Cols.	Variable	Type	Description	Default Value*
Card No. 5: Back End of Yard Travel Time Parameters				
1-5	TTCD(1,1,1)	I	Travel time, class yard E to departure yard E	10
6-10	TTCD(1,1,2)	I	Travel time, class yard E to departure yard W	15
11-15	TTCD(1,2,1)	I	Travel time, class yard W to departure yard E	15
16-20	TTCD(1,2,2)	I	Travel time, class yard W to departure yard W	10
21-25	TTDC(1,1,1)	I	Travel time, departure yard E to class yard E	5
26-30	TTDC(1,1,2)	I	Travel time, departure yard E to class yard W	10
31-35	TTDC(1,2,1)	I	Travel time, departure yard W to class yard E	10
36-40	TTDC(1,2,2)	I	Travel time, departure yard W to class yard W	5
41-45	TTCD(2,1,1)	I	Travel time, class yard E to class clear destination E	10
46-50	TTCD(2,1,2)	I	Travel time, class yard E to class clear destination W	15
51-56	TTCD(2,2,1)	I	Travel time, class yard W to class clear destination E	15
56-60	TTCD(2,2,2)	I	Travel time, class yard W to class clear destination W	10
61-65	TTDC(2,1,1)	I	Travel time, class clear destination E to class yard E	5
66-70	TTDC(2,1,2)	I	Travel time, class clear destination E to class yard W	10
71-75	TTDC(2,2,1)	I	Travel time, class clear destination W to class yard E	10
76-80	TTDC(2,2,2)	I	Travel time, class clear destination W to class yard W	5
Card No. 6: Back End of Yard Travel Time Parameters, Continued				
1-5	TTDD(1)	I	Travel time for an inspection crew to go from E to W departure yard	10
6-10	TTDD(2)	I	Travel time for an inspection crew to go from W to E departure yard	10
11-15	TTXMPL(1)	I	Extra travel time per multiple pull block (blocks in E class yard)	0
16-20	TTXMPL(2)	I	Extra travel time per multiple pull block (blocks in W class yard)	0

TABLE A-1.-CONCLUDED

Cols.	Variable	Type	Description	Default Value*
Card No. 7: Back End of Yard Miscellaneous Parameters				
1-5	ICTOFF	I	Cut-off time period to start making-up departing train, hours:minutes	3:00
6-10	ICTOFB	I	Cut-off time period for putting bypass blocks on departing train, hours:min	1:30
11-15	ICTOFP	I	Cut-off time period for putting previous pulls on departing train, hours:min	1:30
16-20	IENGBR	I	Engine break constant, minutes	10
21-25	METHOD	I	Engine utilization method: 1 = One engine makes up departing train 2 = 1st available engine makes up departing train	1
26-30	ICCPL	I	Coupling start-up delay constant, minutes	5
31-35	RCPL	F	Rate of coupling, min/car	0.5
36-40	ICY	I	Between block make-up break constant, minutes	20
41-45	ICDINS	I	Outbound pre-inspection delay constant, minutes	10
46-50	RDINS	F	Outbound rate of inspection, min/car	0.5

*Note: The colons (:) are shown for clarity only; they are not to be entered as part of the input.

The hump break constant is the minimum time physically possible between successive trains at the hump, measured from the time the last car in one train is humped until the first car on the next train can be humped. This parameter is an attribute of the hump, and does not include travel times between the receiving yard and the hump, or vice versa. When only one hump engine is working, such travel times do, of course, affect the interval between trains at the hump; however, these travel time considerations are properly handled using the travel time parameters on Card No. 3.

CAPACITY allows only 1 or 2 hump leads. If two hump leads are specified, the E receiving yard humps only on the E lead, and the W receiving yard only on the W lead; no crossover humpings are permitted prior to the hump. However, between the hump and the class yard, crossover moves are permitted; the class yard direction being determined individually for each block on a train by that block's direction. Two trains, one E and one W, can be humped concurrently on a two lead hump, provided all the blocks on the E train are also E, and all the blocks on the W train are also W. If a train has a mixed consist of both E and W blocks, (1) it must wait until both hump leads are cleared, and then (2) ties up both humps until its humping is completed. Such mixed consist trains are called "spray trains."

A.1.1.4 Card No. 5. The information on this card specifies various travel times for trim (or auxiliary) engines between subyards as shown in Figure A-1. These travel times should include an allowance for interference between engines when more than one engine is trimming. If the user wishes to prohibit moves between E and W directions, this may be done by restricting the yard these engine crews may work (see the crew description cards).

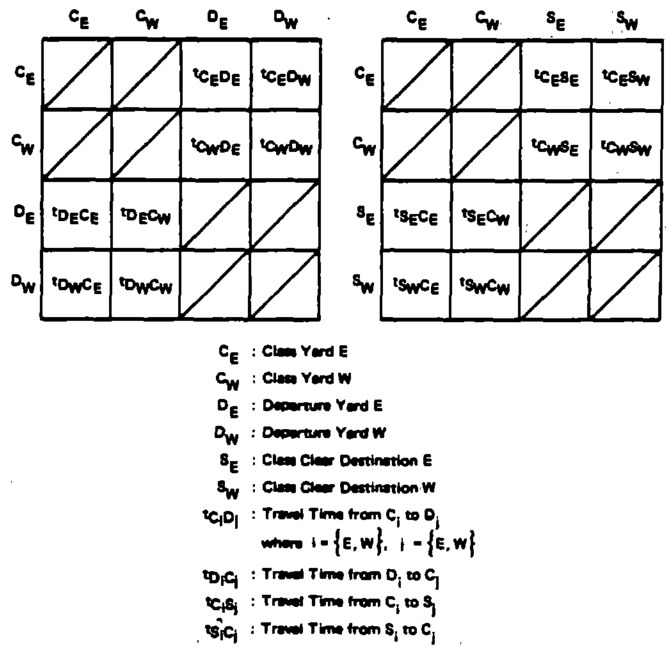


FIGURE A-1. BACK END TRAVEL TIME MATRICES

The class clear destination, which is associated with class clear moves, provides the user with a means of departing cars from the overall yard directly from the class tracks (i.e., skipping the departure yard and outbound inspection). The class clear destination is merely a "sink" where simulated cars disappear; it can be a track to some other part of the yard (e.g., local yard) or a track leading directly out of the yard (e.g., to local receivers or the mainline).* Class clears are also useful in permitting the user to manually simulate rehumping. The class clear removes the cars from the class yard; the user then must code an arrival train (actually these same cars just cleared) which queues for humping. This train should arrive at the receiving yard at or later than the class cleared cars reach the class clear destination.

A.1.1.5 Card No. 6. This card specifies some additional travel time parameters for the back end. The travel times for inspection crews between the E and W departure yards and vice versa are analogous to the similar parameters for the receiving yard. Such moves can be prohibited, if desired, in the crew description cards.

*If a mainline train departs directly from the class yard, note that the outbound inspection is not simulated.

The model allows more than one block at a time to be moved from the class yard to the departure yard or class clear destination. Such moves can either represent reswitched cars already properly ordered on the class track (by rehumping) or a doubling operation. In the latter case, the move will of course take longer. This additional time is approximated in CAPACITY as an additional travel time added to the class yard to departure yard (or class clear destination) travel times on Card 5.* This additional travel time is assessed on a per block basis, counting only those additional blocks over and above the first block combined in a move. If the blocks being moved are already properly ordered, as if they had been reswitched, then this parameter should be entered as zero.

A.1.1.6 Card No. 7. The departure train engine utilization method is specified by the variable METHOD. This value can only be 1 or 2; anything else is defaulted to 1. METHOD = 1 specifies that each block (or group of blocks) to be pulled for a departing train be made up by the same engine (the engine that can start the coupling of the first block or block group soonest); METHOD = 2 specifies that each block (or block group) on the train be made up by that engine that can start coupling that block (or block group) soonest (not necessarily the same engine for each block or block group).

The specification of trim and auxiliary engine crews (see crew description cards) together with METHOD allows the user considerable flexibility in engine assignment schemes in the departure yard. Schemes can range from the most restrictive (each train made up only by a single engine allowed only to work that train's departure) to the most dynamic (each train can be made up by several engines allowed to work both departure yards).

The parameter ICTOFF specifies the cut-off time period for each departing train. This is the time duration between the start of making up the train and the train's scheduled departure time. The value for the cut-off time period specified on this card applies to all departing trains, except where specifically countermanded on a departing train specification card. The cut-off times for putting bypass blocks and for putting previous pull blocks† on departing trains are also specified here (by parameters ICTOFB and ICTOFP, respectively); however, these values apply to all departing trains and cannot be excepted.

The parameters IENGBR, ICCPL, and ICDINS are analogous to the delay constant applied at the start of the receiving yard inspection—a fixed time delay period independent of the size of the task applied at the start of the task. IENGBR applies at the start of a new trim assignment for an engine.‡ ICCPL applies at the start of the coupling task by that same engine crew. ICDINS applies to the departure inspection task by the departure inspection crew. The parameter ICY applies only when METHOD = 2 is specified. Parameter ICY specifies a minimum wait time between attempting to put two blocks on the same departing train. If this parameter value is too small, logical anomalies can occur, such as two blocks being put onto a departing train at virtually the same time. If this parameter is too large, unrealistic inefficiencies can occur in train make-up.

*The blocks are doubled in the class yard, and then only one move is made to the departure yard (or class clear destination) with all the blocks.

†"Previous pull blocks" is used to refer to "early pull blocks" once the latter have been moved to the departure yard (see Section A.1.6).

‡Trim (and auxiliary) engines are assumed to wait in the vicinity of the departure yard (or class clear destination) until they receive their next assignment.

A.1.2 Crew Description Cards

The format of these cards is shown in Table A-2. At least one card must be punched for each crew. A maximum of 50 crews, distributed in any manner between crew types, is permitted.

As specified by ICRTYP, crew types that are not used need not be specified. For example, if all arriving trains skip inspection, no receiving yard inspection crews need be specified. All crews of the same type must be entered as a contiguous set of cards, and those crew types which are entered must be entered in ascending order of crew type code (ICRTYP). Auxiliary engines, crew type code 4, are used only to perform class clears. This crew type need not be specified at all if ordinary trim engines are used to perform all class clears (the crew type to perform this task is specified as a parameter on the departure train card calling for the class clear).

The crew yard restriction, CRWRYD, specifies whether a crew is to work only E or W, or can work both directions. Any mixture of codes E, W, and B may be used, subject to the requirement that any train demanding service of a particular type must have at least one crew eligible to perform that service. Among all eligible crews to perform a service (should there be more than one elibible crew), the crew that can start the task soonest wins the task. In the case of a tie, the crew with the lowest subscript (i.e., the earliest crew in the crew list as entered by the user) wins the task.

The crew processing rate is an optional parameter. If not entered (i.e., the field is blank or zero), the appropriate processing rate from the previously entered parameter cards is used. This feature is primarily useful in simulating crews with extra men; it can also be used in an approximate manner to simulate double-crewed trains.§ Note that if this artifice is used to assign two crews to a train, the queueing of trains waiting for a crew may be incorrect (the extra crew the user envisions as working a double-crewed train may be reported by the model as simultaneously working some other train). The crew utilization statistics will definitely need manual correction. When this artifice is used, the user will generally have to use the option of specifying the specific crew to perform the task (see the arriving and departing train cards) in order to insure the selection of the dummy crew.

Each crew in the yard can have zero or more break periods, specified by the parameters TBRKS and BRKDUR. These are useful for specifying crew down times for shift changes, rest breaks, and meals. If a crew is working at the start of a break period, the crew completes its work; the postponed break is then taken in its entirety.** The break facility can be used to

§By coding a dummy crew AB, which represents both crews A and B. AB's breaks should coincide with A and B's work periods and vice versa.

**Very long pieces of work that cause more than one break to be postponed will cause the postponed break periods to be accumulated and taken together at the end of the work.

TABLE A-2.-INPUT FORMATS FOR CREW DESCRIPTION CARDS

Cols.	Variable	Type	Description
1-5	CREWID	A	Crew name (any alphanumeric—must be unique for each crew).
6-10	ICRTYP	I	Crew type code, as follows: 1 = Receiving yard inspection crew 2 = Hump engine crew 3 = Trim engine crew 4 = Auxiliary trim engine crew 5 = Outbound inspection crew.
11-15	CRWRYD	A	Subyard direction crew can work: E = Can work east direction W = Can work west direction B = Can work both directions.
16-20	CRWRTE	F	Crew processing rate, in min/car, interpreted as follows according to the value of "ICRTYP" coded in Cols. 6-10: 1 Coded = Receiving rate of inspection 2 Coded = Humping rate 3 Coded = Coupling rate 4 Coded = Coupling rate 5 Coded = Outbound inspection rate. Note: If field is 0 or blank, the appropriate parameter for the crew type is obtained from the parameter cards.
21-25 31-35 . . . 71-75	TBRKS(1) TBRKS(2) . . . TBRKS(6)	I I I	Start time of a crew break period (hours:minutes) entered in ascending order by time.
26-30 36-40 . . 76-80	BRKDUR(1) BRKDUR(2) . . BRKDUR(6)	I I I	Duration time of preceding crew break period (hours:minutes). Must not overlap any other break period for the same crew.

Note: Additional cards with ICRTYP, CRWRYD, and CRWRTE blank may be entered as needed to specify TBRKS(7), BRKDUR(7) through TBRKS(12), BRKDUR(12) and so on. Alternatively, no crew breaks at all need be entered, if desired, for any or all crews. A total of 600 crew breaks across all crews may be specified.

simulate crews active for only a single shift. For example, if a crew is to be active for only 8 hours of the day, the period when the crew is off can be coded as a 16 hour break.*

A.1.3 Arriving Train Specification Cards

The format of these cards is shown in Table A-3. One and only one card must be punched for each arrival train. A maximum of 100 arriving trains per day is permitted.

The train direction (specifying the receiving yard the train enters) is specified by TRDIR. This can only be E or W, and must be right justified within the field. Note that there is no restriction that a train designated for a certain direction carry only blocks of that direction. For example, a train designated E can carry a block that goes to the W class yard.

*Note that the break postponing feature allowing completion of current work could cause the crew's off time to be "slid" slightly.

The parameter NOINSP is a code used to specify various special arrival train processing options. For normal processing,† it may be left blank or coded as zero. A code of 1 is used to specify that the train is not to be inspected, but the train still will occupy a track in the receiving yard. A code of 2 causes the train to skip the receiving yard entirely (and, of course, inspection). With a code of 2, the train still must queue for the hump, but the space the train takes up is not accounted for in the model. These special codes facilitate simulating special moves, such as trains from the shop and manually simulated rehumpings. As a further aid to simulating special moves, any of the above codes may be made negative.‡ This causes the train to be designated as a "no-count" train. An alternative car accounting scheme is maintained for the cars on "no-count" trains. At the end of the simulation an

†I.e., the train enters the receiving yard, is inspected, and then humped. The accounting for the train's cars is handled normally.

‡Including zero (0). Special programming is incorporated in CAPACITY to differentiate between "0" and "-0."

TABLE A-3.-INPUT FORMATS FOR ARRIVING TRAIN SPECIFICATION CARDS

Cols.	Variable	Type	Description
1-5	TRNUM	A	Train name or number.
6-10	TRDIR	A	Train direction, E or W (must be right justified).
11-15	NOINSP	I	Train processing code - controls inspection and receiving yard occupancy as follows: 0, -0, or blank - Passes through receiving yard normally. 1 or -1 - Bypasses inspection, but still occupies receiving yard. 2 or -2 - Bypasses receiving yard, goes directly to hump. Note - A negative input code (including -0) flags the train as a "no-count" for which additional output statistics will be printed in the final summary table. These alternate statistics will omit trains coded with this value negative.
16-20	RINCRW	A	(Optional) The specific inspection crew to be assigned. Leave blank if any available inspection crew is OK. Ignored if inspection is skipped.
21-25	EDELH	I	(Optional) Extra delay to hump, i.e., any extra time hump is to be delayed prior to humping this train (hours:min).
26-30	RHMCRW	I	(Optional) The specific hump engine crew to be assigned. Leave blank if any available hump engine crew is OK.
31-35	TRMIX	A	Train's consist mix ID name or number (must correspond to a mix ID name in the consist mix ID cards).
36-40	TRARRT	I	Train's arrival time (hours:min).
41-45	TRNCAR	I	Total number of cars on this train.
46-50 . . . 76-80	BYPASS(1) . . . BYPASS(7)	I	(Optional) A block ID in this train's mix ID that is presorted and so bypasses the hump, going directly to departure yard.

Note: Only one card allowed per train.

additional output column is given in the overall summary table, which does not count the cars in these "no-count" trains as arriving cars.* This is useful in preventing the double counting of cars which are in reality arriving from another part of the simulated yard (e.g., rehumps), aiding manually implemented rehumping. In all other simulation outputs except for the overall summary table, the car counts reported do not distinguish "no-count" cars (i.e., "no-counts" are in fact counted). Designating a train and its cars as a "no-count" in no way changes the manner in which the train and its cars are simulated, but impacts only the aforementioned summary table.

The parameter RINCRW allows the user to designate a specific receiving inspection crew to perform the inspection. A crew of this exact name must be specified among the receiving inspection crews (and the crew must be eligible to work the train's direction), or the program will detect an error. Leaving this field blank will allow the program to select the crew that can start the task soonest, which will generally be more efficient. The parameter RHMCRW performs analogously, allowing the user to specify the hump engine crew.

The parameter EDELH is an extra delay time period associated with humping the train. It is applied at the start of humping and ties up both the hump and hump engine crew for the specified time period, after which humping commences. This parameter is used primarily to facilitate manually implemented rehumping, in which the hump engine enters the class yard via the hump to fetch a string of rehump cars.

The TRMIX field specifies each arriving train's "consist mix ID" name. Each arriving train is assumed to "belong" to a consist mix ID. Each consist mix ID can "own" more than one train. The concept of a consist mix ID is based on the idea that trains with similar origins and destinations may have consists whose block make up is identical on a percentage basis. Thus, only an arriving train's consist mix ID name (specified by TRMIX) and number of cars (specified by TRNCAR) need be known, and

*A column which does count the "no-count" cars is also included.

the number of cars in each block on the train can be calculated. This can greatly reduce user input requirements. The consist mix ID specified by TRMIX must also be specified in the Consist Mix ID Cards, or the program will detect an error.

The train's arrival time is specified by TRARRT. The daily train arrival pattern is repeated for each simulated day, so no arrival day should be specified. Arrival trains are processed exactly in their order of entry by the user, not by arrival time.

Finally, up to seven bypass block numbers (positive integers less than or equal to 200) may optionally be specified on the card in BYPASS(1) through BYPASS(7). As mentioned earlier, these bypass blocks bypass the hump and go directly to the departure yard. These bypass blocks should be specified on the card without intervening blank fields for any of the BYPASS(i), since the program will ignore any positive values to the right of the first blank field. All bypass blocks specified here must also be named as a block in the cards for the train's consist mix ID or the program will detect an error.

A.1.4 Arriving Train Consist Mix ID Specification Cards

The format of these cards is shown in Table A-4. As many cards as needed can be used to specify all the blocks of each consist mix ID, up to a maximum of 200 blocks. Up to 100 consist mix IDs may be specified.* Of course, all the cards for a single consist mix ID must occur consecutively within this group of cards. The consist mix ID name MIXID must be specified on every card. The sequence number, within a single consist mix ID, must start at 1 and be incremented consecutively by 1 for each card needed to specify all the blocks of the consist mix ID.

The blocks and their percentages (or car counts) are specified as ordered pairs (block No., percentage), and should be specified without any intervening blank pairs.

TABLE A-4.-INPUT FORMATS FOR CONSIST MIX ID CARDS

Cols.	Variable	Type	Description
1-5	MIXID	A	Consist mix ID name or number.
6-10	ISEQ	I	Card sequence number within this mix ID.
11-15 21-25 . .	BLKID	I	Block (batch) ID number, or after all blocks entered, finish code of 999.
16-20 26-30	BPCT	F	Percent of cars of the preceding block number in all trains having this consist mix ID. Car counts may also be entered, in which case the program will convert them to percentages summing to 100.

Note: These cards may be repeated as needed within each consist mix ID.

*If desired, this permits a separate mix to be specified for each arriving train.

Each block number must be specified as a positive integer less than or equal to 200, and should be given only once within a single consist mix ID. A maximum of 1500 such pairs may be specified when counted across all consist mix IDs. If car counts rather than block percentages are entered, the program detects this and scales the counts to percentages summing to 100 percent.

A.1.5 Block Assignment Cards

The format of these cards is shown in Table A-5. Following the direction field, the blocks are specified as ordered pairs (block No., track capacity). All the blocks specified on one card are assumed to constitute one class track group; i.e., these blocks are assumed to be stored on a single class track or group of class tracks. The model does not require that the blocks of these class track groups be pulled as a group (although the user can guarantee that this occurs by specifying the blocks constituting the group as a multiple pull on the departure train cards). Since CAPACITY does not internally simulate the implied rehumping, it is the user's responsibility to at least check the front end of the yard simulation output to see that sufficient time exists for rehumping. A better solution is to manually simulate the rehumping using CAPACITY. If every block in the yard is to be assigned to a separate class track, then one card will be required for every block.

TABLE A-5.-INPUT FORMATS FOR BLOCK TO CLASS YARD ASSIGNMENT CARDS

Cols.	Variable	Type	Description
1-5	IDIR	A	Classification subyard direction, E or W (must be right justified).
6-10 16-20 . . . 66-70	IBLKID(1) IBLKID(2) . . . IBLKID(7)	I	A block ID number to be assigned to the classification yard specified by the IDIR value on this card.
11-15 21-25 . . . 71-75	BLKTKL(1) BLKTKL(2) . . . BLKTKL(7)	I	Track capacity (cars) of the class track(s) assigned to to the preceding block ID number.

Note: All the blocks specified on one card (up to 7) are assumed to consittute one class track group (i.e., these blocks are summed together in the block build-up table). As many cards as needed may be used to specify all blocks; additional cards with IDIR field blank may be added as needed, giving IBLKID and BLKTKL subscripts 8-14, 15-21, etc.

For every block a track capacity can optionally be specified. If the track capacity is left blank (or specified as zero), an infinite track capacity is assumed. These track capacity values are used during the simulation of the departure train makeup to determine if additional trip(s) to the classification yard are required (on account of there being more cars in the block than can fit on a single class track). These values are also used in the calculation of the number of tracks required for each class track. If more than one block constitutes the group, the sum of the track capacities of all the blocks in the group is used for the calculation of the number of class tracks required to store the group. This sum does not, however, enter into the departure train pulling process.

Every block must be assigned to one of the classification yards E or W. If any block named previously on a Consist Mix ID card is not specified on a Block Assignment Card, the program will detect an error. All the blocks to be assigned to the eastbound class yard should be given first, followed by the blocks to be assigned to the westbound class yard.

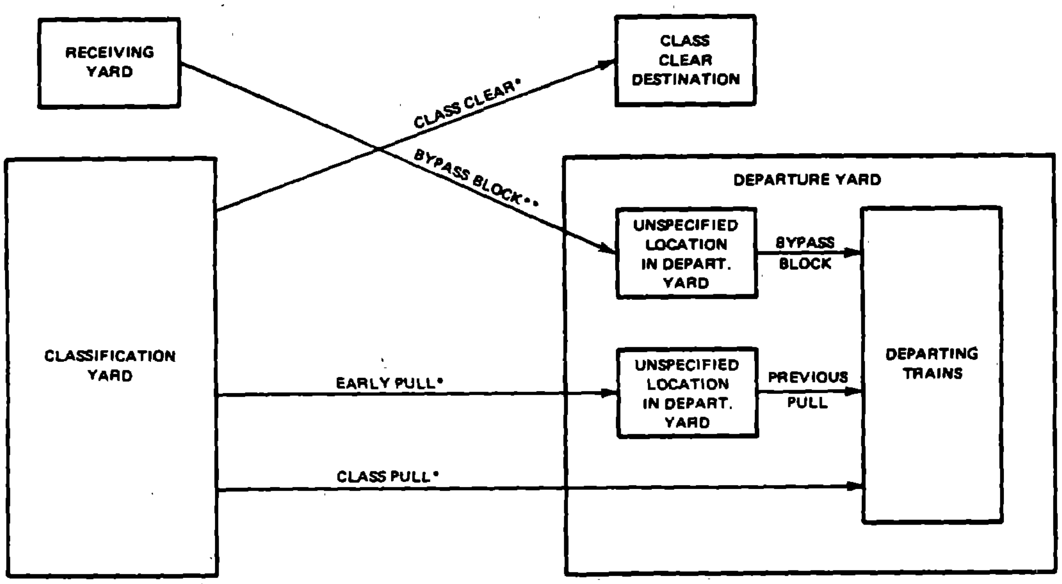
A.1.6 Departure Train and Special Move Specification Cards

Some clarification of the terminology and processing used in the back end simulation is required before the departure train and special move input specifications can be discussed. Figure A-2 shows a schematic diagram of the flows of blocks (cars) in the back-end simulation. Departing trains are made up block by block, with each block constituting a single move from the class yard to the departure yard, unless moves are specifically aggregated by the user (such aggregated moves are called "multiple pulls"). Trimming moves for regular departing trains are designated by the name "CLASS PULL." Each true departing train occupies a departure track from which departure track requirements can be computed. The start of track occupancy for a departing train is taken as the earliest arrival time of any of its component blocks: bypass blocks, previous pull blocks, or regular trim (i.e., class pull) blocks.

In addition to regular departing trains whose cars are trimmed from the class yard, assembled into the train on a departure track, and then departed, CAPACITY allows two types of special moves: "early pulls" and "class clears."

An early pull is a trim operation not associated with a departure of cars from the overall yard--the cars are just shunted from the class yard to the departure yard. This move is generally made well prior to the time the departing train that eventually takes the cars is made up. This move is primarily useful for clearing one or more class tracks that are becoming overloaded. The blocks in the early pull then wait in an unspecified location in the departure yard until the first outbound train that can take them* is made up. The blocks are then put on this outbound train. To avoid a conflict in terminology, when the blocks in what was an early pull are assigned to an outbound train, they are called a "previous pull" (labeled as PREV. PULL in the program output). All the cars in an early pull block will be put on the first outbound train that can take the block; however, not all the blocks that were trimmed in one early pull operation will necessarily be taken by the same outbound train. Once a previous pull has been assigned to its departing train, its track, previously unspecified, is known: it is the same track used by the departing train.

A class clear also removes cars from the class tracks, but such cars are taken directly to a "sink" called the "class clear destination," where they disappear entirely from the simulation. Class clears are useful for (1) removing cars from the class tracks in a manually implemented reswitching simulation using CAPACITY,



Notes:

*Any of these moves can be "doubled", in which case all blocks except the last block are labeled "MULT. PULL" in the simulation output. The last block doubled is labeled by one of the above names, designating the move type.

**The event of entry of a bypass block into the departure yard is not given in the simulation output; however, the bypass block is listed when it is incorporated into the making up of a departing train.

FIGURE A-2. FLOWS OF BLOCKS AND TERMINOLOGY USED IN BACK END SIMULATION

*The eligibility to take these cars is determined on a block-by-block basis, as specified by the consist of the departing train.

(2) removing cars to be shopped or serviced from the class tracks, (3) departing local turns and cuts going to the local yard from the class tracks, and (4) departing mainline trains directly from the class tracks. Note that inspections of the cars on class clears are not simulated in the model.

Early pulls and class clears, because their makeup resembles that of a departing train, are entered to the model intermixed with the departing trains. However, they differ from true departing trains in the following ways:

- Early pulls and class clears are not inspected.
- The destination of a class clear is not the departure yard.
- A class clear can optionally be made up by a special crew type (engine type) called an "auxiliary engine crew."
- Early pulls and class clears are, of course, ineligible to receive cars from bypass blocks and previous pull blocks.

In all other respects, early pulls and class clears are coded by the user and simulated in the same manner as departing trains.

The format of the departing train and special move cards is shown in Table A-6. At least one card (followed by up to four additional cards, if needed) must be punched for each departing train. A maximum of 100 departing trains per day is permitted.

The train direction (specifying the departure yard in which the train is assembled, the yard direction an early pull is taken to, or the class clear destination direction) is specified by DTRDIR. This can only be E or W and must be right justified. As with arriving trains, there is <u>no</u> restriction that departure trains of a certain direction can take only blocks of that same direction.

DTRCDE specifies the departure train type code. This code is used to specify early pull and class clear moves as well as true departing trains. The code used is given in the table. Any of these codes* may further be entered as a negative (minus) value, including "-0"; this specifies the train as a "no-count." No-count departing trains are handled in an exactly analogous manner to no-count arriving trains, except here it is departing rather than arriving cars that are not counted.

The start of activity on each departing train or special move is triggered by the train's or move's cut-off time point; this is computed as the scheduled departure time DTRDPT minus the train's or move's cut-off time period DCTOFF.† Regardless of the order of entry, all departing trains and special moves are processed in order of ascending cut-off time point. To enhance the flexibility in this area, each train or move can optionally be assigned an individual cut-off time period, as specified by the parameter DCTOFF. If this field is entered as zero or blank, the default cut-off time entered in the parameter cards is used. As for arrival trains, the daily arrival pattern is repeated for each simulated day, so no arrival day should be specified when specifying the departure time DTRDPT.

In a manner analogous to arriving trains, the user may, if desired, specify the crews to handle the makeup and inspection of departing trains and the make-up of special moves.‡ The trim (or auxiliary) engine crew is specified by DPLCRW, and the outbound inspection crew by DINCRW. Note that if a trim engine crew is specified, this one engine makes up the entire train, regardless of how the parameter METHOD was specified in the parameter cards.

Each block on the departing train or special move is specified as a member of an ordered pair, the second member being an optional maximum limit of cars from that block to be put on the train or move. If no maximum limit is specified (blank field or zero), an infinite limit is assumed. The blocks taken by the train are specified by DBLOCK(1) through DBLOCK(4), and up to 4 optional continuation cards are allowed, giving up to 20 blocks. No more than 20 blocks may be specified. As with other such lists in CAPACITY, all (block, maximum limit) pairs must be specified from left to right across the card without intervening blank pairs. Obviously each train must have at least one block specified.

The order in which the blocks are listed is important, since the train or move is made up in that order. The blocks are identified to the model as positive integers less than or equal to 200. However, a block number may optionally be prefixed by a minus sign, indicating that it is to be pulled at the same time as the first preceding block number in the list without a minus sign. Such a group of blocks pulled together is called a multiple block pull group; except for the last block of the group, these are indicated together in the output as MULT. PULL. Regardless of whether a block is a member of a multiple block pull group, the maximum car limit specified still applies individually to each block.

In making up each departing train, CAPACITY first searches the departure yard for any bypass blocks and previous pulls to be assigned to this outbound train. Each bypass or previous pull block is assigned to the first train that can take it. Cars in bypass and previous pull blocks count toward the maximum car limit on the train for each block, but are not themselves limited.§ Next CAPACITY simulates the action of the pull engine (or engines, if METHOD = 2 is specified) in travelling to the departure yard to make up the individual blocks (or multiple block pull groups) of the train, or special move in the order specified. The order in which the blocks (or multiple block pull groups) are listed by the user is the order in which blocks (or multiple block pull groups) are pulled from the class tracks. Thus, this order can affect the block build-up history in the class yard as well as the size of the outbound train or special move.

A.2 CAPACITY OUTPUT

This section discusses the nature of the output produced by CAPACITY, illustrated by the output from an

*Logically, coding an early pull as a "no-count" has no effect because the cars do not leave the overall yard. CAPACITY simply ignores the negative code on an early pull.

†The scheduled departure time for an early pull or class clear is a somewhat fictitious concept; however, it is useful in scheduling these activities. This time can perhaps be viewed as the target time by which the user would like to have this activity completed.

‡If an inspection crew is specified for a special move (early pull or class clear), it is ignored.

§Recall that special moves cannot take bypass or previous pull blocks.

TABLE A-6.-INPUT FORMATS FOR DEPARTING TRAIN AND SPECIAL MOVE SPECIFICATION CARDS

Cols.	Variable	Type	Description
1-5	DTRNUM	A	Departure train name or number.
6-10	DTRDIR	A	Departure train direction, E or W (must be right justified).
11-15	DTRCDE	I	Departure train type: 0, -0, or blank - Regular departure train 1 or -1 - Early pull, cars wait on a departure track to be taken by a regular outbound train. 2 or -2 - Class clear, no inspection or departure yard occupancy. Class clear is done by regular trim engine. 3 or -3 - Same as 2, except class clear is done by auxiliary engine. Note: A negative input code (including -0) flags the train as a "no-count" for which additional output statistics will be printed in the final summary table. These alternate statistics will omit trains coded with this value negative.
16-20	DTCOFF	I	Departure train cut-off time period, if different from general cut-off time period specified in parameter cards (if same--leave blank, hours:minutes).
21-25	DTRDPT	I	Departure train departure time (hours:min).
26-30	DPLCRW	A	(Optional) The specific trim engine crew to be assigned this train's make-up. Leave blank if any available trim engine crew is OK. If specified, only this crew makes up the train, regardless of Engine Utilization Method coded.
31-35	DINCRW	A	(Optional) The specific departure train inspection crew to be assigned. Leave blank if any available departure inspection crew is OK. This field is ignored except for departure train types 0 and -0.
36-40	DBLOCK(1)	I	First block to be put on this train.
41-45	DBLKLM(1)	I	Limit of cars from first block to be put on this train.
46-50	DBLOCK(2)	I	Second block to be put on this train.
51-55	DBLKLM(2)	I	Limit of cars from second block to be put on this train.
56-60	DBLOCK(3)	I	Third block to be put on this train.
61-65	DBLKLM(3)	I	Limit of cars from third block to be put on this train.
66-70	DBLOCK(4)	I	Fourth block to be put on this train.
71-75	DBLKLM(4)	I	Limit of cars from fourth block to be put on this train.

Note: Up to four additional cards with DTRNUM, the DBLOCKs, and the DBLKLMs specified, but the other parameters omitted may be added if needed so that up to 20 departure blocks can be specified for one departing train.

example run in Exhibit A-2, attached at the end of this appendix. This run has been taken from the simulation of a real yard, but has been modified slightly for illustrative purposes. The output from CAPACITY is split into two broad categories: echo-back, and simulation results. Each of these is subdivided into several subcategories as follows:

1. Echo-Back
   a. Input parameters
   b. Crew input specifications
   c. Arrival trains
   d. Block class yard assignments
   e. Departure trains
   f. Consist Mix ID summary
2. Simulation Results
   a. Arrival train humping histories (front-end simulation)
   b. Receiving yard occupancy diagram(s)
   c. Departing train (and special move) make-up scenarios (back-end simulation)
   d. Departure yard occupancy diagram(s)
   e. Classification yard block build-up
   f. Crew utilization diagram and statistics
   g. Overall yard summary table.

The remainder of this section discusses each type of output in turn.

A.2.1 Echo-Back of User Input

The echo-back of user input can be dealt with quite briefly here because it follows quite closely the user input specifications discussed previously. This echo-back is quite useful in documenting the exact input that was provided to CAPACITY. To aid in this documentation, the echo-back outputs are carefully annotated to be readable even by someone not very familiar with the details of the input requirements.

On the first page of output, the parameters specified by (or defaulted from) the general yard parameter cards are listed out. The next page or set of pages lists the crew specification data, essentially in the same form as entered by the user; any defaulted crew inspection rates will have been replaced by the actual values the model will use, as obtained from the parameter cards. The third set of pages lists the arrival train input data. The fourth set of pages lists the block class yard assignments. Here, each class yard block group is listed separately. The groups are numbered by the program, the direction of each group is given, and the blocks constituting each group are enumerated (see Exhibit A-2). The fifth set of pages lists the departure train input data; any defaulted cut-off times will have been replaced by the general cut-off time from the parameter cards. Finally, the sixth set of pages gives a combined summary of the Consist Mix ID information and block assignment. Here, first each Consist Mix ID name is given, followed by a list of trains having that consist mix ID. Then the block percentages for each block of the consist mix ID are listed, the direction of the block being given in parentheses immediately following the block number. Refer to Exhibit A-2 for an example.

A.2.2 Arrival Train Humping Histories (Front-End Simulation)

A simulation summary table is generated containing one line giving the history of every arriving train processed. Those values which are additive from one train to another are summed at the bottom of the table. All times, including sums, are given in the table in units of days:hours:minutes, with intervening colons as indicated. For example, referring to Exhibit A-2, the arrival time of the 99th train processed (S222) is given as 3:16:25, meaning day 3 at 4:25 p.m. The end receiving yard occupancy time printed will depend upon the receiving yard type coded by the user. Other aspects of this table are obvious, and do not need further discussion.

At the bottom of the table summary statistics for the receiving yard are given. These quantities are calculated strictly over the requested print period and so cover an integral multiple of 24 hours. Note that the definitions of total cars in and out in the summary table differ from the definitions of the sums of quantities printed for the above humping history table, since the latter sums include all trains printed (which usually overlap the start and the end of the print period by a considerable margin). The meaning of "cars in" and "cars out" in the summary table is obvious; the total car hours is that part of the detention time* of each car that is exclusively within the requested print period window, summed over all cars. The average detention time is the total car hours divided by the average of cars in and cars out, and is only approximate if the yard is oversaturated. The percent hump utilization is computed as 100 times the ratio of actual time spent in humping to the time in the appropriate multiple of 24 hours. This ratio is divided by 2 for a dual-lead hump.

A.2.3 Receiving Yard Occupancy Diagrams and Track Requirements

This information is repeated for each print day and for each receiving yard direction. This yard occupancy diagram is essentially a queueing diagram, with trains listed along the Y-axis on the left and time going along the X-axis. A line of asterisks represents the time the train is occupying the receiving yard; this line starts when the train enters the yard and ends when the train exits the yard. The exit time of the train is the end receiving yard occupancy time; this depends upon the receiving yard type coded by the user.† A rough idea of receiving yard track requirements can be immediately gleaned with a quick glance at the diagram. However, CAPACITY computes the actual track requirement needed to avoid queueing of arriving trains. Track lengths required, based on arriving train sizes, are also given. These requirements are calculated using a simple algorithm, essentially a quantitization from the diagram (using exact times, however).

A.2.4 Departing Train and Special Move Make-Up Scenarios

The make-up history of each departing train and special move is given in the table labeled DEPARTING TRAIN MAKE-UP SCENARIOS. As with the arrival train processing scenario, all times are given in days:hours:minutes. Each block put on the train is listed on a separate line. If bypass blocks or previous pulls are assigned to a regular departing train, they are listed first, followed by the pull histories of individual blocks from the class tracks. Bypass blocks are designated in

*From train arrival time to end hump time.

†Note that the end receiving yard occupancy, and thus, the occupancy diagram, does not include the entire history given in the history table; the latter includes the travel time to the hump and the actual humping.

the Pull Type column as BYPASS; previous pulls are listed in this column as PREV. PULL. For regular departing trains as well as for special moves, all the blocks of a multiple-block pull are listed separately; all blocks of the multiple block pull except the last are designated in the Pull Type column as MULT. PULL. The last block, as with a single block pull, designates the end of the multiple-block pull group, as well as the type of move. Pulls for regular departing trains are denoted by CLASS PULL, pulls for early pulls are denoted by EARLY PULL, and pulls for class clears are labeled CLASS CLEAR. Engine and pull scenario information is listed only for this last block line of the multiple block pull. More than one trip to the class yard for the same block (or multiple block pull group) may be required when the number of cars in the block (or block member of a multiple block pull group) exceeds the class track capacity of that block (or block member of a multiple-block pull group). When this occurs, pulls for the same block (or multiple block pull group) will be listed for the departing train for each time such a repeat trip is made.

After the last block to be pulled for a departure train or special move is listed, a summary line for each train (or move) is printed. For departure trains, in addition to listing total cars for the train, the line gives the start of occupancy time of the departure track. The start of occupancy may occur quite a bit earlier than the cut-off time of the train if bypass blocks or previous pulls have been stored on the tracks awaiting the make-up of the train. Also given is the performance of the yard in making each train's schedule, and the lateness, where appropriate.

At the bottom of the departing train make-up scenario table is an overall departure yard summary. This summary is analogous to that in the receiving yard history output. Bypass blocks, early pulls (which become previous pulls once they enter the departure yard), and class clears are included in the summary statistics as well as true departing trains. In computing these statistics, a car's detention time in the yard encompasses:

- For regular trim moves: From coupling time in the class yard through departure from the yard on a regular departing train.
- For bypass blocks: From arrival in the departure yard through departure from the yard on a regular departing train.
- For early pulls: From coupling in the class yard through departure from the departure yard as a previous pull in a regular departing train.
- For class clears: From coupling time in the class yard through the end of the pull (trim) move at the class clear destination.

In some cases the user may inadvertently move cars into the departure yard as bypass blocks or early pull blocks, but never specify these blocks as a part of the consist of any regular departing trains. When this happens, the cars will accumulate in the departure yard indefinitely. The program will detect this accumulation and print a warning message between the summary line for the trim scenarios and the summary table. Such cars will be counted in the "cars in" and "car hours" statistics in the summary table, but will not be counted in the departure yard occupancy diagram and track requirements computations (see below). If there are very many cars that accumulate in this manner, the "car hours" and "average detention time" summary statistics will be inflated in reflection of this accumulation. Such an accumulation is usually indicative of an error on the part of the user. The user should be on the lookout for this warning so he can remedy this situation in a subsequent run. An example of this situation has deliberately been created in Exhibit A-2.

A.2.5 Departure Yard Occupancy Diagrams and Track Requirements

This information is analogous to that given for the receiving yard(s). The information is repeated for each print day and departure yard direction. Only true departing trains are listed in the diagram; however, car counts and start occupancy times reflect cars added to the train from previous pull (i.e., early pull) blocks and bypass blocks. As with the receiving yard, the number of tracks required and their lengths are given. A glance at the departure yard occupancy diagrams given in Exhibit A-2 shows the inefficiencies of the extended occupancy times arising when bypass or previous pull blocks are stored on the departure tracks. Such storage can add considerably to departure yard track requirements.

A.2.6 Class Yard Block Build-Up Histories

The next outputs given by CAPACITY are class yard block build-up histories. The histories are repeated for each print day and class yard direction. Each block in a class yard takes one line. The maximum number of cars occurring within each hour for each block is listed for each hour of the day. Note that this is <u>not</u> the same as a "snapshot" of the number of cars at each hourly point of the day. The maximum number of cars within the hour, as given by CAPACITY, is a much more useful indication of block build-up. These maximum car counts are summed over all member blocks for each class yard block group.* At the right of the table the maximum number of cars occurring for that day in each block or block group is given. A second column gives the number of tracks required (assuming no dynamic track assignment) for each block (or class yard group), as computed from the daily maximum and the track length specified by the user. The third and fourth columns to the right of the table give the counts of cars in and out of the classification for the print day; if these two values are not approximately equal, it is indicative either of oversaturation within the yard or of the user failing to specify that block within the consist of some departing train (or special move). The car hours for that block or block group for the day are listed in a fifth column.

If no dynamic assignment of blocks to the class tracks is to be performed, then there is a one-to-one mapping from the block build-up to the class tracks. If track lengths are specified by the user, then the number of tracks required is as specified in the table; if the user did not code a track length, then the maximum number of cars occurring for that day would be the minimum storage required on the class track(s) for that block or class yard group. Although CAPACITY does not perform a dynamic track assignment, the user can easily perform one from this CAPACITY output. To do this, one need merely look for pairs of blocks whose non-zero entries occur at mutually disjoint times. For example, one block might only have cars in the class yard between the hours 0300 to 1100; a second might only have cars in the class yard between the hours 1400 and 2100. If such pairs are found, the two blocks making the pair

*Note that occasionally this class yard block group sum can be a conservative upper bound on the number of cars rather than the actual maximum. This can occur when the car count maxima for the individual member blocks of the group occur at different times within the hour.

are natural candidates to dynamically share the same class track. Of course, this sharing can be extended to three or more blocks as well.

At the bottom of each class yard block build-up table, by day and direction, is given a short summary table. This table gives cars in, cars out, total car hours, and average detention time in a manner analogous to the similar table printed for the front- and back-end simulations.

A.2.7 Crew Utilization Diagram and Statistics

Summaries of crew utilization are given next, in both a graphical and quantitative manner. All crew types are summarized together on the same pages allowing quick cross-reference. However, each crew type is set off visually from the others. First a graphical summary, the crew utilization diagram, is given. This diagram is structured somewhat in the manner of the yard occupancy diagrams. Along the Y-axis each crew is listed by its 5-character user-specified ID, CREWID. Time extends along the X-axis. Times that crews are working in the east subyard appropriate to their duties are indicated in the diagram by E; similarly, times that crews are working the west subyard are indicated by W. Periods when breaks were actually taken are indicated by asterisks (*). Times that crews were idle, but could have worked, are blank. At the extreme right of the diagram, the crew type code ICRTYP is given under the heading TP. The resolution of this diagram is only to within plus or minus one character,* so it should not be used in a detailed quantitative analysis.

Quantitative results are, however, given in the crew utilization summary statistics immediately following the diagram. Here, each crew is listed, followed by its type code ICRTYP. Four columns follow. The first gives the total work hours for the day; the second gives the total break hours for the day;† the next two columns give the percent crew utilization based on two definitions of crew available time. In the first percent utilization column, crew break periods are counted as idle time, so the total work hours are divided simply by the 24 hours of the day.‡ In the second percent utilization column, crew break periods are not considered idle time; in this instance the total work hours are divided by 24 hours less the total daily break hours. Overall information taken over (1) all crews of the same type and (2) all crews of all types is listed in the right-hand part of the table. Overall work and break hours are sums, denoted by (S); overall utilizations are averages, denoted by (A).

A.2.8 Overall Yard Summary Statistics

The final portion of the CAPACITY output is an overall yard summary, by subyard type (receiving, classification, and departure) and for the yard as a whole taken over all three subyards. Cars in, cars out, total car hours, and average car detention time are given for each of the three subyards and for the overall yard. The subyard statistics summarize those same values given previously in the summary tables immediately following the detailed outputs for each of the three subyard types.

The statistics for the overall yard are given twice; in the first "overall" column cars in "no-count" trains are, in fact, included in the "cars in" and "cars out" tallies; in the second "overall" column, cars in these trains are excluded from these tallies. "Cars in" in the "overall" columns are identical to "cars in" for the receiving yard;§ "cars out" are identical to "cars out" for the departure yard.§ If the "cars in" tally significantly exceeds the "cars out" tally, this is usually indicative either of oversaturation or of the user failing to "hook" some blocks to outbound trains or class clears. The total car hours in the two "overall" columns are identical.** The average detention time is the total car hours divided by the mean value of the "cars in" and "cars out" (as appropriate to the column). This average detention time is exact when the yard is not oversaturated, and approximate if it is.††

A.3 THE CAPACITY PROGRAM

This section describes the implementation of the CAPACITY model as a computer program.

A.3.1 General

The CAPACITY program is written in near ANSI Fortran IV. With little or no modification, it should be executable on any modern computer system having a moderate to large memory. It has been run on a CDC 6400, where it required approximately 134,000 octal words of memory. It executes very fast; a typical running time for a three-day simulation of a large yard (e.g., as in Exhibit A-2) is about 15 seconds. The approximate running time for the same run on an IBM 3033 should be about 1.0 to 1.5 seconds.

Some small differences exist between CDC and IBM versions of the program. Table A-7 documents these differences. This table can also serve as a guide to programmers implementing CAPACITY on other manufacturers' computers.

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*This means, for example, that two break periods, each 20 minutes in duration, could vary in representation from 1 to 3 asterisks. This is apparent in some of the breaks in Exhibit A-2.

†The total break hours for the day will, in some cases, be only approximate in oversaturated non-steady-state conditions.

‡Recall that each crew is specified on a 24-hour basis, regardless of the 8-hour (or so) shifts of personnel.

§Minus "no counts" in the second "overall" column.

**If "no counts" are used only for manually implemented rehumping, the total car hours in the two columns are theoretically identical.

††For the "overall" column that is adjusted for "no counts," the average detention time in a manually implemented rehump simulation is approximately that which includes rehump detention time, provided that the user has insured (1) to code departing class clears which "hook" to arriving dummy trains as "no counts," (2) that there is a negligible time gap between the disappearance of a group of cars as a class clear and its reappearance as a dummy arriving train, and (3) that the number of cars removed in the class clear is equal to the number of cars in the dummy arriving train.

TABLE A-7.-DIFFERENCES BETWEEN CDC AND IBM VERSIONS OF CAPACITY

CDC	IBM
• Variable locations containing 5 to 8 characters are stored in single precision: All statements "ƀƀƀƀƀƀDOUBLE PRECISION..." should be converted to comment "CƀƀƀƀƀDOUBLE PRECISION..." globally throughout program deck.	• Variable locations containing 5 to 8 characters are stored in double precision: All comment statements "CƀƀƀƀƀDOUBLE PRECISION..." should be converted to "ƀƀƀƀƀƀDOUBLE PRECISION..." globally throughout program deck.
• Hollerith fields in format statements should all be delimited by double quotes ("): Convert all single quotes (') to double quotes (") globally throughout program deck.	• Hollerith fields in format statements should all be delimited by single quotes ('): Convert all double quotes (") to single quotes (') globally throughout program deck.
• Main program name card specifying all files used is required: Statement "CƀƀƀƀƀPROGRAM CAPACY..." should be converted to "ƀƀƀƀƀƀPROGRAM CAPACY..."	• Main program name card not allowed: statement "ƀƀƀƀƀƀPROGRAM CAPACY..." should be converted to comment "CƀƀƀƀƀPROGRAM CAPACY..."

Notes: (1) ƀ denotes a blank column.

(2) Main program name card should be left in as a comment in IBM version, as it serves to identify the program, and to specify all files used.

The files used by CAPACITY are indicated in Table A-8. In addition to the standard input and output files (units 5 and 6, respectively), CAPACITY uses the two additional special purpose files shown.

TABLE A-8.-CAPACITY FILE USAGE

File Number	Description
1	This produces output for the CAPCON program, and is irrelevant unless the user is planning to run CAPCON. CAPACITY does not write on this file unless the parameter IOFLG on Parameter Card 2 is set to produce this file. It is the user's responsibility to attend to the ultimate disposition of this file.
5	This is the input, card-image file read by CAPACITY.
6	This is the output, line-printer formatted file produced by CAPACITY. It contains carriage control characters in column 1.
8	This is a coded "scratch" file used internally by CAPACITY during execution. It is of no interest to the user, and should be discarded at the end of program execution or at the end of the job.

A.3.2 The CAPACITY Subprograms

This section discusses each of the CAPACITY subprogram modules. CAPACITY consists of 25 subprogram modules, including the main program, but excluding compiler intrinsic functions (such as IABS) and system-defined I/O subprograms. These 25 subprograms and their interrelationships are shown in Figure A-3. The action of each of these subprograms is now briefly described. Detailed information and documentation is contained within the subprograms.

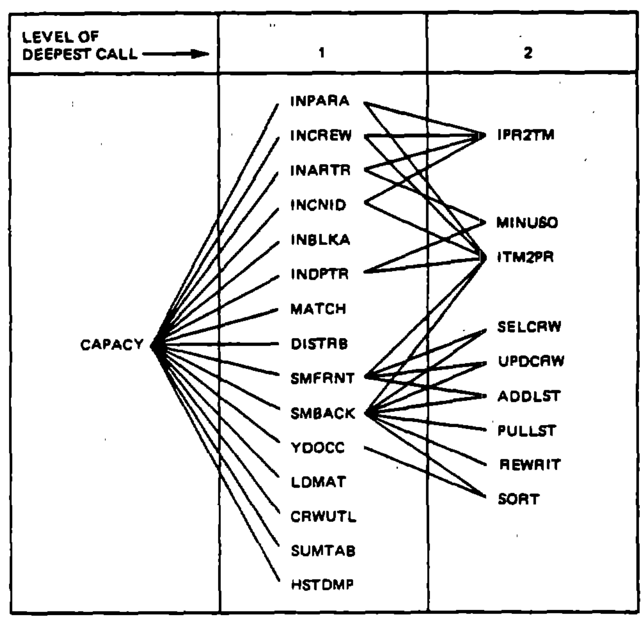


FIGURE A-3. CAPACITY SUBPROGRAMS AND CALLING HIERARCHY

A.3.2.1 Main program CAPACY

The six character name of this main program is a contraction of the eight character name of the model CAPACITY. A maximum of six characters has been adopted for all names in CAPACITY in keeping with the ANSI Fortran specifications. This main program serves only three purposes: (1) all common blocks used in the program are defined here in a common location at the beginning of this main program module; (2) program constants, primarily dimension sizes, are also defined in one common location here; and (3) to serve as a calling program for various subroutines where the actual calculations of the CAPACITY model are performed.

A.3.2.2 Subroutine INPARA

This subroutine reads the parameter cards for the simulation, sets inputted blank (i.e., 0) values to the default values, and sets up various internal variables and arrays in accordance with the inputted parameter values.

A.3.2.3 Subroutine INCREW

This subroutine reads and processes crew definition cards entered by the user, checks the entered data for correctness, and sets up various internal crew related arrays for the simulation. It also produces the echo-back table of crew input information.

A.3.2.4 Subroutine INARTR

Thie subroutine reads the arrival train input cards, sets up various arrays related to arrival trains, and checks the entered data for correctness. It also prints the arrival train echo-back table.

A.3.2.5 Subroutine INCNID

This subroutine reads the consist mix ID cards, checks the entered data for correctness, and sets up various internal arrays defining the consist mix ID information to be used for the run.

A.3.2.6 Subroutine INBLKA

This subroutine reads the assignment of blocks to the east or west classification yards, the track lengths assigned to each block, and the class yard group in which blocks are stored. It checks the entered data for correctness and sets up various internal arrays related to each block's classification yard location.

A.3.2.7 Subroutine INDPTR

This subroutine reads the departing train and special moves input cards, checks the entered data for correctness, and sets up various arrays related to this information. It also prints the related echo-back table.

A.3.2.8 Subroutine MATCH

This subroutine matches input items (stored in various arrays) from the various input card blocks, sets pointers specifying the interrelationships, checks for errors, and prints out the consist mix ID table.

A.3.2.9 Subroutine DISTRB

This subroutine performs the synthetic distribution of the cars of incoming trains to blocks, using a consist mix ID information to do this.

A.3.2.10 Subroutine MINUSO

This is a utility subroutine to scan a nominal I5 field for a negative number which can include a "-0" (minus 0). The field must actually be read into a 5-cell array on a 5A1 format and then be passed to this subroutine as a parameter. The subroutine also checks for bad data within the 5-character field.

A.3.2.11 Subroutine SMFRNT

This subroutine performs most of the processing in connection with the front-end simulation, i.e., the processing of arrival trains from their arrival through their humping. Most of the logic of this portion of the simulation is contained within this subroutine. However, several utility subroutines are called to perform common and repetitive calculations. This subroutine prints the arriving trains' history table during the course of conducting the front-end simulation.

A.3.2.12 Subroutine SMBACK

This subroutine simulates the making up of departure trains and special moves in the back end of the yard. Like the front-end simulation, most of the logic and calculations pertaining to the back-end simulation are contained within this subroutine. Again, however, several utility subroutines are called to perform common and repetitive functions. The departure train and special moves make-up scenario table is printed during the course of this simulation.

A.3.2.13 Subroutine REWRIT

At the outset of the simulation of the trimming operations for a departing train (or special move), it is not always possible to tell whether the train's history is to be printed. In particular at this time departing trains fall into two categories: (1) those which it is known for sure will be printed, and (2) those for which it is unknown prior to simulating the trimming operations whether to print. A copy of the printed output for the second group of trains is routed to an alternate file (unit 8). After the trimming simulation for each of the second group of trains is complete, if it is determined that the train's trimming history should be printed, unit 8 is rewound and the output which was written thereon is copied to the printer. Subroutine REWRIT determines whether each train's trimming history needs to be printed and handles the copying from unit 8 to the printer for those trains of the second group above that are to be printed.

A.3.2.14 Subroutine SELCRW

This subroutine functions as a utility subroutine for both the front- and back-end simulations. It controls the logic to select a crew to perform a particular task. If the task has been assigned to a specific crew by the user, this subroutine selects that crew. Otherwise, the crew that can start the job earliest wins the job. In the case of a tie, the crew with the lowest subscript wins the job.

A.3.2.15 <u>Subroutine UPDCRW</u>

This subroutine updates the availability parameters of a selected crew once that crew has completed its assigned task. This subroutine adds crew breaks accruing during the last work period to the crew availability time if needed. This subroutine also stores crew work statistics for the utilization output.

A.3.2.16 <u>Subroutine ADDLST</u>

This subroutine maintains a linked list which stores the arrival of all cars to: (1) the classification tracks, (2) the departure yard as bypass blocks, and (3) the departure yard as early pulls. The information maintained consists of the time of occurrence of each event of an arrival of a new group of cars to a block, and the accumulation of cars associated with this event. The subroutine also maintains all linkage pointers associated with the list.

A.3.2.17 <u>Subroutine PULLST</u>

This subroutine controls removals of cars from the list maintained by the previous subroutine. For the classification tracks this removal is the event of a trim move from the classification yard; for bypass blocks and early pull blocks (now called previous pull blocks), this event is the assignment of this block to a true departing train. This subroutine also converts the information maintained in the linked list from an accumulative count to the current car count as a function of time. This subroutine returns the number of cars involved in the pull assignment to the calling program.

A.3.2.18 <u>Subroutine YDOCC</u>

This subroutine prints the yard occupancy diagrams and track requirements for both the receiving yard and departure yard. The computations involved are identical for both subyards. The subroutine performs these tasks using data stored by the front- or back-end simulation subroutines, as applicable.

A.3.2.19 <u>Subroutine SORT</u>

This subroutine performs a tagged sort using an algorithm most efficient for small, nearly already ordered central memory arrays. The key array is sorted into descending order and a parallel array is permuted in the same manner as the key array. This subroutine provides one common facility for all sorting within the CAPACITY model.

A.3.2.20 <u>Subroutine LDMAT</u>

This subroutine prints the classification yard block buildup matrices. This task is performed by examining the block history data contained within the linked list arrays.

A.3.2.21 <u>Subroutine CRWUTL</u>

This subroutine prints the crew utilization diagram, one diagram for each simulated day, for all crews regardless of type. It also computes and prints utilization statistics. This task is performed by examining the crew utilization history information stored by the crew updating subroutine.

A.3.2.22 <u>Subroutine SUMTAB</u>

This subroutine prints the overall yard summary table for the run, using car hours and cars input and output information stored by the two simulation subroutines and by the classification yard block buildup matrix subroutine.

A.3.2.23 <u>Subroutine HSTDMP</u>

This subroutine dumps selected contents of the block history linked list to an optional output file for further processing.

A.3.2.24 <u>Function IPR2TM</u>

This utility function converts times input as five-digit integers in the form days:hours:minutes to minutes only.

A.3.2.25 <u>Subroutine ITM2PR</u>

This subroutine translates time from integer minutes to an 8-character alphanumeric image in the form days:hours:minutes. The time in this form is returned in an eight-cell alphanumeric array. The day portion and its following colon is suppressed if less than one day.

Exhibit A-1

SAMPLE CAPACITY INPUT LISTING
CORRESPONDS TO SAMPLE OUTPUT IN EXHIBIT A-2

```
CAPACITY DEMONSTRATION RUN
    0     3     3
   35    05    15    30     0     0    30
    1    15    2.     5   .33     1
  115    10   115    10    15    15     5     5    10    40    10    40     5     5     5     5

  200    30    05     1     1     4   .20     1    15   .50
99999
RINS1     1     E        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
RINS2     1     E        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
RINS3     1     E        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
RINS4     1     W        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
RINS5     1     W        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
RINS6     1     W        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
HUMP1     2     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
HUMP2     2     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
HUMP3     2     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
TRIM1     3     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
TRIM2     3     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
XTRIM     3     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
INDUS     3     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
ROAD1     3     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
ROAD2     3     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
ROAD3     3     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
ROAD4     3     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
ROAD5     4     B
ROAD6     4     B
ROAD7     4     B
ROAD8     4     B
ROAD9     4     B
DINS1     5     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
DINS2     5     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
DINS3     5     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
DINS4     5     B        0430    30 0750     20 1230    30 1550    20 2030    30 2350    20
99999
   XT     E     0           0      RHCON 0030    40
 RAMP     W     2           0       RAMP 0200    44
 S118     W     0           0       S118 0045    69
CRBW1     E     0           0      CRBW1 0120    67
SHOPA     W     0           0      SHOPA 0330    20
R110A     W     0           0      R110A 0100   108
 R290     W     0           0       R290 0515    72    52
CTV23     E     0           0      CTV23 0645    29
S156A     W     0           0      S156A 0400   115
 1RW6     E     0           0       1RW6 0430    88
SPTY4     E     0           0      SPTY4 0535   124
 S154     W     0           0       S154 0620   158
 RFP2     E     0           0       RFP2 0720    19
NPY4B     E     0           0      NPY4B 0700    49
 R120     W     0           0       R120 0710   130
RUPY4     E     0           0      RUPY4 0835    30
RUPYA     E     0           0      RUPYA 0835    72
 S158     W     0           0       S158 1000    67
 R112     W     0           0       R112 1000    12
ERPY4     E     0           0      ERPY4 0900    63
 R176     W     0           0       R176 1055    41    52
SHOPP     W     1           0      SHOPP 1600    18
REHMP     E    -2           0      RHCON 1658    40
  COX     W     0           0        COX 1408    49
 S222     W     0           0       S222 1625     5
 R190     W     0           0       R190 1045   117
R110B     W     0           0      R110B 1140   110
NPY5A     E     0           0      NPY5A 1510    67
SPY4X     E     0           0      SPY4X 1510   102
 R276     W     0           0       R276 1730    49    52
CPY4A     E     0           0      CPY4A 1715    97
 CRYD     E     0           0       CRYD 1945    17
 C490     W     0           0       C490 1840    71
 2RW6     W     0           0       2RW6 2100    81
B0685     W     0          12      B0685 2130    62
S156B     W     0           0      S156B 2145    76
BOVGN     W     0           0      BOVGN 2200    49
99999
```

RHCON	1	81	1.	82	1.	83	3.	84	4.	999					
RAMP	1	105	1.	118	8.	122	2.	125	2.	14	13.	13	1.	36	17.
RAMP	2	999													
CTV23	1	112	3.	116	2.	121	19.	122	3.	124	1.	999			
RFP2	1	111	4.	115	6.	123	1.	138	1.	139	1.	999			
SHOPA	1	110	1.	111	1.	112	1.	113	1.	115	1.	120	1.	123	1.
SHOPA	2	9	1.	10	1.	21	1.	22	1.	26	1.	29	1.	32	1.
SHOPA	3	138	1.	139	1.	35	2.	50	1.	999					
CRBW1	1	104	3.	105	2.	108	1.	109	1.	111	8.	113	9.	114	6.
CRBW1	2	115	1.	117	3.	118	2.	119	2.	121	7.	123	4.	126	6.
CRBW1	3	132	2.	135	2.	136	5.	999							
1RW6	1	101	1.	104	6.	108	1.	109	2.	110	3.	111	20.	112	4.
1RW6	2	113	8.	114	11.	115	3.	117	1.	119	3.	120	1.	121	1.
1RW6	3	123	5.	125	1.	126	14.	131	3.	999					
SPTY4	1	103	2.	104	7.	106	6.	108	1.	109	8.	110	3.	111	15.
SPTY4	2	112	4.	113	4.	114	29.	115	8.	117	3.	121	2.	123	7.
SPTY4	3	126	6.	131	3.	132	7.	135	1.	136	3.	137	6.	999	
NPY4B	1	104	4.	108	2.	109	3.	111	6.	112	1.	113	2.	114	10.
NPY4B	2	115	3.	117	5.	118	1.	121	1.	126	5.	128	3.	132	1.
NPY4B	3	136	1.	137	1.	999									
SHOPP	1	104	2.	109	1.	111	5.	115	1.	118	1.	123	1.	126	2.
SHOPP	2	131	1.	138	1.	35	3.	999							
NPY5A	1	104	6.	108	3.	109	4.	110	2.	111	13.	112	3.	113	6.
NPY5A	2	114	8.	115	5.	117	3.	119	1.	120	3.	121	2.	125	1.
NPY5A	3	128	5.	132	1.	136	1.	137	1.	999					
RUPYA	1	104	1.	106	1.	108	1.	109	10.	111	15.	113	5.	114	7.
RUPYA	2	115	1.	117	4.	120	3.	121	3.	123	3.	126	8.	131	1.
RUPYA	3	132	1.	137	3.	136	4.	999							
RUPY4	1	108	2.	109	3.	111	5.	113	3.	114	5.	117	3.	123	3.
RUPY4	2	128	2.	129	1.	132	3.	138	1.	999					
ERPY4	1	108	2.	109	5.	111	9.	112	5.	113	6.	114	9.	115	3.
ERPY4	2	117	6.	119	4.	121	5.	123	3.	126	2.	128	1.	131	1.
ERPY4	3	132	2.	999											
SPY4X	1	104	11.	106	1.	108	2.	109	6.	110	7.	111	20.	113	3.
SPY4X	2	114	15.	115	8.	117	12.	121	1.	123	3.	126	9.	137	2.
SPY4X	3	138	2.	999											
CPY4A	1	103	1.	104	1.	108	9.	109	4.	110	3.	111	29.	113	4.
CPY4A	2	114	9.	115	6.	119	1.	123	7.	128	3.	135	1.	136	1.
CPY4A	3	137	6.	138	1.	999									
2RW6	1	104	5.	106	2.	109	6.	110	5.	111	21.	112	1.	113	6.
2RW6	2	114	13.	115	3.	117	9.	119	1.	123	2.	126	1.	131	3.
2RW6	3	132	1.	136	1.	999									
CRYD	1	104	3.	106	1.	108	1.	110	2.	111	1.	113	2.	114	4.
CRYD	2	117	1.	123	2.	999									
B0685	1	104	4.	106	9.	109	2.	110	1.	111	6.	112	1.	113	14.
B0685	2	114	9.	117	1.	123	1.	126	5.	130	1.	131	3.	132	1.
B0685	3	136	2.	999											
BOVGN	1	104	1.	106	1.	108	3.	109	3.	110	3.	111	11.	112	1.
BOVGN	2	113	3.	114	3.	115	1.	117	2.	120	1.	121	2.	123	1.
BOVGN	3	125	3.	126	4.	130	2.	131	3.	139	1.	999			
S118	1	3	3.	9	1.	12	4.	13	3.	16	7.	22	1.	23	1.
S118	2	24	1.	26	3.	29	4.	30	1.	32	5.	33	8.	35	13.
S118	3	37	1.	39	4.	43	2.	44	1.	45	2.	48	1.	999	
R110A	1	2	3.	3	7.	10	2.	12	1.	14	2.	21	1.	22	1.
R110A	2	23	3.	24	3.	26	1.	27	3.	29	8.	30	2.	32	16.
R110A	3	33	2.	34	4.	37	7.	42	1.	43	1.	45	6.	50	2.
R110A	4	51	1.	4	3.	32	2.	34	3.	999					
S156A	1	2	4.	3	2.	4	1.	8	1.	9	1.	12	1.	13	3.
S156A	2	14	2.	18	1.	21	1.	22	2.	23	5.	24	7.	28	2.
S156A	3	29	8.	30	4.	32	8.	33	6.	34	7.	35	8.	37	6.
S156A	4	39	8.	42	1.	44	4.	45	3.	37	4.	4	1.	17	1.
S156A	5	32	2.	35	1.	999									
R290	1	2	1.	3	3.	9	4.	11	5.	16	3.	18	1.	21	1.
R290	2	24	7.	26	2.	32	1.	33	1.	35	6.	37	2.	38	2.
R290	3	39	1.	44	1.	45	2.	51	1.	52	18.	999			
S154	1	4	2.	16	1.	24	4.	26	7.	28	4.	29	2.	32	7.
S154	2	33	9.	34	2.	35	11.	37	8.	39	4.	44	1.	45	2.
S154	3	49	5.	6	2.	9	1.	10	2.	11	1.	14	1.	16	3.
S154	4	21	1.	22	3.	23	5.	28	2.	29	6.	30	5.	32	13.
S154	5	33	6.	34	5.	35	10.	37	10.	39	4.	42	2.	43	2.
S154	6	45	2.	51	2.	999									
R120	1	3	6.	4	1.	6	1.	14	1.	21	2.	24	1.	28	5.
R120	2	27	2.	29	5.	32	4.	33	1.	34	2.	35	6.	37	2.
R120	3	38	3.	39	2.	42	3.	44	1.	50	1.	51	1.	3	1.
R120	4	4	1.	6	1.	9	2.	12	2.	16	1.	18	4.	21	2.
R120	5	22	3.	24	2.	26	3.	28	1.	29	15.	30	2.	32	20.
R120	6	33	2.	34	4.	35	7.	37	3.	39	2.	44	1.	50	4.
R120	7	51	2.	999											
R176	1	23	1.	24	1.	38	9.	43	1.	50	2.	52	27.	999	
S222	1	4	1.	35	1.	38	1.	43	1.	50	1.	999			
R276	1	2	1.	6	1.	22	1.	23	2.	24	3.	29	1.	32	6.
R276	2	33	6.	34	1.	35	2.	37	2.	38	3.	39	1.	43	2.
R276	3	44	1.	45	2.	50	2.	52	12.	999					
S158	1	4	5.	6	2.	13	9.	17	1.	22	1.	23	2.	24	2.
S158	2	28	7.	29	3.	30	4.	32	14.	33	1.	34	3.	35	7.
S158	3	37	1.	39	1.	48	1.	49	1.	51	2.	999			
R190	1	4	1.	18	1.	26	3.	29	4.	30	3.	32	4.	33	1.
R190	2	34	4.	35	2.	50	2.	3	2.	9	1.	10	1.	11	1.
R190	3	13	4.	14	1.	20	1.	22	3.	24	1.	26	2.	29	3.
R190	4	30	3.	32	13.	33	3.	34	4.	35	17.	37	1.	39	7.
R190	5	42	1.	43	9.	44	1.	49	1.	50	11.	51	1.	999	
COX	1	2	1.	10	1.	13	1.	14	2.	16	1.	18	2.	23	2.
COX	2	29	2.	32	10.	33	5.	35	1.	37	1.	48	2.	49	16.
COX	3	51	1.	999											

S156B	1	2	1.	4	3.	10	1.	12	3.	14	2.	16	4.	18	1.
S156B	2	23	1.	24	6.	28	1.	30	1.	32	9.	33	2.	34	3.
S156B	3	35	13.	37	10.	39	12.	43	1.	44	1.	45	1.	999	
R110B	1	3	4.	4	1.	9	3.	14	2.	16	1.	17	1.	18	1.
R110B	2	21	2.	23	1.	24	3.	26	3.	28	2.	29	8.	30	5.
R110B	3	32	20.	35	15.	37	3.	39	2.	45	1.	49	2.	50	4.
R110B	4	51	1.	3	3.	10	5.	21	2.	23	3.	27	2.	29	6.
R110B	5	32	1.	35	2.	39	1.	43	4.	50	1.	999			
C490	1	3	1.	4	2.	9	2.	11	24.	12	3.	14	5.	16	1.
C490	2	21	3.	22	2.	24	2.	26	1.	30	2.	32	7.	33	2.
C490	3	34	6.	35	3.	37	2.	51	1.	999					
R112	1	3	1.	23	1.	28	1.	30	1.	32	2.	35	3.	37	2.
R112	2	49	1.	999											
99999															
E	101	0	102	0	105	0									
E	2	0	137	0											
E	3	0	136	0											
E	112	0													
E	131	0													
E	132	0													
E	122	0													
E	118	0													
E	106	0													
E	103	0	110	0											
E	8	0	9	0	10	0	11	0							
E	12	0													
E	13	0													
E	124	0	116	0											
E	109	0													
E	104	0													
E	108	0													
E	121	0	128	0											
E	126	0													
E	19	0	21	0											
E	22	0													
E	23	0													
E	119	0	120	0	125	0	130	0							
E	115	0	117	0											
E	81	0	82	0	83	0	84	0							
W	123	0													
W	28	0													
W	113	0													
W	114	0													
W	111	0													
W	30	0													
W	27	0													
W	29	0													
W	31	0	32	0											
W	34	0													
W	33	0													
W	35	0	36	0											
W	37	0													
W	38	0													
W	26	0													
W	14	0	17	0	16	0	18	0							
W	42	0													
W	43	0													
W	45	0													
W	39	0													
W	6	0													
W	44	0	138	0											
W	20	0													
W	48	0													
W	49	0													
W	4	0	129	0	139	0									
W	24	0													
W	51	0	135	0	52	0									
W	50	0													

99999												
TPY97	E	2	0200	0215XTRIM	48	0						
PY97	W	3	0045	0300	49	0	37	0				
TPYSE	W	1	0200	0230XTRIM	35	0	-36	0	24	0		
PYSEA	W	0	0115	0345ROAD3	35	1	-24	1				
TS84	E	1	0130	1100TRIM1	14	0	-17	0	-16	0	-18	0
NE84	E	0	0130	1230ROAD1	14	1	17	1	16	1	18	1
PYAB	W	3	0115	1530	33	0	34	0				
TPYEN	W	1	0100	1530XTRIM	32	0						
PYENA	W	0	0115	1645	32	1						
PYSEB	W	3	0115	1745	35	0	-36	0				
TWR7	W	1	0115	1700XTRIM	42	0	43	0	45	0	39	0
WR7	W	0	0115	1815ROAD1	42	1	43	1	45	1	39	1
TPYAL	E	2	0200	1800TRIM2	27	0						
PYAL	W	3	0115	1915	30	0	29	0				
TPYMO	E	1	0130	1745TRIM1	19	0	-21	0	-22	0	-23	0
PYMO	E	0	0115	1945ROAD2	21	1	-22	1	-23	1		
TTV24	E	2	0200	1945TRIM2	20	0	38	0				
TV24	W	3	0115	2100	26	0						
TS682	E	1	0130	2130TRIM2	11	0	-9	0	-10	0	-8	0
TS682					-13	0	-12	0				
BO682	E	0	0115	2330ROAD1	11	1	9	1	10	1	8	1
BO682					13	1	12	1				
PYENB	W	3	0115	2345	28	0	31	0	-32	0		
CRYD	E	2	0200	0800	6	0						
T159	E	1	0200	2330TRIM1	110	0	-103	0	-111	0		
SO159	E	0	0015	0100ROAD2	119	1	103	1	111	1		
TS105	E	1	0055	2355TRIM1	123	0	-113	0	-126	0	-115	0
TS105					-117	0						
RF105	E	0	0045	0245ROAD3	125	1	123	1	113	1	115	1
RF105					117	1	126	1				
EP173	W	1	0100	1900TRIM1	109	0	104	0				
T173	W	1	0200	0345TRIM2	109	0	104	0	108	0		
SO173	W	0	0005	0415ROAD2	109	1	104	1	108	1		
TS219	W	2	0115	0530TRIM1	101	0	-105	0	-102	0		
TS275	E	1	0115	0645TRIM2	124	0	-114	0				
RF275	E	0	0045	0730ROAD3	124	1	114	1				
T175	E	2	0200	0745TRIM1	122	0						
RF175	W	3	0045	0830	118	0						
SO221	W	3	0045	0930	111	0	104	0				
TS227	W	2	0045	1045TRIM1	116	0						
TS109	E	1	0130	1100TRIM2	128	0	-121	0	-126	0		
RF109	E	0	0045	1230ROAD2	128	1	121	1	126	1		
T155	E	1	0200	1630TRIM2	112	0	-111	0				
SO155	E	0	0030	1700ROAD2	110	1	112	1	[illegible]	1		
SOUYD	W	3	0045	1745	106	0						
TS111	E	1	0200	1500TRIM1	115	0	-117	0				
T111	W	1	0200	2145XTRIM	113	0	126	0				
RF111	W	0	0045	2230ROAD2	113	1	126	1				
X111	E	0	0045	2230ROAD3	115	1	117	1	81	[illegible]	-82	0
X111					-83	0	-84	0				
TS289	E	1	0200	1530TRIM1	119	0	-120	0	-125	0	-130	0
TS289					-123	0	-114	0				
RF289	E	0	0045	1830ROAD3	120	1	123	1	114	1		
T495	E	1	0200	1015TRIM2	131	0	-132	0				
CO495	E	0	0045	1100ROAD2	131	1	130	1	132	1		
TK46	E	2	0100	1700XTRIM	44	0	138	0				
TK50	E	2	0100	2330INDUS	4	0	129	0	139	0		
TK52	E	2	0100	1800XTRIM	51	0	52	0	135	0		
TK53A	E	2	0005	0600TRIM1	50	0						
TK53B	E	2	0005	1600TRIM1	50	0						
TK53C	E	2	0005	2200TRIM2	50	0						
EP28	E	1	0100	2300TRIM2	114	0						
SHOPA	W	2	0030	0330XTRIM	2	0	-137	0	-3	0	-136	0
SHOPB	E	2	0100	1600XTRIM	2	0	-137	0	-3	0	-136	0
EP24P	E	1	0130	2000TRIM2	115	0	-117	0				
EP19	E	1	0005	1300XTRIM	126	0						
EP24A	E	1	0005	0900XTRIM	115	0	-117	0				
EP18	E	1	0035	0700XTRIM	121	0	-128	0				
29A40	E	1	0005	0130XTRIM	14	0	-17	0	-16	0	-18	0
29A40					-111	0						
REHMP	E	-3	0030	1700ROAD7	81	0	-82	0	-83	0	-84	0
99999												

Exhibit A-2

SAMPLE CAPACITY OUTPUT LISTING
CORRESPONDS TO SAMPLE INPUT IN EXHIBIT A-1

```
SRI RAIL YARD CAPACITY SIMULATION MODEL - CAPACITY DEMONSTRATION RUN

SIMULATION CONTROL PARAMETERS -
 CODE TO PRODUCE OUTPUT FOR *CAPCON*/*CONFLICT*                        =     0
 NUMBER OF SIMULATED DAYS                                              =     3
 DAY TO START PRINTED OUTPUT                                           =     3

FRONT END OF YARD TRAVEL TIME PARAMETERS -
 FROM RECEIVING YARD E TO HUMP, HOURS:MINUTES                          =     0:35
 FROM RECEIVING YARD W TO HUMP, HOURS:MINUTES                          =     0:05
 FROM HUMP TO RECEIVING YARD E, HOURS:MINUTES                          =     0:15
 FROM HUMP TO RECEIVING YARD W, HOURS:MINUTES                          =     0:30
 INSPECTION CREWS FROM REC. E TO REC. W, HOURS:MINUTES                 =     0:10
 INSPECTION CREWS FROM REC. W TO REC. E, HOURS:MINUTES                 =     0:10
 TRAVEL TIME REC. TO DEP. YARDS (BYPASS BLOCKS), HOURS:MINUTES         =     0:30

FRONT END OF YARD MISCELLANEOUS PARAMETERS -
 RECEIVING YARD TYPE CODE                                              =     1
 PRE-INSPECTION DELAY CONSTANT, HOURS:MINUTES                          =     0:15
 RATE OF INSPECTION, MINUTES/CAR                                       =     2.00
 HUMP BREAK CONSTANT, HOURS:MINUTES                                    =     0:05
 HUMPING RATE, MINUTES/CAR                                             =      .33
 NUMBER OF HUMP LEADS                                                  =     1

BACK END OF YARD TRAVEL TIME PARAMETERS -
 FROM CLASS YARD E TO DEPARTURE YARD E, HOURS:MINUTES                  =     1:15
 FROM CLASS YARD E TO DEPARTURE YARD W, HOURS:MINUTES                  =     0:10
 FROM CLASS YARD W TO DEPARTURE YARD E, HOURS:MINUTES                  =     1:15
 FROM CLASS YARD W TO DEPARTURE YARD W, HOURS:MINUTES                  =     0:10
 FROM DEPARTURE YARD E TO CLASS YARD E, HOURS:MINUTES                  =     0:15
 FROM DEPARTURE YARD E TO CLASS YARD W, HOURS:MINUTES                  =     0:15
 FROM DEPARTURE YARD W TO CLASS YARD E, HOURS:MINUTES                  =     0:05
 FROM DEPARTURE YARD W TO CLASS YARD W, HOURS:MINUTES                  =     0:05
 FROM CLASS YARD E TO CLASS CLEAR DEST. E, HOURS:MINUTES               =     0:10
 FROM CLASS YARD E TO CLASS CLEAR DEST. W, HOURS:MINUTES               =     0:40
 FROM CLASS YARD W TO CLASS CLEAR DEST. E, HOURS:MINUTES               =     0:10
 FROM CLASS YARD W TO CLASS CLEAR DEST. W, HOURS:MINUTES               =     0:40
 FROM CLASS CLEAR DEST. E TO CLASS YARD E, HOURS:MINUTES               =     0:05
 FROM CLASS CLEAR DEST. E TO CLASS YARD W, HOURS:MINUTES               =     0:05
 FROM CLASS CLEAR DEST. W TO CLASS YARD E, HOURS:MINUTES               =     0:05
 FROM CLASS CLEAR DEST. W TO CLASS YARD W, HOURS:MINUTES               =     0:05

BACK END OF YARD TRAVEL TIME PARAMETERS (CONTINUED) -
 INSPECTION CREWS FROM DEP. E TO DEP. W, HOURS:MINUTES                 =     0:10
 INSPECTION CREWS FROM DEP. W TO DEP. E, HOURS:MINUTES                 =     0:10
 EXTRA TRAVEL TIME PER ADDITIONAL MULT. PULL BLOCK (E), HOURS:MIN.     =     0:00
 EXTRA TRAVEL TIME PER ADDITIONAL MULT. PULL BLOCK (W), HOURS:MIN.     =     0:00

BACK END OF YARD MISCELLANEOUS PARAMETERS -
 CUT-OFF TIME PERIOD, HOURS:MINUTES                                    =     2:00
 CUT-OFF TIME PERIOD (BYPASS BLOCKS), HOURS:MINUTES                    =     0:30
 CUT-OFF TIME PERIOD (PREV. PULL BLOCKS), HOURS:MINUTES                =     0:05
 ENGINE BREAK CONSTANT, HOURS:MINUTES                                  =     0:01
 ENGINE UTILIZATION METHOD                                             =     1
 COUPLING START-UP DELAY CONSTANT, HOURS:MINUTES                       =     0:04
 COUPLING RATE, MINUTES/CAR                                            =      .20
 BETWEEN BLOCK MAKE-UP BREAK CONSTANT, HOURS:MINUTES                   =     0:01
 OUTBOUND PRE-INSPECTION DELAY CONSTANT, HOURS:MINUTES                 =     0:15
 OUTBOUND RATE OF INSPECTION, MINUTES/CAR                              =      .50
```

CAPACITY DEMONSTRATION RUN

CREW INPUT DATA --

CREW I.D.	CREW TYPE	YARD RESTRICT. E/W/B	PROCESS RATE MIN/CAR	CREW BREAK START TIME, HR:MIN (BREAK DURATION, HR:MIN)					
RINS1	1	E	2.00	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
RINS2	1	E	2.00	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
RINS3	1	E	2.00	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
RINS4	1	W	2.00	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
RINS5	1	W	2.00	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
RINS6	1	W	2.00	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
HUMP1	2	B	.33	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
HUMP2	2	B	.33	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
HUMP3	2	B	.33	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
TRIM1	3	B	.20	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
TRIM2	3	B	.20	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
XTRIM	3	B	.20	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
INDUS	3	B	.20	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
ROAD1	3	B	.20	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
ROAD2	3	B	.20	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
ROAD3	3	B	.20	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
ROAD4	3	B	.20	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
ROAD5	4	B	.20						
ROAD6	4	B	.20						
ROAD7	4	B	.20						
ROAD8	4	B	.20						
ROAD9	4	B	.20						
DINS1	5	B	.50	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
DINS2	5	B	.50	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
DINS3	5	B	.50	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)
DINS4	5	B	.50	4:30(0:30)	7:50(0:20)	12:30(0:30)	15:50(0:20)	20:30(0:30)	23:50(0:20)

CAPACITY DEMONSTRATION RUN

ARRIVAL TRAIN INPUT DATA -

ARRIVAL TRAIN NO.	E/W	TRAIN PROC. CODE	SPEC. INSP. CREW	EXTRA DELAY TO HUMP	SPEC. HUMP CREW	CONSIST MIX I.D.	ARRIVAL TIME	NO. CARS	------------------BYPASS BLOCK ID=S------------------
XT	E	0		0:00		RHCON	0:30	40	
RAMP	W	2		0:00		RAMP	2:00	44	
S118	W	0		0:00		S118	0:45	69	
CRBW1	E	0		0:00		CRBW1	1:20	67	
SHOPA	W	0		0:00		SHOPA	3:30	20	
R110A	W	0		0:00		R110A	1:00	108	
R290	W	0		0:00		R290	5:15	72	62
CTV23	E	0		0:00		CTV23	6:45	29	
S156A	W	0		0:00		S156A	4:00	115	
1RW6	E	0		0:00		1RW6	4:30	68	
SPTY4	E	0		0:00		SPTY4	5:35	124	
S154	W	0		0:00		S154	6:20	156	
RFP2	E	0		0:00		RFP2	7:20	19	
NPY4B	E	0		0:00		NPY4B	7:00	49	
R120	W	0		0:00		R120	7:10	130	
RUPY4	E	0		0:00		RUPY4	8:35	30	
RUPYA	E	0		0:00		RUPYA	8:35	72	
S156	W	0		0:00		S156	10:00	67	
R112	W	0		0:00		R112	10:00	12	
ERPY4	E	0		0:00		ERPY4	9:00	63	
R176	W	0		0:00		R176	10:55	41	62
SHOPP	W	1		0:00		SHOPP	16:00	18	
REHMP	E	-2		0:00		RHCON	16:58	40	
COX	W	0		0:00		COX	14:08	49	
S222	W	0		0:00		S222	16:25	5	
R190	W	0		0:00		R190	10:45	117	
R110B	W	0		0:00		R110B	11:40	110	
NPY5A	E	0		0:00		NPY5A	15:10	67	
SPY4X	E	0		0:00		SPY4X	15:10	102	
R276	W	0		0:00		R276	17:30	49	62
CPY4A	E	0		0:00		CPY4A	17:15	97	
CRYD	E	0		0:00		CRYD	19:45	17	
C490	W	0		0:00		C490	18:40	71	
2RW6	W	0		0:00		2RW6	21:00	81	
BO685	W	0		0:12		BO685	21:30	62	
S156B	W	0		0:00		S156B	21:45	76	
BOVGN	W	0		0:00		BOVGN	22:00	49	

CAPACITY DEMONSTRATION RUN

BLOCK CLASS YARD ASSIGNMENTS

CLASS YARD GROUP 1 DIRECTION = E
BLOCKS - SUM 101 102 105
TRACK LENGTH (CARS) - 0 0 0 0

CLASS YARD GROUP 2 DIRECTION = E
BLOCKS - SUM 2 137
TRACK LENGTH (CARS) - 0 0 0

CLASS YARD GROUP 3 DIRECTION = E
BLOCKS - SUM 3 136
TRACK LENGTH (CARS) - 0 0 0

CLASS YARD GROUP 4 DIRECTION = E
BLOCKS - SUM 112
TRACK LENGTH (CARS) - 0 0

CLASS YARD GROUP 5 DIRECTION = E
BLOCKS - SUM 131
TRACK LENGTH (CARS) - 0 0

CLASS YARD GROUP 6 DIRECTION = E
BLOCKS - SUM 132
TRACK LENGTH (CARS) - 0 0

CLASS YARD GROUP 7 DIRECTION = E
BLOCKS - SUM 122
TRACK LENGTH (CARS) - 0 0

CLASS YARD GROUP 8 DIRECTION = E
BLOCKS - SUM 118
TRACK LENGTH (CARS) - 0 0

CLASS YARD GROUP 9 DIRECTION = E
BLOCKS - SUM 106
TRACK LENGTH (CARS) - 0 0

CLASS YARD GROUP 10 DIRECTION = E
BLOCKS - SUM 103 110
TRACK LENGTH (CARS) - 0 0 0

```
CAPACITY DEMONSTRATION RUN

BLOCK CLASS YARD ASSIGNMENTS

 CLASS YARD GROUP 11      DIRECTION =     E
     BLOCKS                 -   SUM    8    9   10   11
     TRACK LENGTH (CARS) -      0    0    0    0    0

 CLASS YARD GROUP 12      DIRECTION =     E
     BLOCKS                 -   SUM   12
     TRACK LENGTH (CARS) -      0    0

 CLASS YARD GROUP 13      DIRECTION =     E
     BLOCKS                 -   SUM   13
     TRACK LENGTH (CARS) -      0    0

 CLASS YARD GROUP 14      DIRECTION =     E
     BLOCKS                 -   SUM  124  118
     TRACK LENGTH (CARS) -      0    0    0

 CLASS YARD GROUP 15      DIRECTION =     E
     BLOCKS                 -   SUM  109
     TRACK LENGTH (CARS) -      0    0

 CLASS YARD GROUP 16      DIRECTION =     E
     BLOCKS                 -   SUM  104
     TRACK LENGTH (CARS) -      0    0

 CLASS YARD GROUP 17      DIRECTION =     E
     BLOCKS                 -   SUM  108
     TRACK LENGTH (CARS) -      0    0

 CLASS YARD GROUP 18      DIRECTION =     E
     BLOCKS                 -   SUM  121  128
     TRACK LENGTH (CARS) -      0    0    0

 CLASS YARD GROUP 19      DIRECTION =     E
     BLOCKS                 -   SUM  126
     TRACK LENGTH (CARS) -      0    0

 CLASS YARD GROUP 20      DIRECTION =     E
     BLOCKS                 -   SUM   19   21
     TRACK LENGTH (CARS) -      0    0    0
```

```
CAPACITY DEMONSTRATION RUN

BLOCK CLASS YARD ASSIGNMENTS

 CLASS YARD GROUP 21      DIRECTION =     E
     BLOCKS                 -   SUM   22
     TRACK LENGTH (CARS) -      0    0

 CLASS YARD GROUP 22      DIRECTION =     E
     BLOCKS                 -   SUM   20
     TRACK LENGTH (CARS) -      0    0

 CLASS YARD GROUP 23      DIRECTION =     E
     BLOCKS                 -   SUM  119  120  125  130
     TRACK LENGTH (CARS) -      0    0    0    0    0

 CLASS YARD GROUP 24      DIRECTION =     E
     BLOCKS                 -   SUM  115  117
     TRACK LENGTH (CARS) -      0    0    0

 CLASS YARD GROUP 25      DIRECTION =     E
     BLOCKS                 -   SUM   61   62   63   64
     TRACK LENGTH (CARS) -      0    0    0    0    0

 CLASS YARD GROUP 26      DIRECTION =     W
     BLOCKS                 -   SUM  123
     TRACK LENGTH (CARS) -      0    0

 CLASS YARD GROUP 27      DIRECTION =     W
     BLOCKS                 -   SUM   28
     TRACK LENGTH (CARS) -      0    0

 CLASS YARD GROUP 28      DIRECTION =     W
     BLOCKS                 -   SUM  113
     TRACK LENGTH (CARS) -      0    0

 CLASS YARD GROUP 29      DIRECTION =     W
     BLOCKS                 -   SUM  114
     TRACK LENGTH (CARS) -      0    0

 CLASS YARD GROUP 30      DIRECTION =     W
     BLOCKS                 -   SUM  111
     TRACK LENGTH (CARS) -      0    0
```

```
CAPACITY DEMONSTRATION RUN

BLOCK CLASS YARD ASSIGNMENTS

 CLASS YARD GROUP 31      DIRECTION =     W
    BLOCKS                -    SUM   30
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 32      DIRECTION =     W
    BLOCKS                -    SUM   27
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 33      DIRECTION =     W
    BLOCKS                -    SUM   29
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 34      DIRECTION =     W
    BLOCKS                -    SUM   31    32
    TRACK LENGTH (CARS) -       0     0     0

 CLASS YARD GROUP 35      DIRECTION =     W
    BLOCKS                -    SUM   34
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 36      DIRECTION =     W
    BLOCKS                -    SUM   33
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 37      DIRECTION =     W
    BLOCKS                -    SUM   35    36
    TRACK LENGTH (CARS) -       0     0     0

 CLASS YARD GROUP 38      DIRECTION =     W
    BLOCKS                -    SUM   37
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 39      DIRECTION =     W
    BLOCKS                -    SUM   38
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 40      DIRECTION =     W
    BLOCKS                -    SUM   26
    TRACK LENGTH (CARS) -       0     0
```

```
CAPACITY DEMONSTRATION RUN

BLOCK CLASS YARD ASSIGNMENTS

 CLASS YARD GROUP 41      DIRECTION =     W
    BLOCKS                -    SUM   14    17    16    18
    TRACK LENGTH (CARS) -       0     0     0     0     0

 CLASS YARD GROUP 42      DIRECTION =     W
    BLOCKS                -    SUM   42
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 43      DIRECTION =     W
    BLOCKS                -    SUM   43
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 44      DIRECTION =     W
    BLOCKS                -    SUM   45
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 45      DIRECTION =     W
    BLOCKS                -    SUM   39
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 46      DIRECTION =     W
    BLOCKS                -    SUM    6
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 47      DIRECTION =     W
    BLOCKS                -    SUM   44   138
    TRACK LENGTH (CARS) -       0     0     0

 CLASS YARD GROUP 48      DIRECTION =     W
    BLOCKS                -    SUM   20
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 49      DIRECTION =     W
    BLOCKS                -    SUM   48
    TRACK LENGTH (CARS) -       0     0

 CLASS YARD GROUP 50      DIRECTION =     W
    BLOCKS                -    SUM   49
    TRACK LENGTH (CARS) -       0     0
```

CAPACITY DEMONSTRATION RUN

BLOCK CLASS YARD ASSIGNMENTS

```
CLASS YARD GROUP 51     DIRECTION =    W
   BLOCKS               -   SUM   4   129   139
     TRACK LENGTH (CARS) -     0   0     0     0

CLASS YARD GROUP 52     DIRECTION =    W
   BLOCKS               -   SUM  24
     TRACK LENGTH (CARS) -     0   0

CLASS YARD GROUP 53     DIRECTION =    W
   BLOCKS               -   SUM  51   135    52
     TRACK LENGTH (CARS) -     0   0     0     0

CLASS YARD GROUP 54     DIRECTION =    W
   BLOCKS               -   SUM  50
     TRACK LENGTH (CARS) -     0   0
```

CAPACITY DEMONSTRATION RUN

DEPARTURE TRAIN INPUT DATA -

DEPART. TRAIN NO.	E/W	TRAIN TYPE CODE	CUT-OFF TIME PERIOD	SCHED. DEPART. TIME	SPEC. TRIM CREW	SPEC. INSP. CREW	-----BLOCKS PULLED FOR THIS TRAIN (CAR LIMIT ON TRAIN OF EACH BLOCK)-----
TPY97	E	2	2:00	2:15	XTRIM		48(0)
PY97	W	3	0:45	3:00			49(0) 37(0)
TPYSE	W	1	2:00	2:30	XTRIM		35(0) -35(0) 24(0)
PYSEA	W	0	1:15	3:45	ROAD3		35(1) -24(1)
TS64	E	1	1:30	11:00	TRIM1		14(0) -17(0) -16(0) -18(0)
NE64	E	0	1:30	12:30	ROAD1		14(1) 17(1) 16(1) 18(1)
PYAB	W	3	1:15	15:30			33(0) 34(0)
TPYEN	W	1	1:00	15:30	XTRIM		32(0)
PYENA	W	0	1:15	16:45			32(1)
PYSEB	W	3	1:15	17:45			35(0) -36(0)
TWR7	W	1	1:15	17:00	XTRIM		42(0) 43(0) 45(0) 39(0)
WR7	W	0	1:15	18:15	ROAD1		42(1) 43(1) 45(1) 39(1)
TPYAL	E	2	2:00	18:00	TRIM2		27(0)
PYAL	W	3	1:15	19:15			30(0) 29(0)
TPYMO	E	1	1:30	17:45	TRIM1		19(0) -21(0) -22(0) -23(0)
PYMO	E	0	1:15	19:45	ROAD2		21(1) -22(1) -23(1)
TTV24	E	2	2:00	19:45	TRIM2		20(0) 38(0)
TV24	W	3	1:15	21:00			26(0)
TS662	E	1	1:30	21:30	TRIM2		11(0) -9(0) -10(0) -8(0) -13(0) -12(0)
BO662	E	0	1:15	23:30	ROAD1		11(1) 9(1) 10(1) 8(1) 13(1) 12(1)
PYENB	W	3	1:15	23:45			28(0) 31(0) -32(0)
CRYD	E	2	2:00	6:00			6(0)
T159	E	1	2:00	23:30	TRIM1		110(0)-103(0)-111(0)
SO159	E	0	0:15	1:00	ROAD2		119(1) 103(1) 111(1)
TS105	E	1	0:55	23:55	TRIM1		123(0)-113(0)-126(0)-115(0)-117(0)
RF105	E	0	0:45	2:45	ROAD3		125(1) 123(1) 113(1) 115(1) 117(1) 126(1)
EP173	W	1	1:00	19:00	TRIM1		109(0) 104(0)
T173	W	1	2:00	3:45	TRIM2		109(0) 104(0) 108(0)
SO173	W	0	0:05	4:15	ROAD2		109(1) 104(1) 108(1)
TS219	W	2	1:15	5:30	TRIM1		101(0)-105(0)-102(0)
TS275	E	1	1:15	6:45	TRIM2		124(0)-114(0)
RF275	E	0	0:45	7:30	ROAD3		124(1) 114(1)
T175	E	2	2:00	7:45	TRIM1		122(0)
RF175	W	3	0:45	8:30			118(0)
SO221	W	3	0:45	9:30			111(0) 104(0)
TS227	W	2	0:45	10:45	TRIM1		116(0)
TS109	E	1	1:30	11:00	TRIM2		125(0)-121(0)-126(0)
RF109	E	0	0:45	12:30	ROAD2		125(1) 121(1) 126(1)
T155	E	1	2:00	16:30	TRIM2		112(0)-111(0)
SO155	E	0	0:30	17:00	ROAD2		110(1) 112(1) 111(1)
SOUYD	W	3	0:45	17:45			106(0)
TS111	E	1	2:00	15:00	TRIM1		115(0)-117(0)
T111	W	1	2:00	21:45	XTRIM		113(0) 126(0)
RF111	W	0	0:45	22:30	ROAD2		113(1) 126(1)
X111	E	0	0:45	22:30	ROAD3		115(1) 117(1) 81(0) -82(0) -83(0) -84(0)
TS289	E	1	2:00	15:30	TRIM1		119(0)-120(0)-125(0)-130(0)-123(0)-114(0)

CAPACITY DEMONSTRATION RUN

DEPARTURE TRAIN INPUT DATA -

DEPART. TRAIN NO.	E/W	TRAIN TYPE CODE	CUT-OFF TIME PERIOD	SCHED. DEPART. TIME	SPEC. TRIM CREW	SPEC. INSP. CREW	-----BLOCKS PULLED FOR THIS TRAIN (CAR LIMIT ON TRAIN OF EACH BLOCK)-----
RF289	E	0	0:45	18:30	ROAD3		120(1) 123(1) 114(1)
T495	E	1	2:00	10:15	TRIM2		131(0)-132(0)
CO495	E	0	0:45	11:00	ROAD2		131(1) 130(1) 132(1)
TK48	E	2	1:00	17:00	XTRIM		44(0) 138(0)
TK50	E	2	1:00	23:30	INDUS		4(0) 129(0) 139(0)
TK52	E	2	1:00	18:00	XTRIM		51(0) 52(0) 135(0)
TK53A	E	2	0:05	6:00	TRIM1		50(0)
TK53B	E	2	0:05	16:00	TRIM1		50(0)
TK53C	E	2	0:05	22:00	TRIM2		50(0)
EP28	E	1	1:00	23:00	TRIM2		114(0)
SHOPA	W	2	0:30	3:30	XTRIM		2(0)-137(0) -3(0)-136(0)
SHOPB	E	2	1:00	16:00	XTRIM		2(0)-137(0) -3(0)-136(0)
EP24P	E	1	1:30	20:00	TRIM2		115(0)-117(0)
EP19	E	1	0:05	13:00	XTRIM		126(0)
EP24A	E	1	0:05	9:00	XTRIM		115(0)-117(0)
EP16	E	1	0:35	7:00	XTRIM		121(0)-128(0)
29A40	E	1	0:05	1:30	XTRIM		14(0) -17(0) -16(0) -18(0)-111(0)
REHMP	E	-3	0:30	17:00	ROAD7		81(0) -82(0) -83(0) -84(0)

CAPACITY DEMONSTRATION RUN

CONSIST MIX ID SUMMARY TABLE -

CONSIST MIX ID NAME - RHCON

TRAINS HAVING THIS CONSIST MIX ID -- XT REHMP

BLOCK NO. (E/W) - PERCENTAGE -- 81(E)- 11.1 82(E)- 11.1 83(E)- 33.3 84(E)- 44.4

CONSIST MIX ID NAME - RAMP

TRAINS HAVING THIS CONSIST MIX ID -- RAMP

BLOCK NO. (E/W) - PERCENTAGE -- 105(E)- 2.3 118(E)- 16.2 122(E)- 4.5 125(E)- 4.5 14(W)- 29.5 19(E)- 2.3
38(W)- 38.6

CONSIST MIX ID NAME - CTV23

TRAINS HAVING THIS CONSIST MIX ID -- CTV23

BLOCK NO. (E/W) - PERCENTAGE -- 112(E)- 10.7 116(E)- 7.1 121(E)- 67.9 122(E)- 10.7 124(E)- 3.6

CONSIST MIX ID NAME - RFP2

TRAINS HAVING THIS CONSIST MIX ID -- RFP2

BLOCK NO. (E/W) - PERCENTAGE -- 111(W)- 30.8 115(E)- 46.2 123(W)- 7.7 138(W)- 7.7 139(W)- 7.7

CONSIST MIX ID NAME - SHOPA

TRAINS HAVING THIS CONSIST MIX ID -- SHOPA

BLOCK NO. (E/W) - PERCENTAGE -- 110(E)- 5.3 111(W)- 5.3 112(E)- 5.3 113(W)- 5.3 115(E)- 5.3 120(E)- 5.3
123(W)- 5.3 9(E)- 5.3 10(E)- 5.3 21(E)- 5.3 22(E)- 5.3 28(W)- 5.3
29(W)- 5.3 32(W)- 5.3 108(W)- 5.3 139(W)- 5.3 35(W)- 10.5 50(W)- 5.3

CONSIST MIX ID NAME - CRBW1

TRAINS HAVING THIS CONSIST MIX ID -- CRBW1

BLOCK NO. (E/W) - PERCENTAGE -- 104(E)- 4.7 105(E)- 3.1 108(E)- 1.6 109(E)- 1.6 111(W)- 12.5 113(W)- 14.1
114(W)- 9.4 115(E)- 1.6 117(E)- 4.7 118(E)- 3.1 119(E)- 3.1 121(E)- 10.9
123(W)- 6.2 126(E)- 9.4 132(E)- 3.1 135(W)- 3.1 138(W)- 7.8

CONSIST MIX ID NAME - 1RW6

TRAINS HAVING THIS CONSIST MIX ID -- 1RW6

BLOCK NO. (E/W) - PERCENTAGE -- 101(E)- 1.1 104(E)- 6.8 108(E)- 1.1 109(E)- 2.3 110(E)- 3.4 111(W)- 22.7
112(E)- 4.5 113(W)- 9.1 114(W)- 12.5 115(E)- 3.4 117(E)- 1.1 119(E)- 3.4
120(E)- 1.1 121(E)- 1.1 123(W)- 5.7 125(E)- 1.1 126(E)- 15.9 131(E)- 3.4

CAPACITY DEMONSTRATION RUN

CONSIST MIX ID SUMMARY TABLE -

CONSIST MIX ID NAME - SPTY4

TRAINS HAVING THIS CONSIST MIX ID -- SPTY4

BLOCK NO. (E/W) - PERCENTAGE -- 103(E)- 1.6 104(E)- 5.7 106(E)- 4.9 108(E)- .8 109(E)- 4.9 110(E)- 2.4
111(W)- 12.2 112(E)- 3.3 113(W)- 3.3 114(W)- 23.6 115(E)- 6.5 117(E)- 2.4
121(E)- 1.6 123(W)- 5.7 126(E)- 4.9 131(E)- 2.4 132(E)- 5.7 135(W)- .8
136(E)- 2.4 137(E)- 4.9

CONSIST MIX ID NAME - NPY4B

TRAINS HAVING THIS CONSIST MIX ID -- NPY4B

BLOCK NO. (E/W) - PERCENTAGE -- 104(E)- 8.2 106(E)- 4.1 109(E)- 6.1 111(W)- 12.2 112(E)- 2.0 113(W)- 4.1
114(W)- 20.4 115(E)- 6.1 117(E)- 10.2 118(E)- 2.0 121(E)- 2.0 126(E)- 10.2
128(E)- 6.1 132(E)- 2.0 136(E)- 2.0 137(E)- 2.0

CONSIST MIX ID NAME - SHOPP

TRAINS HAVING THIS CONSIST MIX ID -- SHOPP

BLOCK NO. (E/W) - PERCENTAGE -- 104(E)- 11.1 109(E)- 5.6 111(W)- 27.8 115(E)- 5.6 118(E)- 5.6 123(W)- 5.6
126(E)- 11.1 131(E)- 5.6 138(W)- 5.6 35(W)- 16.7

CONSIST MIX ID NAME - NPY6A

TRAINS HAVING THIS CONSIST MIX ID -- NPY6A

BLOCK NO. (E/W) - PERCENTAGE -- 104(E)- 8.8 106(E)- 4.4 109(E)- 5.9 110(E)- 2.9 111(W)- 19.1 112(E)- 4.4
113(W)- 8.8 114(W)- 11.8 115(E)- 7.4 117(E)- 4.4 119(E)- 1.5 120(E)- 4.4
121(E)- 2.9 125(E)- 1.5 126(E)- 7.4 132(E)- 1.5 136(E)- 1.5 137(E)- 1.5

CONSIST MIX ID NAME - RUPYA

TRAINS HAVING THIS CONSIST MIX ID -- RUPYA

BLOCK NO. (E/W) - PERCENTAGE -- 104(E)- 1.4 106(E)- 1.4 108(E)- 1.4 109(E)- 14.1 111(W)- 21.1 113(W)- 7.0
114(W)- 9.9 115(E)- 1.4 117(E)- 5.6 120(E)- 4.2 121(E)- 4.2 123(W)- 4.2
126(E)- 11.3 131(E)- 1.4 132(E)- 1.4 137(E)- 4.2 138(W)- 5.6

CONSIST MIX ID NAME - RUPY4

TRAINS HAVING THIS CONSIST MIX ID -- RUPY4

BLOCK NO. (E/W) - PERCENTAGE -- 106(E)- 6.5 109(E)- 9.7 111(W)- 16.1 113(W)- 9.7 114(W)- 16.1 117(E)- 9.7
123(W)- 9.7 126(E)- 6.5 129(W)- 3.2 132(E)- 9.7 138(W)- 3.2

CAPACITY DEMONSTRATION RUN

CONSIST MIX ID SUMMARY TABLE -

CONSIST MIX ID NAME - ERPY4

TRAINS HAVING THIS CONSIST MIX ID -- ERPY4

BLOCK NO. (E/W) - PERCENTAGE --
108(E)- 3.2 109(E)- 7.9 111(W)- 14.3 112(E)- 7.9 113(W)- 9.5 114(W)- 14.3
116(E)- 4.8 117(E)- 9.5 119(E)- 6.3 121(E)- 7.9 123(W)- 4.8 126(E)- 3.2
128(E)- 1.6 131(E)- 1.6 132(E)- 3.2

CONSIST MIX ID NAME - SPY4X

TRAINS HAVING THIS CONSIST MIX ID -- SPY4X

BLOCK NO. (E/W) - PERCENTAGE --
104(E)- 10.8 106(E)- 1.0 108(E)- 2.0 109(E)- 5.9 110(E)- 6.9 111(W)- 19.6
113(W)- 2.9 114(W)- 14.7 115(E)- 7.8 117(E)- 11.8 121(E)- 1.0 123(W)- 2.9
126(E)- 8.8 137(E)- 2.0 138(W)- 2.0

CONSIST MIX ID NAME - CPY4A

TRAINS HAVING THIS CONSIST MIX ID -- CPY4A

BLOCK NO. (E/W) - PERCENTAGE --
103(E)- 1.2 104(E)- 1.2 108(E)- 10.5 109(E)- 4.7 110(E)- 9.5 111(W)- 33.7
113(W)- 4.7 114(W)- 10.5 115(E)- 7.0 119(E)- 1.2 123(W)- 8.1 128(E)- 9.5
135(W)- 1.2 136(E)- 1.2 137(E)- 7.0 138(W)- 1.2

CONSIST MIX ID NAME - 2RW6

TRAINS HAVING THIS CONSIST MIX ID -- 2RW6

BLOCK NO. (E/W) - PERCENTAGE --
104(E)- 6.2 106(E)- 2.5 109(E)- 7.5 110(E)- 6.2 111(W)- 28.2 112(E)- 1.2
113(W)- 7.5 114(W)- 16.2 115(E)- 3.7 117(E)- 11.2 119(E)- 1.2 123(W)- 2.5
128(E)- 1.2 131(E)- 3.7 132(E)- 1.2 138(E)- 1.2

CONSIST MIX ID NAME - CRYD

TRAINS HAVING THIS CONSIST MIX ID -- CRYD

BLOCK NO. (E/W) - PERCENTAGE --
104(E)- 17.6 106(E)- 5.9 108(E)- 5.9 110(E)- 11.8 111(W)- 5.9 113(W)- 11.8
114(W)- 23.5 117(E)- 5.9 123(W)- 11.8

CONSIST MIX ID NAME - BC685

TRAINS HAVING THIS CONSIST MIX ID -- BC685

BLOCK NO. (E/W) - PERCENTAGE --
104(E)- 6.7 106(E)- 15.0 109(E)- 3.3 110(E)- 1.7 111(W)- 10.0 112(E)- 1.7
113(W)- 23.3 114(W)- 15.0 117(E)- 1.7 123(W)- 1.7 128(E)- 8.3 130(E)- 1.7
131(E)- 5.0 132(E)- 1.7 136(E)- 3.3

CAPACITY DEMONSTRATION RUN

CONSIST MIX ID SUMMARY TABLE -

CONSIST MIX ID NAME - SCVGN

TRAINS HAVING THIS CONSIST MIX ID -- SCVGN

BLOCK NO. (E/W) - PERCENTAGE --
104(E)- 2.0 106(E)- 2.0 108(E)- 6.1 109(E)- 6.1 110(E)- 6.1 111(W)- 22.4
112(E)- 2.0 113(W)- 6.1 114(W)- 6.1 115(E)- 2.0 117(E)- 4.1 120(E)- 2.0
121(E)- 4.1 123(W)- 2.0 125(E)- 6.1 128(E)- 8.2 130(E)- 4.1 131(E)- 6.1
139(W)- 2.0

CONSIST MIX ID NAME - S118

TRAINS HAVING THIS CONSIST MIX ID -- S118

BLOCK NO. (E/W) - PERCENTAGE --
3(E)- 4.3 8(E)- 1.4 12(E)- 5.8 13(E)- 4.3 18(W)- 10.1 22(E)- 1.4
23(E)- 1.4 24(W)- 1.4 26(W)- 4.3 29(W)- 5.8 30(W)- 1.4 32(W)- 11.6
33(W)- 11.6 35(W)- 18.8 37(W)- 1.4 39(W)- 5.8 43(W)- 2.9 44(W)- 1.4
45(W)- 2.9 48(W)- 1.4

CONSIST MIX ID NAME - R110A

TRAINS HAVING THIS CONSIST MIX ID -- R110A

BLOCK NO. (E/W) - PERCENTAGE --
2(E)- 3.5 3(E)- 8.2 10(E)- 2.4 12(E)- 1.2 14(W)- 2.4 21(E)- 1.2
22(E)- 1.2 23(E)- 3.5 24(W)- 3.5 26(W)- 1.2 27(W)- 3.5 29(W)- 9.4
30(W)- 2.4 32(W)- 18.8 33(W)- 2.4 34(W)- 4.7 37(W)- 8.2 42(W)- 1.2
43(W)- 1.2 45(W)- 7.1 50(W)- 2.4 51(W)- 1.2 4(W)- 3.5 32(W)- 2.4
34(W)- 3.5

CONSIST MIX ID NAME - S156A

TRAINS HAVING THIS CONSIST MIX ID -- S156A

BLOCK NO. (E/W) - PERCENTAGE --
2(E)- 3.7 3(E)- 1.9 4(W)- .9 8(E)- .9 9(E)- .9 12(E)- .9
13(E)- 2.8 14(W)- 1.9 16(W)- .9 21(E)- .9 22(E)- 1.9 23(E)- 4.7
24(W)- 6.5 28(W)- 1.9 29(W)- 7.5 30(W)- 3.7 32(W)- 7.5 33(W)- 5.6
34(W)- 6.5 35(W)- 7.5 37(W)- 7.5 39(W)- 7.5 42(W)- .9 44(W)- 3.7
45(W)- 2.8 37(W)- 3.7 4(W)- .9 17(W)- .9 32(W)- 1.9 35(W)- .9

CONSIST MIX ID NAME - R290

TRAINS HAVING THIS CONSIST MIX ID -- R290

BLOCK NO. (E/W) - PERCENTAGE --
2(E)- 1.6 3(E)- 4.8 8(E)- 6.5 11(E)- 8.1 16(W)- 4.8 18(W)- 1.6
21(E)- 1.6 24(W)- 11.3 26(W)- 3.2 32(W)- 1.6 33(W)- 1.6 35(W)- 9.7
37(W)- 3.2 38(W)- 3.2 39(W)- 1.6 44(W)- 1.6 45(W)- 3.2 51(W)- 1.6
52(W)- 29.0

CAPACITY DEMONSTRATION RUN

CONSIST MIX ID SUMMARY TABLE -

CONSIST MIX ID NAME - S154

TRAINS HAVING THIS CONSIST MIX ID -- S154

BLOCK NO. (E/W) - PERCENTAGE --

4(W)- 1.3	16(W)- .6	24(W)- 2.5	26(W)- 4.5	28(W)- 2.6	29(W)- 1.3
32(W)- 4.5	33(W)- 5.7	34(W)- 1.3	35(W)- 7.0	37(W)- 5.1	39(W)- 2.5
44(W)- .6	45(W)- 1.3	49(W)- 3.2	6(W)- 1.3	9(E)- .6	10(E)- 1.3
11(E)- .6	14(W)- .6	16(W)- 1.9	21(E)- .6	22(E)- 1.9	23(E)- 3.2
26(W)- 1.3	29(W)- 3.6	30(W)- 3.2	32(W)- 5.3	33(W)- 3.8	34(W)- 3.2
35(W)- 6.4	37(W)- 6.4	39(W)- 2.5	42(W)- 1.3	43(W)- 1.3	45(W)- 1.3
51(W)- 1.3					

CONSIST MIX ID NAME - R120

TRAINS HAVING THIS CONSIST MIX ID -- R120

BLOCK NO. (E/W) - PERCENTAGE --

3(E)- 4.4	4(W)- .7	6(W)- .7	14(W)- .7	21(E)- 1.5	24(W)- .7
26(W)- 3.6	27(W)- 1.5	29(W)- 3.6	32(W)- 2.9	33(W)- .7	34(W)- 1.5
35(W)- 5.8	37(W)- 1.5	38(W)- 2.2	39(W)- 1.5	42(W)- 2.2	44(W)- .7
50(W)- .7	51(W)- .7	3(E)- .7	4(W)- .7	6(W)- .7	9(E)- 1.5
12(E)- 1.5	16(W)- .7	18(W)- 2.9	21(E)- 1.5	22(E)- 2.2	24(W)- 1.5
26(W)- 2.2	28(W)- .7	29(W)- 10.9	30(W)- 1.5	32(W)- 14.6	33(W)- 1.5
34(W)- 2.9	35(W)- 5.1	37(W)- 2.2	39(W)- 1.5	44(W)- .7	50(W)- 2.9
51(W)- 1.5					

CONSIST MIX ID NAME - R176

TRAINS HAVING THIS CONSIST MIX ID -- R176

BLOCK NO. (E/W) - PERCENTAGE --

23(E)- 2.4	24(W)- 2.4	38(W)- 22.0	43(W)- 2.4	50(W)- 4.9	52(W)- 65.9

CONSIST MIX ID NAME - S222

TRAINS HAVING THIS CONSIST MIX ID -- S222

BLOCK NO. (E/W) - PERCENTAGE --

4(W)- 20.0	35(W)- 20.0	38(W)- 20.0	43(W)- 20.0	50(W)- 20.0

CONSIST MIX ID NAME - R276

TRAINS HAVING THIS CONSIST MIX ID -- R276

BLOCK NO. (E/W) - PERCENTAGE --

2(E)- 2.0	6(W)- 2.0	22(E)- 2.0	23(E)- 4.1	24(W)- 8.1	29(W)- 2.0
32(W)- 12.2	33(W)- 12.2	34(W)- 2.0	35(W)- 4.1	37(W)- 4.1	38(W)- 6.1
39(W)- 2.0	43(W)- 4.1	44(W)- 2.0	45(W)- 4.1	50(W)- 4.1	52(W)- 24.5

CAPACITY DEMONSTRATION RUN

CONSIST MIX ID SUMMARY TABLE -

CONSIST MIX ID NAME - S156

TRAINS HAVING THIS CONSIST MIX ID -- S156

BLOCK NO. (E/W) - PERCENTAGE --

4(W)- 7.5	6(W)- 3.0	13(E)- 13.4	17(W)- 1.5	22(E)- 1.5	23(E)- 3.0
24(W)- 3.0	28(W)- 10.4	29(W)- 4.5	30(W)- 6.0	32(W)- 20.9	33(W)- 1.5
34(W)- 4.5	35(W)- 10.4	37(W)- 1.5	39(W)- 1.5	48(W)- 1.5	49(W)- 1.5
51(W)- 3.0					

CONSIST MIX ID NAME - R190

TRAINS HAVING THIS CONSIST MIX ID -- R190

BLOCK NO. (E/W) - PERCENTAGE --

4(W)- .9	16(W)- .9	26(W)- 2.6	29(W)- 3.4	30(W)- 2.6	32(W)- 3.4
33(W)- .9	34(W)- 3.4	35(W)- 1.7	50(W)- 1.7	3(E)- 1.7	9(E)- .9
10(E)- .9	11(E)- .9	13(E)- 3.4	14(W)- .9	20(W)- .9	22(E)- 2.6
24(W)- .9	26(W)- 1.7	29(W)- 2.6	30(W)- 2.6	32(W)- 11.1	33(W)- 2.6
34(W)- 3.4	35(W)- 14.5	37(W)- .9	39(W)- 6.0	42(W)- .9	43(W)- 7.7
44(W)- .9	49(W)- .9	50(W)- 9.4	51(W)- .9		

CONSIST MIX ID NAME - COX

TRAINS HAVING THIS CONSIST MIX ID -- COX

BLOCK NO. (E/W) - PERCENTAGE --

2(E)- 2.1	10(E)- 2.1	13(E)- 2.1	14(W)- 4.2	16(W)- 2.1	18(W)- 4.2
23(E)- 4.2	29(W)- 4.2	32(W)- 20.8	33(W)- 10.4	35(W)- 2.1	37(W)- 2.1
48(W)- 4.2	49(W)- 33.3	51(W)- 2.1			

CONSIST MIX ID NAME - S156B

TRAINS HAVING THIS CONSIST MIX ID -- S156B

BLOCK NO. (E/W) - PERCENTAGE --

2(E)- 1.3	4(W)- 3.9	10(E)- 1.3	12(E)- 3.9	14(W)- 2.6	16(W)- 5.3
18(W)- 1.3	23(E)- 1.3	24(W)- 7.9	28(W)- 1.3	30(W)- 1.3	32(W)- 11.8
33(W)- 2.6	34(W)- 3.9	35(W)- 17.1	37(W)- 13.2	39(W)- 15.8	43(W)- 1.3
44(W)- 1.3	45(W)- 1.3				

CONSIST MIX ID NAME - R110B

TRAINS HAVING THIS CONSIST MIX ID -- R110B

BLOCK NO. (E/W) - PERCENTAGE --

3(E)- 3.5	4(W)- .9	9(E)- 2.6	14(W)- 1.7	16(W)- .9	17(W)- .9
18(W)- .9	21(E)- 1.7	23(E)- .9	24(W)- 2.6	26(W)- 2.6	28(W)- 1.7
29(W)- 7.0	30(W)- 4.3	32(W)- 17.4	35(W)- 13.0	37(W)- 2.6	39(W)- 1.7
45(W)- .9	49(W)- 1.7	50(W)- 3.5	51(W)- .9	3(E)- 2.6	10(E)- 4.3
21(E)- 1.7	23(E)- 2.6	27(W)- 1.7	29(W)- 5.2	32(W)- .9	35(W)- 1.7
39(W)- .9	43(W)- 3.5	50(W)- .9			

CAPACITY DEMONSTRATION RUN

CONSIST MIX ID SUMMARY TABLE -

CONSIST MIX ID NAME - C490

TRAINS HAVING THIS CONSIST MIX ID -- C490

BLOCK NO. (E/W) - PERCENTAGE --

3(E)- 1.4	4(W)- 2.9	9(E)- 2.9	11(E)- 34.8	12(E)- 4.3	14(W)- 7.2
16(W)- 1.4	21(E)- 4.3	22(E)- 2.9	24(W)- 2.9	26(W)- 1.4	30(W)- 2.9
32(W)- 10.1	33(W)- 2.9	34(W)- 5.7	35(W)- 4.3	37(W)- 2.9	61(W)- 1.4

CONSIST MIX ID NAME - R112

TRAINS HAVING THIS CONSIST MIX ID -- R112

BLOCK NO. (E/W) - PERCENTAGE --

3(E)- 8.3	23(E)- 8.3	28(W)- 8.3	30(W)- 8.3	32(W)- 16.7	35(W)- 25.0
57(W)- 16.7	49(W)- 8.3				

CAPACITY DEMONSTRATION RUN

ARRIVING TRAIN HISTORIES -

NO.	TRAIN	E/W	NO. BYP. CARS	NO. HUMP CARS	NO. TOT. CARS	ARR. TIME	QUEUE TIME INSP.	INSP. CREW	START INSP.	INSP. PER.	END INSP.	QUEUE TIME HUMP	HUMP CREW	EXTRA DELAY HUMP	START HUMP	HUMP PER.	END HUMP	END REC.YD. OCC.
71	2RV6	W	0	61	61	2:21:00	0:15	RINS4	2:21:15	2:42	2:23:57	0:00	HUMP1	0:00	3:00:02	0:27	3:00:29	3:00:24
72	BO685	W	0	62	62	2:21:30	0:15	RINS6	2:21:45	2:04	2:23:49	0:51	HUMP2	0:12	3:00:57	0:20	3:01:17	3:01:12
73	S156B	W	0	76	76	2:21:45	0:17	RINS5	2:22:02	2:32	3:00:34	0:43	HUMP3	0:00	3:01:22	0:25	3:01:47	3:01:42
74	BOVGN	W	0	49	49	2:22:00	2:04	RINS6	3:00:04	1:38	3:01:42	0:05	HUMP1	0:00	3:01:52	0:16	3:02:08	3:02:03
75	. XT	E	0	40	40	3:00:30	0:15	RINS1	3:00:45	1:20	3:02:05	0:00	HUMP2	0:00	3:02:40	0:13	3:02:53	3:02:18
76	RAMP	W	0	44	44	3:02:00		BYPASS REC. YD.				0:58	HUMP1	0:00	3:02:58	0:15	3:03:13	
77	S118	W	0	69	69	3:00:45	0:15	RINS4	3:01:00	2:18	3:03:18	0:00	HUMP3	0:00	3:03:23	0:23	3:03:46	3:03:41
78	CRSW1	E	0	67	67	3:01:20	0:15	RINS2	3:01:35	2:14	3:03:49	0:00	HUMP1	0:00	3:04:24	0:22	3:04:46	3:04:11
79	SHOPA	W	0	20	20	3:03:30	0:15	RINS4	3:03:45	0:40	3:04:25	0:21	HUMP2	0:00	3:04:51	0:07	3:04:58	3:04:53
80	R110A	W	0	108	108	3:01:00	0:15	RINS5	3:01:15	3:36	3:04:51	0:07	HUMP3	0:00	3:05:03	0:36	3:05:39	3:05:34
81	R290	W	22	50	72	3:05:15	0:15	RINS4	3:05:30	1:40	3:07:10	0:00	HUMP1	0:00	3:07:15	0:17	3:07:32	3:07:27
82	CTV23	E	0	29	29	3:06:45	0:15	RINS1	3:07:00	0:58	3:07:58	0:00	HUMP1	0:00	3:08:33	0:10	3:08:43	3:08:08
83	S156A	W	0	115	115	3:04:00	0:15	RINS6	3:04:15	3:50	3:08:05	0:38	HUMP2	0:00	3:08:48	0:38	3:09:26	3:09:21
84	1RV6	E	0	86	86	3:04:30	0:45	RINS2	3:05:15	2:56	3:08:11	0:45	HUMP3	0:00	3:09:31	0:29	3:10:00	3:09:25
85	SPTY4	E	0	124	124	3:05:35	0:15	RINS3	3:05:50	4:08	3:09:58	0:00	HUMP1	0:00	3:10:33	0:41	3:11:14	3:10:39
86	S154	W	0	156	156	3:06:20	0:15	RINS5	3:06:35	5:16	3:11:51	0:00	HUMP1	0:00	3:11:56	0:52	3:12:48	3:12:43
87	RFP2	E	0	19	19	3:07:20	1:13	RINS1	3:08:33	0:38	3:09:11	3:07	HUMP2	0:00	3:12:53	0:06	3:12:59	3:12:24
88	NPY4B	E	0	49	49	3:07:00	1:46	RINS2	3:08:46	1:38	3:10:24	2:05	HUMP3	0:00	3:13:04	0:16	3:13:20	3:12:45
89	R120	W	0	130	130	3:07:10	0:15	RINS4	3:07:25	4:20	3:11:45	2:03	HUMP1	0:00	3:13:53	0:43	3:14:36	3:14:31
90	RUPY4	E	0	30	30	3:08:35	0:51	RINS1	3:09:26	1:00	3:10:26	3:40	HUMP2	0:00	3:14:41	0:10	3:14:51	3:14:16
91	RUPYA	E	0	72	72	3:08:35	1:58	RINS3	3:10:33	2:24	3:12:57	1:24	HUMP3	0:00	3:14:56	0:24	3:15:20	3:14:45
92	S158	W	0	67	67	3:10:00	0:15	RINS6	3:10:15	2:14	3:12:29	2:51	HUMP1	0:00	3:15:25	0:22	3:15:47	3:15:42
93	R112	W	0	12	12	3:10:00	2:20	RINS4	3:12:20	0:24	3:12:44	3:03	HUMP2	0:00	3:15:52	0:04	3:15:56	3:15:51
94	ERPY4	E	0	63	63	3:09:00	1:39	RINS2	3:10:39	2:06	3:12:45	2:50	HUMP3	0:00	3:16:10	0:21	3:16:31	3:15:56
95	R176	W	27	14	41	3:10:55	1:31	RINS5	3:12:26	0:28	3:12:54	3:46	HUMP1	0:00	3:16:45	0:05	3:16:50	3:16:45
96	SHOPP	W	0	18	18	3:16:00		SKIP INSPECTION				0:50	HUMP2	0:00	3:16:55	0:06	3:17:01	3:16:56
97	REHMP	E	0	40	40	3:16:58		BYPASS REC. YD.				0:08	HUMP1	0:00	3:17:06	0:13	3:17:19	
98	COX	W	0	48	48	3:14:08	0:15	RINS4	3:14:23	1:38	3:16:01	1:20	HUMP3	0:00	3:17:26	0:16	3:17:42	3:17:37
99	S222	W	0	5	5	3:16:25	0:15	RINS4	3:16:40	0:10	3:16:50	0:52	HUMP2	0:00	3:17:47	0:02	3:17:49	3:17:44
100	R180	W	0	117	117	3:10:45	1:59	RINS6	3:12:44	3:54	3:16:38	1:11	HUMP1	0:00	3:17:54	0:39	3:18:33	3:18:28
101	R110B	W	0	110	110	3:11:40	1:59	RINS5	3:13:39	3:40	3:17:19	1:14	HUMP2	0:00	3:18:38	0:36	3:19:14	3:19:09
102	NPY5A	E	0	67	67	3:15:10	0:15	RINS1	3:15:25	2:14	3:17:39	1:05	HUMP3	0:00	3:19:19	0:22	3:19:41	3:19:06
103	SPY4X	E	0	102	102	3:15:10	0:15	RINS2	3:15:25	3:24	3:18:49	0:22	HUMP1	0:00	3:19:46	0:34	3:20:20	3:19:45
104	R270	W	12	37	49	3:17:30	0:15	RINS4	3:17:45	1:14	3:18:59	1:21	HUMP2	0:00	3:20:25	0:12	3:20:37	3:20:32
105	CPY4A	E	0	97	97	3:17:15	0:15	RINS3	3:17:30	3:14	3:20:44	0:00	HUMP1	0:00	3:21:19	0:32	3:21:51	3:21:16
106	CRYD	E	0	17	17	3:19:45	0:15	RINS1	3:20:00	0:34	3:20:34	0:47	HUMP3	0:00	3:21:56	0:06	3:22:02	3:21:27
107	C490	W	0	71	71	3:18:40	0:15	RINS3	3:18:55	2:22	3:21:17	0:45	HUMP2	0:00	3:22:07	0:23	3:22:30	3:22:25
108	2RV6	W	0	61	61	3:21:00	0:15	RINS4	3:21:15	2:42	3:23:57	0:00	HUMP1	0:00	4:00:02	0:27	4:00:29	4:00:24
109	BO685	W	0	62	62	3:21:30	0:15	RINS6	3:21:45	2:04	3:23:49	0:51	HUMP2	0:12	4:00:57	0:20	4:01:17	4:01:12
110	S156B	W	0	76	76	3:21:45	0:17	RINS5	3:22:02	2:32	4:00:34	0:43	HUMP3	0:00	4:01:22	0:25	4:01:47	4:01:42
111	BOVGN	W	0	48	48	3:22:00	2:04	RINS6	4:00:04	1:38	4:01:42	0:05	HUMP1	0:00	4:01:52	0:16	4:02:08	4:02:03
			-----	-----	-----		------			------		------		------		------		
			61	2634	2695		1:08:43			3:12:24		1:16:51		0:24		14:31		

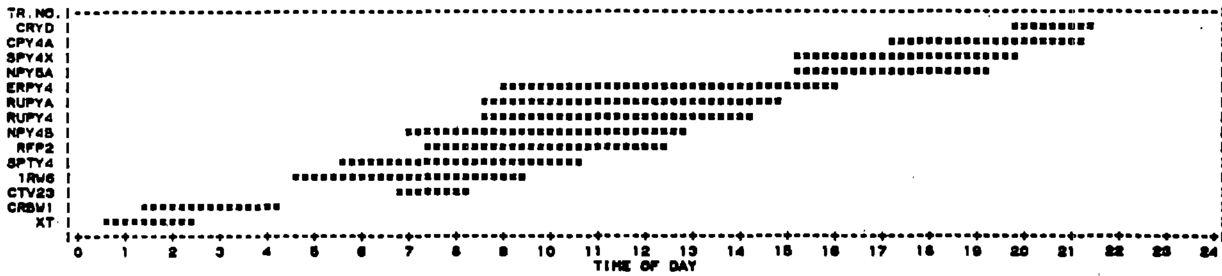
CAPACITY DEMONSTRATION RUN

RECEIVING YARD SUMMARY STATISTICS STRICTLY OVER THE 24 HOURS OF THE REQUESTED PRINT PERIOD --

	BYPASS	HUMP	BOTH
CARS IN	61	2366	2427
CARS OUT	61	2366	2427
TOTAL CAR HOURS	30.50	11860.93	11891.43
AVERAGE DETENTION TIME, HOURS	.50	5.02	4.91
HUMP UTILIZATION, PERCENT (1 HUMP)	NA	54.37	NA

CAPACITY DEMONSTRATION RUN

EAST RECEIVING YARD OCCUPANCY DIAGRAM FOR DAY 3 -

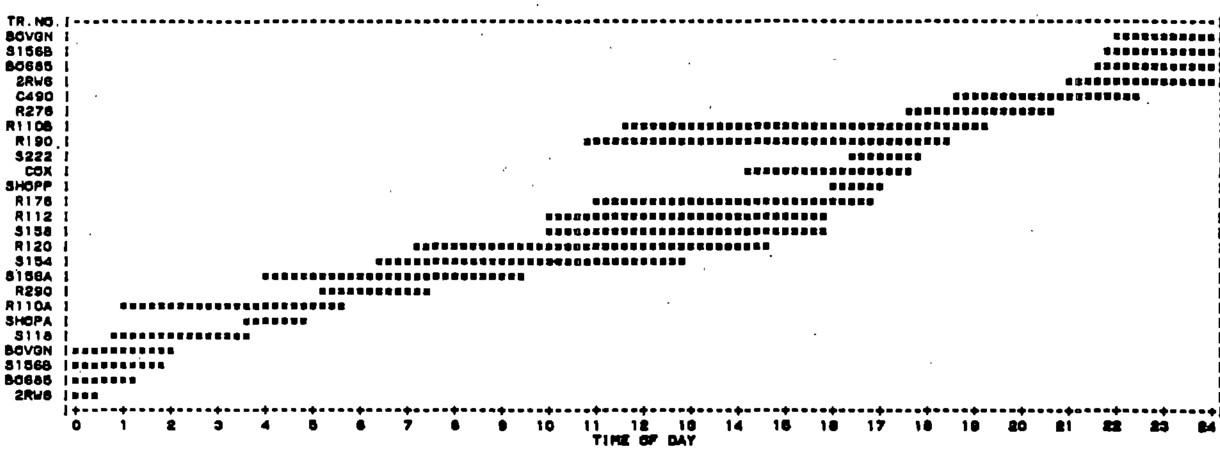


EAST RECEIVING YARD TRACK REQUIREMENTS -

TRACK NO.	MIN. LENG. REQUIRED (CARS)
1	124
2	97
3	72
4	63
5	49
6	30
7	19

CAPACITY DEMONSTRATION RUN

WEST RECEIVING YARD OCCUPANCY DIAGRAM FOR DAY 3 -



WEST RECEIVING YARD TRACK REQUIREMENTS -

TRACK NO.	MIN. LENG. REQUIRED (CARS)
1	158
2	130
3	117
4	110
5	87
6	41
7	12

CAPACITY DEMONSTRATION RUN

DEPARTING TRAIN MAKE-UP SCENARIOS --

NO.	TRAIN OR MOVE NAME	DEST. E/W	BLOCK NO.	BLOCK E/W	PULL TYPE	TRIM(AUX) ENGINE CREW	START COUPLE	START PULL	END PULL	NO. CARS	TOTAL CARS	START OCC. OP.TRK.	INSP. CREW	START INSP.	END INSP.	SCHED.	LATE
122	X111	E	115		PREV. PULL					35							
122	X111	E	117		PREV. PULL					37							
122	X111	E	81	E	MULT. PULL					4							
122	X111	E	82	E	MULT. PULL					4							
122	X111	E	83	E	MULT. PULL					13							
122	X111	E	84	E	CLASS PULL	ROAD3	2:22:05	2:22:13	2:23:28	19							
											112	2:10:34	DINS2	2:23:43	3:00:39	2:22:30	2:09
124	EP28	E	114	W	EARLY PULL	TRIM2	2:23:11	2:23:22	3:00:37	57							
											57					2:23:00*	
126	PYENS	W	28	W	CLASS CLR.	ROAD5	2:22:40	2:22:44	2:23:24	18							
126	PYENS	W	32	W	CLASS CLR.	ROAD5	2:23:34	2:23:49	3:00:29	75							
											93					2:23:45*	
128	TS105	E	123	W	MULT. PULL					23							
128	TS105	E	113	W	MULT. PULL					10							
128	TS105	E	126	E	MULT. PULL					3							
128	TS105	E	115	E	MULT. PULL					20							
128	TS105	E	117	E	EARLY PULL	TRIM1	2:23:35	2:23:49	3:01:04	16							
											72					2:23:55*	
129	TPY97	E	46	W	CLASS CLR.	XTRIM	3:00:25	3:00:26	3:00:36	4							
											4					3:02:15*	
130	TPYSE	W	35	W	MULT. PULL					44							
130	TPYSE	W	36	W	EARLY PULL	XTRIM	3:00:46	3:00:55	3:01:05	0							
130	TPYSE	W	24	W	EARLY PULL	XTRIM	3:01:15	3:01:24	3:01:34	47							
											91					3:02:30*	
131	S0159	E	119		PREV. PULL					12							
131	S0159	E	103		PREV. PULL					3							
131	S0159	E	111		PREV. PULL					67							
											82	2:16:28	DINS3	3:01:00	3:01:41	3:01:00	0:41
132	29A40	E	14	W	MULT. PULL					12							
132	29A40	E	17	W	MULT. PULL					2							
132	29A40	E	16	W	MULT. PULL					8							
132	29A40	E	18	W	MULT. PULL					8							
132	29A40	E	111	W	EARLY PULL	XTRIM	3:01:44	3:02:02	3:03:17	62							
											92					3:01:30*	
133	T173	W	109	E	EARLY PULL	TRIM2	3:02:05	3:02:10	3:02:20	23							
133	T173	W	104	E	EARLY PULL	TRIM2	3:02:30	3:02:35	3:02:45	25							
133	T173	W	108	E	EARLY PULL	TRIM2	3:02:55	3:03:01	3:03:11	31							
											79					3:03:45*	
134	RF105	E	125		PREV. PULL					7							
134	RF105	E	123		PREV. PULL					23							
134	RF105	E	113		PREV. PULL					10							
134	RF105	E	115		PREV. PULL					20							
134	RF105	E	117		PREV. PULL					16							
134	RF105	E	126		PREV. PULL					14							
											90	2:14:37	DINS2	3:02:15	3:03:00	3:02:45	0:15
135	PY97	W	49	W	CLASS CLR.	ROAD5	3:02:25	3:02:30	3:03:10	27							

CAPACITY DEMONSTRATION RUN

DEPARTING TRAIN MAKE-UP SCENARIOS --

NO.	TRAIN OR MOVE NAME	DEST. E/W	BLOCK NO.	BLOCK E/W	PULL TYPE	TRIM(AUX) ENGINE CREW	START COUPLE	START PULL	END PULL	NO. CARS	TOTAL CARS	START OCC. OP.TRK.	INSP. CREW	START INSP.	END INSP.	SCHED.	LATE
135	PY97	W	37	W	CLASS CLR.	ROAD5	3:03:20	3:03:34	3:04:14	70							
											97					3:03:00*	
136	PYSEA	W	35		PREV. PULL					44							
136	PYSEA	W	24		PREV. PULL					47							
											91	3:01:05	DINS1	3:02:45	3:03:31	3:03:45	0:00
137	SHOPA	W	2	E	MULT. PULL					3							
137	SHOPA	W	137	E	MULT. PULL					10							
137	SHOPA	W	3	E	MULT. PULL					11							
137	SHOPA	W	136	E	CLASS CLR.	XTRIM	3:03:37	3:03:43	3:04:23	5							
											29					3:03:30*	
138	S0173	W	109		PREV. PULL					57							
138	S0173	W	104		PREV. PULL					51							
138	S0173	W	108		PREV. PULL					31							
											139	2:19:31	DINS1	3:04:25	3:05:36	3:04:15	1:20
139	TS219	W	101	E	MULT. PULL					1							
139	TS219	W	105	E	MULT. PULL					3							
139	TS219	W	102	E	CLASS CLR.	TRIM1	3:04:35	3:04:36	3:05:16	0							
											4					3:05:30*	
140	TS275	E	124	E	MULT. PULL					1							
140	TS275	E	114	W	EARLY PULL	TRIM2	3:05:40	3:05:47	3:07:02	32							
											33					3:06:45*	
141	T175	E	122	E	CLASS CLR.	TRIM1	3:05:56	3:05:57	3:06:07	5							
											5					3:07:45*	
142	TK53A	E	50	W	CLASS CLR.	TRIM1	3:06:17	3:06:18	3:06:28	4							
											4					3:06:00*	
143	CRYD	E	6	W	CLASS CLR.	XTRIM	3:06:10	3:06:11	3:06:21	7							
											7					3:08:00*	
144	EP16	E	121	E	MULT. PULL					24							
144	EP16	E	128	E	EARLY PULL	XTRIM	3:06:35	3:06:41	3:07:56	4							
											28					3:07:00*	
145	RF275	E	124		PREV. PULL					1							
145	RF275	E	114		PREV. PULL					89							
											90	3:00:37	DINS2	3:07:17	3:08:02	3:07:30	0:32
146	RF175	W	118	E	CLASS CLR.	ROAD5	3:07:55	3:07:57	3:08:37	12							
											12					3:08:30*	
147	T495	E	131	E	MULT. PULL					18							
147	T495	E	132	E	EARLY PULL	TRIM2	3:08:35	3:08:42	3:09:57	19							
											37					3:10:15*	
148	S0221	W	111	W	CLASS CLR.	ROAD5	3:08:55	3:08:59	3:09:39	21							
148	S0221	W	104	E	CLASS CLR.	ROAD5	3:09:49	3:09:50	3:10:30	3							
											24					3:09:30*	
149	EP24A	E	115	E	MULT. PULL					6							
149	EP24A	E	117	E	EARLY PULL	XTRIM	3:09:15	3:09:19	3:10:54	15							
											21					3:09:00*	
150	TS84	E	14	W	MULT. PULL					20							
150	TS84	E	17	W	MULT. PULL					1							

CAPACITY DEMONSTRATION RUN

DEPARTING TRAIN MAKE-UP SCENARIOS --

NO.	TRAIN OR MOVE NAME	DEST. E/W	BLOCK NO.	BLOCK E/W	PULL TYPE	TRIM(AUX) ENGINE CREW	START COUPLE	START PULL	END PULL	NO. CARS	TOTAL CARS	START OCC. DP.TRK.	INSP. CREW	START INSP.	END INSP.	SCHED.	LATE
150	TS84	E	16	W	MULT. PULL					14							
150	TS84	E	16	W	EARLY PULL	TRIM1	3:09:40	3:09:48	3:11:03	3							
											36					3:11:00■	
151	TS109	E	121	E	MULT. PULL					21							
151	TS109	E	126	E	EARLY PULL	TRIM2	3:10:17	3:10:27	3:11:42	30							
											51					3:11:00■	
152	TS227	W	116	E	CLASS CLR.	TRIM1	3:11:23	3:11:23	3:12:03	2							
											2					3:10:45■	
153	CO495	E	131		PREV. PULL					18							
153	CO495	E	130		PREV. PULL					2							
153	CO495	E	132		PREV. PULL					19							
											39	2:16:26	DINS2	3:10:30	3:10:50	3:11:00	0:00
154	NE84	E	14		PREV. PULL					32							
154	NE84	E	17		PREV. PULL					3							
154	NE84	E	16		PREV. PULL					22							
154	NE84	E	18		PREV. PULL					11							
											68	3:03:17	DINS2	3:11:18	3:11:52	3:12:30	0:00
155	RF109	E	128		PREV. PULL					4							
155	RF109	E	121		PREV. PULL					45							
155	RF109	E	126		PREV. PULL					30							
											79	3:07:56	DINS3	3:12:00	3:12:40	3:12:30	0:10
156	EP19	E	126	E	EARLY PULL	XTRIM	3:13:20	3:13:22	3:14:37	11							
											11					3:13:00■	
157	TS111	E	118	E	MULT. PULL					21							
157	TS111	E	117	E	EARLY PULL	TRIM1	3:13:10	3:13:15	3:14:30	4							
											25					3:15:00■	
158	TS289	E	119	E	MULT. PULL					12							
158	TS289	E	120	E	MULT. PULL					9							
158	TS289	E	125	E	MULT. PULL					7							
158	TS289	E	130	E	MULT. PULL					3							
158	TS289	E	123	W	MULT. PULL					22							
158	TS289	E	114	W	EARLY PULL	TRIM1	3:14:50	3:15:11	3:16:26	51							
											104					3:15:30■	
159	PYAB	W	33	W	CLASS CLR.	ROAD5	3:14:26	3:14:36	3:15:16	56							
159	PYAB	W	34	W	CLASS CLR.	ROAD5	3:15:26	3:15:36	3:16:16	51							
											107					3:15:30■	
160	TPYEN	W	32	W	EARLY PULL	XTRIM	3:14:57	3:15:16	3:15:26	95							
											95					3:15:30■	
161	T155	E	112	E	MULT. PULL					24							
161	T155	E	111	W	EARLY PULL	TRIM2	3:14:50	3:15:04	3:16:19	47							
											71					3:16:30■	
162	SHOPB	E	2	E	MULT. PULL					9							
162	SHOPB	E	137	E	MULT. PULL					10							
162	SHOPB	E	3	E	MULT. PULL					23							
162	SHOPB	E	136	E	CLASS CLR.	XTRIM	3:15:36	3:15:46	3:15:56	4							
											46					3:16:00■	

CAPACITY DEMONSTRATION RUN

DEPARTING TRAIN MAKE-UP SCENARIOS --

NO.	TRAIN OR MOVE NAME	DEST. E/W	BLOCK NO.	BLOCK E/W	PULL TYPE	TRIM(AUX) ENGINE CREW	START COUPLE	START PULL	END PULL	NO. CARS	TOTAL CARS	START OCC. DP.TRK.	INSP. CREW	START INSP.	END INSP.	SCHED.	LATE
163	PYENA	W	32		PREV. PULL					95							
											95	3:15:26	DINS1	3:15:45	3:16:33	3:16:45	0:00
164	TWR7	W	42	W	EARLY PULL	XTRIM	3:16:25	3:16:27	3:16:37	8							
164	TWR7	W	43	W	EARLY PULL	XTRIM	3:16:47	3:16:52	3:17:02	23							
164	TWR7	W	45	W	EARLY PULL	XTRIM	3:17:12	3:17:17	3:17:27	23							
164	TWR7	W	39	W	EARLY PULL	XTRIM	3:17:37	3:17:47	3:17:57	51							
											105					3:17:00■	
165	TK538	E	50	W	CLASS CLR.	TRIM1	3:17:06	3:17:07	3:17:17	7							
											7					3:16:00■	
166	TPYAL	E	27	W	CLASS CLR.	TRIM2	3:16:59	3:17:01	3:17:11	8							
											8					3:18:00■	
167	TK46	E	44	W	CLASS CLR.	XTRIM	3:18:07	3:18:09	3:18:19	12							
167	TK46	E	138	W	CLASS CLR.	XTRIM	3:18:29	3:18:32	3:18:42	16							
											28					3:17:00■	
168	TPYMO	E	21	E	MULT. PULL					16							
168	TPYMO	E	22	E	MULT. PULL					18							
168	TPYMO	E	23	E	EARLY PULL	TRIM1	3:17:27	3:17:39	3:18:54	28							
											62					3:17:45■	
169	PYSEB	W	35	W	MULT. PULL					91							
169	PYSEB	W	36	W	CLASS CLR.	ROAD5	3:16:40	3:16:58	3:17:38	0							
											91					3:17:45■	
170	SO155	E	110		PREV. PULL					30							
170	SO155	E	112		PREV. PULL					24							
170	SO155	E	111		PREV. PULL					109							
											163	2:23:15	DINS2	3:16:45	3:18:07	3:17:00	1:07
171	REHMP	E	81	E	MULT. PULL					4							
171	REHMP	E	82	E	MULT. PULL					4							
171	REHMP	E	83	E	MULT. PULL					13							
171	REHMP	E	84	E	CLASS CLR.	ROAD7	3:16:40	3:16:48	3:16:58	19							
											40					3:17:00■	
172	WR7	W	42		PREV. PULL					8							
172	WR7	W	43		PREV. PULL					23							
172	WR7	W	45		PREV. PULL					23							
172	WR7	W	39		PREV. PULL					51							
											105	3:16:37	DINS1	3:18:12	3:19:05	3:18:15	0:50
173	SOUYD	W	106	E	CLASS CLR.	ROAD6	3:17:10	3:17:14	3:17:54	19							
											19					3:17:45■	
174	TK52	E	51	W	CLASS CLR.	XTRIM	3:18:52	3:18:55	3:19:05	13							
174	TK52	E	135	W	CLASS CLR.	XTRIM	3:19:15	3:19:16	3:19:26	4							
											17					3:18:00■	
175	TTV24	E	20	W	CLASS CLR.	TRIM2	3:17:55	3:17:55	3:18:05	1							
175	TTV24	E	38	W	CLASS CLR.	TRIM2	3:18:15	3:18:22	3:18:32	35							
											36					3:19:45■	
176	RF289	E	120		PREV. PULL					9							
176	RF289	E	123		PREV. PULL					22							
176	RF289	E	114		PREV. PULL					51							
											82	3:16:26	DINS3	3:18:00	3:18:41	3:18:30	0:11

CAPACITY DEMONSTRATION RUN

DEPARTING TRAIN MAKE-UP SCENARIOS --

NO.	TRAIN OR MOVE NAME	DEST. E/W	BLOCK NO.	BLOCK E/W	PULL TYPE	TRIM(AUX) ENGINE CREW	START COUPLE	START PULL	END PULL	NO. CARS	TOTAL CARS	START OCC. DP.TRK.	INSP. CREW	START INSP.	END INSP.	SCHED.	LATE
177	PYAL	W	30	W	CLASS CLR.	ROAD5	3:18:10	3:18:17	3:18:57	34							
177	PYAL	W	29	W	CLASS CLR.	ROAD5	3:19:07	3:19:22	3:20:02	75							
											109					3:19:15*	
178	EP173	W	109	E	EARLY PULL	TRIM1	3:19:14	3:19:21	3:19:31	34							
178	EP173	W	104	E	EARLY PULL	TRIM1	3:19:41	3:19:46	3:19:56	26							
											60					3:16:00*	
179	PYMO	E	21		PREV. PULL					16							
179	PYMO	E	22		PREV. PULL					16							
179	PYMO	E	23		PREV. PULL					26							
											62	3:16:54	DINS2	3:19:09	3:19:40	3:19:46	0:00
180	EP24P	E	116	E	MULT. PULL					8							
180	EP24P	E	117	E	EARLY PULL	TRIM2	3:18:42	3:18:47	3:20:02	18							
											26					3:20:00*	
181	TV24	W	26	W	CLASS CLR.	ROAD6	3:19:56	3:20:02	3:20:42	33							
											33					3:21:00*	
182	T111	W	113	W	EARLY PULL	XTRIM	3:19:56	3:20:09	3:20:19	69							
182	T111	W	126	E	EARLY PULL	XTRIM	3:20:29	3:20:35	3:20:46	26							
											97					3:21:46*	
183	TS682	E	11	E	MULT. PULL					34							
183	TS682	E	9	E	MULT. PULL					17							
183	TS682	E	10	E	MULT. PULL					14							
183	TS682	E	8	E	MULT. PULL					1							
183	TS682	E	13	E	MULT. PULL					21							
183	TS682	E	12	E	EARLY PULL	TRIM2	3:20:22	3:20:42	3:21:57	14							
											101					3:21:30*	
184	T159	E	110	E	MULT. PULL					30							
184	T159	E	103	E	MULT. PULL					3							
184	T159	E	111	W	EARLY PULL	TRIM1	3:21:40	3:22:00	3:23:16	67							
											100					3:23:30*	
185	RF111	W	113		PREV. PULL					69							
185	RF111	W	126		PREV. PULL					28							
											97	3:20:19	DINS1	3:22:00	3:22:49	3:22:30	0:19
186	X111	E	116		PREV. PULL					35							
186	X111	E	117		PREV. PULL					37							
186	X111	E	81	E	MULT. PULL					4							
186	X111	E	82	E	MULT. PULL					4							
186	X111	E	83	E	MULT. PULL					13							
186	X111	E	84	E	CLASS PULL	ROAD3	3:22:06	3:22:13	3:23:28	19							
											112	3:10:34	DINS2	3:23:40	4:00:39	3:22:30	2:09
187	TK53C	E	50	W	CLASS CLR.	TRIM2	3:22:47	3:22:51	3:23:01	21							
											21					3:22:00*	
188	EP28	E	114	W	EARLY PULL	TRIM2	3:23:11	3:23:22	4:00:37	57							
											57					3:23:00*	
189	BO682	E	11		PREV. PULL					34							
189	BO682	E	9		PREV. PULL					17							
189	BO682	E	10		PREV. PULL					14							

CAPACITY DEMONSTRATION RUN

DEPARTING TRAIN MAKE-UP SCENARIOS --

NO.	TRAIN OR MOVE NAME	DEST. E/W	BLOCK NO.	BLOCK E/W	PULL TYPE	TRIM(AUX) ENGINE CREW	START COUPLE	START PULL	END PULL	NO. CARS	TOTAL CARS	START OCC. DP.TRK.	INSP. CREW	START INSP.	END INSP.	SCHED.	LATE
189	BO682	E	8		PREV. PULL					1							
189	BC682	E	13		PREV. PULL					21							
189	BO682	E	12		PREV. PULL					14							
											101	3:21:57	DINS3	3:22:30	3:23:21	3:23:30	0:00
190	PYENS	W	28	W	CLASS CLR.	ROAD5	3:22:40	3:22:44	3:23:24	18							
190	PYENS	W	32	W	CLASS CLR.	ROAD5	3:23:34	3:23:49	4:00:29	75							
											93					3:23:45*	
191	TK50	E	4	W	CLASS CLR.	INDUS	3:22:40	3:22:46	3:22:56	23							
191	TK50	E	129	W	CLASS CLR.	INDUS	3:23:06	3:23:05	3:23:16	1							
191	TK50	E	139	W	CLASS CLR.	INDUS	3:23:25	3:23:26	3:23:36	3							
											27					3:23:30*	
192	TS105	E	123	W	MULT. PULL					23							
192	TS105	E	113	W	MULT. PULL					10							
192	TS105	E	126	E	MULT. PULL					3							
192	TS105	E	115	E	MULT. PULL					20							
192	TS105	E	117	E	EARLY PULL	TRIM1	3:23:36	3:23:49	4:01:04	16							
											72					3:23:55*	
195	SO159	E	119		PREV. PULL					12							
195	SO159	E	103		PREV. PULL					3							
195	SO159	E	111		PREV. PULL					67							
											82	3:16:26	DINS3	4:01:00	4:01:41	4:01:00	0:41
198	RF105	E	125		PREV. PULL					7							
198	RF105	E	123		PREV. PULL					23							
198	RF105	E	113		PREV. PULL					10							
198	RF105	E	115		PREV. PULL					20							
198	RF105	E	117		PREV. PULL					16							
198	RF105	E	126		PREV. PULL					14							
											90	3:14:37	DINS2	4:02:15	4:03:00	4:02:45	0:15
202	SO173	W	109		PREV. PULL					57							
202	SO173	W	104		PREV. PULL					51							
202	SO173	W	106		PREV. PULL					31							
											139	3:19:31	DINS1	4:04:25	4:05:35	4:04:15	1:20
217	CO495	E	131		PREV. PULL					18							
217	CO495	E	130		PREV. PULL					3							
217	CO495	E	132		PREV. PULL					17							
											38	3:16:26	DINS2	4:10:30	4:10:49	4:11:00	0:00
234	SO155	E	110		PREV. PULL					30							
234	SO155	E	112		PREV. PULL					11							
234	SO155	E	111		PREV. PULL					62							
											103	3:23:15	DINS2	4:16:45	4:17:37	4:17:00	0:37
											----						------
											3022**						12:36

*NOTE -- INCLUDED FOR REFERENCE ONLY: EARLY PULLS DO NOT LEAVE YARD ON THIS SCHEDULE, CLASS CLEARS LEAVE YARD AT EACH END PULL TIME.
**NOTE -- CARS IN EARLY PULLS ARE NOT COUNTED TOWARD THIS SUM.

CAPACITY DEMONSTRATION RUN

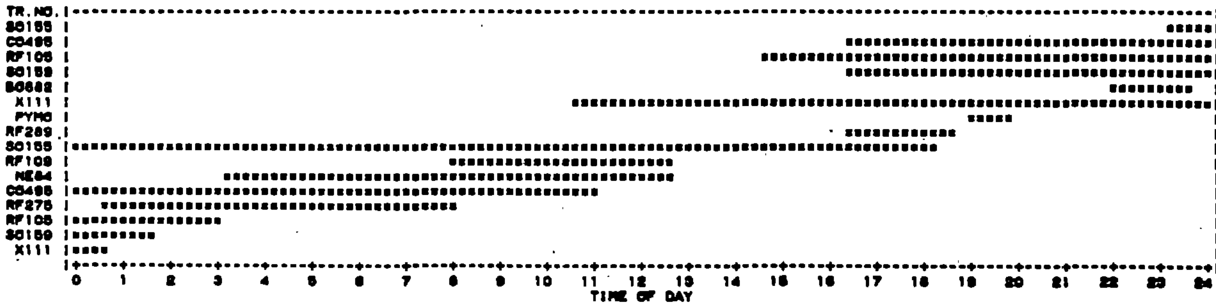
BYPASS   BLOCKS ENTERING BUT NEVER LEAVING DEPARTURE YARD -   52

DEPARTURE YARD SUMMARY STATISTICS STRICTLY OVER THE 24 HOURS OF THE REQUESTED PRINT PERIOD --

CARS IN	2427
CARS OUT	2365
TOTAL CAR HOURS	11894.00
AVERAGE DETENTION TIME, HOURS	4.96

CAPACITY DEMONSTRATION RUN

EAST DEPARTURE YARD OCCUPANCY DIAGRAM FOR DAY 3 -

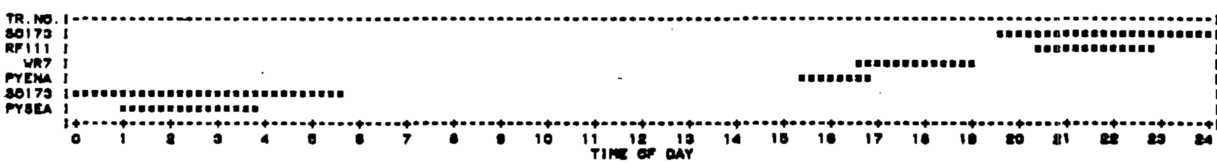


EAST DEPARTURE YARD TRACK REQUIREMENTS -

TRACK NO.	MIN. LENG. REQUIRED (CARS)
1	163
2	112
3	101
4	80
5	62
6	39

CAPACITY DEMONSTRATION RUN

WEST DEPARTURE YARD OCCUPANCY DIAGRAM FOR DAY 3 -



WEST DEPARTURE YARD TRACK REQUIREMENTS -

TRACK NO.	MIN. LENG. REQUIRED (CARS)
1	139
2	87

CAPACITY DEMONSTRATION RUN

EAST CLASS YARD BLOCK BUILD-UP MATRIX FOR DAY 3

BLK.	GRP.	MAXIMUM NUMBER OF CARS FOR HOUR BEGINNING AT																								MAX	NO.	CARS	CARS	CAR
NO.	NO.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	FOR DAY	TRKS. REQD.	IN	OUT	HRS.
101	1	1	1	1	1	1*	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	19
105	1	2	2	2	3	3*	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3		3	3	49
SUM	1	3	3	3	4	4	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	1	4	4	68
2	2	2	3	3	3*	0	4	4	5	5	9	9	9	9	9	9	9*	0	1	1	1	2	2	2	2	9		12	12	91
107	2	10	10	10	10*	0	0	0	0	0	0	0	6	6	7	7	10*	0	0	0	1	3	10	10	10	10		20	20	92
SUM	2	12	13	13	13	0	4	4	5	5	9	9	15	15	16	16	19	0	1	1	2	5	12	12	12	19	1	32	32	183
3	3	11	11	11	11*	3	12	12	15	15	17	17	17	17	17	20	23*	1	1	3	10	10	10	11	11	23		34	34	261
136	3	3	5	5	5*	0	0	0	0	0	0	0	3	3	4	4	4*	0	0	0	1	1	2	2	2	5		9	9	37
SUM	3	14	16	16	16	3	12	12	15	15	17	17	20	20	21	27	27	1	1	3	11	11	12	13	13	27	1	43	43	298
112	4	8	10	11	11	12	12	12	12	15	15	19	23	23	24	24*	0	5	5	5	6	6	6	6	6	24	1	24	24	273
131	5	12	15	16	16	16	16	16	16	16*	0	3	6	6	6	6	7	8	9	9	9	9	9	9	9	16	1	16	16	246
132	6	16	17	17	17	19	19	19	19	19*	0	0	7	7	8	11	12	14	14	14	15	15	15	15	15	19	1	19	19	307
122	7	3	3	3	5	5	5*	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	5	1	5	5	69
118	8	2	2	2	10	12	12	12	12*	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	12	1	12	12	77
106	9	2	11	12	12	12	12	12	12	12	12	12	16	16	16	16	19	19	19*	0	0	1	1	2	2	19	1	19	19	235
103	10	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3	3	3	3*	1	1	3		3	3	45
110	10	10	11	14	14	15	15	15	15	15	15	18	21	21	21	21	21	21	21	21	23	30	30*	5	5	30		30	30	400
SUM	10	11	12	15	15	16	16	16	16	16	16	19	24	24	24	24	24	24	24	24	26	33	33	6	6	33	1	33	33	445
8	11	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1*	0	0	0	1		1	1	11
9	11	2	2	2	3	4	4	4	9	9	10	10	10	11	11	13	13	13	13	14	17	17*	0	2	2	17		17	17	175
10	11	0	1	1	1	2	5	5	5	5	5	5	5	7	7	7	7	7	8	9	14	14*	0	0	0	14		14	14	103
11	11	26	26	26	26	26	26	26	32	32	32	32	32	33	33	33	33	33	33	34	34	34*	0	26	26	34		34	34	655
SUM	11	28	29	29	30	32	35	35	46	46	48	48	48	52	52	54	54	54	55	58	66	66	0	28	28	66	1	66	66	944
12	12	5	6	6	10	10	11	11	11	11	12	12	12	12	12	14	14	14	14	14	14	14*	0	0	0	14	1	14	14	225
13	13	0	0	0	4	4	4	4	4	4	7	7	7	7	7	7	16	16	17	21	21	21*	0	0	0	21	1	21	21	161
124	14	1	1	1	1	1	1*	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	21
116	14	0	0	0	0	0	0	0	0	2	2	2	2*	0	0	0	0	0	0	0	0	0	0	0	0	2		2	2	5

CAPACITY DEMONSTRATION RUN

EAST CLASS YARD BLOCK BUILD-UP MATRIX FOR DAY 3

BLK.	GRP.	MAXIMUM NUMBER OF CARS FOR HOUR BEGINNING AT																								MAX	NO.	CARS	CARS	CAR
NO.	NO.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	FOR DAY	TRKS. REQD.	IN	OUT	HRS.
SUM	14	1	1	1	1	1	1	0	0	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	3	1	3	3	26
109	15	21	23	23*	3	4	4	4	4	4	4	6	12	12	16	16	28	33	34	34	34*	10	16	16	16	34	1	57	57	310
104	16	20	24	25*	0	3	3	3	3	3	3*	8	13	13	17	17	18	18	20	20	26*	11	12	16	16	26	1	54	54	269
108	17	28	28	31*	0	1	1	1	1	1	1	2	3	3	5	7	8	10	10	10	19	15	25	26	28	31	1	31	31	236
121	18	14	14	16	16	24	24	24*	0	20	20	21*	2	2	3	3	6	11	11	11	13	14	14	14	14	24		45	45	259
126	18	4	4	4	4	4	4	4*	0	0	0	0	0	0	3	3	3	4	4	4	4	4	4	4	4	4		4	4	66
SUM	18	18	18	20	20	28	28	28	0	20	20	21	2	2	6	6	9	15	15	15	17	18	18	18	18	28	1	49	49	325
128	19	1	8	10	10	16	16	16	16	16	16	30*	6	6	11*	2	10	12	14	14	19	28*	3	3	0*	30	1	72	72	215
21	20	7	7	7	7	8	9	9	10	10	11	11	11	12	12	16	16	16	16*	0	4	4	4	7	7	16		16	16	204
SUM	20	7	7	7	7	8	9	9	10	10	11	11	11	12	12	16	16	16	16	0	4	4	4	7	7	16	1	16	16	204
22	21	6	6	6	7	8	9	9	9	9	11	11	11	14	14	17	18	18	18*	3	3	4	4	6	6	18	1	18	18	206
23	22	8	9	9	10	10	14	14	14	14	19	19	19	24	24	24	27	28	28*	2	6	6	6	6	6	28	1	28	28	323
119	23	7	7	7	7	9	9	9	9	9	9	12	12	12	12	12*	0	4	4	4	5	5	6	6	6	12		12	12	174
120	23	6	6	7	7	8	8	8	8	8	8	9	9	9	9	9*	3	3	3	3	6	6	6	6	6	9		9	9	156
125	23	1	1	4	6	6	6	6	6	6	6	7	7	7	7	7*	0	0	0	0	1	1	1	1	1	7		7	7	85
130	23	0	1	3	3	3	3	3	3	3	3	3	3	3	3	3*	0	0	0	0	0	0	0	0	0	3		3	3	39
SUM	23	14	15	21	23	26	26	26	26	26	26	31	31	31	31	31	3	7	7	7	12	12	13	13	13	31	1	31	31	454
115	24	3	3	4	4	6	6	6	6	6	6*	3	11	21	21*	3	4	7	8	8*	5	13	20	20	20*	21		55	55	154
117	24	9	10	12	12	15	15	15	15	15	15*	1	4	4	5*	8	12	18	18	18*	3	15	16	16	16*	18		53	53	241
SUM	24	12	13	16	16	21	21	21	21	21	21	4	15	25	26	11	16	25	26	26	8	28	36	36	36	36	1	108	108	395
81	25	0	0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4*	4	4	4	4	4	4*	0	4		8	8	74
82	25	0	0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4*	4	4	4	4	4	4*	0	4		8	8	74
83	25	0	0	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13*	13	13	13	13	13	13*	0	13		26	26	241
84	25	0	0	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19*	19	19	19	19	19	19*	0	19		38	38	362
SUM	25	0	0	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	0	40	1	80	80	742

* DENOTES PULL OCCURRED DURING NAMED HOUR -- NOTE NUMBER OF CARS PULLED NOT NECESSARILY SAME AS MAXIMUM NUMBER OF CARS FOR HOUR

CAPACITY DEMONSTRATION RUN

EAST CLASS YARD SUMMARY STATISTICS STRICTLY OVER THE 24 HOURS OF THE ABOVE TABLE --

CARS IN	857
CARS OUT	857
TOTAL CAR HOURS	7227.62
AVERAGE DETENTION TIME, HOURS	8.43

CAPACITY DEMONSTRATION RUN

WEST CLASS YARD BLOCK BUILD-UP MATRIX FOR DAY 3

BLK. NO.	GRP. NO.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MAX FOR DAY	NO. TRKS. REQD.	CARS IN	CARS OUT	CAR HRS.
		MAXIMUM NUMBER OF CARS FOR HOUR BEGINNING AT																												
123	26	2	3	4	4	9	9	9	9	9	9	14	21	22	22	22=	6	9	10	10	10	13	21	23	23=	23	1	45	45	262
28	27	0	1	1	1	1	1	1	1	1	3	3	3	7	7	8	16	16	16	16	18	18	18	18=	0	18	1	18	18	157
113	28	6	21	24	24	35	35	35	35	35	35	43	47	47	49	52	57	63	63	63	69=	3	8	10	10=	69	1	79	79	825
114	29	13	23	26	26	32	32=	0	0	0	0	11	41	41	51	51=	11	20	20	20	28	43	53	57	57=	57	1	140	140	540
111	30	56	62=	11	11	21	21	21	21	21=	0	20	35	41	47	47=	21	30	35	35	47	67	67=	34	34	67	1	197	197	704
30	31	13	14	14	16	15	16	18	18	18	22	22	22	27	27	29	34	34	34	34=	11	11	11	13	13	34	1	34	34	445
27	32	2	2	2	2	2	6	6	6	6	6	6	6	6	6	8	8	8=	0	0	2	2	2	2	2	8	1	8	8	94
29	33	14	14	14	18	19	28	28	28	28	37	37	37	45	45	63	66	66	68	75	75=	14	14	14	14	75	1	75	75	766
32	34	0	9	9	17	18	40	40	41	41	52	52	52	73	73	95=	16	16	26	43	62	68	68	75	75=	95		170	170	919
SUM	34	0	9	9	17	18	40	40	41	41	52	52	52	73	73	95	16	16	26	43	62	68	68	75	75	95	1	170	170	919
34	35	18	21	21	21	21	30	30	30	30	38	38	38	45	45	51	51=	3	3	11	11	12	12	18	18	51	1	51	51	659
33	36	21	23	23	31	31	34	34	35	35	41	41	41	56	56	56=	4	4	9	13	13	19	19	21	21	56	1	56	56	614
35	37	44=	13	13	26	29	29	29	37	37	47	47	47	68	68	81	91	91=	5	24	39	41	41	44	44	91		135	135	912
SUM	37	44	13	13	26	29	29	29	37	37	47	47	47	68	68	81	91	91	5	24	39	41	41	44	44	91	1	135	135	912
37	38	60	70	70	70=	1	10	10	12	12	25	25	25	43	43	48	51	51	52	53	56	58	58	60	60	70	1	70	70	932
38	39	3	3	3	20	20	20	20	22	22	22	22	22	22	22	25	25	34	35	35=	0	3	3	3	3	35	1	35	35	366
28	40	1	1	1	4	5	6	6	8	8	8	8	8	17	17	25	25	25	25	30	33=	0	0	1	1	33	1	33	33	239
14	41	12	12=	2	15	15	18	18	18	18	20=	0	0	1	1	2	2	2	4	5	7	7	7	12	12	20		32	32	169
17	41	2	2=	0	0	0	0	0	0	0	1=	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2		3	3	17
16	41	8	8=	4	11	11	11	11	14	14	14=	0	0	4	4	5	5	5	6	6	7	7	7	8	8	14		22	22	160
18	41	8	8=	1	1	1	1	1	2	2	3=	0	0	0	0	4	4	4	6	7	8	8	8	8	8	8		11	11	85
SUM	41	30	30	7	27	27	30	30	34	34	38	0	0	5	5	11	12	12	17	19	24	24	24	30	30	38	1	68	68	450
42	42	1	1	1	1	1	2	2	2	2	3	3	3	5	6	8	8	8=	0	1	1	1	1	1	1	8	1	8	8	52
43	43	17	18	18	20	20	21	21	21	21	21	21	21	23	23	23	23	23=	2	11	16	17	17	17	17	23	1	23	23	434
45	44	3	4	4	6	6	14	14	16	16	19	19	19	23	23	23	23	23	23=	0	1	3	3	3	3	23	1	23	23	258

CAPACITY DEMONSTRATION RUN

WEST CLASS YARD BLOCK BUILD-UP MATRIX FOR DAY 3

BLK. NO.	GRP. NO.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MAX FOR DAY	NO. TRKS. REQD.	CARS IN	CARS OUT	CAR HRS.
		MAXIMUM NUMBER OF CARS FOR HOUR BEGINNING AT																												
39	45	11	23	23	27	27	27	27	28	28	38	38	33	46	46	50	51	51	51=	7	10	11	11	11	11	51	1	51	51	639
6	46	7	7	7	7	7	7	7=	0	0	0	0	0	2	2	4	6	6	6	6	6	7	7	7	7	7	1	7	7	104
44	47	2	3	3	4	4	4	4	5	5	9	9	9	10	10	12	12	12	12	12=	1	2	2	2	2	12		12	12	133
136	47	3	3	3	3	9	9	9	9	9	9	9	9	10	10	11	15	15	16	16=	0	2	3	3	3	16		16	16	170
SUM	47	5	6	6	7	13	13	13	14	14	18	18	18	20	20	23	27	27	28	28	1	4	5	5	5	28	1	28	28	304
20	48	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1=	1	1	1	1	1	1	1	1	1	1	23
48	49	4=	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	4	4	4	4	4	4	4	4	1	4	4	43
49	50	27	27	27=	0	0	0	0	0	0	0	0	0	5	5	5	7	7	24	25	27	27	27	27	27	27	1	27	27	260
4	51	0	3	3	3	3	7	7	7	7	9	9	9	11	11	13	18	18	19	20	21	21	21	23=	0	23		23	23	240
129	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1=	1		1	1	8
139	51	0	0	1	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3=	3		3	3	50
SUM	51	0	3	4	4	5	9	9	9	9	11	11	11	14	14	17	22	22	23	24	25	25	25	27	4	27	1	27	27	299
24	52	47	47=	6	7	7	11	11	20	20	28	28	28	32	32	35	37	38	38	39	42	45	45	47	47	47	1	47	47	680
51	53	2	2	2	2	2	3	3	4	4	4	4	4	6	6	9	11	11	12	13=	1	1	1	2	2	13		13	13	101
135	53	1	1	1	1	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4=	0	1	1	1	4		4	4	56
SUM	53	3	3	3	3	5	6	6	7	7	7	7	8	10	10	13	15	15	16	17	5	1	2	3	3	17	1	17	17	160
50	54	0	0	0	0	1	4	4=	0	0	0	0	0	0	0	6	6	7	7=	14	19	21	21	21=	0	21	1	32	32	96

= DENOTES PULL OCCURRED DURING NAMED HOUR -- NOTE NUMBER OF CARS PULLED NOT NECESSARILY SAME AS MAXIMUM NUMBER OF CARS FOR HOUR

WEST CLASS YARD SUMMARY STATISTICS STRICTLY OVER THE 24 HOURS OF THE ABOVE TABLE --

CARS IN	1509
CARS OUT	1509
TOTAL CAR HOURS	12134.88
AVERAGE DETENTION TIME, HOURS	8.04

CAPACITY DEMONSTRATION RUN

CREW UTILIZATION DIAGRAM FOR DAY 3 -

```
CR.NO. |------------------------------------------------------------------------------------------------------------------------| TP
RINS1  |** EEEEEEEE            ***       EEEEEEE**EEEEEEEEEE          ***          EEEEEEEEEEEEE**       EEEEE**           **|  1
RINS2  |**      EEEEEEEEEEEEE  **EEEEEEEEEEEEEEEEE**EEEEEEEEEEEEEEEEEEEEE**        EEEEEEEEEEEEEEEEEE**     ***              **|  1
RINS3  |**                     ***  EEEEEEEEEEEEEEEEEEEEEEE**EEEEEEEEEEEEEE**         ***   EEEEEEEEEEEEEEEEEEE**            **|  1
RINS4  |W*  WWWWWWWWWWWWWWWWWWWWW***WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW*WWWW**    WWWWWWWWWW**WW   WWWWWWWW      **WWWWWWWWWWWWWWW|  1
RINS5  |WWWW**WWWWWWWWWWWWWWWWWW***    WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW**WWW**WWWWWWWWWWWWWWWWWWWWW*    WWWWWWWWWWWWW***WWWWWWWWWW|  1
RINS6  |WWWWWWWWWW*            WWWWWWWWWWWWWWWWWWWW*****   WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW****               ***  WWWWWWWWWWW|  1
       |------------------------------------------------------------------------------------------------------------------------|
HUMP1  |WWW** WWWWWWWWWW EEEEEEE**      WWWWWWEEEEEE*    EEEEEEEEWWWWWWW***WWWWWWWWWWW*WWWEEEWWWWWWEEEEEEEEEEEEEEEE***      WWWW|  2
HUMP2  |*WWWWWW   EEEEEE       WWWWW**             **WWWWWW              EEEEEE** EEEEEE WWWWW*WWWWWWWWWWWWW   WWWWW***WWWWWW     **|  2
HUMP3  |**  WWWWWW    WWWWWW  WWWWWWW***           *** EEEEEEEE          EEEEEEE**EEEEEEEEEEEEEE*WWWWW  EEEEEEE    **EEEEEEE      **|  2
       |------------------------------------------------------------------------------------------------------------------------|
TRIM1  |EEEEEEE**              WWWWWW***EEE      ***       EEEEEEEEWWWWW  **EEEEEEEEEEEEEEEEEEE**EEEEEEEEEEEEWWWWW  ***  EEEEEEEEEEEEE|  3
TRIM2  |EEEE**     WWWWWWWW    ***  EEEEEEEE    **EEEEEEEEEEEEEEEEEEEE    ***          EEEEEEEEEEE*EEE  EEEEEEEEEEEEEEEEEEEEEEE**EEEEEEEE|  3
XTRIM  |*EEEWWWWWEEEEEEEEEEWWWWWW***     EEEEEEEEEEE*     EEEEEEEEE       **EEEEEEEEEEWWWWEEE*WWWWWWWWWEEEEEEE WWWWWW**            **|  3
INDUS  |**                     ***          ***                    ***           ***                     ***            EEEEEE**|  3
ROAD1  |**                     ***          ***                    ***           ***                     ***                  **|  3
ROAD2  |**                     ***          ***                    ***           ***                     ***                  **|  3
ROAD3  |**                     ***          ***                    ***           ***                     ***     EEEEEEEEE    **|  3
ROAD4  |**                     ***          ***                    ***           ***                     ***                  **|  3
       |------------------------------------------------------------------------------------------------------------------------|
ROAD5  |WWW        WWWWWWWWWWW                 WWWWWWWWWWWWWWW                 WWWWWWWWWWW WWWWWW WWWWWWWWWWW            WWWWWWWWW|  4
ROAD6  |                                                                          WWWWWW        WWWWWW                          |  4
ROAD7  |                                                                        EEE                                             |  4
ROAD8  |                                                                                                                        |  4
ROAD9  |                                                                                                                        |  4
       |------------------------------------------------------------------------------------------------------------------------|
DINS1  |**            WWWWWW  WWWWWWWWW**          ***                    ***         WWWWWW*    WWWWWW        ***  WWWWWW      **|  5
DINS2  |EEEE**    EEEEEE       ***         EEEEEE**        EEEEEEEEE   ***          *** EEEEEEEEE   EEEE       ***              EEEE|  5
DINS3  |**  EEEEE              ***          ***             EEEEE***                ***       EEEEE           ***   EEEEEEE     **|  5
DINS4  |**                     ***          ***                    ***              ***                       ***                  **|  5
       |+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+|
        0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24
                                                        TIME OF DAY
```

LEGEND: E = CREW WORKING E TRAIN W = CREW WORKING W TRAIN * = CREW ON BREAK

CAPACITY DEMONSTRATION RUN

CREW UTILIZATION STATISTICS FOR DAY 3 -

CREW I.D.	CREW TYPE	TOTAL WORK HRS FOR DAY	TOTAL BRK. HRS FOR DAY	UTIL.: PCT OF 24 HRS	UTIL.:PCT. OF 24 HRS. LESS BRKS.	OVERALL ((S) = SUM, (A) = AVERAGE) TOTAL WORK HRS FOR DAY	TOTAL BRK. HRS FOR DAY	UTIL.: PCT OF 24 HRS	UTIL.:PCT. OF 24 HRS. LESS BRKS.
RINS1	1	8.23	2.50	34.31	38.29				
RINS2	1	13.56	2.50	56.46	63.02				
RINS3	1	10.52	2.50	43.82	48.91				
RINS4	1	17.35	2.50	72.29	80.70				
RINS5	1	19.40	2.50	80.83	90.23				
RINS6	1	14.92	2.50	62.16	69.38				
CREW TYPE 1:						83.97(S)	15.00(S)	58.31(A)	65.09(A)
HUMP1	2	16.40	2.50	68.33	76.28				
HUMP2	2	11.68	2.50	48.68	54.34				
HUMP3	2	11.56	2.50	48.12	53.72				
CREW TYPE 2:						39.63(S)	7.50(S)	55.05(A)	61.45(A)
TRIM1	3	14.43	2.50	60.14	67.13				
TRIM2	3	15.13	2.50	63.06	70.39				
XTRIM	3	14.75	2.50	61.46	68.60				
INDUS	3	1.10	2.50	4.58	5.12				
ROAD1	3	0.00	2.50	0.00	0.00				
ROAD2	3	0.00	2.50	0.00	0.00				
ROAD3	3	1.72	2.50	7.15	7.98				
ROAD4	3	0.00	2.50	0.00	0.00				
CREW TYPE 3:						47.13(S)	20.00(S)	24.55(A)	27.40(A)
ROAD5	4	11.77	0.00	49.03	49.03				
ROAD6	4	1.85	0.00	7.71	7.71				
ROAD7	4	.47	0.00	1.94	1.94				
ROAD8	4	0.00	0.00	0.00	0.00				
ROAD9	4	0.00	0.00	0.00	0.00				
CREW TYPE 4:						14.08(S)	0.00(S)	11.74(A)	11.74(A)
DINS1	5	5.68	2.50	23.68	26.43				
DINS2	5	6.97	2.50	29.03	32.40				
DINS3	5	3.88	2.50	16.16	18.06				
DINS4	5	0.00	2.50	0.00	0.00				
CREW TYPE 5:						16.53(S)	10.00(S)	17.22(A)	19.22(A)
OVERALL:						201.36(S)	52.50(S)	32.27(A)	35.23(A)

CAPACITY DEMONSTRATION RUN

OVERALL YARD SUMMARY STATISTICS, STRICTLY OVER THE 24 HOURS OF THE REQUESTED PRINT PERIOD --

	RECEIVING YARD	CLASS YARD	DEPARTURE YARD	OVERALL	OVERALL ADJ. FOR NO COUNTS
CARS IN	2427	2368	2427	2427	2387
CARS OUT	2427	2368	2365	2365	2325
TOTAL CAR HOURS	11911.43	19362.60	11694.00	43167.93	43167.93
AVERAGE DETENTION TIME, HOURS	4.91	8.16	4.96	18.02	18.32

APPENDIX B: INPUT, OUTPUT, AND PROGRAM DOCUMENTATION FOR PROFILE

This appendix describes the input, output, and program structure of the PROFILE model. The reader should refer to Chapter 12 for a discussion of the model itself. This appendix has been written assuming that the reader is familiar with the material in Chapter 12 pertaining to the model.

B.1 PROGRAM INPUT REQUIREMENTS

PROFILE inputs are divided into four groups of cards:*

- Title card
- Parameter card
- Track section cards
- Car description cards.

The formats of these cards are given in Table B-1, a listing of a sample PROFILE input is given in Exhibit B-1, found at the end of this appendix. All fields on all cards, excepting alphanumeric titling information, are 10-columns wide. This greatly simplifies the user's preparation of input. Table B-1 is largely self-explanatory; however, elaboration will be given where warranted.

B.1.1 Parameter Cards

The parameters specified on card type 2 are general: the time step Δt, the hump speed, the data print interval, switches controlling printing of tables and plots, and the printer width (in characters). To model event occurrences accurately, the time step chosen should be sufficiently small but not too small as to cause an inordinate increase in running time. One second is usually satisfactory. However, users requiring the utmost accuracy can make this parameter as small as 0.01 second without experiencing an undue increase in execution time.† The output frequency of the car history tables and time-space diagram are controlled by the data print interval variable, which should be chosen in integral multiples of the time step but should never be less than the time step.

The parameters ITABLE and IPLOT specify selection of the output options. Specifying ITABLE=1 generates a numerical output table for each simulated car. Specifying IPLOT=1 produces three plots and a time-space diagram, all on the printer. Either parameter can be set to zero; however, specifying both parameters as zero results in ITABLE being set to 1 and IPLOT to zero. The parameter MTSPA is effective only when IPLOT=1. It allows the user to set an upper limit on

TABLE B-1.-PROFILE INPUT FORMATS

Cols.	Variable	Type	Description
Card Type 1: Title Card			
1-80	TITLE	A	Any title information for the run
Card Type 2: General Simulation Parameters			
1-10	DELT	F	Time step, Δt, seconds.
11-20	HMPSPD	F	Hump speed, miles per hour.
21-30	PRNTYM	F	Data print interval, seconds.
31-40	ITABLE	I	Table output switch (1 = print).
41-50	IPLOT	I	Plot output switch (1 = print).
51-60	ICHAR	I	Printer page width (characters).
61-70	MTSPA	I	Maximum number of time-space diagrams to be drawn (0 entry = no limit).
Card Type 3: Track Section Geometric Data (1st Card)			
1-10	TLNGTH	F	Length of track section, feet.
11-20	GRADE	F	Grade of track, percent (if a vertical curve, field must be blank, not zero).
21-30	RS(1)	F	Rolling resistance, static, easy-rolling car, (lb/ton).
31-40	RS(2)	F	Rolling resistance, static hard-rolling car, (lb/ton).
41-50	RV(1)	F	Rolling resistance, velocity, easy-rolling car, (lb/ton)/(ft/s).
51/60	RV(2)	F	Rolling resistance, velocity, hard-rolling car, (lb/ton)/(ft/s).
61-70	RC	F	Horizontal curve resistance (lb/ton).
Card Type 3: Track Section Geometric Data (2nd Card)			
1-10	SWLOSS	F	Switch loss (feet of velocity head).
11-20	DVH(1)	F	Velocity head to be extracted by retarder from car 1, feet.
21-30	DVH(2)	F	Velocity head to be extracted by retarder from car 2, feet.
31-40	DVH(3)	F	Velocity head to be extracted by retarder from car 3, feet.
41-50	RETMAX	F	Maximum retardation of the retarder, feet of velocity head.
51-80	DESCR	A	Any desired alphanumeric descriptive information
Note: For each track section prepare a pair of cards of type 3. A maximum of 120 track sections is allowed. The set of track section cards must be followed by two blank cards.			

*In this discussion the input data will be referred to as if it were on cards. Of course, it is realized that in most modern time-sharing computer environments such input would be maintained on a card image disk file.

†When a Δt of 1 second is used, the vast majority of the computer time is used performing output. Decreasing Δt to 0.01 seconds only approximately doubles running time.

TABLE B-1.-CONCLUDED

Cols.	Variable	Type	Description
Card Type 4: Car Data			
1-10	ITYPE	I	Type of roller, 1 = easy, 2 = hard.
11-20	CARL	F	Car length, feet.
21-30	WHEELB	F	Car wheelbase, feet.
31-40	WEIGHT	F	Weight of car, tons.
41-50	XIG	F	Equivalent rotational weight of all the wheels, tons.
51-60	WINDRS	F	Wind resistance, static (lb/ton).
61-70	WINDRV	F	Wind resistance, velocity (lb/ton)/(ft/s).
Note: One card for each car. A maximum of 3 cars is allowed. After the last car, one blank card is required.			

the number of time-space diagram segments produced (see Section B.2 for a description of the time-space diagrams). The parameter ICHAR facilitates obtaining the plotted outputs on a standard narrow-carriage 80-column terminal. If ICHAR is specified as 80, all printer plots will be formatted for 80-column width; specifying ICHAR as 132 formats all outputs for the standard wide-carriage line printer.*

B.1.2 Track Section Geometric Data

The track geometric data, card type 3, comprise the bulk of the user input. The user must supply a pair of cards of this type for each track section. A maximum of 120 track sections are permitted. The geometric data coding sheets for card type 3, given in Figures B-1 and B-2, have proven invaluable in numerous yard profile studies.

The GRADE parameter field, if left blank, indicates that the track section is part of a vertical curve. A single vertical curve may consist of more than one track section; of course, all the track sections comprising the vertical curve must be contiguous. No matter how many track sections comprise the single vertical curve, only a single parabolic curve is used. Note that special logic is included in PROFILE to detect a blank GRADE field—coding a zero in this field specifies a zero (i.e., perfectly flat) grade, not a vertical curve.

PROFILE can optionally simulate each car's breakaway in the vicinity of the hump crest. The selection of this option is signalled to the program by coding the first track section with a negative (i.e., uphill) or zero (i.e., flat) grade. This grade must then be followed by a track section with the GRADE field blank, indicating the crest vertical curve. The crest vertical curve must then be followed by a track section with a positive (i.e., downhill) grade. The minus, blank, and positive grade sections entered as above need not be single sections. However, all characteristics affecting a car's rolling behavior, excepting the grades as specified above, must remain constant within the crest area or the program will detect an error. Also, the departing grade from the crest must be steep enough to accelerate the hardest rolling car. If the first track section specified has a positive grade, the program bypasses the crest computations and starts each car as a free body exactly at the beginning of this section.

The static and velocity resistances are specified separately for each track section for the two types of cars, easy-roller or hard-roller. Specifying rolling resistances in this manner allows them to vary along the length of the simulated track.

The curve loss is specified in terms of its equivalent resistance in lbs/ton. If the curve loss is expressed in feet of head, this may be converted to the equivalent resistance by

$$c_r = 2000 \frac{C_L}{L} \quad , \qquad \text{(B.1)}$$

where c_r = curve loss as an equivalent resistance in lb/ton,

C_L = curve loss in terms of velocity head, ft,

L = total length of the curve, ft.

The total length of the curve used in the above computation will often extend across many track sections, in which case L is the sum of the individual track section lengths. The quantity c_r computed as above is then entered as one common value in the curve resistance fields for all track sections on the curve. Entering curve loss in the above manner emphasizes that a curve loss is spread out as a resistance along the length of the curve.

The switch loss occurs almost at a point; consequently it is entered as a velocity head loss over a short section of track. If one assumes that the loss takes place entirely at the switch point, the switch loss track section should be located there; similarly if one assumes the loss takes place entirely at the frog, the switch loss track section should be located there. In either case, the switch loss track section should be coded as a very short section; in all applications of the model a 1-ft section has been used for this purpose. Two switch loss sections, one for the point and one for the frog, may be entered if desired. Losses due to a change of a car's direction when it takes the curve may be entered separately as an equivalent curve resistance.

Parameters pertaining to retardation are required as shown. These parameters are entered only for retarder track sections; for other track sections these fields should be left blank. It is the user's responsibility to select the amount of retardation to be applied to each simulated car. No retarder logics are simulated in PROFILE. A separate field is provided to enter the retardation applied to each simulated car. Entering the retardation in this manner permits the flexibility to test retardation schemes where two identical cars (e.g., both easy-rollers) are retarded differently.

The last field in the track geometry cards is an optional alphanumeric title or name for the track section. It can contain any desired characters. This field is printed as a location identifier on each line in the car history tables, greatly facilitating the examination of these outputs. For this reason, it is recommended that the user make the effort to select unique and useful names for each track section.

*More precisely, any value for NCHAR less than 132 results in the three plots being formatted for 80 columns; any value less than 110 results in the time-space diagram being formatted for 80 columns.

PROFILE YARD GEOMETRIC DESIGN DESCRIPTION – FIRST CARD OF CARD TYPE 3 PAIR

LENGTH OF TRACK SECTION (FEET)	GRADE OF TRACK SECTION (PERCENT)	STATIC ROLLING RESISTANCE, EASY ROLLER (LB/TON)	STATIC ROLLING RESISTANCE, HARD ROLLER (LB/TON)	VELOCITY ROLLING RESISTANCE, EASY ROLLER (LB/TON)/(FT/SEC)	VELOCITY ROLLING RESISTANCE, HARD ROLLER (LB/TON)/(FT/SEC)	HORIZONTAL CURVE RESISTANCE (LB/TON)	
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69 70	71 72 73 74 75 76 77 78 79 80

FIGURE B-1. CODING SHEET FOR PROFILE YARD GEOMETRIC DATA – PART 1

PROFILE YARD GEOMETRIC DESCRIPTION – SECOND CARD OF CARD TYPE 3 PAIR

SWITCH LOSS (FT. OF VEL. HEAD)	VELOCITY HEAD EXTRACTED FROM CAR 1 (FEET)	VELOCITY HEAD EXTRACTED FROM CAR 2 (FEET)	VELOCITY HEAD EXTRACTED FROM CAR 3 (FEET)	MAXIMUM RETARDATION OF THE RETARDER (FEET)	SECTION DESCRIPTION
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
1 2 3 4 5 6 7 8 9 10	11 12 13 14 15 16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31 32 33 34 35 36 37 38 39 40	41 42 43 44 45 46 47 48 49 50	51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

FIGURE B-2. CODING SHEET FOR PROFILE YARD GEOMETRIC DATA – PART 2

B.1.3 Car Data

Additional data for the cars constitute the final set of information specified to the program. First, the type of car must be specified (easy- or hard-rolling). Then the car length and wheelbase must be specified. The wheelbase is used only in the breakaway calculations at the crest. It must be greater than zero, but must not exceed the car length. If either of the preceding is violated or if the wheelbase field is blank, it is set equal to the car length.

Next, the car's weight and an extra weight to reflect wheel rotation are specified, both in tons. This additional weight reflects the rotational energy of the wheels and axles (flywheel effect) as discussed in Section 12.1.3.1. Leaving the additional weight field blank is the same as setting this weight to zero, and the effect of the rotating wheels and axles is neglected.

In addition to the static and velocity-dependent rolling resistances that may vary with each track section (and so were entered to the model on the Track Section Geometric Data Cards), each car is associated with optional static (lb/ton) and velocity-dependent (lb/ton per ft/s) wind-resistance terms. These values may vary depending on the type of car (box car, flat car, gondola, etc.).

B.2 PROFILE OUTPUT

This section describes the output available from the PROFILE program. A complete sample output is contained in Exhibit B-2. This output corresponds to the input given in Exhibit B-2, and is based on a modification of an actual profile design proposed for CONRAIL's Elkhart Yard.

The output from PROFILE is divided essentially into four parts:

- Echo-back of input data
- Error messages and undesirable events occurring during simulation
- Car history tables
- Graphical outputs.

These output types occur essentially in the order listed.* Each of these will now be discussed in turn.

B.2.1 Echo-Back of Input Data

The first two (or more) pages of the PROFILE simulation output consist primarily of an echo-back of the input data supplied to the model by the user. This echo-back is presented in a carefully annotated manner, and can serve to identify the details of the simulated design and run. This output can stand by itself, with little or no need to refer to the input format information of Section B.1.

The model control parameters comprise the first page of the echo-back; these are shown in the top portion of the first page of Exhibit B-2.

The specified track geometric data comprise the bulk of the echo-back. These data are arranged into a table starting on the first page of the output immediately below the parameter information. The information in this table is nearly identical to that specified on card type 3 of the input, except that the track sections are numbered and accumulative distances to the end of each section are given for user convenience. Each pair of input cards of type 3 become a single line in this table.

If the dynamics at the hump crest are being simulated, the location of the hump crest as calculated by the program is given immediately following the geometric data table. This distance is referenced to the beginning of the first track section.

The last portion of the echo-back consists of the characteristics of cars that are to be simulated, except for track section-dependent rolling resistances, which were given earlier with the track data. Appended to the echo-back of the car data are the computed breakaway point location and the downward offset of the car's center of gravity relative to the crest elevation. These are, respectively, the distances B and δ_c in Figure 12-23. Under certain geometric conditions the breakaway point can occur prior to the hump crest; when this occurs, the breakaway point value outputted is negative. If the dynamics at the hump crest are not being simulated, zeros are output in these two fields.

B.2.2 Errors and Undesirable Events

Immediately after the car data (on the same page) is found a list of user errors detected or undesirable events that may have occurred during the course of the simulation. The latter information comprises the first part of the simulation output proper. For example, in Exhibit B-2, reports of a catch-up within one control section of a retarder, and of a collision between two cars can be seen. The simulation is halted if a collision between two cars occurs, or if a car stops; the program then proceeds to produce the outputs.

User errors detected by the program may also be reported here. In some cases these are only warnings; the program makes a logical assumption and continues its calculations. In other cases, the detected error is fatal; the program will refuse to proceed any further until the user rectifies the error. In the latter case, no further output is produced by the program.

B.2.3 Car History Tables

These tables comprise the bulk of the numerical output from the PROFILE simulation. One table, often several pages long, is printed for each car. This table is quite important, since the user will usually have to obtain numerical quantities from this table in order to decide upon the configuration of inputs specifying the next PROFILE run.

Examples of these tables can be seen in Exhibit B-2. These tables give the position of each car at uniform, user-specified intervals of time. Additionally, the positions of the cars are reported at every track section boundary. Each row contains pertinent information giving a complete status of the named car. The information reported includes car travel time (time since the reported car crested the hump), system time (time since the first car crested the hump), distance of the car's center of gravity from the hump crest, time and distance headways to the preceding car,+ instantaneous

*In some cases, the error messages may be intermixed among the car data echo-back lines.

+Time and distance headways reported by the model are from the trailing coupler of the lead car to the leading coupler of the trailing car.

velocity and velocity head, and the track section location of the car's center of gravity.

B.2.4 Graphical Outputs

Optional graphical outputs are produced on the line printer or terminal by PROFILE. Although this means of producing these outputs is quick, the user is cautioned that the resolution of the medium is low. Nonetheless, these graphical outputs are useful in obtaining a quick grasp of the behavior of the cars in the run.

The first plot shows the yard profile--distance from the start of track Section 1 being given across the page, and elevation below the crest being given down the page. The hump crest is evident in this plot in Exhibit B-2.

The second plot graphs the speed of each simulated car as a function of its distance. As above, distance is shown across the page; velocity is plotted down the page. In this plot in Exhibit B-2 note: (1) the constant speed of the cars until they breakaway from the cut, (2) the sudden drops in the speeds, signifying retardation.

The third plot shows the headways between successive cars (down the page) as a function of distance (across the page). One of the most important objectives of the hump design process is to control these headways. In a glance this plot shows how well this objective has been achieved. Car 3 catching car 2 is evident in this plot in Exhibit B-2 as the point where the curve, labelled "3", goes to zero. Note also the zero headways in the origin area of the plot. These reflect the zero headways while the cars are still connected in the cut.

The last plot produced is a time-space diagram. This plot shows distance across the page at a fixed scale of 1 space = 10 ft, and time down the page at a scale such that each line is equal to the data print interval of the Car History Tables discussed above. In this plot, each car will be graphed as a zone of several spaces (e.g., 6 spaces for a 60-ft car) representing the length of the car. The "empty" horizontal gaps between the cars represent the (coupler-to-coupler) distance headways, and the vertical gaps the (coupler-to-coupler) time headway.

In order to preserve sufficient resolution, the time-space diagram is of necessity printed in several pieces. First, the distance segment from 0 to 1000 feet* is printed, extending across as many pages as necessary to include all of the last car's "time-space trajectory." Then the distance segment from 100 to 2000 feet† is printed in the same manner. As many plots as necessary are printed so as to include all of each car's time-space trajectory. The user, if desired, may limit the number of distance segments printed via the parameter MTSPA on card type 2. When this is done, segments are printed starting from distance 0 until the limit is exceeded.

For all distance segments plotted, lines for which no cars would be in that segment of the diagram are not printed. In Exhibit B-2, for example, the second segment of the time-space diagram starts at system time 80 seconds--the time the leading coupler of the first simulated car passed the 1000-ft point.

---

*0 to 700 feet if the output is formatted for an 80-column terminal.

†700 to 1400 feet if the output is formatted for an 80-column terminal.

B.3 THE PROFILE PROGRAM

This section describes the implementation of the PROFILE model as a computer program.

B.3.1 General

The PROFILE program is written in near ANSI Fortran IV. With little or no modification, it should be executable on any modern computer system having a moderate-sized memory. It has been run on a CDC 6400, where it required approximately 102,000 octal words of memory. It executes very fast; a typical running time for the three-car 1.0-second Δt simulation shown in Exhibit A-2 is about 10 seconds. The approximate running time for the same run on an IBM 3033 should be about 1.0 seconds.

Some small differences exist between CDC and IBM versions of the program. Table B-2 documents these differences. This table can also serve as a guide to programmers implementing PROFILE on other manufacturers' computers.

PROFILE uses only the standard input and output files. These are indicated in Table B-3.

B.3.2 The PROFILE Subprograms

This section discusses each of the PROFILE subprogram modules. PROFILE consists of 12 subprogram modules, including the main program, but excluding system-defined I/O subprograms and compiler intrinsic functions (such as IABS and, in the case of the CDC version, the dummy functions mentioned in Table B-2). These 12 subprograms and their interrelationships are shown in Figure B-3. The action of each of these subprograms is now briefly described. Detailed information and documentation is contained within the program itself.

B.3.2.1 Main Program PROFYL

The name of the main subprogram, PROFYL, is a phonetic shortening of the overall program name PROFILE. All names in PROFILE are restricted to, at most, six characters, in keeping with ANSI standards.

The bulk of the computations in the program are performed in this main subprogram. However, a number of common and repetitive calculations are done in several utility subroutines. The structure of the main PROFYL subprogram, which is identical to the structure of the model as a whole, is diagrammed in simplified form in Figure B-4.

B.3.2.2 Subroutine EXMCST

This subroutine is used only when the breakaway calculations are being performed at the crest. It explores the inputted geometric data to establish the crest area geometry and sets up variables defining this geometry. It also checks the geometry and the car's resistances for correctness and for conformance with the assumptions used in the crest breakaway calculations.

B.3.2.3 Subroutine CREST

This subroutine is used only when the breakaway calculations are being performed at the crest. It controls the iterative calculations (using subroutine INTHAF) which locate each car's breakaway point at the crest, and sets up arrays defining this behavior.

TABLE B-2.-DIFFERENCES BETWEEN CDC AND IBM VERSIONS OF PROFILE

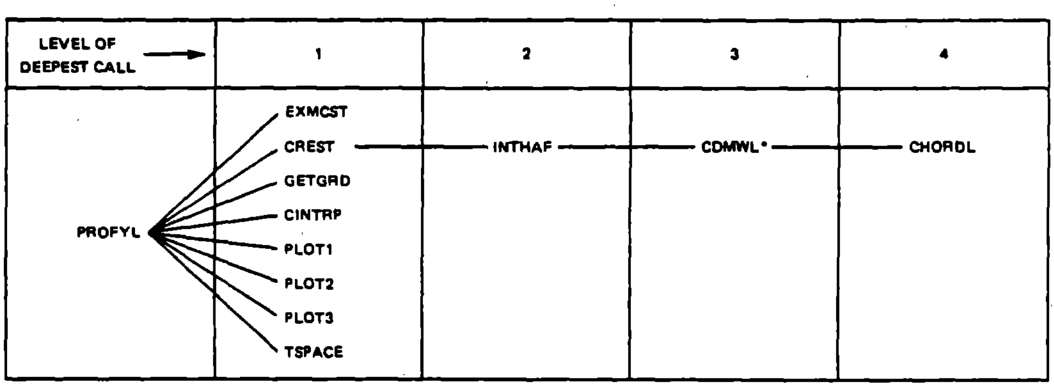
CDC	IBM
• All statements: "bbbbbbDOUBLE PRECISION..." should be converted to comments: "CbbbbbDOUBLE PRECISION..." globally throughout the program deck. The large, 60-bit CDC word size has sufficient precision for all calculations.	• All comment statements: "CbbbbbDOUBLE PRECISION..." should be converted to: "bbbbbbDOUBLE PRECISION..." globally throughout the program deck. The small, 32-bit IBM word size has insufficient precision for certain calculations.
• Dummy single precision functions substituting for double precision ones must be added as follows: DEXP, DSQRT. They must all be listed in "EXTERNAL..." statements in all subprograms that reference them.	• Remove the dummy functions DEXP and DSQRT—the standard Fortran functions with these names are used. Remove all references to DEXP and DSQRT from "EXTERNAL..." statements.
• Hollerith fields in format statements should all be delimited by double quotes ("): Convert all single quotes (') globally throughout program deck.	• Hollerith fields in format statements should all be delimited by single quotes ('): Convert all double quotes (") to single quotes (') globally throughout program deck.
• Main program name card specifying all files used is required: Statement "CbbbbbPROGRAM PROFILE..." should be converted to "bbbbbbPROGRAM PROFILE..."	• Main program name card not allowed: Statement "bbbbbbPROGRAM PROFILE..." should be converted to comment "CbbbbbPROGRAM PROFILE..."

Notes: (1) b denotes a blank column.

(2) Main program name card should be left in as a comment in IBM version, as it serves to identify the program and to specify all files used.

TABLE B-3.-PROFILE FILE USAGE

File Number	Description
5	This is the input, card image file read by PROFILE.
6	This is the output, line printer formatted file produced by PROFILE. It contains carriage control characters in column 1.



Notes:
*Call to function CDMWL is passed to subroutine INTHAF as an argument by subroutine CREST.

FIGURE B-3. PROFILE SUBPROGRAMS AND CALLING HIERARCHY

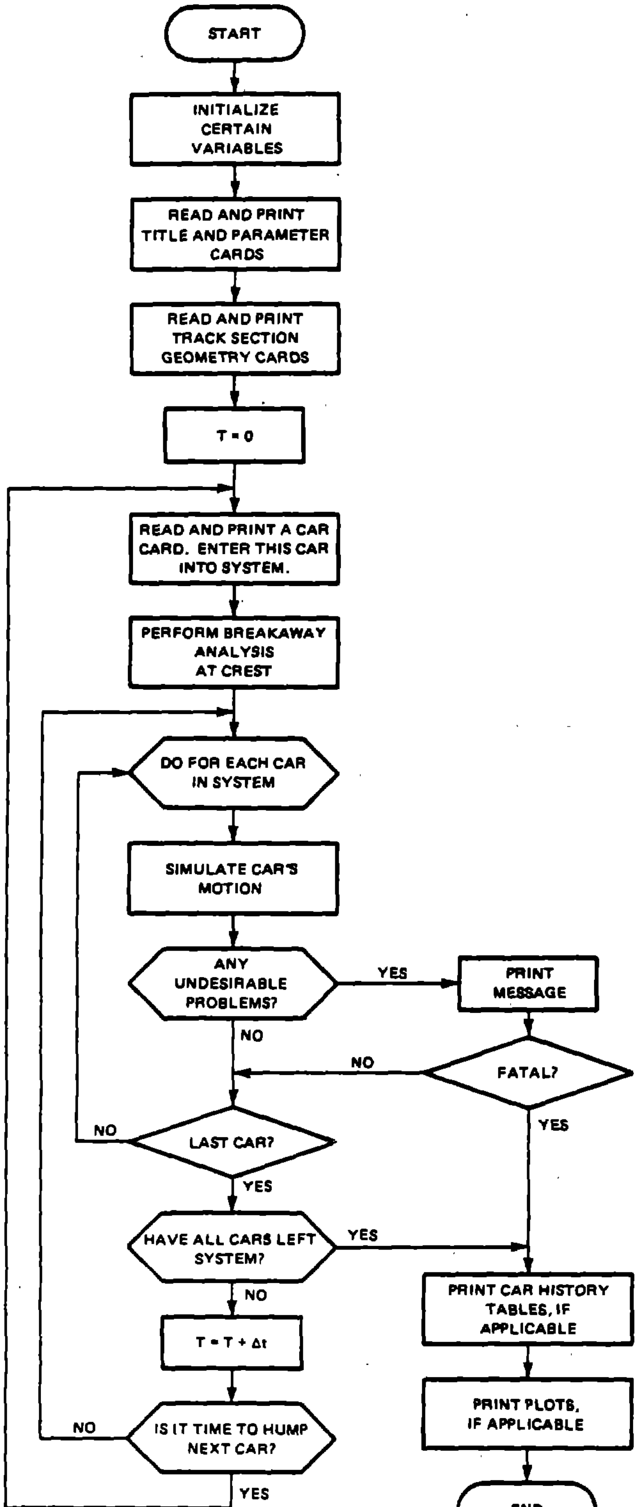


FIGURE B-4. SIMPLIFIED FLOWCHART OF MAIN SUBPROGRAM PROFYL

B.3.2.4 Subroutine INTHAF

This subroutine is a general purpose algorithm for locating a zero of an arbitrary function on a bounded interval containing a single zero. The algorithm operates by reducing the interval size at each iteration by a factor of 2. The portion of the interval retained at each iteration is that which is found to contain the root.

B.3.2.5 Function CDMWL

To find a car's breakaway point, the chord whose slope is equal to the car's resistance and whose length equals the car's wheelbase must be found. Function CDMWL converts the above problem into one of finding the root of a function. Using a trial location for the center of the car's trailing truck as the independent variable, the chord length is found by calling function CHORDL. The problem is then converted into one of finding a zero by subtracting the car's wheelbase from the length of the trial chord.

B.3.2.6 Function CHORDL

This function, given the crest geometry, finds the length of a chord joining two points on the top of rail profile. The chord has a slope equal to the car's resistance. The chord length is found as a function of a trial location for the center of the car's trailing truck.

B.3.2.7 Subroutine GETGRD

This subroutine computes the instantaneous grade at any point on a vertical curve section as a function of distance.

B.3.2.8 Subroutine CINTRP

This utility subroutine performs an interpolation to find the value of a continuous function (y) at an intermediate point x, and the derivative of that function (y') at that point, given function values y_1 and y_2, and the derivatives y_1' and y_2' at two known bounding points x_1 and x_2. The interpolation is performed by fitting a cubic polynomial to the known data.

B.3.2.9 Subroutine PLOT1

This subroutine is called once per plot to define the scope of a plot which is actually to be drawn later by subroutine PLOT3. Subroutines PLOT1, PLOT2, and PLOT3 communicate among themselves using data stored in the common block PLOT. Collectively, these three subroutines control the plotting of (1) the yard profile, (2) the simulated cars' speeds, and (3) the simulated headways between cars.

B.3.2.10 Subroutine PLOT2

This subroutine is called once per plotted point to enter the point to be plotted as data into the PLOT common block.

B.3.2.11 Subroutine PLOT3

This subroutine is called once per plot to actually draw the plot out on the line printer, using data that have been stored in the common block PLOT by subroutines PLOT1 and PLOT2.

B.3.2.12 Subroutine TSPACE

This subroutine "draws" the time-space diagram on the line printer. This is done using car history data stored in certain car history arrays by the PROFYL main program.

Exhibit B-1

SAMPLE PROFILE INPUT LISTING CORRESPONDING TO SAMPLE OUTPUT IN EXHIBIT B-2

```
PROFILE DEMONSTRATION RUN
     1.        2.5        1.          1          1        132
   20.0       -2.0       2.00       18.00
                                                   APPROACH TO CREST
   80.0                  2.00       18.00
                                                   CREST VC
   10.0       3.00       2.00       18.00
                                                   EVC TO SCALE
  105.0        3.0       2.00       18.00
                                                   SCALE
    10.        3.5       2.00       18.00
                                                   SCALE TO K SW
    1.0        4.0       2.00       18.00                      10.81
   .025                                            KING SW
   42.0        4.0       2.00       18.00                      10.81
                                                   KSW 1 E SW1
    8.0        4.0       2.00       18.00
                                                   KSW TO BHC1
   50.0        4.0       2.00       18.00
                                                   BHC1 TO EHC1
   34.0        4.0       2.00       18.00                       6.55
                                                   HC1 TO BVC2
   10.0        4.0       2.00       18.00
                                                   BVC2 TO MASTER
   66.0        4.0       2.00       18.00
              4.61       4.62        4.61     4.62MASTER 1
  115.5        4.0       2.00       18.00
              1.43       5.76        1.43     8.40MASTER 2
   29.0                  2.00       15.00
                                                   MASTER TO SW2
    1.0        .50       2.00       15.00                      12.55
   .025                                            SW 2
   50.0        .50       2.00       15.00                      12.55
                                                   SW2 TO ESW2
  134.0        .50       2.00       15.00                      10.00
                                                   ESW2 TO TAN ESW
   50.0        .50       2.00       15.00
                                                   EHC2 TO TANESW
   68.0        .50       2.00       15.00
                                                   TAN ESW TO ESCAPE SW
    1.0        .50       2.00       15.00
   .025                                            ESCAPE SW
   15.0        .50       2.00       15.00
                                                   ESCAPE SW TO BVC3
   10.0                  2.00       15.00
                                                   BVC3 TO GP 8 RET
  115.5       1.18       2.00       15.00
              0.00       7.62        0.00     8.40GROUP RET.
   10.0                  2.00       12.00
                                                   GRP. RET. TO SW 3
    1.0        0.0       2.00       12.00                       7.64
   .025                                            SW 3
   50.0        0.0       2.00       12.00                       7.64
                                                   SW 3 TO ESW3
   45.0        0.0       2.00       12.00
                                                   ESW3 TO SW4
    1.0        0.0       2.00       12.00                      14.64
   .025                                            SW4
   42.0        0.0       2.00       12.00                      14.64
                                                   SW 4 TO ESW4
   46.0        0.0       2.00       12.00
                                                   ESW4 TO SW5
    1.0        0.0       2.00       12.00                       6.76
   .025                                            SW 5
   42.0        0.0       2.00       12.00                       6.76
                                                   SW 5 TO ESW5
   46.0        0.0       2.00       12.00
                                                   ESW5 TO CL
  314.0        0.0       2.00       12.00                       6.61
                                                   CL PT TO TAN PT
  200.0        .15       2.00       12.00
                                                   TAN PT TO INERT RET

      2        60.        55.         30.        1.
      1        60.        55.         70.        1.
      2        60.        55.         30.        1.
```

Exhibit B-2

SAMPLE PROFILE OUTPUT LISTING CORRESPONDING TO SAMPLE INPUT IN EXHIBIT B-1

SRI HUMP PROFILE SIMULATION - PROFILE DEMONSTRATION RUN

SIMULATION TIME STEP, DELTA T, SEC	1.0000
HUMP SPEED, MILES PER HOUR	2.5000
DATA PRINT INTERVAL, SEC	1.00
TABLE SWITCH	1
PLOT SWITCH	1
PRINTER WIDTH (CHARACTERS)	132
MAXIMUM NUMBER OF TIME-SPACE DIAGRAMS	-0

T R A C K   D A T A

TRK SEC NO.	LENG (FT)	CUM. LENG (FT)	GRADE (PCT)	RESISTANCES: ROLLING: STATIC (LB/TON) EASY	STATIC (LB/TON) HARD	VELOCITY (LB/TON)/(FT/SEC) EASY	VELOCITY (LB/TON)/(FT/SEC) HARD	HORIZ. CURVE (LB/T)	SWITCH LOSS (FT OF VELOC. HEAD)	RETARDATION (FT. OF VEL. HEAD) CAR 1	CAR 2	CAR 3	MAX. RETARDATION (FT OF VELOC. HEAD)	DESCRIPTION
1	20.0	20.0	-2.00	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	APPROACH TO CREST
2	80.0	100.0	VC	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	CREST VC
3	10.0	110.0	3.00	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	EVC TO SCALE
4	105.0	215.0	3.00	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	SCALE
5	10.0	225.0	3.50	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	SCALE TO K SW
6	1.0	226.0	4.00	2.00	18.00	-0.00	-0.00	10.81	.03	-0.00	-0.00	-0.00	-0.00	KING SW
7	42.0	268.0	4.00	2.00	18.00	-0.00	-0.00	10.81	-0.00	-0.00	-0.00	-0.00	-0.00	KSW 1 E SW1
8	8.0	276.0	4.00	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	KSW TO BHC1
9	50.0	326.0	4.00	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	BHC1 TO EHC1
10	34.0	360.0	4.00	2.00	18.00	-0.00	-0.00	8.65	-0.00	-0.00	-0.00	-0.00	-0.00	HC1 TO BVC2
11	10.0	370.0	4.00	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	BVC2 TO MASTER
12	66.0	436.0	4.00	2.00	18.00	-0.00	-0.00	-0.00	-0.00	4.61	4.62	4.61	4.62	MASTER 1
13	115.5	551.5	4.00	2.00	18.00	-0.00	-0.00	-0.00	-0.00	1.43	5.78	1.43	8.40	MASTER 2
14	29.0	580.5	VC	2.00	15.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	MASTER TO SW2
15	1.0	581.5	.50	2.00	15.00	-0.00	-0.00	12.55	.03	-0.00	-0.00	-0.00	-0.00	SW 2
16	50.0	631.5	.50	2.00	15.00	-0.00	-0.00	12.55	-0.00	-0.00	-0.00	-0.00	-0.00	SW2 TO ESW2
17	134.0	765.5	.50	2.00	15.00	-0.00	-0.00	10.00	-0.00	-0.00	-0.00	-0.00	-0.00	ESW2 TO TAN ESW
18	50.0	815.5	.50	2.00	15.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	EHC2 TO TANESW
19	68.0	883.5	.50	2.00	15.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	TAN ESW TO ESCAPE SW
20	1.0	884.5	.50	2.00	15.00	-0.00	-0.00	-0.00	.03	-0.00	-0.00	-0.00	-0.00	ESCAPE SW
21	15.0	899.5	.50	2.00	15.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	ESCAPE SW TO BVC3
22	10.0	909.5	VC	2.00	15.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	BVC3 TO GP 8 RET
23	115.5	1025.0	1.18	2.00	15.00	-0.00	-0.00	-0.00	-0.00	0.00	7.62	0.00	8.40	GROUP RET.
24	10.0	1035.0	VC	2.00	12.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	GRP. RET. TO SW 3
25	1.0	1036.0	0.00	2.00	12.00	-0.00	-0.00	7.84	.03	-0.00	-0.00	-0.00	-0.00	SW 3
26	50.0	1086.0	0.00	2.00	12.00	-0.00	-0.00	7.84	-0.00	-0.00	-0.00	-0.00	-0.00	SW 3 TO ESW3
27	45.0	1131.0	0.00	2.00	12.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	ESW3 TO SW4
28	1.0	1132.0	0.00	2.00	12.00	-0.00	-0.00	14.64	.03	-0.00	-0.00	-0.00	-0.00	SW4
29	42.0	1174.0	0.00	2.00	12.00	-0.00	-0.00	14.64	-0.00	-0.00	-0.00	-0.00	-0.00	SW 4 TO ESW4
30	46.0	1220.0	0.00	2.00	12.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	ESW4 TO SW5
31	1.0	1221.0	0.00	2.00	12.00	-0.00	-0.00	6.76	.03	-0.00	-0.00	-0.00	-0.00	SW 5
32	42.0	1263.0	0.00	2.00	12.00	-0.00	-0.00	6.76	-0.00	-0.00	-0.00	-0.00	-0.00	SW 5 TO ESW5
33	46.0	1309.0	0.00	2.00	12.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	ESW5 TO CL
34	314.0	1623.0	0.00	2.00	12.00	-0.00	-0.00	6.61	-0.00	-0.00	-0.00	-0.00	-0.00	CL PT TO TAN PT
35	200.0	1823.0	.15	2.00	12.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	TAN PT TO INERT RET

HUMP CREST = 52.0 CUM. LENG (FT)

C A R   D A T A

TYPE OF ROLLER, 1 = EASY, 2 = HARD

CAR NO.	TYPE ROLLER	CAR LENGTH (FT)	CAR WHEELB (FT)	WEIGHT OF CAR (TONS)	EXTRA WEIGHT WHEEL ROTATION (TONS)	WIND RESIS STAT (LB/T)	WIND RESIS VELOC (LB/T)/(FPS)	COMPUTED BREAKAWAY POINT REL TO CREST (FT)	COMPUTED DOWNWARD C. G. OFFSET (FT)
1	2	60.00	55.00	30.00	1.00	-0.00	-0.00	14.40	.301
2	1	60.00	55.00	70.00	1.00	-0.00	-0.00	1.60	.237
3	2	60.00	55.00	30.00	1.00	-0.00	-0.00	14.40	.301

WARNING - CARS 1 AND 2 CATCH UP IN RETARDER, TRACK SECTION = 23

A COLLISION OCCURRED AT TIME 120.83 SEC. BETWEEN
CAR 2 - VEL = 2.12 MPH, DIST = 1179.08 FT., TIME ON TRACK = 104.17 SEC.
CAR 3 - VEL = 12.11 MPH, DIST = 1119.08 FT., TIME ON TRACK = 87.81 SEC.

CAR NO. 1

CAR TRAVEL TIME (SEC)	SYSTEM TIME (SEC)	DISTANCE ALONG TRACK (FT)	DISTANCE HEADWAY BETWEEN PREC CAR (FT)	TIME HEADWAY BETWEEN PREC CAR (SEC)	INSTANTANEOUS VELOCITY (FT/SEC)	INSTANTANEOUS VELOCITY (MPH)	VELOCITY HEAD (FT)	TRACK SECTION NUMBER	TRACK SECTION DESCRIPTION
0.000	0.000	0.000	NA	NA	3.667	2.500	.216	0/ 1	****TRACK SECTION BOUNDARY****
1.000	1.000	3.667	NA	NA	3.667	2.500	.216	1	APPROACH TO CREST
2.000	2.000	7.333	NA	NA	3.667	2.500	.216	1	APPROACH TO CREST
3.000	3.000	11.000	NA	NA	3.667	2.500	.216	1	APPROACH TO CREST
4.000	4.000	14.667	NA	NA	3.667	2.500	.216	1	APPROACH TO CREST
5.000	5.000	18.333	NA	NA	3.667	2.500	.216	1	APPROACH TO CREST
5.455	5.455	20.000	NA	NA	3.667	2.500	.216	1/ 2	****TRACK SECTION BOUNDARY****
6.000	6.000	22.000	NA	NA	3.667	2.500	.216	2	CREST VC
7.000	7.000	25.667	NA	NA	3.667	2.500	.216	2	CREST VC
8.000	8.000	29.333	NA	NA	3.667	2.500	.216	2	CREST VC
9.000	9.000	33.000	NA	NA	3.667	2.500	.216	2	CREST VC
10.000	10.000	36.667	NA	NA	3.667	2.500	.216	2	CREST VC
11.000	11.000	40.333	NA	NA	3.667	2.500	.216	2	CREST VC
12.000	12.000	44.000	NA	NA	3.667	2.500	.216	2	CREST VC
13.000	13.000	47.667	NA	NA	3.667	2.500	.216	2	CREST VC
14.000	14.000	51.333	NA	NA	3.667	2.500	.216	2	CREST VC
15.000	15.000	55.000	NA	NA	3.667	2.500	.216	2	CREST VC
16.000	16.000	58.667	NA	NA	3.667	2.500	.216	2	CREST VC
17.000	17.000	62.333	NA	NA	3.667	2.500	.216	2	CREST VC
18.000	18.000	66.000	NA	NA	3.667	2.500	.216	2	CREST VC
19.000	19.000	69.674	NA	NA	3.684	2.512	.218	2	CREST VC
20.000	20.000	73.387	NA	NA	3.743	2.552	.225	2	CREST VC
21.000	21.000	77.182	NA	NA	3.846	2.622	.237	2	CREST VC
22.000	22.000	81.102	NA	NA	3.994	2.723	.256	2	CREST VC
23.000	23.000	85.192	NA	NA	4.188	2.855	.281	2	CREST VC
24.000	24.000	89.501	NA	NA	4.430	3.021	.315	2	CREST VC
25.000	25.000	94.079	NA	NA	4.724	3.221	.358	2	CREST VC
26.000	26.000	98.977	NA	NA	5.073	3.459	.413	2	CREST VC
26.200	26.200	100.000	NA	NA	5.150	3.511	.426	2/ 3	****TRACK SECTION BOUNDARY****
27.000	27.000	104.252	NA	NA	5.481	3.737	.482	3	EVC TO SCALE
28.000	28.000	109.969	NA	NA	5.953	4.059	.569	3	EVC TO SCALE
28.005	28.005	110.000	NA	NA	5.956	4.060	.569	3/ 4	****TRACK SECTION BOUNDARY****
29.000	29.000	116.192	NA	NA	6.493	4.427	.677	4	SCALE
30.000	30.000	122.994	NA	NA	7.110	4.848	.811	4	SCALE
31.000	31.000	130.442	NA	NA	7.781	5.305	.972	4	SCALE
32.000	32.000	138.551	NA	NA	8.436	5.752	1.142	4	SCALE
33.000	33.000	147.314	NA	NA	9.090	6.198	1.326	4	SCALE
34.000	34.000	156.731	NA	NA	9.745	6.644	1.524	4	SCALE
35.000	35.000	166.803	NA	NA	10.399	7.090	1.735	4	SCALE
36.000	36.000	177.529	NA	NA	11.053	7.536	1.960	4	SCALE
37.000	37.000	188.909	NA	NA	11.708	7.983	2.199	4	SCALE
38.000	38.000	200.944	NA	NA	12.362	8.429	2.452	4	SCALE
39.000	39.000	213.633	NA	NA	13.016	8.875	2.719	4	SCALE
39.105	39.105	215.000	NA	NA	13.085	8.921	2.747	4/ 5	****TRACK SECTION BOUNDARY****
39.852	39.852	225.000	NA	NA	13.690	9.334	3.007	5/ 6	****TRACK SECTION BOUNDARY****
39.925	39.925	226.000	NA	NA	13.692	9.335	3.008	6/ 7	****TRACK SECTION BOUNDARY****
40.000	40.000	227.033	NA	NA	13.752	9.376	3.034	7	KSW 1 E SW1
41.000	41.000	241.183	NA	NA	14.549	9.920	3.397	7	KSW 1 E SW1

CAR NO. 1 (CONTINUED)

CAR TRAVEL TIME (SEC)	SYSTEM TIME (SEC)	DISTANCE ALONG TRACK (FT)	DISTANCE HEADWAY BETWEEN PREC CAR (FT)	TIME HEADWAY BETWEEN PREC CAR (SEC)	INSTANTANEOUS VELOCITY (FT/SEC)	INSTANTANEOUS VELOCITY (MPH)	VELOCITY HEAD (FT)	TRACK SECTION NUMBER	TRACK SECTION DESCRIPTION
42.000	42.000	256.131	NA	NA	15.347	10.464	3.779	7	KSW 1 E SW1
42.758	42.758	268.000	NA	NA	15.952	10.876	4.083	7/ 8	****TRACK SECTION BOUNDARY****
43.000	43.000	271.882	NA	NA	16.186	11.035	4.203	8	KSW TO BHC1
43.253	43.253	276.000	NA	NA	16.429	11.202	4.331	8/ 9	****TRACK SECTION BOUNDARY****
44.000	44.000	288.550	NA	NA	17.151	11.694	4.720	9	BHC1 TO EHC1
45.000	45.000	306.184	NA	NA	18.117	12.352	5.267	9	BHC1 TO EHC1
46.000	46.000	324.784	NA	NA	19.083	13.011	5.843	9	BHC1 TO EHC1
46.064	46.064	326.000	NA	NA	19.144	13.053	5.881	9/10	****TRACK SECTION BOUNDARY****
47.000	47.000	344.291	NA	NA	19.924	13.585	6.370	10	HC1 TO BVC2
47.776	47.776	360.000	NA	NA	20.570	14.025	6.790	10/11	****TRACK SECTION BOUNDARY****
48.000	48.000	364.635	NA	NA	20.787	14.173	6.933	11	BVC2 TO MASTER
48.257	48.257	370.000	NA	NA	21.034	14.342	7.099	11/12	****TRACK SECTION BOUNDARY****
49.000	49.000	385.303	NA	NA	20.135	13.728	6.505	12	MASTER 1
50.000	50.000	404.832	NA	NA	18.924	12.903	5.746	12	MASTER 1
51.000	51.000	423.151	NA	NA	17.713	12.077	5.035	12	MASTER 1
51.744	51.744	436.000	NA	NA	16.812	11.462	4.535	12/13	****TRACK SECTION BOUNDARY****
52.000	52.000	440.316	NA	NA	16.960	11.564	4.615	13	MASTER 2
53.000	53.000	457.568	NA	NA	17.540	11.959	4.937	13	MASTER 2
54.000	54.000	475.398	NA	NA	18.120	12.355	5.269	13	MASTER 2
55.000	55.000	493.808	NA	NA	18.701	12.750	5.611	13	MASTER 2
56.000	56.000	512.799	NA	NA	19.281	13.146	5.965	13	MASTER 2
57.000	57.000	532.370	NA	NA	19.861	13.542	6.329	13	MASTER 2
57.950	57.950	551.500	NA	NA	20.412	13.917	6.685	13/14	****TRACK SECTION BOUNDARY****
58.000	58.000	552.521	NA	NA	20.462	13.951	6.718	14	MASTER TO SW2
59.000	59.000	573.275	NA	NA	21.046	14.349	7.107	14	MASTER TO SW2
59.343	59.343	580.500	NA	NA	21.066	14.363	7.120	14/15	****TRACK SECTION BOUNDARY****
59.391	59.391	581.500	NA	NA	21.016	14.329	7.087	15/16	****TRACK SECTION BOUNDARY****
60 000	60.000	594.255	NA	NA	20.849	14.215	6.975	16	SW2 TO ESW2
61.000	61.000	614.968	NA	NA	20.576	14.029	6.793	16	SW2 TO ESW2
61.808	61.808	631.500	NA	NA	20.355	13.878	6.648	16/17	****TRACK SECTION BOUNDARY****
62.000	62.000	635.408	NA	NA	20.310	13.848	6.619	17	ESW2 TO TAN ESW
63.000	63.000	655.601	NA	NA	20.076	13.688	6.467	17	ESW2 TO TAN ESW
64.000	64.000	675.560	NA	NA	19.843	13.529	6.318	17	ESW2 TO TAN ESW
65.000	65.000	695.286	NA	NA	19.609	13.370	6.170	17	ESW2 TO TAN ESW
66.000	66.000	714.778	NA	NA	19.375	13.210	6.023	17	ESW2 TO TAN ESW
67.000	67.000	734.036	NA	NA	19.141	13.051	5.879	17	ESW2 TO TAN ESW
68.000	68.000	753.060	NA	NA	18.908	12.892	5.736	17	ESW2 TO TAN ESW
68.661	68.661	765.500	NA	NA	18.753	12.786	5.643	17/18	****TRACK SECTION BOUNDARY****
69.000	69.000	771.860	NA	NA	18.727	12.768	5.627	18	EHC2 TO TANESW
70.000	70.000	790.548	NA	NA	18.649	12.715	5.580	18	EHC2 TO TANESW
71.000	71.000	809.158	NA	NA	18.571	12.662	5.534	18	EHC2 TO TANESW
71.342	71.342	815.500	NA	NA	18.544	12.644	5.518	18/19	****TRACK SECTION BOUNDARY****
72.000	72.000	827.690	NA	NA	18.493	12.609	5.488	19	TAN ESW TO ESCAPE SW
73.000	73.000	846.145	NA	NA	18.415	12.556	5.441	19	TAN ESW TO ESCAPE SW
74.000	74.000	864.521	NA	NA	18.337	12.503	5.395	19	TAN ESW TO ESCAPE SW
75.000	75.000	882.819	NA	NA	18.259	12.450	5.350	19	TAN ESW TO ESCAPE SW
75.037	75.037	883.500	NA	NA	18.257	12.448	5.348	19/20	****TRACK SECTION BOUNDARY****
75.092	75.092	884.500	NA	NA	18.210	12.416	5.321	20/21	****TRACK SECTION BOUNDARY****

CAR NO. 1 (CONTINUED)

CAR TRAVEL TIME (SEC)	SYSTEM TIME (SEC)	DISTANCE ALONG TRACK (FT)	DISTANCE HEADWAY BETWEEN PREC CAR (FT)	TIME HEADWAY BETWEEN PREC CAR (SEC)	INSTAN-TANEOUS VELOCITY (FT/SEC)	INSTAN-TANEOUS VELOCITY (MPH)	VELOCITY HEAD (FT)	TRACK SECTION NUMBER	TRACK SECTION DESCRIPTION
75.817	75.817	898.500	NA	NA	18.145	12.372	5.283	21/22	====TRACK SECTION BOUNDARY====
76.000	76.000	901.000	NA	NA	18.140	12.368	5.280	22	SVC3 TO GP & RET
76.466	76.466	909.500	NA	NA	18.161	12.382	5.292	22/23	====TRACK SECTION BOUNDARY====
77.000	77.000	919.175	NA	NA	18.232	12.431	5.334	23	GROUP RET.
78.000	78.000	937.474	NA	NA	18.366	12.522	5.412	23	GROUP RET.
79.000	79.000	955.907	NA	NA	18.500	12.614	5.492	23	GROUP RET.
80.000	80.000	974.474	NA	NA	18.634	12.705	5.571	23	GROUP RET.
81.000	81.000	993.175	NA	NA	18.768	12.796	5.652	23	GROUP RET.
82.000	82.000	1012.010	NA	NA	18.902	12.888	5.733	23	GROUP RET.
82.686	82.686	1025.000	NA	NA	18.994	12.950	5.789	23/24	====TRACK SECTION BOUNDARY====
83.000	83.000	1030.978	NA	NA	19.016	12.966	5.802	24	GRP. RET. TO SW 3
83.212	83.212	1035.000	NA	NA	18.992	12.949	5.788	24/25	====TRACK SECTION BOUNDARY====
83.264	83.264	1036.000	NA	NA	18.935	12.910	5.753	25/26	====TRACK SECTION BOUNDARY====
84.000	84.000	1049.849	NA	NA	18.706	12.755	5.616	26	SW 3 TO ESW3
85.000	85.000	1068.396	NA	NA	18.399	12.544	5.431	26	SW 3 TO ESW3
85.965	85.965	1086.000	NA	NA	18.100	12.341	5.257	26/27	====TRACK SECTION BOUNDARY====
86.000	86.000	1086.640	NA	NA	18.094	12.337	5.253	27	ESW3 TO SW4
87.000	87.000	1104.641	NA	NA	17.907	12.209	5.148	27	ESW3 TO SW4
88.000	88.000	1122.464	NA	NA	17.720	12.082	5.036	27	ESW3 TO SW4
88.464	88.464	1131.000	NA	NA	17.629	12.020	4.987	27/28	====TRACK SECTION BOUNDARY====
88.540	88.540	1132.000	NA	NA	17.562	11.974	4.949	28/29	====TRACK SECTION BOUNDARY====
89.000	89.000	1140.026	NA	NA	17.371	11.844	4.842	29	SW 4 TO ESW4
90.000	90.000	1157.181	NA	NA	16.956	11.561	4.613	29	SW 4 TO ESW4
91.000	91.000	1173.840	NA	NA	16.541	11.278	4.390	29	SW 4 TO ESW4
91.004	91.004	1174.000	NA	NA	16.539	11.277	4.389	29/30	====TRACK SECTION BOUNDARY====
92.000	92.000	1190.386	NA	NA	16.353	11.150	4.291	30	ESW4 TO SW5
93.000	93.000	1206.645	NA	NA	16.166	11.022	4.193	30	ESW4 TO SW5
93.830	93.830	1220.000	NA	NA	16.011	10.916	4.113	30/31	====TRACK SECTION BOUNDARY====
93.893	93.893	1221.000	NA	NA	15.944	10.871	4.079	31/32	====TRACK SECTION BOUNDARY====
94.000	94.000	1222.710	NA	NA	15.912	10.849	4.063	32	SW 5 TO ESW5
95.000	95.000	1238.478	NA	NA	15.620	10.650	3.915	32	SW 5 TO ESW5
96.000	96.000	1253.949	NA	NA	15.328	10.451	3.770	32	SW 5 TO ESW5
96.594	96.594	1263.000	NA	NA	15.154	10.332	3.685	32/33	====TRACK SECTION BOUNDARY====
97.000	97.000	1269.140	NA	NA	15.079	10.281	3.648	33	ESW5 TO CL
98.000	98.000	1284.124	NA	NA	14.891	10.153	3.558	33	ESW5 TO CL
99.000	99.000	1298.922	NA	NA	14.704	10.025	3.469	33	ESW5 TO CL
99.688	99.688	1309.000	NA	NA	14.576	9.938	3.409	33/34	====TRACK SECTION BOUNDARY====
100.000	100.000	1313.525	NA	NA	14.485	9.876	3.367	34	CL PT TO TAN PT
101.000	101.000	1327.868	NA	NA	14.195	9.679	3.233	34	CL PT TO TAN PT
102.000	102.000	1341.919	NA	NA	13.905	9.481	3.103	34	CL PT TO TAN PT
103.000	103.000	1355.679	NA	NA	13.615	9.283	2.974	34	CL PT TO TAN PT
104.000	104.000	1369.149	NA	NA	13.325	9.085	2.849	34	CL PT TO TAN PT
105.000	105.000	1382.329	NA	NA	13.035	8.888	2.728	34	CL PT TO TAN PT
106.000	106.000	1395.220	NA	NA	12.745	8.690	2.607	34	CL PT TO TAN PT
107.000	107.000	1407.820	NA	NA	12.455	8.492	2.489	34	CL PT TO TAN PT
108.000	108.000	1420.130	NA	NA	12.166	8.295	2.376	34	CL PT TO TAN PT
109.000	109.000	1432.151	NA	NA	11.876	8.097	2.263	34	CL PT TO TAN PT
110.000	110.000	1443.882	NA	NA	11.586	7.899	2.154	34	CL PT TO TAN PT

CAR NO. 1 (CONTINUED)

CAR TRAVEL TIME (SEC)	SYSTEM TIME (SEC)	DISTANCE ALONG TRACK (FT)	DISTANCE HEADWAY BETWEEN PREC CAR (FT)	TIME HEADWAY BETWEEN PREC CAR (SEC)	INSTAN-TANEOUS VELOCITY (FT/SEC)	INSTAN-TANEOUS VELOCITY (MPH)	VELOCITY HEAD (FT)	TRACK SECTION NUMBER	TRACK SECTION DESCRIPTION
111.000	111.000	1455.322	NA	NA	11.296	7.702	2.047	34	CL PT TO TAN PT
112.000	112.000	1466.473	NA	NA	11.006	7.504	1.944	34	CL PT TO TAN PT
113.000	113.000	1477.334	NA	NA	10.716	7.306	1.842	34	CL PT TO TAN PT
114.000	114.000	1487.904	NA	NA	10.426	7.108	1.744	34	CL PT TO TAN PT
115.000	115.000	1498.185	NA	NA	10.136	6.911	1.648	34	CL PT TO TAN PT
116.000	116.000	1508.176	NA	NA	9.846	6.713	1.555	34	CL PT TO TAN PT
117.000	117.000	1517.877	NA	NA	9.556	6.515	1.466	34	CL PT TO TAN PT
118.000	118.000	1527.288	NA	NA	9.266	6.318	1.378	34	CL PT TO TAN PT
119.000	119.000	1536.409	NA	NA	8.976	6.120	1.293	34	CL PT TO TAN PT
120.000	120.000	1545.240	NA	NA	8.686	5.922	1.211	34	CL PT TO TAN PT
121.000	121.000	1553.781	NA	NA	8.396	5.725	1.131	34	CL PT TO TAN PT

CAR NO. 2

CAR TRAVEL TIME (SEC)	SYSTEM TIME (SEC)	DISTANCE ALONG TRACK (FT)	DISTANCE HEADWAY BETWEEN PREC CAR (FT)	TIME HEADWAY BETWEEN PREC CAR (SEC)	INSTAN-TANEOUS VELOCITY (FT/SEC)	INSTAN-TANEOUS VELOCITY (MPH)	VELOCITY HEAD (FT)	TRACK SECTION NUMBER	TRACK SECTION DESCRIPTION
0.000	16.364	0.000	0.000	0.000	3.667	2.500	.212	0/ 1	****TRACK SECTION BOUNDARY****
.636	17.000	2.333	0.000	0.000	3.667	2.500	.212	1	APPROACH TO CREST
1.636	18.000	6.000	0.000	0.000	3.667	2.500	.212	1	APPROACH TO CREST
2.636	19.000	9.667	.008	.002	3.667	2.500	.212	1	APPROACH TO CREST
3.636	20.000	13.333	.054	.014	3.667	2.500	.212	1	APPROACH TO CREST
4.636	21.000	17.000	.182	.047	3.667	2.500	.212	1	APPROACH TO CREST
5.455	21.818	20.000	.378	.098	3.667	2.500	.212	1/ 2	****TRACK SECTION BOUNDARY****
5.636	22.000	20.667	.436	.109	3.667	2.500	.212	2	CREST VC
6.636	23.000	24.333	.859	.206	3.667	2.500	.212	2	CREST VC
7.636	24.000	28.000	1.501	.342	3.667	2.500	.212	2	CREST VC
8.636	25.000	31.667	2.412	.519	3.667	2.500	.212	2	CREST VC
9.636	26.000	35.333	3.644	.737	3.667	2.500	.212	2	CREST VC
10.636	27.000	39.000	5.252	.986	3.667	2.500	.212	2	CREST VC
11.636	28.000	42.667	7.302	1.282	3.667	2.500	.212	2	CREST VC
12.636	29.000	46.333	9.859	1.628	3.667	2.500	.212	2	CREST VC
13.636	30.000	50.000	12.984	1.995	3.667	2.500	.212	2	CREST VC
14.636	31.000	53.667	16.778	2.395	3.667	2.500	.212	2	CREST VC
15.636	32.000	57.347	21.204	2.824	3.694	2.519	.215	2	CREST VC
16.636	33.000	61.061	26.232	3.272	3.778	2.574	.224	2	CREST VC
17.636	34.000	64.923	31.808	3.732	3.908	2.666	.241	2	CREST VC
18.636	35.000	68.928	37.874	4.198	4.101	2.796	.268	2	CREST VC
19.636	36.000	73.154	44.378	4.656	4.351	2.966	.298	2	CREST VC
20.636	37.000	77.661	51.248	5.106	4.664	3.180	.343	2	CREST VC
21.636	38.000	82.518	58.429	5.538	5.044	3.439	.401	2	CREST VC
22.636	39.000	87.785	65.848	5.948	5.498	3.748	.478	2	CREST VC
23.636	40.000	93.547	73.488	6.330	6.028	4.110	.572	2	CREST VC
24.636	41.000	99.585	81.298	6.680	6.647	4.532	.686	2	CREST VC
24.654	41.017	100.000	81.435	6.688	6.656	4.540	.688	2/ 3	****TRACK SECTION BOUNDARY****
25.636	42.000	106.888	89.243	6.992	7.361	5.019	.843	3	EVC TO SCALE
26.050	42.414	110.000	92.546	7.109	7.688	5.240	.930	3/ 4	****TRACK SECTION BOUNDARY****
26.636	43.000	114.851	97.231	7.262	8.180	5.577	1.054	4	SCALE
27.636	44.000	123.300	105.250	7.488	9.118	6.217	1.309	4	SCALE
28.636	45.000	132.918	113.268	7.661	10.087	6.878	1.603	4	SCALE
29.636	46.000	143.463	121.321	7.797	11.008	7.505	1.908	4	SCALE
30.636	47.000	154.931	129.360	7.901	11.928	8.133	2.241	4	SCALE
31.636	48.000	167.319	137.318	7.979	12.849	8.761	2.600	4	SCALE
32.636	49.000	180.629	144.674	8.038	13.770	9.388	2.986	4	SCALE
33.636	50.000	194.859	149.974	8.083	14.690	10.016	3.399	4	SCALE
34.636	51.000	210.009	153.142	8.116	15.611	10.644	3.838	4	SCALE
34.953	51.317	215.000	153.683	8.125	15.902	10.842	3.983	4/ 5	****TRACK SECTION BOUNDARY****
35.569	51.933	225.000	154.177	8.141	16.567	11.296	4.023	5/ 6	****TRACK SECTION BOUNDARY****
35.629	51.993	226.000	154.199	8.142	16.584	11.307	4.331	6/ 7	****TRACK SECTION BOUNDARY****
35.636	52.000	226.118	154.202	8.143	16.591	11.312	4.335	7	KSW 1 E SW1
36.636	53.000	243.240	154.328	8.163	17.658	12.039	4.811	7	KSW 1 E SW1
37.636	54.000	261.431	153.987	8.176	18.724	12.766	5.522	7	KSW 1 E SW1
37.984	54.347	268.000	153.728	8.180	19.094	13.018	5.742	7/ 8	****TRACK SECTION BOUNDARY****
38.397	54.761	276.000	153.352	8.181	19.606	13.368	6.054	8/ 9	****TRACK SECTION BOUNDARY****
38.636	55.000	280.725	153.084	8.180	19.902	13.570	6.238	9	BHC1 TO EHC1

CAR NO. 2 (CONTINUED)

CAR TRAVEL TIME (SEC)	SYSTEM TIME (SEC)	DISTANCE ALONG TRACK (FT)	DISTANCE HEADWAY BETWEEN PREC CAR (FT)	TIME HEADWAY BETWEEN PREC CAR (SEC)	INSTAN-TANEOUS VELOCITY (FT/SEC)	INSTAN-TANEOUS VELOCITY (MPH)	VELOCITY HEAD (FT)	TRACK SECTION NUMBER	TRACK SECTION DESCRIPTION
39.636	56.000	301.246	151.553	8.164	21.141	14.414	7.039	9	BHC1 TO EHC1
40.636	57.000	323.006	149.364	8.114	22.379	15.258	7.868	9	BHC1 TO EHC1
40.770	57.133	326.000	149.022	8.099	22.543	15.370	8.004	9/10	****TRACK SECTION BOUNDARY****
41.636	58.000	345.952	146.569	7.941	23.499	16.022	8.697	10	HC1 TO BVC2
42.226	58.590	360.000	144.688	7.768	24.149	16.465	9.185	10/11	****TRACK SECTION BOUNDARY****
42.636	58.999	370.000	143.264	7.608	24.656	16.811	9.575	11/12	****TRACK SECTION BOUNDARY****
42.636	59.000	370.014	143.262	7.607	24.656	16.811	9.574	12	MASTER 1
43.636	60.000	394.177	140.078	7.194	23.672	16.140	8.825	12	MASTER 1
44.636	61.000	417.357	137.611	6.892	22.686	15.469	8.107	12	MASTER 1
45.473	61.837	436.000	136.092	6.720	21.864	14.907	7.829	12/13	****TRACK SECTION BOUNDARY****
45.636	62.000	439.561	135.847	6.694	21.806	14.868	7.469	13	MASTER 2
46.636	63.000	461.192	134.409	6.568	21.456	14.629	7.281	13	MASTER 2
47.636	64.000	482.473	133.087	6.495	21.105	14.390	7.016	13	MASTER 2
48.636	65.000	503.403	131.883	6.472	20.755	14.151	6.784	13	MASTER 2
49.636	66.000	523.982	130.798	6.491	20.404	13.912	6.557	13	MASTER 2
50.636	67.000	544.211	129.825	6.521	20.054	13.673	6.334	13	MASTER 2
51.001	67.365	551.500	129.500	6.533	19.926	13.586	6.253	13/14	****TRACK SECTION BOUNDARY****
51.636	68.000	564.360	128.700	6.542	20.556	14.015	6.565	14	MASTER TO SW2
52.415	68.779	580.500	127.215	6.526	20.896	14.247	6.877	14/15	****TRACK SECTION BOUNDARY****
52.463	68.827	581.500	127.113	6.526	20.854	14.219	6.849	15/16	****TRACK SECTION BOUNDARY****
52.636	69.000	585.114	126.746	6.521	20.842	14.210	6.841	16	SW2 TO ESW2
53.636	70.000	605.920	124.629	6.484	20.769	14.161	6.794	16	SW2 TO ESW2
54.636	71.000	626.653	122.505	6.439	20.697	14.112	6.747	16	SW2 TO ESW2
54.871	71.234	631.500	122.007	6.427	20.680	14.100	6.736	16/17	****TRACK SECTION BOUNDARY****
55.636	72.000	647.326	120.365	6.384	20.656	14.084	6.720	17	ESW2 TO TAN ESW
56.636	73.000	667.966	118.179	6.317	20.624	14.062	6.699	17	ESW2 TO TAN ESW
57.636	74.000	688.574	115.947	6.237	20.592	14.040	6.679	17	ESW2 TO TAN ESW
58.636	75.000	709.150	113.669	6.145	20.561	14.019	6.658	17	ESW2 TO TAN ESW
59.636	76.000	729.695	111.305	6.046	20.529	13.997	6.638	17	ESW2 TO TAN ESW
60.636	77.000	750.206	108.967	5.943	20.497	13.975	6.617	17	ESW2 TO TAN ESW
61.383	77.746	765.500	107.322	5.865	20.473	13.959	6.602	17/18	****TRACK SECTION BOUNDARY****
61.636	78.000	770.695	106.779	5.837	20.506	13.981	6.622	18	EHC2 TO TANESW
62.636	79.000	791.264	104.643	5.722	20.633	14.068	6.706	18	EHC2 TO TANESW
63.636	80.000	811.960	102.514	5.594	20.760	14.154	6.788	18	EHC2 TO TANESW
63.807	80.170	815.500	102.152	5.571	20.781	14.169	6.802	18/19	****TRACK SECTION BOUNDARY****
64.636	81.000	832.783	100.392	5.453	20.887	14.241	6.871	19	TAN ESW TO ESCAPE SW
65.636	82.000	853.733	98.277	5.299	21.014	14.327	6.955	19	TAN ESW TO ESCAPE SW
66.636	83.000	874.810	96.168	5.148	21.141	14.414	7.039	19	TAN ESW TO ESCAPE SW
67.047	83.411	883.500	95.262	5.083	21.193	14.450	7.074	19/20	****TRACK SECTION BOUNDARY****
67.094	83.458	884.500	95.154	5.076	21.161	14.428	7.053	20/21	****TRACK SECTION BOUNDARY****
67.636	84.000	895.993	93.850	4.995	21.230	14.475	7.099	21	ESCAPE SW TO BVC3
67.801	84.165	899.500	93.428	4.971	21.251	14.489	7.113	21/22	****TRACK SECTION BOUNDARY****
68.271	84.634	909.500	92.150	4.902	21.361	14.565	7.187	22/23	****TRACK SECTION BOUNDARY****
68.636	85.000	917.191	91.203	4.854	20.721	14.128	6.762	23	GROUP RET.
69.636	86.000	937.037	89.604	4.794	18.969	12.934	5.667	23	GROUP RET.
70.636	87.000	955.130	89.510	4.835	17.218	11.739	4.609	23	GROUP RET.
71.636	88.000	971.472	90.982	4.974	15.466	10.545	3.767	23	GROUP RET.
72.636	89.000	986.063	93.965	5.202	13.715	9.351	2.962	23	GROUP RET.

CAR NO. 2 (CONTINUED)

CAR TRAVEL TIME (SEC)	SYSTEM TIME (SEC)	DISTANCE ALONG TRACK (FT)	DISTANCE HEADWAY BETWEEN PREC CAR (FT)	TIME HEADWAY BETWEEN PREC CAR (SEC)	INSTAN-TANEOUS VELOCITY (FT/SEC)	INSTAN-TANEOUS VELOCITY (MPH)	VELOCITY HEAD (FT)	TRACK SECTION NUMBER	TRACK SECTION DESCRIPTION
73.636	90.000	998.902	98.290	5.514	11.963	8.157	2.254	23	GROUP RET.
74.636	91.000	1009.959	103.951	5.913	10.212	6.962	1.642	23	GROUP RET.
75.636	92.000	1019.325	111.061	6.403	8.460	5.768	1.127	23	GROUP RET.
76.361	92.725	1025.000	117.182	6.816	7.180	4.895	.812	23/24	****TRACK SECTION BOUNDARY****
76.636	93.000	1026.986	119.659	6.981	7.264	4.952	.831	24	GRP. RET. TO SW 3
77.636	94.000	1034.315	126.394	7.575	7.395	5.042	.861	24	GRP. RET. TO SW 3
77.729	94.093	1035.000	129.182	7.629	7.393	5.041	.861	24/25	****TRACK SECTION BOUNDARY****
77.865	94.229	1036.000	130.346	7.710	7.265	4.953	.831	25/26	****TRACK SECTION BOUNDARY****
78.636	95.000	1041.555	136.921	8.172	7.145	4.871	.804	26	SW 3 TO ESW3
79.636	96.000	1048.621	145.328	8.777	6.988	4.765	.769	26	SW 3 TO ESW3
80.636	97.000	1055.531	153.608	9.390	6.832	4.658	.735	26	SW 3 TO ESW3
81.636	98.000	1062.286	161.839	10.010	6.676	4.552	.702	26	SW 3 TO ESW3
82.636	99.000	1068.884	170.039	10.636	6.520	4.446	.669	26	SW 3 TO ESW3
83.636	100.000	1075.325	178.203	11.270	6.364	4.339	.638	26	SW 3 TO ESW3
84.636	101.000	1081.611	186.257	11.909	6.207	4.232	.607	26	SW 3 TO ESW3
85.350	101.713	1086.000	191.922	12.368	6.098	4.158	.585	26/27	****TRACK SECTION BOUNDARY****
85.636	102.000	1087.745	194.173	12.553	6.087	4.150	.584	27	ESW3 TO SW4
86.636	103.000	1093.818	201.862	13.189	6.055	4.129	.577	27	ESW3 TO SW4
87.636	104.000	1099.856	209.293	13.843	6.023	4.107	.571	27	ESW3 TO SW4
88.636	105.000	1105.863	216.466	14.485	5.992	4.085	.565	27	ESW3 TO SW4
89.636	106.000	1111.839	223.381	15.127	5.960	4.064	.559	27	ESW3 TO SW4
90.636	107.000	1117.783	230.037	15.767	5.928	4.042	.553	27	ESW3 TO SW4
91.636	108.000	1123.695	236.435	16.405	5.896	4.020	.548	27	ESW3 TO SW4
92.636	109.000	1129.576	242.575	17.050	5.865	3.999	.542	27	ESW3 TO SW4
92.879	109.243	1131.000	244.028	17.205	5.857	3.993	.540	27/28	****TRACK SECTION BOUNDARY****
93.053	109.416	1132.000	245.071	17.318	5.676	3.870	.507	28/29	****TRACK SECTION BOUNDARY****
93.636	110.000	1135.267	248.814	17.701	5.522	3.765	.480	29	SW 4 TO ESW4
94.636	111.000	1140.657	254.656	18.370	5.257	3.585	.435	29	SW 4 TO ESW4
95.636	112.000	1145.782	260.691	19.053	4.993	3.404	.393	29	SW 4 TO ESW4
96.636	113.000	1150.643	266.690	19.752	4.729	3.224	.352	29	SW 4 TO ESW4
97.636	114.000	1155.240	272.664	20.467	4.465	3.044	.314	29	SW 4 TO ESW4
98.636	115.000	1159.573	278.612	21.197	4.201	2.864	.278	29	SW 4 TO ESW4
99.636	116.000	1163.642	284.534	21.941	3.937	2.684	.244	29	SW 4 TO ESW4
100.636	117.000	1167.447	290.430	22.701	3.673	2.504	.212	29	SW 4 TO ESW4
101.636	118.000	1170.987	296.301	23.477	3.409	2.324	.183	29	SW 4 TO ESW4
102.553	118.916	1174.000	301.658	24.202	3.166	2.159	.158	29/30	****TRACK SECTION BOUNDARY****
102.636	119.000	1174.264	302.144	24.269	3.164	2.157	.158	30	ESW4 TO SW5
103.636	120.000	1177.412	307.828	25.068	3.132	2.135	.154	30	ESW4 TO SW5
104.636	121.000	1180.528	313.283	25.868	3.100	2.114	.151	30	ESW4 TO SW5

CAR NO. 3

CAR TRAVEL TIME (SEC)	SYSTEM TIME (SEC)	DISTANCE ALONG TRACK (FT)	DISTANCE HEADWAY BETWEEN PREC CAR (FT)	TIME HEADWAY BETWEEN PREC CAR (SEC)	INSTAN-TANEOUS VELOCITY (FT/SEC)	INSTAN-TANEOUS VELOCITY (MPH)	VELOCITY HEAD (FT)	TRACK SECTION NUMBER	TRACK SECTION DESCRIPTION
0.000	32.727	0.000	.041	.018	3.667	2.500	.216	0/ 1	****TRACK SECTION BOUNDARY****
.273	33.000	1.000	.081	.022	3.667	2.500	.216	1	APPROACH TO CREST
1.273	34.000	4.667	.257	.068	3.667	2.500	.216	1	APPROACH TO CREST
2.273	35.000	8.333	.595	.148	3.667	2.500	.216	1	APPROACH TO CREST
3.273	36.000	12.000	1.154	.267	3.667	2.500	.216	1	APPROACH TO CREST
4.273	37.000	15.667	1.995	.434	3.667	2.500	.216	1	APPROACH TO CREST
5.273	38.000	19.333	3.182	.647	3.667	2.500	.216	1	APPROACH TO CREST
5.455	38.182	20.000	3.440	.690	3.667	2.500	.216	1/ 2	****TRACK SECTION BOUNDARY****
6.273	39.000	23.000	4.785	.904	3.667	2.500	.216	2	CREST VC
7.273	40.000	26.667	6.881	1.205	3.667	2.500	.216	2	CREST VC
8.273	41.000	30.333	9.552	1.546	3.667	2.500	.216	2	CREST VC
9.273	42.000	34.000	12.888	1.925	3.667	2.500	.216	2	CREST VC
10.273	43.000	37.667	16.985	2.339	3.667	2.500	.216	2	CREST VC
11.273	44.000	41.333	21.987	2.785	3.667	2.500	.216	2	CREST VC
12.273	45.000	45.000	27.915	3.260	3.667	2.500	.216	2	CREST VC
13.273	46.000	48.667	34.796	3.761	3.667	2.500	.216	2	CREST VC
14.273	47.000	52.333	42.597	4.288	3.667	2.500	.216	2	CREST VC
15.273	48.000	56.000	51.319	4.837	3.667	2.500	.216	2	CREST VC
16.273	49.000	59.667	60.962	5.407	3.667	2.500	.216	2	CREST VC
17.273	50.000	63.333	71.525	5.996	3.667	2.500	.216	2	CREST VC
18.273	51.000	67.000	83.009	6.603	3.667	2.500	.216	2	CREST VC
19.273	52.000	70.681	95.434	7.224	3.696	2.520	.219	2	CREST VC
20.273	53.000	74.413	108.827	7.853	3.767	2.568	.228	2	CREST VC
21.273	54.000	78.237	123.194	8.488	3.882	2.647	.242	2	CREST VC
22.273	55.000	82.199	138.526	9.115	4.042	2.756	.262	2	CREST VC
23.273	56.000	86.344	154.902	9.741	4.249	2.897	.290	2	CREST VC
24.273	57.000	90.721	172.285	10.358	4.506	3.072	.326	2	CREST VC
25.273	58.000	95.381	190.572	10.962	4.814	3.282	.372	2	CREST VC
26.200	58.927	100.000	208.222	11.509	5.150	3.512	.426	2/ 3	****TRACK SECTION BOUNDARY****
26.273	59.000	100.376	209.638	11.551	5.179	3.531	.430	3	EVC TO SCALE
27.273	60.000	105.767	226.410	12.121	5.604	3.821	.504	3	EVC TO SCALE
28.005	60.732	110.000	241.250	12.525	5.956	4.061	.569	3/ 4	****TRACK SECTION BOUNDARY****
28.273	61.000	111.612	245.745	12.670	6.094	4.155	.598	4	SCALE
29.273	62.000	117.986	261.575	13.193	6.654	4.537	.711	4	SCALE
30.273	63.000	124.960	276.232	13.689	7.292	4.972	.853	4	SCALE
31.273	64.000	132.590	289.883	14.165	7.960	5.427	1.017	4	SCALE
32.273	65.000	140.677	302.526	14.595	8.614	5.873	1.191	4	SCALE
33.273	66.000	149.818	314.164	15.012	9.268	6.319	1.378	4	SCALE
34.273	67.000	159.414	324.797	15.408	9.923	6.766	1.580	4	SCALE
35.273	68.000	169.664	334.897	15.786	10.577	7.212	1.795	4	SCALE
36.273	69.000	180.568	344.546	16.152	11.232	7.658	2.024	4	SCALE
37.273	70.000	192.127	353.793	16.504	11.886	8.104	2.267	4	SCALE
38.273	71.000	204.340	362.313	16.845	12.540	8.550	2.523	4	SCALE
39.105	71.832	215.000	368.855	17.122	13.085	8.922	2.747	4/ 5	****TRACK SECTION BOUNDARY****
39.273	72.000	217.210	370.116	17.178	13.221	9.014	2.805	5	SCALE TO K SW
39.852	72.579	225.000	374.280	17.366	13.690	9.334	3.007	5/ 6	****TRACK SECTION BOUNDARY****
39.925	72.652	226.000	374.787	17.389	13.692	9.335	3.008	6/ 7	****TRACK SECTION BOUNDARY****
40.273	73.000	230.813	377.153	17.501	13.969	9.524	3.131	7	KSW 1 E SW1

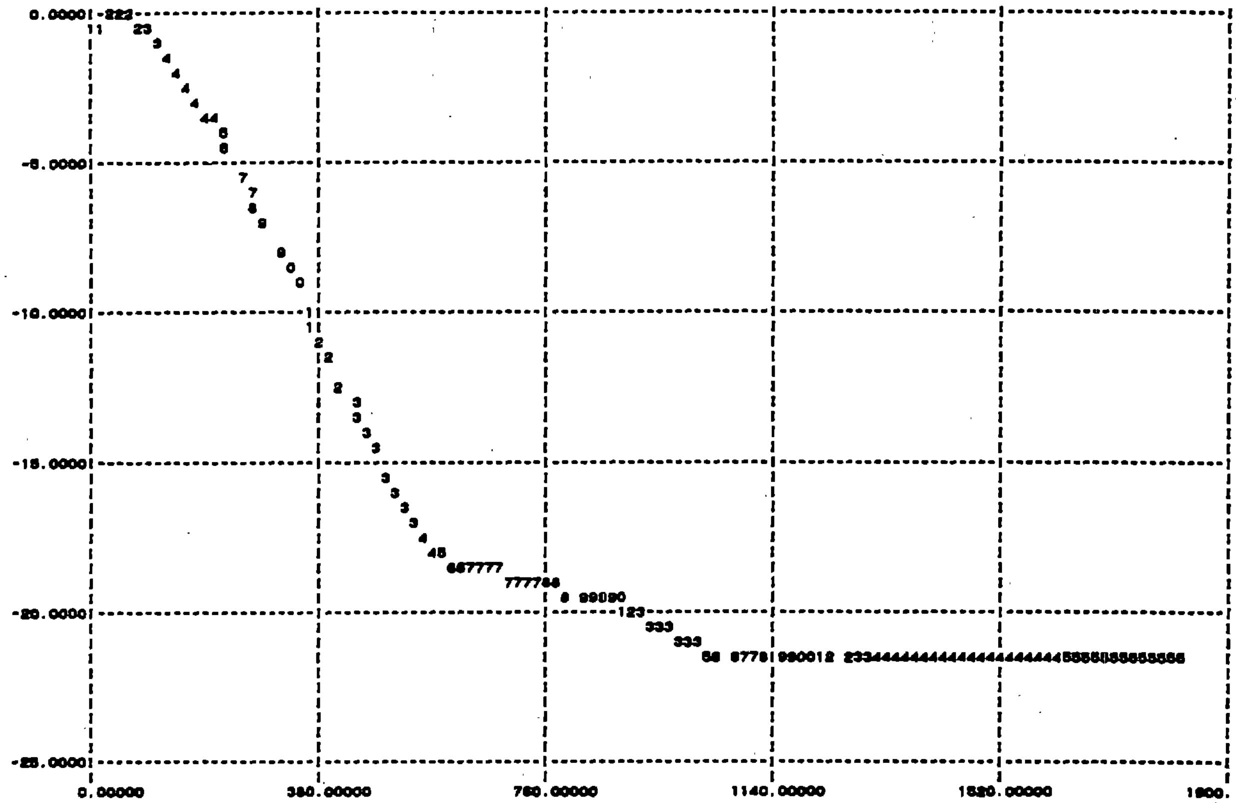
CAR NO. 3 (CONTINUED)

CAR TRAVEL TIME (SEC)	SYSTEM TIME (SEC)	DISTANCE ALONG TRACK (FT)	DISTANCE HEADWAY BETWEEN PREC CAR (FT)	TIME HEADWAY BETWEEN PREC CAR (SEC)	INSTAN-TANEOUS VELOCITY (FT/SEC)	INSTAN-TANEOUS VELOCITY (MPH)	VELOCITY HEAD (FT)	TRACK SECTION NUMBER	TRACK SECTION DESCRIPTION
41.273	74.000	245.181	383.393	17.815	14.767	10.068	3.499	7	KSW 1 E SW1
42.273	75.000	260.346	386.804	18.119	15.564	10.612	3.887	7	KSW 1 E SW1
42.758	75.485	268.000	391.133	18.264	15.952	10.876	4.083	7/ 8	****TRACK SECTION BOUNDARY****
43.253	75.980	276.000	393.281	18.408	16.429	11.202	4.331	8/ 9	****TRACK SECTION BOUNDARY****
43.273	76.000	276.332	393.364	18.413	16.449	11.215	4.341	9	BHC1 TO EHC1
44.273	77.000	293.263	396.945	18.691	17.415	11.874	4.866	9	BHC1 TO EHC1
45.273	78.000	311.161	399.534	18.953	18.381	12.532	5.421	9	BHC1 TO EHC1
46.064	78.791	326.000	400.952	19.134	19.145	13.053	5.881	9/10	****TRACK SECTION BOUNDARY****
46.273	79.000	330.021	401.242	19.178	19.319	13.172	5.989	10	HC1 TO BVC2
47.273	80.000	349.757	402.203	19.333	20.152	13.740	6.516	10	HC1 TO BVC2
47.776	80.503	360.000	402.420	19.386	20.571	14.026	6.790	10/11	****TRACK SECTION BOUNDARY****
48.257	80.984	370.000	402.444	19.420	21.035	14.342	7.100	11/12	****TRACK SECTION BOUNDARY****
48.273	81.000	370.341	402.442	19.420	21.015	14.329	7.087	12	MASTER 1
49.273	82.000	390.751	402.982	19.485	19.805	13.503	6.294	12	MASTER 1
50.273	83.000	409.951	404.859	19.590	18.594	12.678	5.548	12	MASTER 1
51.273	84.000	427.940	408.053	19.740	17.384	11.853	4.849	12	MASTER 1
51.744	84.471	436.000	410.031	19.827	16.813	11.464	4.536	12/13	****TRACK SECTION BOUNDARY****
52.273	85.000	444.989	412.223	19.924	17.120	11.673	4.703	13	MASTER 2
53.273	86.000	462.379	414.688	20.079	17.700	12.068	5.027	13	MASTER 2
54.273	87.000	480.369	414.761	20.191	18.280	12.464	5.362	13	MASTER 2
55.273	88.000	498.939	412.533	20.265	18.860	12.859	5.708	13	MASTER 2
56.273	89.000	518.090	407.973	20.337	19.441	13.255	6.064	13	MASTER 2
57.273	90.000	537.621	401.081	20.390	20.021	13.651	6.432	13	MASTER 2
57.949	90.677	551.500	395.095	20.408	20.413	13.918	6.686	13/14	****TRACK SECTION BOUNDARY****
58.273	91.000	558.146	391.841	20.411	20.701	14.114	6.876	14	MASTER TO SW2
59.273	92.000	579.033	380.291	20.401	21.071	14.365	7.124	14	MASTER TO SW2
59.342	92.070	580.500	379.408	20.400	21.067	14.364	7.121	14/15	****TRACK SECTION BOUNDARY****
59.390	92.117	581.500	378.800	20.399	21.017	14.330	7.088	15/16	****TRACK SECTION BOUNDARY****
60.273	93.000	599.949	367.037	20.389	20.778	14.165	6.926	16	SW2 TO ESW2
61.273	94.000	620.588	353.727	20.388	20.502	13.979	6.745	16	SW2 TO ESW2
61.807	94.534	631.500	346.709	20.392	20.356	13.879	6.649	16/17	****TRACK SECTION BOUNDARY****
62.273	95.000	640.958	340.597	20.398	20.247	13.805	6.578	17	ESW2 TO TAN ESW
63.273	96.000	661.088	327.533	20.419	20.014	13.646	6.427	17	ESW2 TO TAN ESW
64.273	97.000	680.985	314.548	20.450	19.780	13.486	6.278	17	ESW2 TO TAN ESW
65.273	98.000	700.646	301.637	20.490	19.546	13.327	6.130	17	ESW2 TO TAN ESW
66.273	99.000	720.078	288.806	20.543	19.313	13.168	5.985	17	ESW2 TO TAN ESW
67.273	100.000	739.273	276.052	20.612	19.079	13.008	5.841	17	ESW2 TO TAN ESW
68.273	101.000	758.235	263.375	20.698	18.845	12.849	5.698	17	ESW2 TO TAN ESW
68.659	101.386	765.500	258.496	20.735	18.755	12.787	5.644	17/18	****TRACK SECTION BOUNDARY****
69.273	102.000	776.993	250.752	20.799	18.707	12.755	5.615	18	EHC2 TO TANESW
70.273	103.000	795.681	238.155	20.908	18.629	12.702	5.569	18	EHC2 TO TANESW
71.273	104.000	814.251	225.604	21.026	18.551	12.649	5.522	18	EHC2 TO TANESW
71.340	104.067	815.500	224.761	21.035	18.546	12.645	5.519	18/19	****TRACK SECTION BOUNDARY****
72.273	105.000	832.763	213.100	21.152	18.473	12.595	5.476	19	TAN ESW TO ESCAPE SW
73.273	106.000	851.198	200.641	21.286	18.395	12.542	5.430	19	TAN ESW TO ESCAPE SW
74.273	107.000	869.554	188.229	21.388	18.317	12.489	5.384	19	TAN ESW TO ESCAPE SW
75.035	107.763	883.500	178.794	21.416	18.258	12.449	5.349	19/20	****TRACK SECTION BOUNDARY****
75.090	107.817	884.500	178.118	21.417	18.211	12.417	5.321	20/21	****TRACK SECTION BOUNDARY****

CAR NO. 3 (CONTINUED)

CAR TRAVEL TIME (SEC)	SYSTEM TIME (SEC)	DISTANCE ALONG TRACK (FT)	DISTANCE HEADWAY BETWEEN PREC CAR (FT)	TIME HEADWAY BETWEEN PREC CAR (SEC)	INSTAN-TANEOUS VELOCITY (FT/SEC)	INSTAN-TANEOUS VELOCITY (MPH)	VELOCITY HEAD (FT)	TRACK SECTION NUMBER	TRACK SECTION DESCRIPTION
75.273	108.000	887.824	175.871	21.418	18.197	12.407	5.313	21	ESCAPE SW TO BVC3
75.915	108.643	899.500	167.977	21.385	18.147	12.373	5.284	21/22	****TRACK SECTION BOUNDARY****
76.273	109.000	905.986	163.590	21.348	18.144	12.371	5.282	22	BVC3 TO GP & RET
76.466	109.194	909.500	161.204	21.320	18.162	12.383	5.293	22/23	****TRACK SECTION BOUNDARY****
77.273	110.000	924.190	151.077	21.135	18.270	12.457	5.356	23	GROUP RET.
78.273	111.000	942.527	138.129	20.690	18.404	12.548	5.435	23	GROUP RET.
79.273	112.000	960.999	124.783	19.798	18.538	12.640	5.514	23	GROUP RET.
80.273	113.000	979.604	111.039	18.272	18.672	12.731	5.594	23	GROUP RET.
81.273	114.000	998.343	96.897	16.586	18.806	12.822	5.675	23	GROUP RET.
82.273	115.000	1017.217	82.356	14.702	18.940	12.914	5.756	23	GROUP RET.
82.683	115.410	1025.000	76.275	13.861	18.995	12.951	5.790	23/24	****TRACK SECTION BOUNDARY****
83.210	115.937	1035.000	68.393	12.741	18.994	12.950	5.789	24/25	****TRACK SECTION BOUNDARY****
83.262	115.990	1036.000	67.601	12.629	18.936	12.911	5.754	25/26	****TRACK SECTION BOUNDARY****
83.273	116.000	1036.198	67.444	12.606	18.933	12.909	5.752	26	SW 3 TO ESW3
84.273	117.000	1054.976	52.470	10.473	18.624	12.698	5.565	26	SW 3 TO ESW3
85.273	118.000	1073.446	37.541	8.327	18.315	12.487	5.382	26	SW 3 TO ESW3
85.962	118.689	1086.000	27.272	6.646	18.102	12.342	5.258	26/27	****TRACK SECTION BOUNDARY****
86.273	119.000	1091.612	22.652	5.784	18.044	12.302	5.224	27	ESW3 TO SW4
87.273	120.000	1109.562	7.650	2.412	17.857	12.175	5.116	27	ESW3 TO SW4
88.273	121.000	1127.325	-6.797	0.003	17.670	12.047	5.010	27	ESW3 TO SW4

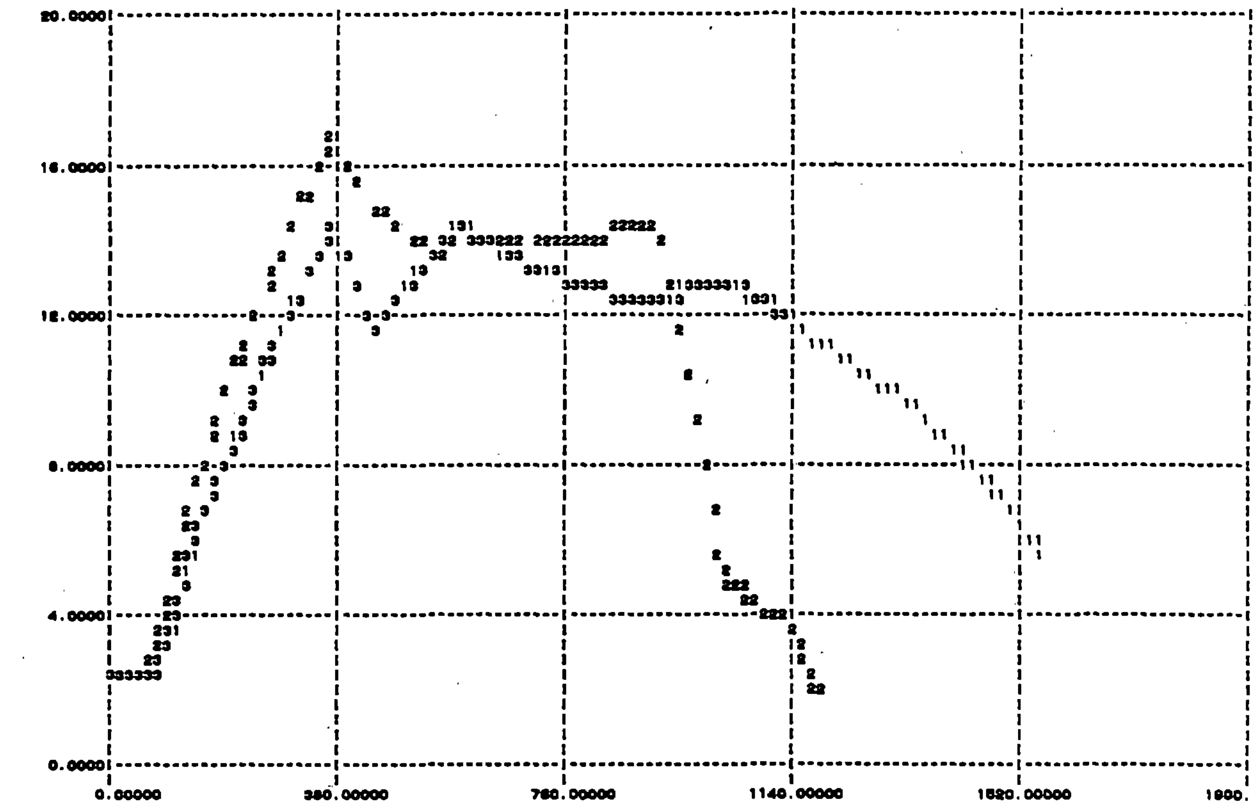
PLOT OF YARD PROFILE - ELEVATION IN FEET (DOWN) VS. DISTANCE IN FEET (ACROSS)



PLOT LEGEND -

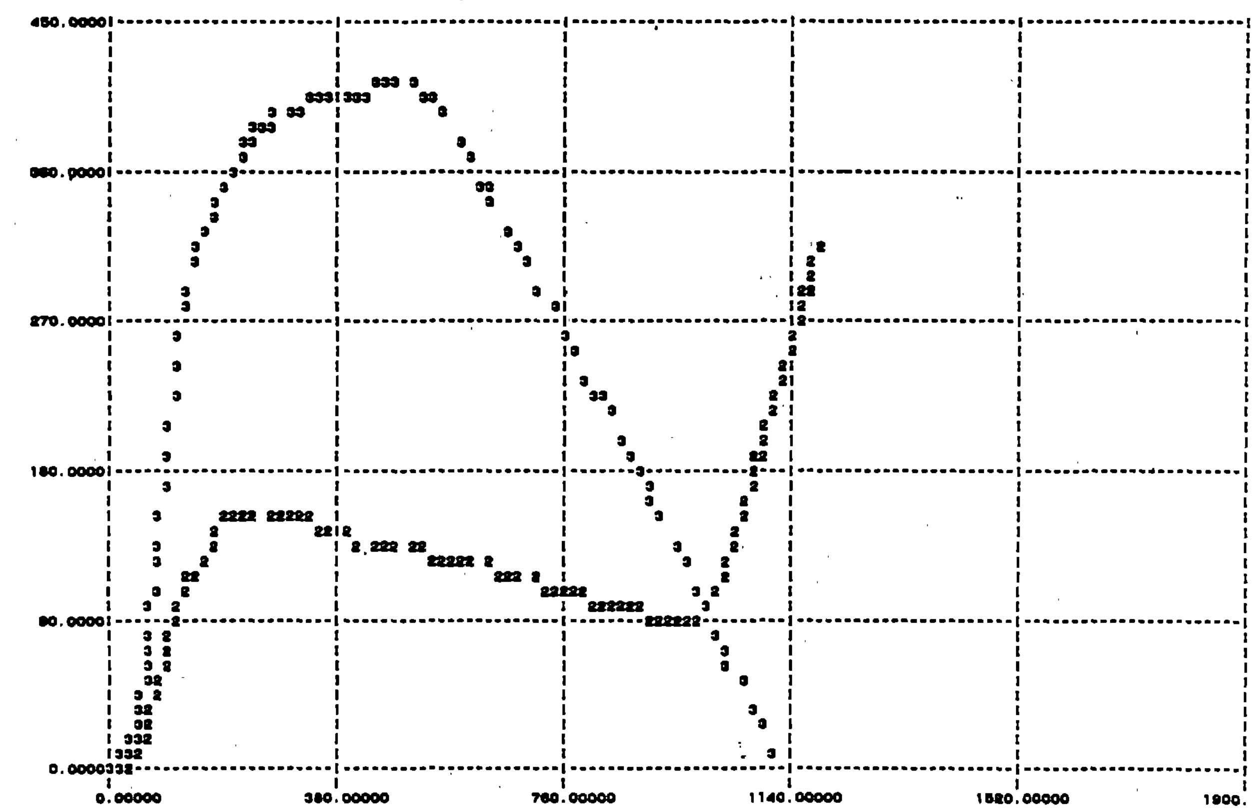
TRACK NO.	PLOTTED NO.	PERCENT GRADE	
1	1	-2.00	
2	2	VC	
3	3	3.00	
4	4	3.00	
5	5	3.50	
6	6	4.00	SWITCH
7	7	4.00	
8	8	4.00	
9	9	4.00	
10	0	4.00	
11	1	4.00	
12	2	4.00	RETARDER
13	3	4.00	RETARDER
14	4	VC	
15	5	.50	SWITCH
16	6	.50	
17	7	.50	
18	8	.50	
19	9	.50	
20	0	.50	SWITCH
21	1	.50	
22	2	VC	
23	3	1.18	RETARDER
24	4	VC	
25	5	0.00	SWITCH
26	6	0.00	
27	7	0.00	
28	8	0.00	SWITCH
29	9	0.00	
30	0	0.00	
31	1	0.00	SWITCH
32	2	0.00	
33	3	0.00	
34	4	0.00	
35	5	.15	

PLOT OF SPEED IN MPH (DOWN) VS. DISTANCE IN FEET (ACROSS)



NOTE - PLOTTED NUMBERS ARE CAR NUMBERS

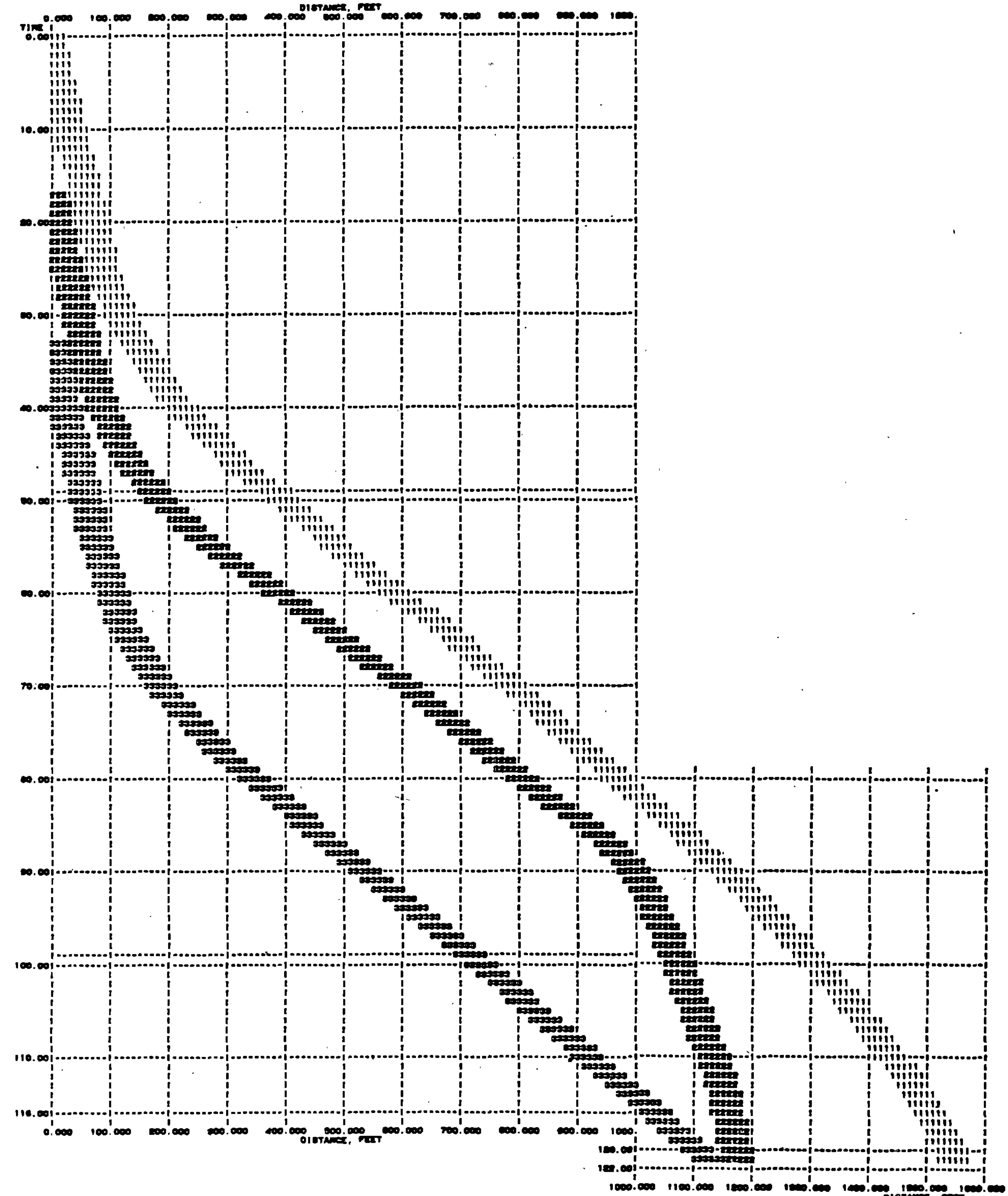
PLOT OF HEADWAY IN FEET (DOWN) VS. DISTANCE IN FEET (ACROSS)



PLOT LEGEND -

HEADWAY BT. CARS	PLOTTED NO.	HEADWAY BT. CARS	PLOTTED NO.
1 AND 2	2	2 AND 3	3

TIME-SPACE DIAGRAM 1 COVERING CUM. DIST. 0. TO 1000. FT. --
SCALE: 1 SPACE HORIZONTAL = 10. FT., 1 SPACE VERTICAL = 1.00 SEC.
NOTE: EACH CAR IS PLOTTED USING ITS NUMBER.



APPENDIX C: INPUT, OUTPUT, AND PROGRAM DOCUMENTATION FOR CONFLICT

This appendix comprises the input and program documentation for the yard throat conflict model CONFLICT, a railroad yard computer-simulation model designed to evaluate throat design and operation-caused throat conflict situations. Since Chapter 13 describes the general philosophy of the model and its application as a yard design tool, the reader should refer to that chapter for a general overview and a brief discussion of input data and input considerations. The appendix has been written assuming that the reader is familiar with Chapter 13.

C.1 CONFLICT USER'S MANUAL

C.1.1 Introduction

The CONFLICT User's Manual describes each data record that makes up the CONFLICT data input stream. Input to CONFLICT consists of several data categories. They are:

- Simulation options, simulation controls, and general parameters
- Yard geometry
  - Link characteristics
  - Route specifications
  - O/D matrix designations
- Engine specifications and assignments
  - Trim engine characteristics
  - Engine work schedule
- Classification track inflow
- Train departure schedule
- Track initialization.

Each set of records must be delimited by a blank card. The only exception is the engine work schedule set. This set must be followed by a card with 9999 right justified in columns 1 through 5.

Data fields in each record are five columns wide and data in those fields are entered right justified, the only exception being the title card at the beginning of the input deck. "Data record" or "data card" are used interchangeably in this appendix. There is no distinction between those terms which sometimes may simply be referred to as "record" or "card." A complete listing of sample data input is given in Exhibit C.1, attached at the end of this appendix.

The program allows the user to specify dual yards by identifying links as belonging either to the east or the west section of the yard. Designation is accomplished by specifying east or west (E or W) on the link input card. However, it should be realized that this assignment is entirely arbitrary and does not refer to true east or west; it simply accomplishes a division within the yard if so desired. If the yard is a single facility, no such designation is necessary and the data field should be left blank.

The input formats for these cards are given in Table C-1. Each card type must be represented at least once, even if the data card is totally blank. Table C-1 describes the data input in sequential order and is self-explanatory in most instances.

TABLE C-1.-CONFLICT INPUT

Description	Card type	Columns	Format	Variable name	Instructions	Comments
Input identification run title	1	1-80	A	TITLE		Will be reproduced in printout.
Output option control link update print option	2	1-5	I	ISW1	0=No printout 1=Write link updates	If 1, link update messages will be written to the simulation log.
Input echo printout		6-10	I	ISW2	0=Echo input 1=No input printout	
Trace printout		11-15	I	ISW3	0=Suppress trace 1=Print trace	This is a debug option. Caution is advised; output is voluminous.
Debug printout		16-20	I	ISW4	0=No printout 1=Print	Additional debug feature; output is voluminous.
Partial program execution		21-25	I	ISW5	0=Execute entire program 1=Input section only	
Yard inflow data printout		26-30	I	ISW6	0=No printout 1=Print	
Route consistency check and printout		31-35	I	ISW7	0=No printout 1=Perform check and print outcome	
Spare		36-40	I	ISW8		Not used.

TABLE C-1.-CONTINUED

Description	Card type	Columns	Format	Variable name	Instructions	Comments
Start of trace printout		41-45	F	TYM1	In running minutes of simulation time	If ISW3 or ISW4 or both are set to 1, a trace and debug printout will be produced for the time interval specified by TYM1 and TYM2.
End ot trace printout		46-50	F	TYM2		
Simulation control	3					
Simulation start time		1-5	I	IBTIME	Military time	i.e., 2:30pm → 1430
Simulation start day		6-10	I	IBDAY	Set to zero	
Simulation end time		11-15	I	IETIME	Military time	
Simulation end day		16-20	I	IEDAY	Set to zero	
Type of yard		21-25	I	JARDTP	0=Pull-back 1=Inline	
General operation and yard parameters	4					
Couple reschedule time		1-5	F	CDELAY	In minutes	
Double reschedule time		6-10	F	DDELAY	In minutes	
Pullout lead delay		11-15	F	PDELAY	In minutes	
Route selection reschedule time		16-20	F	DTSLCT	In minutes	
Route selection delay		21-25	F	DTCLAS	In minutes	
Line-haul engine delay		26-30	F	LHDLAY	In minutes	
Time interval to repeat check of departure track availability		31-35	F	GETDLY	In minutes	
Inspection delay time		36-40	F	DTINSP	In minutes	
Rate of inspection		41-45	F	IRATE	In minutes/car	
Coupling delay time		46-50	F	DTCOUP	In minutes	
Rate of coupling		51-55	F	CRATE	In minutes/car	
Block setout time		56-60	F	DTSETO	In minutes	
Traffic inflow multiplier		61-65	F	TRAFMP		Default value is 1.
Link characteristics[a]	5					J=pointer to LINK.
Link number		1-5	I	LINK(J)		
Length of link		6-10	I	LINK(J+1)	Consistent units, length	
Link type		11-15	I	LINK(J+2)	0=Enroute 1=Pullout lead 2=Classification track 3=Departure track 4=Sink link	
Yard selection link belongs to		20	A	LINK(J+6)	E=east, W=west, Blank=no section assignment	
Route characteristics	6					J=Pointer to ROUTE.
Route number		1-5	I	ROUTE(J)		
Type of route		6-10	I	ROUTE(J+1)	0=Pseudo route 1=Common route	
Number of first link		11-15	I	ROUTE(J+6)		
Number of second link		16-20	I	ROUTE(J+7)		
Number of twelfth link[b]		66-70	I	ROUTE(J+17)		

TABLE C-1.-CONTINUED

Description	Card type	Columns	Format	Variable name	Instructions	Comments
O/D route matrix characteristics[c]	7					
Origin link		1-5	I	IOD		
Destination link		6-10	I	JOD		
Preferred route		11-15	I	ODMTRX(I,J,1)		
Alternate route		16-20	I	ODMTRX(I,J,2)		
Trim engine characteristics[d]	8					J=Pointer to ENGINE.
Engine number		1-5	I	ENGINE(J)		
Engine type		6-10	I	ENGINE(J+2)	1=Switch engine 2=Utility engine	
Maximum pull speed		11-15	I	ENGINE(J+5)	MPH	
Maximum shove speed		16-20	I	ENGINE(J+6)	MPH	
Engine work schedule	9					
Number of first engine assigned		1-5	I	PAR(1)	Set to 0, if any trim engine may get assigned	Input values of PAR will be stored in ESCHED.
Number of second engine assigned		6-10 . . .	I	PAR(2) . . .		
Number of 14th engine assigned		66-70	I	PAR(14)		
Engine work schedule	10					
Activity link		1-5	I	PAR(1)		
Activity number		6-10	I	PAR(2)	A number from 1-11	See ACTIVITY LIST. Refer to ACTIVITY for parameter specifications. All values of PAR are stored in ESCHED.
Activity parameter 1		11-15	I	PAR(3)		
Activity parameter 2		16-20	I	PAR(4) . .		
Activity parameter 12[e]		66-70	I	PAR(14)		
Classification track inflow[f]	11					
Classification track number		1-5	I	PAR(1)		PAR values get stored in CSHED.
Time cars are put on track		6-10	I	PAR(2)		
Block number		11-15	I	PAR(3)	Military time	
Number of cars in block		16-20	I	PAR(4)		
Average length of car in block		21-25	I	PAR(5)	In feet	
Train departure schedule	12					
Train number		1-5	I	TRAINO		Input values are stored in TSCHED.
Train depature time		6-10	I	ITIME	Military time	
Number of blocks for this train		11-15	I	NBLKS		
Train departure schedule[g]	13					
First block number		11-15	I	PAR(1)		
Second block number		16-20 . .	I	PAR(2) . .		
Twelfth block number		66-70	I	PAR(12)		

TABLE C-1.-CONCLUDED

Description	Card type	Columns	Format	Variable name	Instructions	Comments
Track initialization[h]	14					
Track number		1-5	I	PAR(1)		Values of PAR are stored in CUTLST.
Block number		6-10	I	PAR(2)		
Number of cars		11-15	I	PAR(3)		
Average length of cars		16-20	I	PAR(4)	In feet	
Track number		21-25	I	PAR(5)		
Block number		26-30	I	PAR(6)		
Number of cars		31-35	I	PAR(7)		
Average length of cars		36-40	I	PAR(8)	In feet	
Track number		41-45	I	PAR(9)		
Block number		46-50	I	PAR(10)		
Number of cars		51-55	I	PAR(11)		
Average length of cars		56-60	I	PAR(12)	In feet	
Track number		61-65	I	PAR(13)		
Block number		66-70	I	PAR(14)		
Number of cars		71-75	I	PAR(15)		
Average length of cars		76-80	I	PAR(16)	In feet	

Notes:
a) One card for each link. The set of link data cards must be followed by a blank card.
b) If more than 12 link specifications are needed, use a continuation card. Start in columns 11-15. The route data set must be delimited by a blank card.
c) Matrix data set must be followed by a blank card. Data must be in ascending order by origin link.
d) One card for each trim engine. Data set must be followed by a blank card.
e) If more than twelve (12) parameters are needed, use a continuation card starting with columns 11-15 for the next parameter. Omit the entry for the activity link if several activities are performed by one engine at such a link. Each set of activities defining an assignment must be delimited by a blank card. Indicate the end of the set of work assignments by a card with 9999 in columns 1-5.
f) For each new inflow time or new block referring to the same classification track, prepare a continuation card starting with columns 6-10. The set of track inflow cards must be delimited by a blank card.
g) The train departure record for one train consist of two cards generally. If more than 12 blocks go on a train, a continuation card must be prepared starting with columns 11-15 as the first data field. Use a blank card to indicate the end of the data set.
h) Prepare as many cards as needed. Last track number in data set must be zero to indicate end of data set.

C.1.2 Simulation Options, Simulation Controls, and General Parameters

Card Type 1--This card is used to identify the run. Eighty alphanumeric characters are available for this purpose. The run identification will be printed at the top of each page of printed output.

Card Type 2--This card controls the output of the program. The default option for all parameters on this card is 0. This means a blank card would produce the default output. The default values, in most cases, suppress printout that is voluminous and may not be required each time the program is run. The parameter ISW1, when set to 1, will cause the program to write link update messages to the simulation log whenever the head of an engine enters a new link or the tail of an engine or a cut of cars clears a link.

ISW2 suppresses the input echo if set to 1. Under this option only two input echo tables are produced. They are the list of simulation controls and general parameters and the initial classification yard inflow matrix.

The parameters ISW3 and ISW4 are debug options that produce messages from routines belonging to the executive section of the program. Both parameters generate a voluminous output and increase program running time substantially because of considerable I/O interface. ISW3 causes the program to print informative messages upon entering the monitored subroutines. ISW4, in general, traces the route selection process, in particular the contents of variables at crucial decision points in routines SELECT, INROUT, and LUPDAT are printed.

The next parameter, ISW5, allows for partial program execution. If set to 1, the program will exercise only the input routines and depending on the options selected will give the input echo printout, the yard inflow list, and perform a route consistency check. This option is particularly helpful when checking data for correctness and compatibility in the early phases of production runs.

A route consistency check is performed by setting ISW7 equal to 1. Each route is examined for contiguous duplicate links. This means the predecessor link and the sucessor link of the current link are examined and if any of the two equals the current link, a message is printed alerting the user to a data entry error. The route consistency check produces a printout by link listing the routes that contain the link within a specific predecessor-successor sequence.

The last two entries on this card may be used to limit the amount of debug printout. TYM1 and TYM2 are the start and end time of the simulated time frame that need to be traced provided ISW3 or ISW4 or both are set to 1. Input to TYM1 and TYM2 must be given in running minutes of simulated time. This means if the debug option is to be in effect from 14:30 to 16:35 then TYM1 must be inputed as 870 and TYM2 as 995.

Card Type 3--This control card specifies the start and end time of the simulation. The default yard type is a pull-back type with one or more pull-out leads. This is specified in the fifth data field. A 1 in this field is necessary if the operations of an inline yard are simulated.

Card Type 4--Most of the parameters that must be given here are self-explanatory. CDELAY is a delay after an unsuccessful try to capture the classification track for coupling purposes. This means an engine other than the current one is occupying the classification track at that time. After the delay time has elapsed the engine again will try to capture the classification track. DDELAY serves the same purpose, but is used when the engine is to perform a doubling operation. The pull-out lead delay, PDELAY, is the time used by the engine to perform the direction reversal. The route selection reschedule time, DTSLCT, is the time interval needed by the engine to start another selection process after a conflict situation. It is realized that this time may vary widely from case to case in real life. This means that DTSLCT just as CDELAY and DDELAY should be a mean value. The time that an engine will wait after a route selection process until it makes its move is given by DTCLAS. The line-haul engine delay, LHDLAY, is imposed to ensure that the trim engine has enough time to vacate the line-haul engine's destination track. Block pull from a classification track may be inhibited by the unavailability of a departure track when starting to build a new train. GETDLY is the time interval after which the trim engine again tries to capture the departure track prior to going into a route selection process. This delay is repeatedly applied until the depature track becomes free.

The next five parameters deal with work that must be performed before a line-haul engine or a train engine may attempt a route selection. The inspection delay time, DTINSP, is a constant time in minutes that is added to the inspection time derived from the number of cars to be pulled and multiplied by the inspection rate (minutes/car), IRATE. DTINSP may include the time necessary to process paperwork for a departing train and also the average time needed to have an inspection crew available and in place to inspect a departing train.

The total coupling delay time consists of a constant coupling delay time, DTCOUP, and a rate of coupling (minutes/car), CRATE. All times must be given in minutes. The block set-out time, DTSETO, is also given in minutes.

The default value of the traffic inflow multiplier, TRAFMP, is 1. This parameter may be used to vary track inflow equally by a fixed percentage rate. This serves to test throat operations at various traffic levels if one can console oneself to the fact that cars in blocks flowing into the yard increase or decrease equally at the same rate.

C.1.3 Yard Geometry

The next three cards deal with the geometry of the yard. The cards define the individual links, the individual routes, and the origin/destination (OD) route matrix.

Card Type 5--The input data to this record determine the link characteristics. Each link must be numbered. The number is assigned by the user. It must correspond to a distinct section of track between switches in the simulated yard. The link number is entered in the first field of the link characteristic card. Next, the length, in feet, of this section of track must be given. Links are also classified by type. This is done to determine whether the link is an enroute link or an activity link at which a certain engine maneuver or work is performed. Designate the link type by entering one of the following numbers in the link-type field of card 5:

0 = Enroute link
1 = Pull-out lead
2 = Classification track
3 = Departure track
4 = Sink link.

A sink link defines outbound tracks to the mainline or inbound tracks from the mainline.

If a dual yard is simulated, identify the yard section the link belongs to. Two identifiers are possible. They are "E" for east and "W" for west. These identifiers are totally arbitrary. They do not correspond to true east or west. If no yard division is necessary, leave this field blank.

There must be one card for each section of track defined as link. No sequential order by link number needs to be maintained when preparing this data set. The group of all link cards must be followed by a blank card to indicate the end of the link data input.

Card Type 6--A route, in general, is a sequence of links between two activity links. Each route is identified by a user supplied number. Often the path that an engine travels between two activity links may consist of two partial routes, a ladder route and a common route. It is this type of specification that must be entered in the type field of the route characteristics card. A zero (0) specifies a ladder route and a one (1) a common route. This is followed by a sequence of links that make up the partial route. Twelve links may be given on this card. More than twelve links in a route require a continuation card with the thirteenth link number starting in columns 11-15. To indicate the end of the route input, a blank card must follow the set.

No sequential order by route number is required for this input deck. However, a continuation card must always follow the principal data card.

Card Type 7--The origin-destination matrix indicates which common route connects the origin activity link with the next activity link. The latter may not be the final destination but merely a stop at which another route selection may take place. In most cases the first link and last link of a common route are collector links. A collector link joins a common route and a ladder route. This concept is illustrated in Figure C-1.

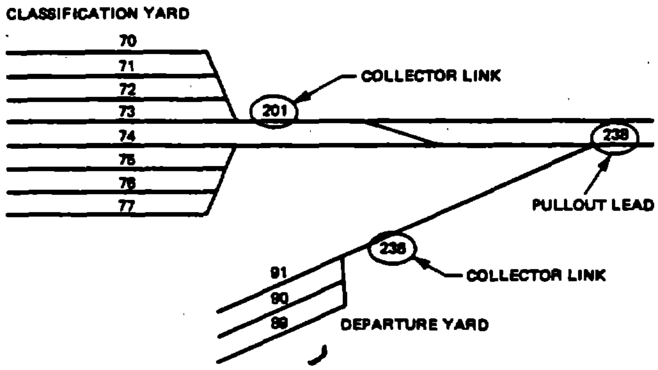


FIGURE C-1. ROUTE COMPOSITION

For example, if the engine wants to travel from track 71 in the classification yard to track 90 in the departure yard, it would first find the collector link associated with the ladder route from track 71. This would be link 201. Next the engine would determine the collector link associated with track 90. This is link 236. Examining the OD matrix (Table C-2), it would find two route numbers listed: the preferred common route 137 and the alternate common route 138. For illustration purposes, let us assume route 137 is free. The engine will choose this route and start its trip. However, route 137 only defines the path from link 201 to link 238, the pull-out lead. After entering the pull-out lead and waiting for a specified time, the engine will start a new route-selection process. This time a common route from link 238 to the collector link 236 of the departure yard is needed. From link 236 it will take a ladder route to link 90. This second selection process is shown by the squares in Table C-2. The common route from link 238 to link 236 is route 127.

The OD matrix input of this example is shown in Table C-3. As shown in the example, these specifications should be made for each origin-destination pair and its intermediate stops.

One card must be made up for each O/D pair. A blank card is necessary to indicate the end of the data set. Care should be taken in keeping this set in ascending order by origin link.

TABLE C-2.-O/D ROUTE MATRIX

	95	108	111	120	130	164	179	186	189	195	201	217	235	236	238	245	247	248	249
95	0	0	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
108	0	0	0	0	0	86	0	0	0	0	0	0	0	166	0	0	0	0	0
	0	0	0	0	0	88	0	0	0	0	0	0	0	-0	0	0	0	0	0
111	154	0	0	0	0	90	0	0	0	0	0	0	0	164	0	0	0	0	0
	-0	0	0	0	0	92	0	0	0	0	0	0	0	-0	0	0	0	0	0
120	0	0	0	0	0	249	0	0	0	0	0	0	0	156	0	0	0	0	0
	0	0	0	0	0	96	0	0	0	0	0	0	0	-0	0	0	0	0	0
130	0	0	0	0	0	98	0	0	0	0	0	0	0	158	0	0	0	0	0
	0	0	0	0	0	100	0	0	0	0	0	0	0	-0	0	0	0	0	0
150	0	0	0	0	0	139	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0
157	0	87	91	95	99	102	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	-0	-0	-0	-0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0
158	0	89	93	96	101	106	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	-0	-0	-0	-0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0
164	0	103	109	109	109	0	0	0	0	160	0	160	0	160	0	0	0	0	0
	0	109	103	103	103	0	0	0	0	-0	0	-0	0	-0	0	0	0	0	0
179	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119	115
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	-0
186	0	0	0	0	0	0	0	0	0	0	0	0	0	121	0	0	0	117	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	123	0	0	0	-0	0
195	0	0	0	0	0	167	0	0	0	0	0	0	0	122	0	0	0	0	0
	0	0	0	0	0	-0	0	0	0	0	0	0	0	124	0	0	0	0	0
201	0	0	0	0	0	162	0	0	0	0	0	0	137	137	137	0	0	0	0
	0	0	0	0	0	-0	0	0	0	0	0	0	138	138	138	0	0	0	0
217	0	0	0	0	0	168	0	0	0	0	0	0	0	125	0	0	0	0	0
	0	0	0	0	0	-0	0	0	0	0	0	0	0	126	0	0	0	0	0
235	0	0	0	0	0	0	0	129	0	129	129	129	0	0	129	0	0	0	0
	0	0	0	0	0	0	0	-0	0	-0	-0	-0	0	0	-0	0	0	0	0
236	0	140	140	140	140	140	0	140	0	140	140	140	0	0	0	145	0	0	0
	0	132	132	132	132	132	0	-0	0	-0	-0	-0	0	0	0	-0	0	0	0
238	0	0	0	0	0	0	0	133	0	135	172	170	128	127	0	0	0	0	0
	0	0	0	0	0	0	0	134	0	136	173	171	-0	-0	0	0	0	0	0
239	0	165	163	157	159	161	0	141	0	142	144	143	0	131	0	0	0	0	0
	0	-0	-0	-0	-0	-0	0	-0	0	-0	-0	-0	0	-0	0	0	0	0	0
242	0	0	0	0	0	0	0	0	0	0	0	0	0	130	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0
245	0	0	0	0	0	0	0	0	0	0	0	0	0	146	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0
246	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	153	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0
248	0	0	0	0	0	0	120	0	116	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	-0	0	-0	0	0	0	0	0	0	0	0	0	0
249	0	0	0	0	0	0	118	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE C-3.-OD MATRIX INPUT

Origin-destination	From link 201 to link 236	From link 238 to link 236
Origin link	201	238
Destination link	236	236
Preferred route	137	127
Alternate route	138	0

C.1.4 Engine Specifications and Assignments

Two types of information concerning engines are required. One relates to the engine itself and is concerned with the type and speed of the engine, the other pertains to the work the engine is to perform.

C.1.4.1 Trim Engine Characteristics

Card Type 8--The input to this car is self-explanatory. Each engine is assigned a number and a type indicator. Always set the type to 1. This identifies a switch engine. The program distinguishes between switch and line-haul engines. Line-haul engines are of type 3. This type number is assigned to the line-haul engine at the time of its assignment to a train. Line-haul engines are created by the program. The speed of the individual line-haul engines is determined at the time of assignment through data furnished by the engine work schedule. It is necessary, however, to assign speed factors to the switch engines on card type 8. The maximum pull speed and the maximum shove speed must be given in miles per hour. One card for each engine is required. The engine data set must be delimited by a blank card.

C.1.4.2 Engine Work Schedule

The engine work schedule lays out the work that needs to be done by the engines. There are two ways of choosing an engine to perform a certain assignment. An assignment may be made to a specific engine, or, if so selected, to the first available engine. The assignment may consist of one or any combination of the following activities (Table C-4).

TABLE C-4.-ENGINE ACTIVITY CODES

Activity code	Description
1	Line-haul engine assignment
2	Train departure
5	Departure track setout
6	Doubling
7	Coupling
8	Classification track pull
9	Class clear
10	Delay
11	Inline doubling

Each activity and its parameters are described below.

C.1.4.2.1 Activity 1: Line-haul Engine Assignment.

Parameters

- Destination link
- Engine ID No. (optional)
- Not used
- Maximum pull speed in mph
- Maximum shove speed in mph
- Train number of train assigned to

The destination link is the track in the departure yard on which the train has been built and to which the line-haul engine is dispatched. Failure to include the train number as one of the parameters will prevent the track from ever becoming available again. The speed of the line-haul engine is determined by two parameters: the maximum pull speed and the maximum shove speed for the engine, both in miles per hour.

C.1.4.2.2 Activity 2: Train Departure.

Parameters

- Destination link number

The destination is the link that connects to the outbound mainline. This must be a link of type 4, a sink link.

C.1.4.2.3 Activity 5: Departure Track Setout.

Parameters

- The link where the engine is to be stationed after the setout and from which it will attempt its next route selection. Set to zero (0) or leave blank if this link is the same as the setout link.

The link specified may be the first link of an escape route. In a cross-over departure yard this link may identify the second section of a split departure track. Route selection will start from this link.

C.1.4.2.4 Activity 6: Doubling.

Parameters

- Destination link number.
- Cut-off time (military time).
- Doubling time (in minutes).
- Block number of block to be moved.
- Maximum number of cars to be pulled. If 0, all cars of this block are pulled.
- Number of resident block with which block to be moved is consolidated.
- Operations indicator: -1 = double only; x > 0 = after doubling couple x additional cars of resident block the cut is to be consolidated with; 0 = couple all cars of resident block on destination track.
- Train to which block to be moved is assigned.
- Number of links occupied by engine for this operation
  - Number of first link
  - Number of second link.

In this doubling operations one block only is moved from one classification track to another and set out there. The user is asked to specify the destination link for the move and the earliest time, the cut-off time, at which the move may occur. The cut-off time must be given in military time (i.e., 1:30 p.m. = 1330). Doubling will take place at this time or later but never before. The duration of the doubling move is determined by the user and so is the block that must be moved. The next parameter requires the maximum number of cars that may be pulled from the block on the origin track. If this parameter is set to zero or left blank, all cars belonging to this block and residing on the track at doubling time are pulled. Specifying the number of cars to be pulled does not quarantee that that many cars will be moved. It merely assures the user that no more cars than this number will be taken from the track and the specified block.

Another data item that need be given is the identification number of the resident block on the destination track. The block moved will lose its original identity. It will be consolidated with the block on the destination track and assume that block's identification number. There are several options that can be selected with this doubling operation. Doubling will only occur if the operations indicator is set to -1. To facilitate successive doubling operations that require coupling before the block can be pulled, the operation indicator can be set so that coupling will occur on the destination track after the doubling operation, i.e., the setout of the block on the destination track.

If the indicator is set to 0, all cars of the block residing on the destination track of the doubling operation will be coupled except for the cars that are being set out on this track by the doubling move and which will be added to the count of cars of the resident block. If the operations indicator is greater than zero, only that many cars of the resident block on the destination track will be coupled.

Other parameters of the doubling operation are the number of the train the block to be moved has to go on and the number of links the engine will occupy in this operation. This then is followed by a list of link identification numbers of those links affected by the move.

The coupling operation associated with the doubling activity can only occur at block setout on the destination track. If there is only one move, or if it is the first one of a series of moves, and if the block on the origin track needs to be coupled prior to doubling, a separate coupling activity must be scheduled for this block on the origin track with the same cut-off time as that of the doubling operation.

C.1.4.2.5 <u>Activity 7: Coupling</u>.

<u>Parameters</u>

- Cutoff time (military time)
- Block number
- Number of cars to be coupled. If 0, all cars of this block are coupled.
- Number of links occupied by engine for this operation. Only the activity link is considered occupied if this parameter is set to zero or left blank.
  - Identification number of first link
  - Identification number of second link.

In most instances, coupling precedes a pulling operation. If this is so, the cutoff time of both the operations should be the same. The same rule applies to the specified block number and the number of cars to be coupled or, in the pull activity, the number of cars to be pulled. The earliest time to start coupling is given by the cutoff time. Any time thereafter is acceptable.

The time needed to perform the coupling activity is a function of the actual number of cars available for coupling and is determined as follows:

Coupling time = constant coupling delay time + (number of cars) × (rate of coupling)

(The constant coupling delay time, DTCOUP, and the rate of coupling, CRATE, are data inputs on card type 4.) The coupling time determines how long the links affected by this operation are unavailable to other engines. The fourth parameter gives the number of links the engine will occupy to perform its maneuvers. This is followed by a list of numbers that identify the links. A zero or a blank for the fourth parameter indicates that the activity link only is used by the engine and is considered occupied for the duration of the computed coupling time.

C.1.4.2.6 <u>Activity 8: Classification Track Pull</u>.

<u>Parameters</u>

- Destination link (departure track)
- Train number
- Cut-off time (military time)
- Block number
- Number of cars to be pulled. If 0, all cars of this block are pulled from this track.

After doubling or coupling, the next activity the engine will engage in is probably a classification track pull. The destination of the block must be given so the engine can select the route from its current position. Route selection may start at the cutoff time or any time thereafter. It is also necessary to identify the train the block will have to go on. This is done by input to the second parameter while the block number associated with the pull is given by the fourth. The user may specify the number of cars to be pulled with the fifth parameter. If the parameter is set to zero or left blank, all cars of the block are taken.

The classification track pull activity must be followed by a setout operation as described under activity 5.

C.1.4.2.7 <u>Activity 9: Classification Track Clear</u>.

<u>Parameters</u>

- Destination link (sink link)
- Cut-off time (military time)
- Block number
- Number of cars to be pulled. If 0, all cars of this block have been pulled.

If the cars on a classification track need rehumping or must be pulled to a maintenance or repair station, the classification track clear activity should be used. The destination link for this move must be a sink link. This means the link is of type 4. Other specifications for this activity are the cutoff time, the number of the block, and number of cars that should be pulled.

C.1.4.2.8 <u>Activity 10: Delay</u>.

<u>Parameters</u>

- Duration of delay (minutes)
- Number of links occupied by engine for this operation

- Number of first link
- Number of second link.

Often delays are incurred because of a bad order or misswitched car that must be removed from a track making the affected track and possibly adjacent links unavailable to other engines. The delay activity may be used to simulate any type of operation or condition that causes a link not to be available for a specified length of time. The user must give the duration of delay in minutes. He also must indicate how many links are affected by the delay and list the identification numbers of those links.

C.1.4.2.9 Activity 11: Inline Doubling.

Parameters

- Final destination
- Train number
- Cutoff time (in military time)
- Operation indicator (-1 = double only, 0 = double and couple).
- Number of moves (Note: One separate card required for each move starting in columns 11-15.)
  - Destination of move
  - Block number of block to be picked up at current location
  - Maximum number of cars to be picked up. Zero if all.

A sample of inline doubling activity is shown in Table C-5.

TABLE C-5.-SAMPLE INPUT OF INLINE DOUBLING ACTIVITY

1	2						
53	11	88	7	300	0	5	
		49	10	0			
		54	24	0			
		60	13	0			
		61	19	0			
		88	52	0			
242	1	88	27	-0	10	10	7
88	2	245					

Inline doubling allows for several doubling moves in succession. Two data cards are necessary for the parameters of this activity. The first card contains the general parameters. They are the final destination, the train number, the cutoff time, the operations indicator and the number of moves.

The final destination is the departure track on which the assembled train is to reside until departure. The train itself is identified by the train number parameter. The inline doubling procedure may not start before the indicated cutoff time. The activity may consist of only the doubling operation or a combined coupling-doubling activity. This means the cars that are pulled from the track will be coupled by the assigned engine before starting the doubling move. A -1 indicates that doubling only may occur. A zero stands for the combined coupling and doubling activity. This card also specifies how many doubling moves are made.

Each move requires a separate card. Starting in columns 11-15 of the move card, the identification number of the destination link for this particular move is entered. This is followed, in columns 16-20, by the block number of the block to be coupled or pulled and residing on the current origin track which may be the destination track of the previous pull. The number of cars to be picked up is the third parameter on the move card. This is the maximum number that may be pulled and may mean that all cars of the block are taken or only a fraction. A zero or blank in this data field lets all cars in the block be pulled.

Card Type 9--This card is a list of engines that may take the next assignment. A zero in columns 1-5 indicates that any available engine may take this assignment. A card of type 9 must precede an engine assignment even if the card is only a blank card.

Card Type 10--A card of type 10 is necessary for each activity. The first entry on this card is the number of the activity link on which the work is performed or will start. This must be entered in columns 1-5. The activity number determines the type of work or operation and is any of those listed in Table C-4, Engine Activity Codes.

Parameters of the activity always start in columns 11-15. If more than twelve parameters are needed, a continuation card may be used starting with the next parameter in columns 11-15.

Several activities may make up one assignment, so there will be several cards of type 10 constituting one assignment. Make sure that each assignment is preceded by a type 9 card. A blank card after an assignment indicates the end of the assignment. The end of the work schedule is given by a card with 9999 in columns 1-5.

C.1.5 Classification Track Inflow

Card Type 11--Inflow to the classification tracks requires five descriptors. The classification track receiving the cars must be identified in addition to the time (military time) that the cars are put on this track. Each cut of cars belongs to a specific block. This means the block number for each cut of cars must be specified as well as the number of cars in the cut. The fifth parameter is the average length of the car in the cut. This length must be given in feet. Sample input is shown in Table C-6.

TABLE C-6.-SAMPLE INPUT: CLASSIFICATION TRACK INFLOW

46	918	49	3	60
46	1425	49	1	60
49	117	24	1	60
49	735	24	1	60
50	200	7	2	60
50	438	7	1	60
50	823	7	1	60
50	901	7	1	60
50	918	7	3	60
50	1009	7	2	60
50	1108	7	2	60
50	1325	7	1	60
50	1404	7	3	60
51	438	9	1	60
52	641	78	2	60
52	918	78	3	60
52	1009	78	1	60
53	438	10	1	60

C.1.6 Train Departure Schedule

Each train departure requires two cards, a card of type 12 and card of type 13.

Card Type 12—This card contains the train number in columns 1-5 and the train departure time in columns 6-10. The train departure time must be given in military time. Columns 11-15 contain the number of blocks that go on the train.

Card Type 13—There must be as many block identification numbers on this card as the number of blocks specified on card type 13, columns 11-15. A blank or zero as identification number will result in an error condition and should be avoided. More than twelve block identification numbers require a continuation card. The first entry on the continuation card should start in columns 11-15. Any data in columns 1-10 on a continuation card are ignored. Delimit the train departure data set by a blank card. An example of input to the train departure schedule is given in Table C-7.

TABLE C-7.-SAMPLE INPUT: TRAIN DEPARTURE SCHEDULE

7	6000	5				
		10	24	13	19	52
8	800	2				
		85	4			
9	800	3				
		8	28	29		
10	830	2				
		34	54			
11	900	1				
		1				

C.1.7 Track Initialization

Card Type 14—A maximum of four assignments may be placed on one card. It is possible to assign several blocks to one track or one block to several tracks or any combination thereof. An assignment requires four data fields, each of 5-character width. These data fields must contain the following information:

- Field 1 - Track number
- Field 2 - Block number
- Field 3 - Number of cars in block
- Field 4 - Average length of car in feet

Prepare as many cars as needed. Sample input is shown in Table C-8.

C.2 CONFLICT OUTPUT

This section describes the output reports generated by CONFLICT. An example of the complete output is given by Exhibit C-2, attached at end of this appendix. Exhibit C-2 is the result of the simulation of trim end activities in a real yard. However, some changes have been made to the input data in order to illustrate specific features. There are three output categories: (1) Input echo-back, (2) display of simulation results, and (3) the simulation log. The input echo-back and the simulation results appear in the following order:

- Input Echo-Back
  - Miscellaneous simulation and run control variables
  - Route consistency check
  - List of links
  - List of routes
  - Origin/Destination route matrix
  - Engine parameters
  - Classification track car inflow
  - Train departure schedule
  - Track initialization
  - Classification yard car inflow per hour.
- Simulation Results
  - Engine movement and conflict delay report
  - Engine load and delay summary
  - Engine activity reports
  - Classification yard car build-up matrix by hour
  - Link occupancy report
  - Route occupancy and conflict delay
  - Train departure report
  - Departure yard occupancy diagram.

C.2.1 Input Echo-Back

The input echo-back of user supplied data is designed to serve as a tool in verifying data correctness and in providing data references for the analysis of the simulation outcome. The echo-back follows closely the input specifications that were discussed in the previous section. The output format has been carefully selected and is self-explanatory. This means that even someone not familiar with the input specifications is able to read and easily understand the underlying data base assumptions.

Coded input has been transformed to English expressions. This is particularly true of the engine work schedule. Each assignment has been translated to a set of easily readable English instructions. The same is true of the train departure schedule.

TABLE C-8.-SAMPLE INPUT: TRACK INITIALIZATION

1	3	14	60	2	6	63	60	2	91	2	60	3	12	54	60
4	23	6	60	4	31	2	60	4	70	2	60	4	84	2	60
4	40	2	60	4	55	12	60	4	42	114	60	5	46	2	60
5	64	2	60	6	33	13	60	7	59	4	60	7	82	9	60
8	25	14	60	9	26	2	60	10	27	186	60	11	30	18	60
12	32	117	60	13	35	40	60	14	36	64	60	15	37	19	60
16	41	37	60	17	43	22	60	18	44	66	60	19	45	43	60
20	50	11	60	20	75	2	60	21	51	18	60	22	53	12	60
23	56	81	60	24	57	44	60	25	58	36	60	25	14	3	60
25	11	2	60	36	60	162	70	27	63	4	60	28	65	35	60
29	66	8	60	20	67	120	60	31	68	22	60	32	71	43	60
33	72	12	60	24	73	86	60	35	74	32	60	36	20	2	60

The input echo printout can be suppressed if the user so desires. This must be specified on card 2 of the input stream. Yard inflow data, by default, are not printed. If the user wants to look at the input echo, he must also select this option on card type 2.

The consistency check looks for adjacent duplicate links in a sequence of links that make up a route. It does so by comparing the predecessor and successor links with the link under examination. If two contiguous link numbers are the same, the following message is printed: LINK NO. xxx ROUTE NO. xxx EQUALS EITHER PREDECESSOR xxx OR SUCCESSOR LINK xxx.

For each link its predecessor and successor links are printed and the numbers of routes that this particular link sequence occurs in. If the predecessor link or successor link is zero, then the examined link is either the first or last link, respectively, in the route. If a link connects to very many different links, the link and the routes it occurs in should be examined by verifying the connections with the help of a blueprint or schematic of the yard track layout.

C.2.2 Classification Yard Car Inflow Per Hour

This matrix summarizes the yard inflow per track and the track initialization data. For each classification track, the track inventory at the beginning of the simulation is given. This is followed by the number of cars flowing onto the track each complete hour of the simulated time frame. The last column shows the highest number of cars that can be expected to travel to that track during one specific hour of the time frame.

C.2.3 Output of Simulation Outcome

The output of the simulation outcome can be divided into two parts. The first part deals with engine movement and activities while the second part concerns itself with track and link occupancy.

C.2.3.1 Engine Movement and Conflict Delay

This report is concerned with the delays caused by conflict as each engine performs its work by moving cars from the classification yard to the departure yard. The report is in chronological order by the end of pull time.

Each engine is listed by its identification number. Information on the engine's movement includes the identification of the block it is pulling and the train the block will go on. Along with the start time (in military time) the origin track number is given as well as the end time of the pull and the destination track number. If a delay occurs while traveling from the origin to the destination track, the route number of the partial route on which the delay takes place and the duration of the delay in minutes is shown. Return trips of an engine from the departure yard to the classification yard or any other location within the yard are easily identified by the zero entries under the block number and train number headings. At the end of the simulation the total conflict delay time for the yard is computed and shown in this report.

C.2.3.2 Engine Load and Delay Summary

This summary indicates how many trips each engine made between the classification yard the departure yard during the simulated time frame. It also shows the total number of cars moved by each engine. The number of delays due to conflict in performing this work is given along with the total time (in minutes) spent in conflict situations. The last column of this summary shows how many cars were delayed due to conflict.

Yard totals have been computed for each category. They show how many trips were made by all the engines and how many cars were moved by them. The total time of incurred conflict delays for the whole yard is also given by this summary.

C.2.3.3 Engine Activity

The engine activity report is a minute-to-minute account of work done by each engine during the simulated time frame. Each symbol in the activity diagram represents one minute of elapsed time. The symbols stand for specific activities and should be read as follows:

C = Coupling
D = Doubling
I = Idle
L = Light engine move
O = Other work
P = Engine pull, heavy
S = Engine shove, heavy
W = Waiting/conflict

A band of three lines depicts 6 hours of time. Time should be read by starting in the upper-left corner of the band or the first symbol of the first line, then down the column of three symbols. The next move should be to the second symbol of the first line. This symbol represents the fourth minute of elapsed time.

In general, each column of three symbols in the band stands for three minutes, as can be seen from the schematic given below:

Min	+	+	+	+	+	+	+	+	+	+	+
1	+	1	4	7	10	13	16	19	22	25	28
2	+	2	5	8	11	14	17	20	23	26	29
3	+	3	6	9	12	15	18	21	24	27	30
	+	-	-	-	-	+	-	-	-	-	+
						15					30

An engine activity diagram is printed for each engine that engages in trim operations. The diagram can cover minute-to-minute activities for a maximum period of 24 hours.

C.2.3.4 Classification Yard Car Build-up Matrix

The classification yard car build-up matrix has been designed to give an hourly account of the classification track inventory. For each track the initial inventory is shown. This is followed by the hourly count of cars on the track. The maximum hourly occupancy for the simulated time, which should not exceed track capacity, is given in the last column of this matrix. If dual classification yards are simulated, a car build-up matrix is prepared for each yard section.

C.2.3.5 Link Occupancy, Route Occupancy, and Conflict Delay

These two reports are very similar; one deals with the link occupany and the other with route choices made by the engines.

The link occupancy report lists only those links that have been traversed either by a single engine or a cut of cars. The number of traversals by engines and cars is given for each link. From this table one easily can determine the most heavily travelled links. Further analysis, using this information, may help to identify possible yard bottlenecks or necessary operational changes.

Only those routes that have been travelled are listed in the route occupancy and conflict delay report. In addition to the number of engines and cars crossing these routes, a count of conflict delays per route is given and the total time of conflict delays incurred on each route is shown.

C.2.3.6 Train Departure Report

The trains in this table are listed in order of their actual departure time from the yard within the simulated time. The scheduled departure time and the actual departure time are given for each listed train. The difference, if any, between these two times is the time that a train has been delayed for departure. No early departures are allowed. The number of cars a train is departing with as well as their total delay time are shown.

Totals show how many trains were built during the simulated time frame and how many cars were removed from the yard by them. Other valuable statistics in this report are the average delay time per train and the average delay time per car, both in minutes.

C.2.3.7 Departure Yard Occupancy Diagram

This diagram shows the departure track occupancy over the simulated time period. The numbers on the left side of the diagram are the departure track numbers. The time of the day is given at the bottom of the diagram. The numbers appearing above and at the beginning of the lines depicting track occupancy are the train numbers of the trains being built on the departure tracks at the indicated times.

There will be two diagrams if dual yards are simulated, one for each section of the yard.

C.2.4 The Simulation Log

The simulation log is a chronological listing of events as they occur during the simulation. Each time an activity or link update begins or ends, a message is written to the log. The log entry shows the number of the engine involved in the particular operation. If a route selection has taken place, the number of the route the engine is traversing is also given. The position of the engine at the time the activity or link update occurs is identified by the link number associated with the message.

The messages to the log vary depending on the operation. A list of the messages as they may occur is given in Table C-9. In addition, each message has a time associated with it, given in military time and indicating the time of event occurrence.

TABLE C-9.-SIMULATION LOG MESSAGES

Event	Message	Routines
Coupling	Ends coupling operation;	COUPLE, DOUBLE, INLINE
	Starts coupling operation.	COUPLE, DOUBLE
Delay	Delay of xxx minutes starts;	DELAY
	Ends delay.	DELAY
Train departure	Is ready to depart for link xxx, train xxx with xxx cars.	DEPART
Doubling	Ends doubling on track xxx.	DOUBLE
	Starts doubling track xxx with xxx cars, block xxx.	DOUBLE
Car pick-up	Cut-off time delay.	GETBLK
	Picks up block xxx with xxx cars, train xxx.	GETBLK
	Picks up (clears track xxx), block xxx with xxx cars.	GETBLK
	Waits for departure of train xxx.	FRETRK
Inline doubling	Begins inline doubling operation.	INLINE
	Ends doubling operation.	INLINE
Engine assignment	Is ready to leave for track xxx.	LHAUL, SELECT
Link update	Enters classification track.	LUPDAT
	Enters departure track.	LUPDAT
	On classification track, clears link xxx.	LUPDAT
	On departure track, clears link xxx.	LUPDAT
	On pull-out lead, clears link xxx.	LUPDAT
	Reverses direction.	LUPDAT
	Train end clears link xxx.	LUPDAT
	Train head enters link.	LUPDAT
	Train leaves system, clears link xxx.	LUPDAT
Route selection	Conflicts with engine xxx, route xxx, link xxx.	SELECT
	No suitable route found.	SELECT
	Reserves routes xxx, xxx, xxx, xxx.	SELECT, INROUT
Car setout	Sets out block xxx with xxx cars.	SETOUT, INLINE
	Track is filled. Total number on track xxx cars.	SETOUT

The simulation log is written to a temporary or local file during the simulation process. This means that the log will not get printed unless the user copies the file to the job output stream via job control cards. The simulation log is written to logical unit 9, so any job control cards set up for the retrieval and printing of the log must make reference to this unit.

A sample copy of the simulation log is given in Exhibit C-2, attached at the end of this appendix.

C.3 THE CONFLICT PROGRAM

This section describes the various routines of the CONFLICT model as a computer program.

C.3.1 General

The CONFLICT program is written in ANSI FORTRAN IV for the CDC 6400. The program requires approximately 150,000 octal words of memory. It is possible to run the conflict program with slight modifications on any computer system having a moderate to large memory. The CDC 6400 version of the conflict model uses an overlay structure which divides the program into four parts. Overlay zero contains all those subprograms that are called from more than one overlay. The program and subroutines that deal with the input and the echo-back of the input are found in overlay 1. Overlay 2 consists of the simulation routines and overlay 3 produces the simulation output.

C.3.2 The CONFLICT Subprograms

This section describes the CONFLICT subprograms. CONFLICT consists of 54 subprograms including the main program. These 54 subprograms and their linkage are shown in Figure C-2. The following describes the purpose of each of these subprograms.

C.3.2.1 Main Program CNFLCT

CNFLCT is the main program. It set the dimensions and maxima of the various data structures in the CONFLICT program. It reads the control variables and the print option parameters. Its main function however, is to call the various overlay programs.

CONFLICT also initializes the event calendar and the link statistics as well as the classification track loadings. It positions the trim engines so that each will appear at the link where the work must be done according to the engine work schedule.

C.3.2.2 Subroutine BUILDM

This routine is strictly a housekeeping routine. It adjusts the cumulative count in the car build-up matrix.

C.3.2.3 Subroutine ERROR

Error processes the error messages identified by a number assigned to it. The routine will stop execution of the program if the error is severe. A list of error messages is given in Table C-10. This list shows the error numbers and the meaning of the error conditions.

C.3.2.4 Function ICKTIM

This function checks if the inputted time is within the limits of 0 and 2400. The routine returns the following values: zero if the time is within limits; 1 if the time is outside those limits.

C.3.2.5 Subroutine LDTRK

This routine updates the track inventory each time the track is entered by a switch engine that has to do work on this track. The routine adjusts the entries in array TRACK and updates the car inflow matrix.

C.3.2.6 Subroutine MILTYM

This subroutine converts running time in minutes to military time.

C.3.2.7 Function MINUTE

Function MINUTE is the inverse of subroutine MYLTYM; it converts military time to running time in minutes.

C.3.2.8 Subroutine PTFLOW

This routine is an output subroutine. It is responsible for the printing of the classification yard inflow matrix and the cumulative classification yard car build-up matrix.

C.3.2.9 Subroutine UNPACK

Three words are returned for each packed word that is passed to this routine. The values are returned individually.

C.3.2.10 Subroutine WTITLE

This routine prints the title of the run on specified input and output pages with a margin of five spaces.

C.3.2.11 Subroutine WTITLL

WTITLL prints the title of the run on input and output pages completely left justified.

C.3.2.12 Program READIN

Program READIN is the first program in overlay (1,0). Its main function is to call, in proper order, subprograms responsible for the processing of the input data to the conflict program.

C.3.2.13 Subroutine CINPUT

CINPUT reads the classification track inflow data. These data determine when and how many cars are to be added to a specific classification track. The data are stored in array CSCHED. An hourly count of car inflow to each track is kept and stored in array CTRACK. These values are to produce the table of the classification yard inflow per hour. If ISW6 is set to 1, this routine echoes back the classification track inflow.

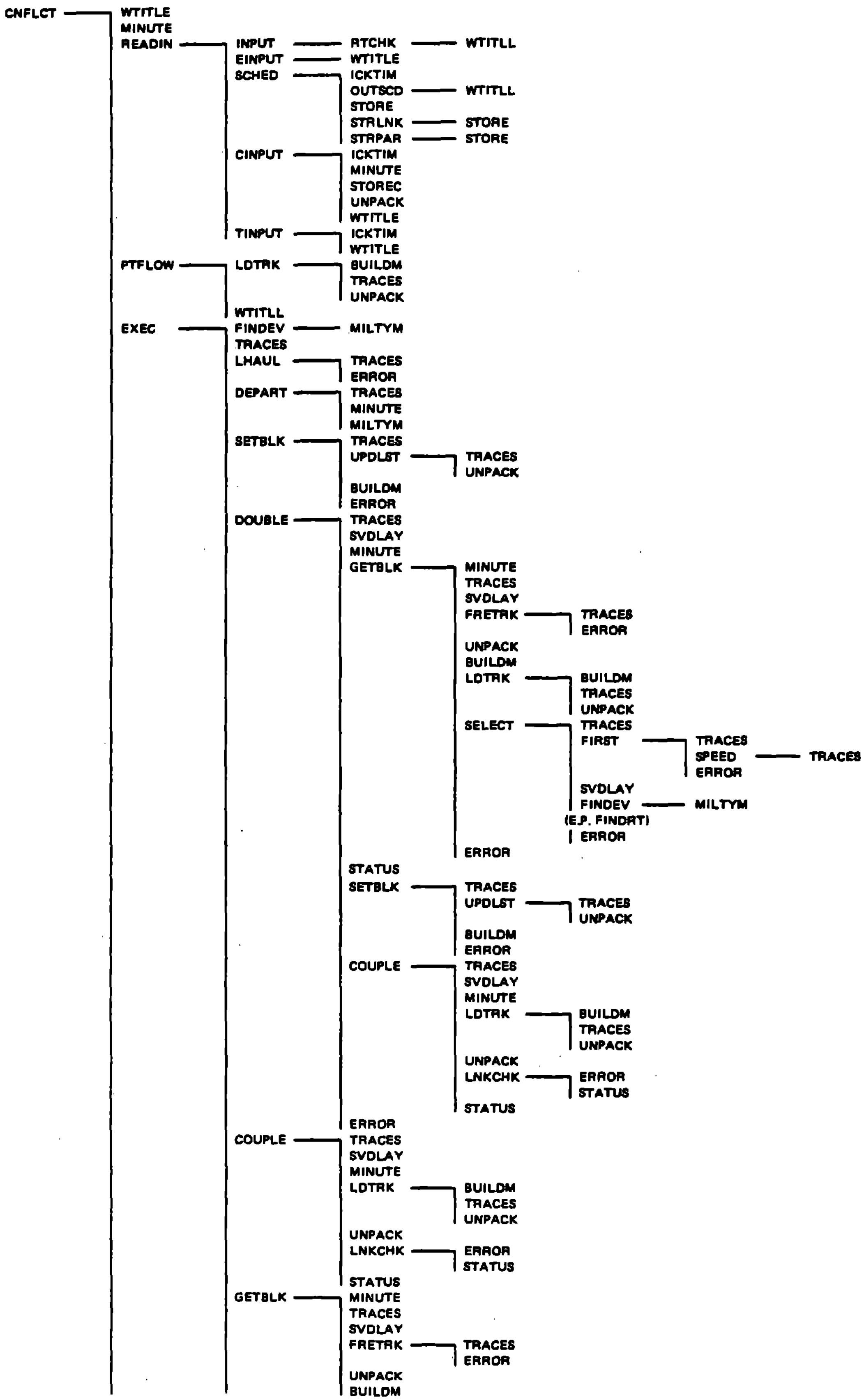


FIGURE C-2. CNFLCT SUBROUTINE LINKAGE

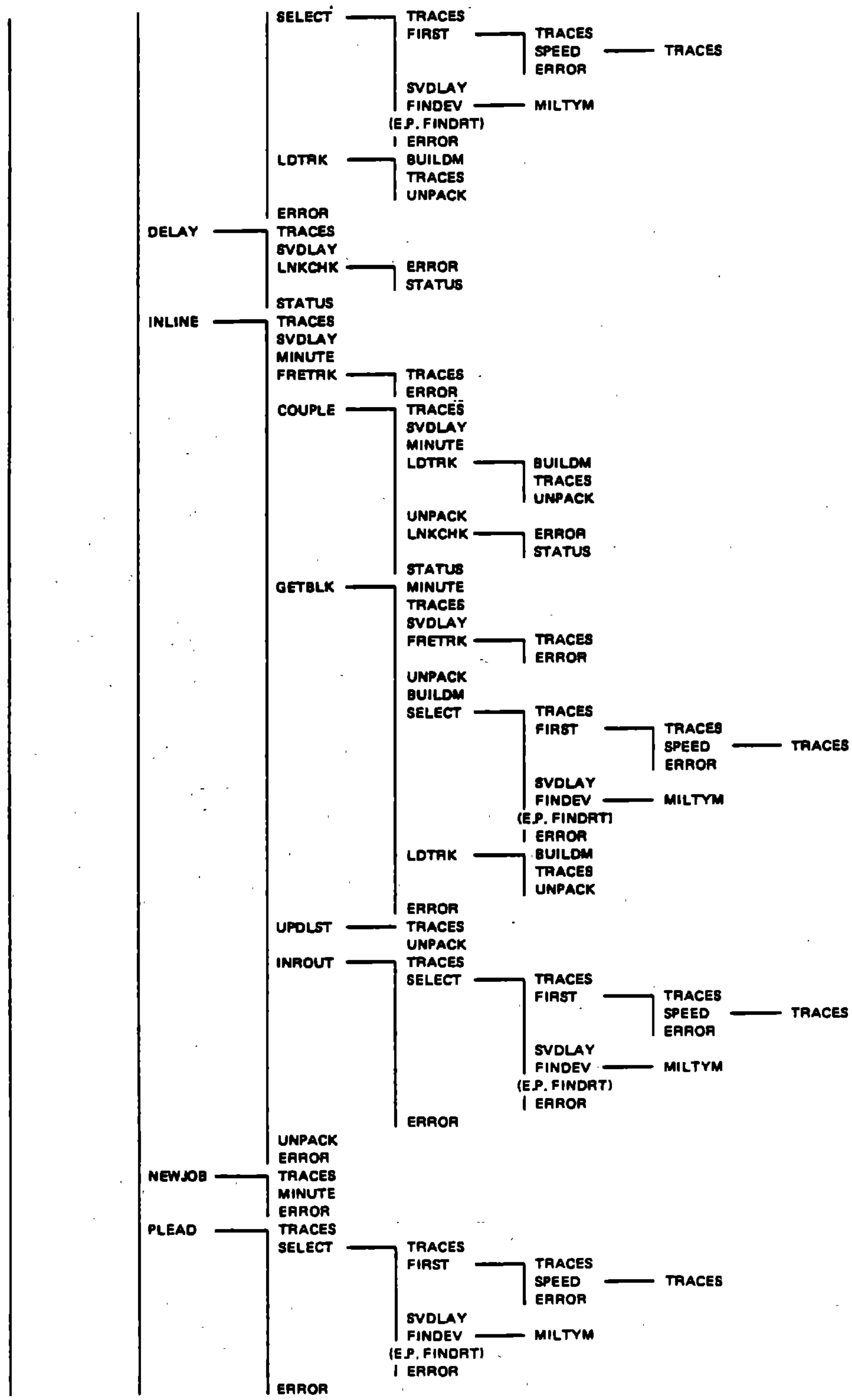


FIGURE C-2. CNFLCT SUBROUTINE LINKAGE (CONTINUED)

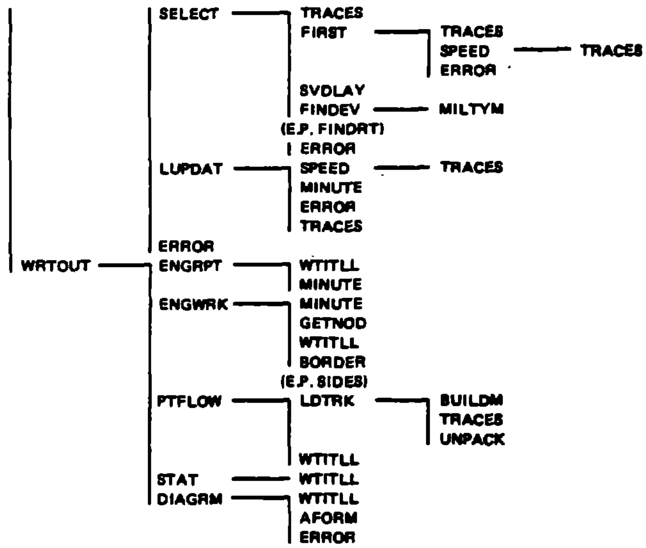


FIGURE C-2. CNFLCT SUBROUTINE LINKAGE (CONCLUDED)

TABLE C-10.-ERROR CONDITIONS

Error number	Error condition
1	Negative time scheduling
2	Time does not advance
3	Activity code is less than or equal to zero
4	Activity code not valid
6	Track is not a classification track
7	No cars on classification track
9	Destination not in the O/D matrix
10	Origin pseudo-link pointer is zero
11	Pointer to 3rd dim. of O/D matrix is zero
12	Pointer to destination pseudo-link is zero
13	Origin not in O/D matrix
14	Dest. link is the same as pullout lead link
17	Route does not contain link
18	This is not the right train for this block
19	Link occupied by standing inventory
20	No job assignment
21	Train not found in train schedule
22	No empty record available for line-haul engine
26	Occupied link not found
27	Link is not a track
28	Pointer to selected route is zero
29	Array DTRACK exceeded
30	No common link found
31	Cut longer than length of available links
32	Array ICROUT exceeded
33	Tail link not found in route list of links
34	No matching link found

C.3.2.14 Subroutine EINPUT

EINPUT reads the engine data and creates an engine record in array ENGINE. It prints out the data if the proper print option has been selected.

C.3.2.15 Subroutine INPUT

This routine reads link, route, and O/D matrix data. It creates records in array TRACK for each link that is either a classification track or a departure track. It sets up the O/D matrix and initializes the arrays IOD and JOD that contain the referenced links of the O/D matrix in ascending order. The combined subscripts of IOD and JOD are the pointers to the rows and columns of the O/D matrix. The routine produces the echo-back listings: LINKS, ROUTES, and O/D ROUTE MATRIX.

C.3.2.16 Subroutine OUTSCD

This routine creates the printed engine work schedule.

C.3.2.17 Subroutine RTCHK

If the route check option has been selected, each link in a route is examined for its predecessor and successor link. If two contiguous links in a route are the same, an error message is printed alerting the user to this condition. The routine produces the route consistency check listing.

C.3.2.18 Subroutine SCHED

Routine SCHED reads the engine activity data. It creates the engine assignment modules and stores the assignment parameters in array ESCHED. Pointers to these modules are saved in array IASGN, which during the simulation portion of the program will get queried whenever a trim engine needs a new assignment.

C.3.2.19 Subroutine STORE

This routine stores a data item in the next available location of ESCHED and checks for overflow conditions.

C.3.2.20 Subroutine STOREC

Two contiguous available locations are taken to store classification track inflow data in array CSCHED. The first location is used for the time that cars are to be put on this track. The second, by means of work packing, stores the block number, the number of cars in the block, and the average length of cars in the block. To prevent overflow, at each store operation a check is made to see if the parameters stored are within array bounds.

C.3.2.21 Subroutine STRLNK

STRLNK stores a list of links associated with an engine activity. It reads a continuation card of the list of links if more than 14 data items are needed for the activity.

C.3.2.22 Subroutine STRPAR

This routine reads and stores the data of each inline doubling move.

C.3.2.23 Subroutine TINPUT

TINPUT reads the data for the train schedule. It creates a fixed-length record for each train in array TSCHED and stores the train-related input parameters in it. If the echo-back printout option is selected, this routine also writes a list of the train schedule to the default output file.

C.3.2.24 Program EXEC

This program is the executive of the simulation part of the program. As such it monitors event processing and link updating. The routine removes engines from the event calendar whenever the engines leave the simulated system or are taken out of service.

C.3.2.25 Subroutine COUPLE

Subroutine COUPLE finds the cut-off time for the coupling operation. If the current time is greater than or equal to that time, the coupling operation will commence by first determining the number of cars on the track that need coupling after a car-inflow update to the track. Links involved in this operation are flagged occupied. A message is written to the simulation log informing of the start of the coupling operation. At the same time an event is placed in the event calendar showing at which time coupling will be finished. To process this scheduled event, routine COUPLE is entered again. The flags are removed from the links, making them again available to other engines and assignments. An end-of-coupling message is written to the simulation log.

C.3.2.26 Subroutine DELAY

This routine schedules an engine delay at a specific link. This delay may cause several links to be unavailable to other engines because the event engine may occupy or block them. Links become free again after the required delay time has elapsed. Messages concerning the start and the end of the delay are written to the simulation log.

C.3.2.27 Subroutine DEPART

DEPART finds the destination of the train--that is it finds the point where the train leaves the system and enters the mainline. A message to the simulation log will show that the line-haul engine is ready to depart. It will also indicate to which system exit point the train will travel.

C.3.2.28 Subroutine DOUBLE

Doubling cannot start until the cut-off time has been satisfied. Any time at or after the cut-off time, the engine will check if the links that it needs for the doubling maneuver are free. If not, the doubling event is scheduled for a later time, depending on DDELAY. Otherwise the number of cars to be moved is determined by a call to routine GETBLK. The status of the involved links is set to "occupied" and a message is written to the simulation log showing that doubling has begun. At the end of the doubling time, the occupancy status is changed to free again. The car inventories of the origin and destination tracks are adjusted to reflect the withdrawal and addition of cars. DOUBLE records the end of the doubling activity in the simulation log.

If in addition the coupling option has been selected, the engine will begin this activity as soon as the cars are deposited on the destination track. Routine COUPLE is called to perform this work. Messages to the log, put out by routine DOUBLE, will inform the user of the start and end of the coupling maneuver.

C.3.2.29 Subroutine FINDEV

This routine finds the next event that must be processed by searching for the minimum time in the calendar of event occurrences.

C.3.2.30 Subroutine FIRST

This routine computes the time for an engine to clear a critical link. A critical link is any link that several engines are vying for to complete their moves. The engine with the shortest time of travel resulting in clearance of the link will be allowed to access it first. This however, is not true if the link in dispute is the last link in the engine's route. In this case, the engine which had reserved the link first will capture it and the route in which the link is embedded.

C.3.2.31 Subroutine FRETRK

FRETRK called from subroutine GETBLK determines if a departure track is free for building a new train. A message is printed if the track is still occupied by a train. Then, after incrementing the current time by a delay time GETDLY, the block-pulling event is scheduled for that later time.

C.3.2.32 Subroutine GETBLK

This routine performs the pulling operation. If the current time is greater than or equal to the cut-off time, a block may be pulled from the classification track. GETBLK compares the current block with the train block sequence. If the pulling sequence is out of order, an informative message is written that may be of interest to the user in determining a possible error condition. There will, however, be no change in the current block pull. If a block pull starts the makeup of a new train, the engine checks if the departure track for the train is free by a call to FRETRK. The block pull event will be rescheduled if the track is still occupied. Each successful block pull is listed in the simulation log by GETBLK. GETBLK also initiates the route selection procedure for the engine.

In addition to train makeup pulling operations, this routine is also used to affect classification track clears.

C.3.2.33 Subroutine INLINE

In this simulation, inline doubling is handled differently from doubling operations in a pull-back style yard. INLINE assumes that the last of the doubling moves is a move to the departure track where the cars finally will be set out in the order that they should appear on the departing train.

Again, doubling will not begin unless the cut-off time is satisfied. The number of cars that must be picked up or that are available for pickup on the track is determined and the length of the cut is calculated from it. Adding this length to the existing length of the train will give the total length of the train. This is a factor in computing how far the engine has to travel to reach that link on which it must reverse its direction of travel and start shoving the cars to the next block pickup. Subroutine INROUT performs this maneuver.

Several messages are written to the simulation log by INLINE. They inform of the start and end of coupling and inline doubling operations. The final set-out of cars by block is also written to the simulation log.

C.3.2.34 Subroutine INROUT

To determine how far and where to the engine has to travel when doing inline doubling, the path from the origin to the intermediary destination must be found. This routine assumes that the engine will travel in the direction of the final destination, the assigned departure track for the train that it is building. The first common link of the routes from the origin link to the final destination and from the intermediary destination to the final destination is found. This common link becomes the direction reversal link once the tail of the train is on it. All links involved in the doubling maneuver are set to "occupied" and are not available to other engines until the links are cleared.

C.3.2.35 Subroutine LHAUL

After comparing the scheduled departure time with the makeup completion time of the train, a line-haul engine is dispatched to the completed train's track at the later of the two times. A message of the line-haul engine assignment is written to the simulation log.

C.3.2.36 Subroutine LNKCHK

This routine checks the link occupancy. If a link is occupied by an engine other than the current one, the event processed by the calling routine is scheduled again after a time interval DELTAT. If all links required by this engine are free, their status will be changed to "occupied" by a call to routine STATUS.

C.3.2.37 Subroutine LUPDAT

Each time an engine enters a new link or clears a link, LUPDAT will perform the necessary updating of pointers and states. It distinguishes between head- and tail-link updates. It also checks if the new link is a pull-out lead, classification track, departure track, or a sink link.

The engine reversal on the pull-out lead is scheduled at the time the tail of the engine clears the link next to the pull-out lead. LUPDAT computes this time. Updating of sink links requires the removal of engines and cars from the system. Adjustments are made in this routine and flags set that cause the final removal of the engine from the event calendar in routine EXEC. Messages to the simulation log inform the user of the time and type of link updates.

C.3.2.38 Subroutine NEWJOB

Each time the engine has completed a job, NEWJOB checks if the assignment has been completed. If not, it will find the next activity link in the assignment. For an activity to occur, the current link of the engine must be the same as the activity link in the assignment schedule. A route selection process will be initiated to get the engine to the activity link if the current link is different.

If a new assignment must be found, the routine will pick the next available assignment that the engine is scheduled to perform. Again, if the next activity link in the new assignment is not the same as the current link, a route selection will take place first to have the engine travel to that link.

The routine initiates line-haul engine events. It creates an engine record for these engines and schedules their entering the system with a route-selection process.

C.3.2.39 Subroutine PLEAD

This routine simulates decisions that are made at the pull-out lead. The engine will reverse its direction. A delay time, defined by input, is added to the reversal operation.

C.3.2.40 Subroutine SELECT

SELECT is one of the most complicated routines of the program. It is responsible for finding an available route for an engine at a route-selection point.

It starts out by determining the type of yard. In an inline yard special tests must be made if the origin link is a departure track. Picking a route from a departure track to a classification track in an inline yard is complicated by the fact that the engine pulls the cuts onto the departure track and blocks its way of return on one side. The engine now must find a route from the end of the departure track to the assigned classification track. So the second collector link, if any, at the other end of the departure track must connect to an escape common route. This must be determined by input, specifically by a sequential ordering in the O/D route matrix, letting the escape route be the alternate route from this particular route selection link.

Each route, in general, consists of several partial routes, an origin-related pseudo-route, a common route, and a destination-related pseudo-route. SELECT inquires which partial route is available. If the partial route is a common route, it interrogates the O/D route matrix and obtains from it the pertinent route number. Each partial route is checked for conflict situations. If two engines need the same link, the engine that clears the link first will win the critical link. The losing engine will again attempt a route selection after a specified time interval unless there exists an alternate route on which it does not encounter a conflict situation. In competing for the same links, line-haul engines will be given preference over trim engines when selecting a route.

C.3.2.41 Subroutine SETBLK

SETBLK deposits a block of cars on a predetermined departure track. It updates the car count and the train length of this track. The routine is also used in doubling operations where cars are temporarily placed on a track. It creates messages from the simulation log informing the user of the setout operation.

C.3.2.42 Function SPEED

This function calculates the speed of the engine depending on the engine's mode of movement. Both pull and shove speeds are determined by this function.

C.3.2.43 Subroutine STATUS

The link occupancy status is set by this routine.

C.3.2.44 Subroutine SYDLAY

This routine updates the cumulative counts of various types of engine delays to be evaluated at the end of the simulation.

C.3.2.45 Subroutine UPDLST

The inventory of each track is kept in a linked list, CUTLST, pointed to by a pointer stored in the track's record, TRACK. Subroutine UPDLST updates CUTLST whenever cars are added or removed from a track.

C.3.2.46 Subroutine TRACES

TRACES is a debug feature. It causes the printing of an informative message in a traced routine. It gives the current values of variables comprising the calendar as well as selected routine-dependent variables. A key to the TRACE printout is given in Table C-11.

C.3.2.47 Program WRTOUT

WRTOUT is the first program of overlay (3,0). As such it controls the sequence and the printing of output reports.

C.3.2.48 Subroutine AFORM

This routine converts an integer value, three digits or less, into an alpha character set.

C.3.2.49 Subroutine BORDER

BORDER produces the frame for the engine activity report. It has an entry point called SIDES. Both BORDER and SIDES are called from ENGWRK.

C.3.2.50 Subroutine DIAGRM

The departure yard occupancy diagram is produced by this routine from data collected during the simulation.

TABLE C-11.-KEY TO TRACE PRINTOUT

Name	Meaning
RTN	Name of routine
TIME	Current event time
TIMEL	Previous event time
IEVENT	Current event number
NEVENT	Number of events in calendar
NOENG	Number of current event engine
ENG	Pointer to current event engine record
ICLNK	Pointer to current link
INLNK	Pointer to next link
IETYP	Event type 0 = Link update, head 1 = Link update, tail -1 = No head update assigned 2 = Line-haul engine update 3 = Sink link return for trim engine
IFLG	Engine status 0 = Enroute 1 = Delayed because of route conflicts 2 = Delayed by conflict, priority in route assignment 3 = Coupling, doubling, or other yardwork -3 = Doubling mode, must be followed by coupling 5 = Idle because of cut-off time conflict 6 = Idle 7 = Delayed because of link conflicts in performing work 8 = Waiting for departure track to clear 9 = Delay on pull-out lead after a route selection
RDLST	Distance along current link at time last event occurred
RTLST	Time the last event occurred
IA	Free parameter, depending on the traced routine
IB	Free parameter, depending on the traced routine
IC	Free parameter, depending on the traced routine
ID	Free parameter, depending on the traced routine
E	Free parameter, depending on the traced routine

C.3.2.51 Subroutine ENGRPT

Two reports are generated by this routine. The reports are on "Engine Movement and Conflict" and "Engine Load and Conflict Delay." The engine movement and conflict report is obtained from data available in the simulation log, while the engine load and delay report is prepared from data collected during the simulation.

C.3.2.52 Subroutine ENGWRK

This is one more output routine. ENGWRK scans the simulation log to obtain individual engine work performance data. Engine activities are identified (Table C-12) by the following activity equivalent numeric and alpha symbols.

TABLE C-12.-ENGINE ACTIVITIES EQUIVALENT SYMBOLS

Type of activity	Numeric symbol	Alpha symbol
Idle	1	I
Coupling	2	C
Doubling	3	D
Other work	4	O
Light engine move	5	L
Engine pull, heavy	6	P
Engine shove, heavy	7	S
Waiting-conflict	8	W

Each symbol in the printed diagram represents one minute of an engine's activity within the simulated time frame.

C.3.2.53 Function GETNOD

GETNOD is a pointer to the next available node in a stack of empty nodes.

C.3.2.54 Subroutine STAT

Three reports are generated by STAT. They are the link occupancy report, the route occupancy and conflict delay report, and the train departure report, each of which is produced from data gathered during the simulation process.

Exhibit C-1

SAMPLE CONFLICT INPUT LISTING CORRESPONDS TO SAMPLE OUTPUT IN EXHIBIT C-2

```
CONFLICT - DEMONSTRATION RUN
    0     0     0     0     0     1     1
    0     0  2400     0
    5     5     1     4     5     2     5     8   .86     2   .41     0  1.2
    1  2915     2     E
    2  3080     2     E
    3  2970     2     E
    4  2970     2     E
    5  2860     2     E
    6  2860     2     E
    7  2750     2     E
    8  2750     2     E
    9  2750     2     E
   10  2585     2     E
   11  2585     2     E
   12  2475     2     E
   13  2475     2     E
   14  2365     2     E
   15  2200     2     E
   16  2200     2     E
   17  2200     2     E
   18  2200     2     E
   19  2090     2     E
   20  2090     2     E
   21  2035     2     E
   22  2035     2     E
   23  1870     2     E
   24  1870     2     E
   25  1815     2     E
   26  1815     2     E
   27  1815     2     E
   28  1870     2     E
   29  1870     2     E
   30  1705     2     E
   31  1705     2     E
   32  1595     2     E
   33  1595     2     E
   34  1540     2     E
   35  1540     2     E
   36  1540     2     E
   37  1430     2     E
   38  1430     2     E
   39  1430     2     E
   40  1430     2     W
   41  1430     2     W
   42  1870     2     W
   43  1870     2     W
   44  1870     2     W
```

45	1815	2	W
46	1815	2	W
47	1815	2	W
48	1705	2	W
49	1705	2	W
50	1595	2	W
51	1595	2	W
52	1485	2	W
53	1485	2	W
54	1485	2	W
55	2090	2	W
56	2090	2	W
57	2090	2	W
58	1925	2	W
59	1925	2	W
60	1870	2	W
61	1870	2	W
62	1705	2	W
63	1705	2	W
64	3135	2	W
65	3135	2	W
66	3025	2	W
67	3025	2	W
68	2915	2	W
69	2915	2	W
70	2860	2	W
71	2860	2	W
72	2860	2	W
81	6720	3	E
82	6660	3	E
83	6600	3	E
84	6540	3	E
85	6960	3	E
86	7020	3	E
87	4380	3	W
88	5400	3	W
89	6120	3	W
90	7500	3	W
91	6460	3	W
92	9999	3	E
95	2450	3	E
101	100	-0	
102	115	-0	
103	116	-0	
104	117	-0	
105	90	-0	
106	120	-0	
107	90	-0	
108	100	-0	
109	225	-0	
110	20	-0	
111	320	-0	
112	90	-0	
113	150	-0	
114	90	-0	
115	85	-0	
116	110	-0	
117	90	-0	
118	220	-0	
119	20	-0	
120	570	-0	
121	90	-0	
122	140	-0	
123	90	-0	
124	115	-0	
125	90	-0	
126	115	-0	
127	80	-0	
128	115	-0	
129	390	-0	
130	390	-0	
131	115	-0	
132	90	-0	
133	115	-0	
	⋮		
195	370	-0	
196	310	-0	
197	90	-0	
198	1350	-0	
199	10	-0	
200	1050	-0	
201	100	-0	
202	80	-0	
203	115	-0	
204	85	-0	
205	115	-0	
206	85	-0	
207	115	-0	
208	80	-0	
209	9999	4	
210	120	-0	
211	85	-0	
212	95	-0	
213	85	-0	
214	115	-0	
215	85	-0	
216	120	-0	
217	500	-0	
218	900	-0	
219	270	-0	
220	15	-0	
221	330	-0	

222	160	-0	
223	1580	-0	
224	1600	-0	
225	175	-0	
226	765	-0	
227	100	-0	
228	110	-0	
229	80	-0	
230	100	-0	
231	90	-0	
232	90	-0	
233	170	-0	
234	15	-0	
235	9999	4	
236	40	-0	
237	270	-0	
238	3135	1	
239	1270	1	
240	430	-0	
241	9999	4	
242	9999	4	
243	130	-0	
244	315	-0	
245	9999	4	
246	100	-0	
247	9999	4	
248	9999	4	W
249	9999	4	W

1	1	101	108				
2	2	101	108				
3	3	103	102	108			
4	4	103	102	108			
5	5	105	104	102	108		
6	6	105	104	102	108		
7	7	107	106	104	102	108	
8	8	107	106	104	102	108	
9	9	106	104	102	108		
10	10	112	111				
11	11	112	111				
12	12	114	113	111			
13	13	114	113	111			
14	14	115	128	113	111		
15	15	115	128	113	111		
16	16	117	116	128	113	111	
17	17	117	116	128	113	111	
18	18	116	128	113	111		
19	19	121	120				
20	20	121	120				
21	21	123	122	120			
22	22	123	122	120			
23	23	125	124	122	120		
24	24	125	124	122	120		
25	25	127	126	124	122	120	
26	26	127	126	124	122	120	
27	27	126	124	122	120		
28	28	132	131	130			
29	29	132	131	130			
30	30	134	133	131	130		
31	31	134	133	131	130		
32	32	136	135	133	131	130	
33	33	136	135	133	131	130	
34	34	138	137	135	133	131	130
35	35	138	137	135	133	131	130
36	36	137	135	133	131	130	
37	37	140	139	130			
38	38	140	139	130			
39	39	139	130				
40	40	179					
41	41	180	179				
42	42	180	179				
43	43	186					
44	44	187	186				
45	45	187	186				
46	46	188	195				
47	47	188	195				
48	48	189	195				
49	49	191	190	189	195		
50	50	191	190	189	195		
51	51	193	192	190	189	195	
52	52	193	192	190	189	195	
53	53	194	192	190	189	195	
54	54	194	192	190	189	195	
55	55	210	217				
56	56	210	217				
57	57	211	217				
58	58	213	212	211	217		
59	59	213	212	211	217		
60	60	215	214	212	211	217	
61	61	215	214	212	211	217	
62	62	216	214	212	211	217	
63	63	216	214	212	211	217	
64	64	202	201				
65	65	202	201				
66	66	204	203	201			

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136	1	238	236	229	228	227	225	223	220	219	200	199	195
137	1	201	221	244	224	227	228	229	236	238			
138	1	201	221	243	220	223	225	227	228	229	236	238	
139	1	150	160	159	156	147	145	164					
78		81	173	172	171	170	169	167	165	164			
80		82	171	170	169	167	165	164					
81		83	170	169	167	165	164						
82		84	169	167	165	164							
83		85	167	165	164								
84		86	165	164									
85		82	166	164									
140	1	236	239										
141	1	239	226	223	220	219	198	197	186				
142	1	239	226	223	220	219	200	199	195				
143	1	239	226	223	220	219	218	217					
144	1	239	226	223	220	243	221	201					
145	1	236	238	245									
146	1	245	238	236									
147		81	246										
148		82	246										
149		83	246										
150		84	246										
151		85	246										
152		86	246										
153	1	246	247										
154	1	111	110	146	147	153	156	159	160	161	95		
155	1	95	161	160	159	156	153	147	146	110	111		
156	1	120	119	149	117	153	156	159	160	162	242	239	
157	1	239	242	162	160	159	156	153	147	149	119	120	
158	1	130	129	119	149	147	153	156	159	160	162	242	239
159	1	239	242	162	160	159	156	153	147	149	119	129	130
160	1	164	145	154	156	159	160	162	242	239			
161	1	239	242	162	160	159	156	154	145	164			
162	1	201	221	243	220	225	227	229	236	237	239		
163	1	239	242	162	160	159	156	153	146	147	110	111	
164	1	111	110	146	147	153	156	159	160	162	242	239	
165	1	239	242	162	159	156	153	147	144	142	141	108	
166	1	108	141	142	144	147	153	156	159	162	242	239	
167	1	195	199	200	219	220	223	226	239				
168	1	217	218	220	223	226	239						
169	1	239	226	223	220	218	217						
170	1	238	236	229	228	227	224	222	220	218	217		
171	1	238	236	229	228	227	225	223	220	218	217		
172	1	238	236	229	228	227	224	244	221	201			
173	1	238	236	229	228	227	225	223	220	243	221	201	

95	111	155	
108	164	86	88
108	236	166	
111	164	90	92
111	95	154	
111	236	164	
120	164	249	96
120	236	156	
130	164	98	100
130	236	158	
150	164	139	
157	164	102	
157	108	87	
157	111	91	
157	120	95	
157	130	99	
158	164	108	
158	108	89	
158	111	93	
158	120	96	
158	130	101	
164	108	103	109
164	111	109	103
164	120	109	103
164	130	109	103
164	195	160	
164	236	160	
164	217	160	
179	249	115	
179	248	119	
186	248	117	
186	236	121	123
195	236	122	124
195	164	167	
201	164	162	
201	235	137	138
201	236	137	138
201	238	137	138
217	236	125	126
217	164	168	
235	238	129	
235	186	129	
235	195	129	
235	217	129	
235	201	129	
236	108	140	132
236	111	140	132
236	164	140	132
236	186	140	
236	195	140	
236	217	140	
236	201	140	
236	245	145	
236	120	140	132
236	130	140	132
238	186	133	134
238	195	135	136
238	201	172	173
238	217	170	171

```
238  236  128
238  236  127
239  164  161
239  108  165
239  120  157
239  130  159
239  186  141
239  195  142
239  217  143
239  201  144
239  236  131
239  111  163
242  236  130
245  236  146
246  247  163
248  179  120
248  189  118
249  179  118

  1    1    6    4
  2    1    6    4

  1    2
 68    7    0   85   53
 68    8   88    1    0   85   53
 88    5
 67    7    0    4   55
 67    8   88    1    0    4   55
 88    5
242    1   88   21   -0   10   10    1
 88    2  245

  1    2
 56    7   15   22    0
 56    8   91    2   15   22    0
 91    5
242    1   91   22   -0   10   10    2
 91    2  245

  1    2
 59    7  200   39   39
 59    8   87    3  200   39   39
 87    5
 57    7  200   62    0
 57    8   87    3  200   62    0
 87    5
242    1   87   23   -0   10   10    3
 87    2  245

  1    2
 45    7  200    1   33
 45    8   89    4  200    1   33
 89    5
 45    7  200    1   33
 45    8   89    4  200    1   33
 89    5
 45    7  200    1   33
 45    8   89    4  200    1   33
 89    5
242    1   89   24   -0   10   10
 89    2  245

  1    2
 69    7  200    5   53
 69    8   90    5  200    5   53
 90    5
 69    7  200    5   53
 69    8   90    5  200    5   53
 90    5
242    1   90   25   -0   10   10    5
 90    2  245

  1    2
 52    7  200   78    0
 52    8   87    6  200   78    0
 87    5
242    1   87   26   -0   10   10    6
 87    2  245
                    .
                    .
                    .
 59    8   91    3 1500   39    0
 91    5

  1    2
 68    7 1500   85   53
 68    8   90   19 1500   85   53
 90    5
 67    7 1500    4   55
 67    8   90   19 1500    4   55
 90    5
242    1   90   36   -0   10   10   19
 90    2  245

  1    2
 45    7 1530    1   33
 45    8   89   20 1530    1   33
 89    5
 45    7 1530    1   33
 45    8   89   20 1530    1   33
 89    5
242    1   89   37   -0   10   10   20
 89    2  245
```

```
   1     2
  62     7  1700    87     0
  62     8    89    21  1700    87     0
  89     5
 242     1    89    38    -0    10    10    21
  89     2   245

   1     2
  69     7  1900     5    53
  69     8    90    22  1900     5    53
  90     5
  69     7  1900     5    53
  69     8    90    22  1900     5    53
  90     5
  63     7  1900    88     0
  63     8    90    22  1900    88     0
  90     5
 242     1    90    39    -0    10    10    22
  90     2   245

9999
   1    10     3     2    60
   1   522     3     1    60
   1  1404     3     1    60
   1  1638     3     3    60
   1  1951     3     1    60
   2    10     6    15    60
   2   418     6     1    60
   2   522     6     5    60
   2  1009     6     8    60
   2  1108     6     1    60
   2  1425     6     1    60
   2  1539     6     1    60
   2  1539    91     1    60
   2  1951     6     6    60
   2  2047     6     1    60
   3   418    12     2    60
   3   522    12     2    60
               .
               .
               .
  70   325    54     8    60
  70   418    54     1    60
  70   546    54     1    60
  70   641    54     1    60
  70   735    54     1    60
  70   823    54    15    60
  70   901    54     2    60
  70  1108    54     1    60
  70  1425    54     1    60
  70  1539    54     1    60
  70  1638    54     2    60
  70  1722    54     1    60
  70  1807    54     1    60
  70  2047    54     6    60
  70  2152    54     1    60
  70  2243    54     1    60
  70  2328    54     3    60
  71    10    80     2    60
  71   117    80     5    60
  71   200    80     3    60
  71   236    80     2    60
  71   325    80     3    60
  71   418    80     6    60
  71   438    80     1    60
  71   522    80     3    60
  71   546    80     5    60
  71   641    80     2    60
  71   735    80     4    60
  71   823    80     3    60
  71   901    80     3    60
  71  1009    80     4    60
  71  1108    80     6    60
  71  1325    80     3    60
  71  1404    80     2    60
  71  1539    79     1    60
  71  1638    80     3    60
  71  1722    80     3    60
  71  1807    80     3    60
  71  1841    80     2    60
  71  1951    80     6    60
  71  2047    80     4    60
  71  2152    80     3    60
  71  2243    80     3    60
  71  2328    80     3    60
  72    10    83     5    60
  72   200    83     2    60
  72   236    83     2    60
  72   418    83     1    60
  72   522    83     1    60
  72   546    83     1    60
  72   735    83     1    60
  72  1108    83     1    60
  72  1404    83     2    60
  72  1638    83     1    60
  72  1722    83     4    60
  72  1041    83     2    60
  72  1951    83     3    60

   1   300     2
              85     4
   2   315     1
```

		22				
3	500	2				
		39	62			
4	500	1				
		1				
5	500	1				
		5				
6	500	1				
		78				
7	600	5				
		10	24	13	19	52
8	800	2				
		85	4			
9	800	3				
		8	26	29		
10	830	2				
		34	54			
11	900	1				
		1				
12	900	3				
		9	7	49		
13	1000	2				
		13	19			
14	1100	2				
		85	4			
15	1300	2				
		5	88			
16	1330	1				
		28				
17	1700	1				
		22				
18	1800	1				
		39				
19	1800	2				
		85	4			
20	1830	1				
		1				
21	2000	1				
		67				
22	2200	2				
		5	88			

1	3	14	60	2	6	63	60	2	91	2	60	3	12	54	60
4	23	6	60	4	31	2	60	4	70	2	60	4	84	2	60
4	40	2	60	4	55	12	60	4	42	114	60	5	46	2	60
5	64	2	60	6	33	13	60	7	58	4	60	7	82	8	60
8	25	14	60	9	26	2	60	10	27	186	60	11	90	18	60
12	32	117	60	13	35	40	60	14	36	64	60	15	37	19	60
16	41	37	60	17	43	22	60	18	44	66	60	19	45	43	60
20	50	11	60	20	76	2	60	21	51	18	60	22	53	12	60
23	56	81	60	24	57	44	60	25	58	36	60	25	14	3	60
25	11	2	60	26	60	162	60	27	63	4	60	28	65	55	60
29	66	8	60	30	67	120	60	31	68	22	60	32	71	43	60
33	72	12	60	34	73	86	60	35	74	32	60	36	20	2	60
37	21	80	60	38	15	292	60	38	16	31	60	38	18	147	60
38	76	128	60	38	77	137	60	38	97	2	60	38	96	2	60
39	2	52	60	39	38	48	60	39	99	0	60	40	81	0	60
41	199	0	60	42	86	0	60	43	29	14	60	44	101	0	60
45	1	30	60	46	49	3	60	47	111	0	60	48	115	0	60
49	24	1	60	50	7	9	60	51	9	0	60	52	78	28	60
53	10	0	60	54	13	23	60	55	8	5	60	56	22	35	60
57	62	27	60	58	116	0	60	59	39	7	60	60	19	10	60
61	52	20	60	62	87	0	60	63	88	0	60	64	34	33	60
65	28	30	60	66	105	0	60	67	4	37	60	68	85	38	60
69	5	42	60	70	84	18	60	71	80	0	60	71	79	2	60
71	47	0	60	71	48	0	60	71	61	0	60	72	83	45	60
0	0	0	0												

Exhibit C-2

SAMPLE CONFLICT OUTPUT LISTING CORRESPONDS TO SAMPLE INPUT IN EXHIBIT C-1

CONFLICT - DEMONSTRATION RUN

MISCELLANEOUS SIMULATION AND CONTROL VARIABLES

TYPE OF YARD	PULL-BACK
SIMULATION START TIME (MILITARY TIME)	0
SIMULATION START DAY	0
SIMULATION END TIME (MILITARY TIME)	2400
SIMULATION END DAY	0
TIME AFTER WHICH ENGINE AGAIN TRIES TO CAPTURE A CLASSIFICATION TRACK TO COUPLE CARS (MIN)	5.00
TIME AFTER WHICH ENGINE AGAIN TRIES TO CAPTURE A CLASSIFICATION TRACK TO DOUBLE CARS (MIN)	5.00
PULL-OUT LEAD DELAY (MIN)	1.00
TIME AFTER A CONFLICT SITUATION AT WHICH ENGINE WILL ATTEMPT ANOTHER ROUTE SELECTION (MIN)	4.00
DELAY AFTER A ROUTE SELECTION BEFORE ENGINE STARTS TO MOVE OR PULL CARS (MIN)	5.00
LINE-HAUL ENGINE DELAY TO ENSURE THAT TRIM ENGINE VACATES TRACK (MIN)	2.00
TIME AFTER WHICH ENGINE CHECKS AGAIN ON THE AVAILABILITY OF A DEPARTURE TRACK FOR BLOCK SETOUT (MIN)	5.00
INSPECTION DELAY TIME (MIN)	5.00
RATE OF INSPECTION (MIN/CAR)	.56
COUPLING DELAY TIME (MIN)	2.00
RATE OF COUPLING (MIN/CAR)	.41
BLOCK SETOUT TIME (MIN)	0.00
TRAFFIC INFLOW MULTIPLIER	1.20

LINK NO. 158 ROUTE NO. 101 EQUALS EITHER PREDECESSOR 0 OR SUCCESSOR LINK 158

LINK NO. 158 ROUTE NO. 101 EQUALS EITHER PREDECESSOR 158 OR SUCCESSOR LINK 153

CONFLICT - DEMONSTRATION RUN

ROUTE CONSISTENCY CHECK

LINK NO.	PRED LINK	SUCC LINK	ROUTE NUMBER(S) OF LINK SEQUENCE OCCURRENCE						
	2	108	2						
102	103	108	3	4					
	104	108	5	6	7	8	9		
103	3	102	3						
	4	102	4						
104	105	102	5	6					
	106	102	7	8	9				
105	5	104	5						
	6	104	6						
106	9	104	9						
	107	104	7	8					
107	7	106	7						
	8	106	8						
108	0	141	86	88	166				
	101	0	1	2					
	102	0	3	4	5	6	7	8	9
	141	0	87	89	165				
110	111	146	90	92	154	164			
	118	146	94	98					
	146	111	91	93	155				
	146	118	95	99					
	147	111	163						
111	0	110	90	92	154	164			
	110	0	91	93	155	163			
	112	0	10	11					
	113	0	12	13	14	15	16	17	18
112	10	111	10						
	11	111	11						
113	114	111	12	13					
	128	111	14	15	16	17	18		
114	12	113	12						
	13	113	13						
115	14	128	14						

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CONFLICT - DEMONSTRATION RUN

ROUTE CONSISTENCY CHECK

LINK NO.	PRED LINK	SUCC LINK	ROUTE NUMBER(S) OF LINK SEQUENCE OCCURRENCE
1	0	101	1
2	0	101	2
3	0	103	3
4	0	103	4
5	0	105	5
6	0	105	6
7	0	107	7
8	0	107	8
9	0	108	9
10	0	112	10
11	0	112	11
12	0	114	12
13	0	114	13
14	0	115	14
15	0	115	15
16	0	117	16
17	0	117	17
18	0	118	18
19	0	121	19
20	0	121	20
21	0	123	21
22	0	123	22
23	0	125	23

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CONFLICT - DEMONSTRATION RUN

L I N K S

LINK NUMBER	LINK LENGTH (FT)	LINK TYPE	YARD SECTION	LINK NUMBER	LINK LENGTH (FT)	LINK TYPE	YARD SECTION	LINK NUMBER	LINK LENGTH (FT)	LINK TYPE	YARD SECTION	LINK NUMBER	LINK LENGTH (FT)	LINK TYPE	YARD SECTION
1	2915	2	E	2	3080	2	E	3	2970	2	E	4	2970	2	E
5	2860	2	E	6	2860	2	E	7	2750	2	E	8	2750	2	E
9	2750	2	E	10	2585	2	E	11	2585	2	E	12	2475	2	E
13	2475	2	E	14	2365	2	E	15	2200	2	E	16	2200	2	E
17	2200	2	E	18	2200	2	E	19	2090	2	E	20	2090	2	E
21	2035	2	E	22	2035	2	E	23	1870	2	E	24	1870	2	E
25	1815	2	E	26	1815	2	E	27	1815	2	E	28	1870	2	E
29	1870	2	E	30	1705	2	E	31	1705	2	E	32	1595	2	E
33	1596	2	E	34	1540	2	E	35	1540	2	E	36	1540	2	E
37	1430	2	E	38	1430	2	E	39	1430	2	E	40	1430	2	W
41	1430	2	W	42	1870	2	W	43	1870	2	W	44	1870	2	W
45	1815	2	W	46	1815	2	W	47	1815	2	W	48	1705	2	W
49	1705	2	W	50	1595	2	W	51	1595	2	W	52	1485	2	W
53	1485	2	W	54	1485	2	W	55	2090	2	W	56	2090	2	W
57	2090	2	W	58	1925	2	W	59	1925	2	W	60	1870	2	W
61	1870	2	W	62	1705	2	W	63	1705	2	W	64	3135	2	W
65	3135	2	W	66	3025	2	W	67	3025	2	W	68	2915	2	W
69	2915	2	W	70	2860	2	W	71	2860	2	W	72	2860	2	W
81	6720	3	E	82	6660	3	E	83	6600	3	E	84	6540	3	E
85	6960	3	E	86	7020	3	E	87	4360	3	W	88	5400	3	W
89	6120	3	W	90	7500	3	W	91	5460	3	W	92	9999	3	E
95	2450	3	E	101	100	-0		102	115	-0		103	116	-0	
104	117	-0		105	90	-0		106	120	-0		107	90	-0	
108	100	-0		109	225	-0		110	20	-0		111	320	-0	
112	90	-0		113	150	-0		114	90	-0		115	85	-0	
116	110	-0		117	90	-0		118	220	-0		119	20	-0	
120	570	-0		121	90	-0		122	140	-0		123	90	-0	
124	115	-0		125	90	-0		126	115	-0		127	80	-0	
128	115	-0		129	390	-0		130	390	-0		131	115	-0	
132	90	-0		133	115	-0		134	90	-0		135	115	-0	
136	90	-0		137	115	-0		138	90	-0		139	550	-0	
140	130	-0		141	480	-0		142	15	-0		143	220	-0	

CONFLICT - DEMONSTRATION RUN

L I N K S

LINK NUM-BER	LINK LENGTH (FT)	LINK TYPE	YARD SEC-TION	LINK NUM-BER	LINK LENGTH (FT)	LINK TYPE	YARD SEC-TION	LINK NUM-BER	LINK LENGTH (FT)	LINK TYPE	YARD SEC-TION	LINK NUM-BER	LINK LENGTH (FT)	LINK TYPE	YARD SEC-TION
144	210	-0		145	40	-0		146	920	-0		147	120	-0	
148	105	-0		149	1270	-0		150	2050	4		151	9999	4	
152	270	-0		153	100	-0		154	180	-0		155	200	-0	
156	90	-0		157	3200	1		158	3200	1		159	210	-0	
160	20	-0		161	115	-0		162	80	-0		163	2450	-0	
164	90	-0		165	95	-0		166	95	-0		167	100	-0	
168	440	-0		169	90	-0		170	100	-0		171	95	-0	
172	175	-0		173	15	-0		174	1	-0		175	9999	4	
176	9999	4		177	4700	-0		178	9999	4		179	15	-0	
180	85	-0		181	120	-0		182	1	4		183	780	-0	
184	390	-0		185	1	4		186	25	-0		187	105	-0	
188	115	-0		189	85	-0		190	105	-0		191	85	-0	
192	115	-0		193	85	-0		194	140	-0		195	370	-0	
196	310	-0		197	90	-0		198	1350	-0		199	10	-0	
200	1050	-0		201	100	-0		202	80	-0		203	115	-0	
204	85	-0		205	115	-0		206	85	-0		207	115	-0	
208	80	-0		209	9999	4		210	120	-0		211	85	-0	
212	95	-0		213	85	-0		214	115	-0		215	85	-0	
216	120	-0		217	560	-0		218	900	-0		219	270	-0	
220	15	-0		221	330	-0		222	160	-0		223	1580	-0	
224	1600	-0		225	175	-0		226	765	-0		227	100	-0	
228	110	-0		229	80	-0		230	100	-0		231	90	-0	
232	90	-0		233	170	-0		234	15	-0		235	9999	4	
236	40	-0		237	270	-0		238	3135	1		239	1270	1	
240	430	-0		241	9999	4		242	9999	4		243	130	-0	
244	315	-0		245	9999	4		246	100	-0		247	9999	4	
248	9999	4	W	249	9999	4	W								

CONFLICT - DEMONSTRATION RUN

R O U T E S

NUMBER	ROUTE NUMBER	ROUTE TYPE	NO. OF LINKS	LINK NUMBERS
1	1	-0	3	1 101 108
2	2	-0	3	2 101 108
3	3	-0	4	3 103 102 108
4	4	-0	4	4 103 102 108
5	5	-0	5	5 105 104 102 108
6	6	-0	5	6 105 104 102 108
7	7	-0	6	7 107 106 104 102 108
8	8	-0	6	8 107 106 104 102 108
9	9	-0	5	9 106 104 102 108
10	10	-0	3	10 112 111
11	11	-0	3	11 112 111
12	12	-0	4	12 114 113 111
13	13	-0	4	13 114 113 111
14	14	-0	5	14 115 128 113 111
15	15	-0	5	15 115 128 113 111
16	16	-0	6	16 117 116 128 113 111
17	17	-0	6	17 117 118 128 113 111
18	18	-0	5	18 116 128 113 111
19	19	-0	3	19 121 120
20	20	-0	3	20 121 120
21	21	-0	4	21 123 122 120
22	22	-0	4	22 123 122 120
23	23	-0	5	23 125 124 122 120
24	24	-0	5	24 125 124 122 120
25	25	-0	6	25 127 126 124 122 120
26	26	-0	6	26 127 126 124 122 120
27	27	-0	5	27 126 124 122 120
28	28	-0	4	28 132 131 130
29	29	-0	4	29 132 131 130
30	30	-0	5	30 134 133 131 130
31	31	-0	5	31 134 133 131 130
32	32	-0	6	32 136 135 133 131 130
33	33	-0	6	33 136 135 133 131 130
34	34	-0	7	34 138 137 135 133 131 130
35	35	-0	7	35 138 137 135 133 131 130
36	36	-0	6	36 137 135 133 131 130
37	37	-0	4	37 140 139 130
38	38	-0	4	38 140 139 130
39	39	-0	3	39 139 130
40	40	-0	2	40 179
41	41	-0	3	41 180 179
42	42	-0	3	42 180 179
43	43	-0	2	43 186
44	44	-0	3	44 187 186
45	45	-0	3	45 187 188

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R O U T E S

NUMBER	ROUTE NUMBER	ROUTE TYPE	NO. OF LINKS	LINK NUMBERS
136	137	1	9	201 221 244 224 227 228 229 236 238
137	138	1	11	201 221 243 220 223 225 227 228 229 236 238
138	139	1	7	150 160 159 156 147 145 164
139	140	1	2	236 239
140	141	1	8	239 226 223 220 219 198 197 186
141	142	1	8	239 226 223 220 219 200 199 195
142	143	1	7	239 226 223 220 219 218 217
143	144	1	7	239 226 223 220 243 221 201
144	145	1	3	236 238 245
145	146	1	3	245 238 236
146	147	-0	2	81 246
147	148	-0	2	82 246
148	149	-0	2	83 246
149	150	-0	2	84 246
150	151	-0	2	85 246
151	152	-0	2	86 246
152	153	1	2	246 247
153	154	1	10	111 110 146 147 153 156 159 160 161 95
154	155	1	10	95 161 160 159 156 153 147 146 110 111
155	156	1	11	120 119 149 117 153 156 159 160 162 242 239
156	157	1	11	239 242 162 160 159 156 153 147 149 119 120
157	158	1	12	130 129 119 149 147 153 156 159 160 162 242 239
158	159	1	12	239 242 162 160 159 156 153 147 149 119 129 130
159	160	1	9	164 145 154 156 159 160 162 242 239
160	161	1	9	239 242 162 160 159 156 154 145 164
161	162	1	10	201 221 243 220 225 227 229 236 237 239
162	163	1	11	239 242 162 160 159 156 153 146 147 110 111
163	164	1	11	111 110 146 147 153 156 159 160 162 242 239
164	165	1	11	239 242 162 159 156 153 147 144 142 141 108
165	166	1	11	108 141 142 144 147 153 156 159 162 242 239
166	167	1	8	195 199 200 219 220 223 226 239
167	168	1	6	217 218 220 223 226 239
168	169	1	6	239 226 223 220 218 217
169	170	1	10	238 236 229 228 227 224 222 220 218 217
170	171	1	10	238 236 229 228 227 225 223 220 218 217
171	172	1	9	238 236 229 228 227 224 244 221 201
172	173	1	11	238 236 229 228 227 225 223 220 243 221 201

CONFLICT - DEMONSTRATION RUN

O/D R O U T E M A T R I X

I	95	108	111	120	130	164	179	186	189	195	201	217	235	236	238	245	247	248	249
95	0	0	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
108	0	0	0	0	0	86	0	0	0	0	0	0	0	166	0	0	0	0	0
	0	0	0	0	0	88	0	0	0	0	0	0	0	-0	0	0	0	0	0
111	154	0	0	0	0	90	0	0	0	0	0	0	0	164	0	0	0	0	0
	-0	0	0	0	0	92	0	0	0	0	0	0	0	-0	0	0	0	0	0
120	0	0	0	0	0	249	0	0	0	0	0	0	0	156	0	0	0	0	0
	0	0	0	0	0	96	0	0	0	0	0	0	0	-0	0	0	0	0	0
130	0	0	0	0	0	98	0	0	0	0	0	0	0	158	0	0	0	0	0
	0	0	0	0	0	100	0	0	0	0	0	0	0	-0	0	0	0	0	0
150	0	0	0	0	0	139	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0
157	0	87	91	95	99	102	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	-0	-0	-0	-0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0
158	0	89	93	96	101	108	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	-0	-0	-0	-0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0
164	0	103	109	109	109	0	0	0	0	160	0	160	0	160	0	0	0	0	0
	0	109	103	103	103	0	0	0	0	-0	0	-0	0	-0	0	0	0	0	0
179	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119	115
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	-0
186	0	0	0	0	0	0	0	0	0	0	0	0	0	121	0	0	0	117	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	123	0	0	0	-0	0
195	0	0	0	0	0	167	0	0	0	0	0	0	0	122	0	0	0	0	0
	0	0	0	0	0	-0	0	0	0	0	0	0	0	124	0	0	0	0	0
201	0	0	0	0	0	162	0	0	0	0	0	0	137	137	137	0	0	0	0
	0	0	0	0	0	-0	0	0	0	0	0	0	138	138	138	0	0	0	0
217	0	0	0	0	0	168	0	0	0	0	0	0	0	125	0	0	0	0	0
	0	0	0	0	0	-0	0	0	0	0	0	0	0	126	0	0	0	0	0
235	0	0	0	0	0	0	0	129	0	129	129	129	0	0	129	0	0	0	0
	0	0	0	0	0	0	0	-0	0	-0	-0	-0	0	0	-0	0	0	0	0
236	0	140	140	140	140	140	0	140	0	140	140	140	0	0	0	145	0	0	0
	0	132	132	132	132	132	0	-0	0	-0	-0	-0	0	0	0	-0	0	0	0
238	0	0	0	0	0	0	0	133	0	135	172	170	128	127	0	0	0	0	0
	0	0	0	0	0	0	0	134	0	136	173	171	-0	-0	0	0	0	0	0
239	0	165	163	157	159	161	0	141	0	142	144	143	0	131	0	0	0	0	0
	0	-0	-0	-0	-0	-0	0	-0	0	-0	-0	-0	0	-0	0	0	0	0	0
242	0	0	0	0	0	0	0	0	0	0	0	0	0	130	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0
245	0	0	0	0	0	0	0	0	0	0	0	0	0	146	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0
246	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	153	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0
248	0	0	0	0	0	0	120	0	118	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	-0	0	-0	0	0	0	0	0	0	0	0	0	0
249	0	0	0	0	0	0	116	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0

CONFLICT - DEMONSTRATION RUN

E N G I N E S

ENGINE NUMBER	ENGINE TYPE	MAXIMUM PULL SPEED (MPH)	MAXIMUM SHOVE SPEED (MPH)
1	1	6	4
2	1	6	4

CONFLICT - DEMONSTRATION RUN

E N G I N E   W O R K   S C H E D U L E

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ASSIGNMENT     1
ASSIGNED ENGINE(S) -     1    2
      LINK   68
                COUPLE CARS AT TIME     0 OR LATER
                      COUPLE  53 CARS OF BLOCK 65
                      ENGINE IS ALLOWED TO OCCUPY LINK(S)    68
      LINK   68
                MOVE  53 CARS OF BLOCK      65 TO LINK    88 FOR TRAIN     1
                      CUTOFF TIME FOR PULL      0
      LINK   88
                SET OUT CARS
      LINK   67
                COUPLE CARS AT TIME     0 OR LATER
                      COUPLE  55 CARS OF BLOCK  4
                      ENGINE IS ALLOWED TO OCCUPY LINK(S)    67
      LINK   67
                MOVE  55 CARS OF BLOCK       4 TO LINK    88 FOR TRAIN     1
                      CUTOFF TIME FOR PULL      0
      LINK   88
                SET OUT CARS
      LINK 242
                MOVE LINE-HAUL ENGINE    21 TO LINK    88 TO PULL TRAIN     1
      LINK   88
                DEPART TRAIN FOR LINK  245

ASSIGNMENT     2
ASSIGNED ENGINE(S) -     1    2
      LINK   56
                COUPLE CARS AT TIME    15 OR LATER
                      COUPLE ALL CARS OF BLOCK  22
                      ENGINE IS ALLOWED TO OCCUPY LINK(S)    56
      LINK   56
                MOVE ALL CARS OF BLOCK      22 TO LINK    91 FOR TRAIN     2
                      CUTOFF TIME FOR PULL     15
      LINK   91
                SET OUT CARS
      LINK 242
                MOVE LINE-HAUL ENGINE    22 TO LINK    91 TO PULL TRAIN     2
      LINK   91
                DEPART TRAIN FOR LINK  245

ASSIGNMENT     3
ASSIGNED ENGINE(S) -     1    2
      LINK   59
                COUPLE CARS AT TIME  200 OR LATER
                      COUPLE  39 CARS OF BLOCK 39
                      ENGINE IS ALLOWED TO OCCUPY LINK(S)    59
      LINK   59
                MOVE  39 CARS OF BLOCK      39 TO LINK    87 FOR TRAIN     3
                      CUTOFF TIME FOR PULL    200
      LINK   87

                SET OUT CARS
      LINK   57
                COUPLE CARS AT TIME  200 OR LATER
                      COUPLE ALL CARS OF BLOCK  62
                      ENGINE IS ALLOWED TO OCCUPY LINK(S)    57
      LINK   57
                MOVE ALL CARS OF BLOCK      62 TO LINK    87 FOR TRAIN     3
                      CUTOFF TIME FOR PULL    200
      LINK   87
                SET OUT CARS
      LINK 242
                MOVE LINE-HAUL ENGINE    23 TO LINK    87 TO PULL TRAIN     3
      LINK   87
                DEPART TRAIN FOR LINK  245
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ASSIGNMENT     4
ASSIGNED ENGINE(S) -     1    2
     LINK  45
          COUPLE CARS AT TIME  200 OR LATER
               COUPLE  33 CARS OF BLOCK  1
               ENGINE IS ALLOWED TO OCCUPY LINK(S)    45
     LINK  45
          MOVE  33 CARS OF BLOCK      1 TO LINK    89 FOR TRAIN     4
               CUTOFF TIME FOR PULL   200
     LINK  89
          SET OUT CARS
     LINK  45
          COUPLE CARS AT TIME  200 OR LATER
               COUPLE  33 CARS OF BLOCK  1
               ENGINE IS ALLOWED TO OCCUPY LINK(S)    45
     LINK  45
          MOVE  33 CARS OF BLOCK      1 TO LINK    89 FOR TRAIN     4
               CUTOFF TIME FOR PULL   200
     LINK  89
          SET OUT CARS
     LINK  45
          COUPLE CARS AT TIME  200 OR LATER
               COUPLE  33 CARS OF BLOCK  1
               ENGINE IS ALLOWED TO OCCUPY LINK(S)    45
     LINK  45
          MOVE  33 CARS OF BLOCK      1 TO LINK    89 FOR TRAIN     4
               CUTOFF TIME FOR PULL   200
     LINK  89
          SET OUT CARS
     LINK 242
          MOVE LINE-HAUL ENGINE   24 TO LINK    89 TO PULL TRAIN     4
     LINK  89
          DEPART TRAIN FOR LINK  245

ASSIGNMENT     5
ASSIGNED ENGINE(S) -     1    2
     LINK  69
          COUPLE CARS AT TIME  200 OR LATER
               COUPLE  53 CARS OF BLOCK  5
               ENGINE IS ALLOWED TO OCCUPY LINK(S)    69
     LINK  69
          MOVE  53 CARS OF BLOCK      5 TO LINK    90 FOR TRAIN     5
               CUTOFF TIME FOR PULL   200
     LINK  90
                              .
                              .
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C L A S S I F I C A T I O N   T R A C K   I N F L O W

TRACK NO.	TRACK E/W	ARRIVING TIME	BLOCK NO.	NUMBER OF CARS	AVG. LENGTH OF CAR
1	E	10	3	2	60
		522	3	1	60
		1404	3	1	60
		1638	3	4	60
		1951	3	1	60
2	E	10	6	16	60
		416	6	1	60
		522	6	6	60
		1009	6	10	60
		1106	6	1	60
		1425	6	1	60
		1539	6	1	60
		1539	91	1	60
		1951	6	7	60
		2047	6	1	60
3	E	416	12	2	60
		522	12	2	60
		546	12	7	60
		901	12	7	60
		1106	12	7	60
		1325	12	1	60
		1539	12	1	60
		1638	12	2	60
		1722	12	1	60
4	E	10	42	2	60
		117	42	4	60
		200	42	1	60
		236	42	1	60
		325	42	1	60
		325	55	7	60
		416	42	1	60
		436	42	1	60
		436	70	1	60
		522	42	16	60
		641	42	2	60
		735	42	6	60
		916	23	2	60
		916	42	6	60
		1009	42	1	60
		1106	42	1	60
		1404	42	1	60
		1425	23	1	60
		1425	64	1	60
		1539	31	1	60
		1539	40	1	60

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CONFLICT - DEMONSTRATION RUN

T R A I N   S C H E D U L E

TRAIN	1	DEPARTURE DAY/TIME	0	300			
		NUMBER OF BLOCKS	2				
		BLOCK NUMBER(S)	65	4			
TRAIN	2	DEPARTURE DAY/TIME	0	315			
		NUMBER OF BLOCKS	1				
		BLOCK NUMBER(S)	22				
TRAIN	3	DEPARTURE DAY/TIME	0	500			
		NUMBER OF BLOCKS	2				
		BLOCK NUMBER(S)	39	62			
TRAIN	4	DEPARTURE DAY/TIME	0	500			
		NUMBER OF BLOCKS	1				
		BLOCK NUMBER(S)	1				
TRAIN	5	DEPARTURE DAY/TIME	0	500			
		NUMBER OF BLOCKS	1				
		BLOCK NUMBER(S)	5				
TRAIN	6	DEPARTURE DAY/TIME	0	500			
		NUMBER OF BLOCKS	1				
		BLOCK NUMBER(S)	78				
TRAIN	7	DEPARTURE DAY/TIME	0	600			
		NUMBER OF BLOCKS	5				
		BLOCK NUMBER(S)	10	24	13	19	52
TRAIN	8	DEPARTURE DAY/TIME	0	800			
		NUMBER OF BLOCKS	2				
		BLOCK NUMBER(S)	65	4			
TRAIN	9	DEPARTURE DAY/TIME	0	800			
		NUMBER OF BLOCKS	3				
		BLOCK NUMBER(S)	6	28	29		
TRAIN	10	DEPARTURE DAY/TIME	0	830			
		NUMBER OF BLOCKS	2				
		BLOCK NUMBER(S)	34	54			
TRAIN	11	DEPARTURE DAY/TIME	0	900			
		NUMBER OF BLOCKS	1				
		BLOCK NUMBER(S)	1				
TRAIN	12	DEPARTURE DAY/TIME	0	900			
		NUMBER OF BLOCKS	3				
		BLOCK NUMBER(S)	9	7	49		
TRAIN	13	DEPARTURE DAY/TIME	0	1000			
		NUMBER OF BLOCKS	2				
		BLOCK NUMBER(S)	13	19			
TRAIN	14	DEPARTURE DAY/TIME	0	1100			
		NUMBER OF BLOCKS	2				
		BLOCK NUMBER(S)	65	4			
TRAIN	15	DEPARTURE DAY/TIME	0	1300			
		NUMBER OF BLOCKS	2				
		BLOCK NUMBER(S)	6	68			
TRAIN	16	DEPARTURE DAY/TIME	0	1330			
		NUMBER OF BLOCKS	1				
		BLOCK NUMBER(S)	28				
TRAIN	17	DEPARTURE DAY/TIME	0	1700			
		NUMBER OF BLOCKS	1				
		BLOCK NUMBER(S)	22				
TRAIN	18	DEPARTURE DAY/TIME	0	1800			
		NUMBER OF BLOCKS	1				
		BLOCK NUMBER(S)	39				
TRAIN	19	DEPARTURE DAY/TIME	0	1600			
		NUMBER OF BLOCKS	2				
		BLOCK NUMBER(S)	65	4			
TRAIN	20	DEPARTURE DAY/TIME	0	1830			
		NUMBER OF BLOCKS	1				
		BLOCK NUMBER(S)	1				
TRAIN	21	DEPARTURE DAY/TIME	0	2000			
		NUMBER OF BLOCKS	1				
		BLOCK NUMBER(S)	87				
TRAIN	22	DEPARTURE DAY/TIME	0	2200			
		NUMBER OF BLOCKS	2				
		BLOCK NUMBER(S)	5	88			

CONFLICT - DEMONSTRATION RUN

T R A C K   I N I T I A L I Z A T I O N

TRACK NUMBER	BLOCK NUMBER	NUMBER OF CARS	AVERAGE LENGTH OF CAR
1	3	14	60
2	6	63	60
2	91	2	60
3	12	54	60
4	23	6	60
4	31	2	60
4	70	2	60
4	84	2	60
4	40	2	60
4	55	12	60
4	42	114	60
5	46	2	60
5	54	2	60
6	33	13	60
7	59	4	60
7	82	9	60
8	25	14	60
9	26	2	60
10	27	186	60
11	30	18	60
12	32	117	60
13	35	40	60
14	36	64	60
15	37	19	60
16	41	37	60
17	43	22	60
18	44	66	60
19	45	43	60
20	50	11	60
20	75	2	60
21	51	16	60
22	53	12	60
23	56	81	60
24	57	44	60
25	58	36	60
25	14	3	60
25	11	2	60
26	60	162	60
27	63	4	60
28	65	35	60
29	66	8	60
30	67	120	60
31	68	22	60
32	71	43	60
33	72	12	60

CONFLICT - DEMONSTRATION RUN

WEST CLASSIFICATION YARD INFLOW PER HOUR

TRK. NO.	TRK. INV.*	NUMBER OF CARS ADDED DURING HOUR BEGINNING AT 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MAXIMUM FOR DAY
40	0	0	1	2	1	1	2	1	1	0	0	2	1	0	1	1	0	1	0	1	1	0	0	1	1	2
42	0	1	1	0	1	1	1	1	1	1	1	2	1	0	1	0	0	0	1	1	0	1	1	1	0	2
43	14	0	0	16	0	0	0	0	0	0	0	0	0	0	4	0	1	0	0	0	0	0	12	0	0	16
45	30	0	24	28	25	26	4	21	26	0	2	0	20	0	2	6	20	13	18	4	0	13	24	13	14	28
46	3	0	8	0	1	0	0	6	0	5	4	0	0	0	0	1	0	0	0	2	0	0	0	0	0	8
49	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
50	9	0	1	2	0	1	0	0	0	1	5	2	2	0	1	4	0	0	1	2	0	0	0	0	0	5
51	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
52	26	0	0	0	0	0	0	2	0	0	4	1	0	0	0	0	1	0	17	0	0	6	0	0	0	17
53	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
54	23	0	1	0	0	0	0	4	7	4	0	0	9	0	0	1	8	1	0	9	2	1	0	4	1	9
55	5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	4
56	35	0	4	5	2	12	0	0	8	1	1	0	7	0	0	1	1	10	6	10	0	2	2	8	7	12
57	27	0	2	0	0	0	0	4	6	1	4	0	0	0	0	1	1	5	6	0	0	12	2	0	1	12
59	7	0	19	0	1	9	7	11	1	4	0	1	0	0	0	2	1	0	0	0	5	2	0	0	0	19
60	10	0	0	4	1	1	0	0	0	0	0	0	2	0	1	0	1	0	1	0	0	8	0	0	0	8
61	20	0	5	2	2	2	0	0	2	5	1	0	6	0	0	1	0	0	5	1	0	2	0	0	0	6
62	0	0	0	0	0	0	0	6	0	0	0	0	12	0	0	0	12	0	0	0	0	0	0	0	0	12
63	0	0	0	0	0	0	0	12	0	0	0	0	24	0	0	0	24	0	0	0	0	0	0	0	0	24
64	33	0	2	3	11	1	1	1	1	16	1	1	1	0	0	1	1	2	1	2	0	8	1	2	2	16
65	30	0	6	2	1	5	0	6	4	6	11	8	16	0	30	1	13	11	0	0	1	6	0	2	1	30
67	37	0	14	12	19	8	0	12	18	1	7	0	24	0	0	2	26	0	1	1	0	6	6	6	11	26
68	38	1	5	17	2	11	7	12	5	5	4	0	28	0	0	1	26	2	6	2	0	6	6	14	8	28
69	42	1	28	13	11	18	3	0	8	5	6	0	19	0	56	3	5	5	4	11	0	7	8	23	12	56
70	18	0	2	2	10	1	1	1	1	18	2	0	1	0	0	1	1	2	1	1	0	7	1	1	4	18
71	2	2	6	6	4	8	10	2	5	4	4	5	7	0	4	2	1	4	4	6	7	5	4	4	4	10
72	45	6	0	4	0	1	2	0	1	0	0	0	1	0	0	2	0	1	5	2	4	0	0	0	0	6

*INVENTORY AT START OF SIMULATION

CONFLICT - DEMONSTRATION RUN

ENGINE MOVEMENT AND CONFLICT DELAY

NO.	ENG NO.	BLK NO.	TRAIN NO.	START TIME PULL	TRK NO.	END TIME PULL	TRK NO.	RTE NO.	DELAY DUE TO CNFLCT (MIN)	RTE NO.	DELAY DUE TO CNFLCT (MIN)	RTE NO.	DELAY DUE TO CNFLCT (MIN)	RTE NO.	DELAY DUE TO CNFLCT (MIN)	RTE NO.	DELAY DUE TO CNFLCT (MIN)	RTE NO.	DELAY DUE TO CNFLCT (MIN)
1	1	85	1	18	68	40	88	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	0	40	88	50	67	0	0	0	0	0	0	0	0	0	0	0	0
3	2	22	2	31	56	110	91	125	20	0	0	0	0	0	0	0	0	0	0
4	2	0	0	110	91	130	59	0	0	0	0	0	0	0	0	0	0	0	0
5	1	4	1	107	67	137	88	137	12	0	0	0	0	0	0	0	0	0	0
6	1	0	0	137	88	150	45	0	0	0	0	0	0	0	0	0	0	0	0
7	2	39	3	213	59	234	87	0	0	0	0	0	0	0	0	0	0	0	0
8	2	0	0	234	87	248	57	0	0	0	0	0	0	0	0	0	0	0	0
9	1	1	4	214	45	304	89	121	32	0	0	0	0	0	0	0	0	0	0
10	1	0	0	304	89	329	45	140	4	75	8	0	0	0	0	0	0	0	0
11	2	62	3	302	57	347	87	125	28	0	0	0	0	0	0	0	0	0	0
12	2	0	0	347	87	403	69	0	0	0	0	0	0	0	0	0	0	0	0
13	1	1	4	344	45	421	89	0	0	0	0	121	20	0	0	0	0	0	0
14	1	0	0	421	89	435	45	0	0	0	0	0	0	0	0	0	0	0	0
15	2	5	5	424	69	450	90	0	0	0	0	0	0	0	0	0	0	0	0
16	2	0	0	450	90	506	69	0	0	0	0	0	0	0	0	0	0	0	0
17	1	1	4	449	45	531	89	121	24	0	0	0	0	0	0	0	0	0	0
18	1	0	0	531	89	550	52	0	0	0	0	0	0	0	0	0	0	0	0
19	2	5	5	528	69	601	90	137	12	0	0	0	0	0	0	0	0	0	0
20	1	78	6	602	52	625	87	0	0	0	0	0	0	0	0	0	0	0	0
21	2	0	0	601	90	628	53	142	12	0	0	0	0	0	0	0	0	0	0
22	1	0	0	625	87	636	68	0	0	0	0	0	0	0	0	0	0	0	0
23	2	10	7	630	53	656	88	0	0	122	16	0	0	0	0	0	0	0	0
24	2	0	0	656	88	718	49	140	4	74	4	0	0	0	0	0	0	0	0
25	2	24	7	721	49	735	88	0	0	0	0	0	0	0	0	0	0	0	0
26	2	0	0	735	88	750	54	0	0	0	0	0	0	0	0	0	0	0	0
27	1	85	14	717	68	758	90	137	20	0	0	0	0	0	0	0	0	0	0
28	1	0	0	758	90	809	67	0	0	0	0	0	0	0	0	0	0	0	0
29	2	13	7	801	54	826	88	122	8	0	0	0	0	0	0	0	0	0	0
30	2	0	0	826	88	840	60	0	0	0	0	0	0	0	0	0	0	0	0
31	1	4	14	831	67	858	90	0	0	0	0	0	0	0	0	0	0	0	0
32	1	0	0	858	90	912	55	0	0	0	0	0	0	0	0	0	0	0	0
33	2	19	7	849	60	926	88	125	12	60	12	0	0	0	0	0	0	0	0
34	2	0	0	926	88	940	61	0	0	0	0	0	0	0	0	0	0	0	0
35	1	8	9	916	55	951	91	55	16	125	8	0	0	0	0	0	0	0	0
36	1	0	0	951	91	1001	65	0	0	0	0	0	0	0	0	0	0	0	0
37	2	52	7	955	61	1021	88	125	8	0	0	0	0	0	0	0	0	0	0
38	2	0	0	1021	88	1031	64	0	0	0	0	0	0	0	0	0	0	0	0
39	1	26	9	1025	65	1055	91	66	8	0	0	0	0	0	0	0	0	0	0
40	2	34	10	1054	64	1125	89	127	4	0	0	0	0	0	0	0	0	0	0
41	1	0	0	1055	91	1128	43	77	16	140	4	0	0	0	0	0	0	0	0
42	2	0	0	1125	89	1136	70	0	0	0	0	0	0	0	0	0	0	0	0
43	1	29	9	1143	43	1205	91	0	0	0	0	0	0	0	0	0	0	0	0
44	2	54	10	1157	70	1230	89	137	8	127	4	0	0	0	0	0	0	0	0
45	1	0	0	1205	91	1231	45	77	12	0	0	0	0	0	0	0	0	0	0
46	2	0	0	1230	89	1244	51	0	0	0	0	0	0	0	0	0	0	0	0
47	2	9	12	1247	51	1302	87	0	0	0	0	0	0	0	0	0	0	0	0
48	2	0	0	1302	87	1332	50	140	4	73	12	0	0	0	0	0	0	0	0
49	1	1	11	1346	45	1408	89	0	0	0	0	0	0	0	0	0	0	0	0
50	1	0	0	1408	89	1422	45	0	0	0	0	0	0	0	0	0	0	0	0
51	2	7	12	1344	50	1436	87	0	0	0	0	122	36	0	0	0	0	0	0
52	2	0	0	1436	87	1455	46	0	0	0	0	0	0	0	0	0	0	0	0
53	1	1	11	1436	45	1510	89	121	16	0	0	0	0	0	0	0	0	0	0
54	1	0	0	1510	89	1528	45	0	0	0	0	0	0	0	0	0	0	0	0
55	2	49	12	1508	46	1541	87	122	16	0	0	0	0	0	0	0	0	0	0
56	1	1	11	1542	45	1605	89	0	0	0	0	0	0	0	0	0	0	0	0
57	2	0	0	1541	87	1608	54	142	12	0	0	0	0	0	0	0	0	0	0
58	1	0	0	1605	89	1616	68	0	0	0	0	0	0	0	0	0	0	0	0
59	2	13	13	1620	54	1644	88	0	0	122	8	0	0	0	0	0	0	0	0
60	1	65	14	1625	68	1658	90	137	20	0	0	0	0	0	0	0	0	0	0
61	2	0	0	1644	88	1658	60	0	0	0	0	0	0	0	0	0	0	0	0
62	1	0	0	1658	90	1708	69	0	0	0	0	0	0	0	0	0	0	0	0
63	2	19	13	1702	60	1724	88	125	12	0	0	0	0	0	0	0	0	0	0
64	2	0	0	1724	88	1735	71	0	0	0	0	0	0	0	0	0	0	0	0
65	1	5	15	1730	69	1807	87	69	8	137	8	0	0	0	0	0	0	0	0
66	1	0	0	1807	87	1822	63	0	0	0	0	0	0	0	0	0	0	0	0
67	2	80	-0	1755	71	1856	65	137	24	0	0	0	0	0	0	0	0	0	0
68	1	88	15	1835	63	1909	87	125	16	0	0	0	0	0	0	0	0	0	0
69	1	0	0	1909	87	1922	56	0	0	0	0	0	0	0	0	0	0	0	0
70	2	28	16	1920	65	1947	91	0	0	0	0	0	0	0	0	0	0	0	0
71	1	22	2	1938	56	2004	88	125	8	0	0	0	0	0	0	0	0	0	0
72	2	0	0	1947	91	2029	59	77	28	0	0	0	0	0	0	0	0	0	0
73	1	0	0	2004	88	2039	68	140	8	74	16	0	0	0	0	0	0	0	0
74	2	39	3	2044	59	2108	91	0	0	0	0	0	0	0	0	0	0	0	0
75	2	0	0	2108	91	2121	45	0	0	0	0	0	0	0	0	0	0	0	0
76	1	85	19	2101	68	2130	90	0	0	0	0	137	8	0	0	0	0	0	0
77	1	0	0	2130	90	2141	67	0	0	0	0	0	0	0	0	0	0	0	0
78	2	1	20	2136	45	2157	89	121	4	0	0	0	0	0	0	0	0	0	0
79	2	0	0	2157	89	2211	45	0	0	0	0	0	0	0	0	0	0	0	0
80	1	4	19	2203	67	2230	90	0	0	0	0	0	0	0	0	0	0	0	0
81	1	0	0	2230	90	2249	62	0	0	0	0	0	0	0	0	0	0	0	0
82	2	1	20	2225	45	2303	89	121	20	0	0	0	0	0	0	0	0	0	0
83	2	0	0	2303	89	2313	69	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS									456		100		64		0		0		0

TOTAL CONFLICT DELAY TIME FOR YARD - 620

CONFLICT - DEMONSTRATION RUN

E N G I N E   L O A D   A N D   D E L A Y   S U M M A R Y

ENGINE NO.	NO. OF TRIPS	NO. OF CARS MOVED	NO. OF CONFLICT DELAYS	TOTAL TIME OF CONFLICT DELAYS (MIN)	NO. OF CARS DELAYED
1	40	693	22	292	439
2	44	629	25	328	423
TOTALS	84	1322	47	620	862

CONFLICT - DEMONSTRATION RUN

E N G I N E   A C T I V I T Y

ENGINE NO. 1

```
MIN ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
     +                                                                                                                        +
 1   + CCCCCCPPPPPPPPLLLCCCCCCWWWWPPPPPPLLLLOOOCCCCCWWWWWWWWWWWWPPPOPPWWWWLLLLCCCCCWWWWWWWWPPPOPLLLLLCCCCCWWWWWWWWWPPPOPPLOLLLLCCC +
 2   + CCCCCCPPPPPPPOLLLCCCCCWWWWPPPPPPOLLLLOOOCCCCCWWWWWWWWWWWWPPPPPPWWWWOLLLLCCCCCWWWWWWWPPPPPPOLLLLCCCCWWWWWWWWWPPPPPPLLLLLLLCCC +
 3   + CCCCCCPPPPPPPLLLCCCCCCWWWWPPPOPPLLLLOOOCCCCWWWWWWWWWWWWPPPPPPWWWWLLLLCCCCCWWWWWWWPPPPPPLLLLCCCCCWWWWWWWWWPPPPPPLLLLLLLCCCC +
     ++----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+ +
     +    15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60 +
     +                    1                   2                   3                   4                   5                   6 +
     +                                                                                                                        +
     +                                                                                                                        +
     +                                                                                                                        +
     +                                                                                                                        +
 1   + CPPPPPOPPLLLCCCCCCCIIIIIIIWWWWWWPPPOPPPLLLCCCCCCCCPPPPPOPPPLLLLCCWWWWWWWWPPOLLLLCCCCCCCCWWPPPPPPPPWWWWWWOLLLLCCCCCPPPPP +
 2   + CPPPPPPPOLLLCCCCCCCIIIIIIIWWWWWPPPPPPPPLLLLCCCCCCCPPPPPPPPPPLLLLLCWWWWWWWWPPPPOLLCCCCCCCCWWWPPPPPPPPWWWWWWLLLLCCCCCPPPPPO +
 3   + PPPPPPPPLLLLCCCCCCCIIIIIIWWWWWWPPPPPPPPOLLLCCCCCCCPPPPPPPPPPOLLLLCWWWWWWWWPPPPLLLCCCCCCCCWWWPPPOPPPWWWWWWLLLLCCCCCPPPPPP +
     ++----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+ +
     +    15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60 +
     +                    7                   8                   9                  10                  11                  12 +
     +                                                                                                                        +
     +                                                                                                                        +
     +                                                                                                                        +
     +                                                                                                                        +
 1   + PPWWWWOLLLLCCCCCIIIIIIIIIIIIIIIIIIIIIIPPPPPPPOLLLLCCCCWWWWWWPPPOPPLOLLLLCCCCPPPPPPPPPLLLLCCCWWWWWWPPPPPLLLCCCCCCCCWWWWWWPPPO +
 2   + PPWWWWLLLLCCCCCIIIIIIIIIIIIIIIIIIIIIIIPPPPPPPPLLLLCCCCCWWWWWPPPPPPLLLLLLCCCCCPPPPPOPPLLLCCCWWWWWWWPPPPOLLLCCCCCCCWWWWWWPPPPP +
 3   + PWWWWLLLLLCCCCCIIIIIIIIIIIIIIIIIIIIIIIPPPPPOPLLLLLCCCCCWWWWWPPPPPPLLLLLLCCCCCPPPPPPPPOLLLCCCWWWWWWWPPOPLLLCCCCCCCCWWWWWPPPPP +
     ++----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+ +
     +    15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60 +
     +                   13                  14                  15                  16                  17                  18 +
     +                                                                                                                        +
     +                                                                                                                        +
     +                                                                                                                        +
     +                                                                                                                        +
 1   + PPPLLLLLCCCCWWWWWPPPPPPOLLLLCCCCCWWWPPPOPPWWWWWWWWWLLLCCCCCCCCCWWPPPPPPPPLLLLCCCCCCCPPPPPPPPPPLLLLLLLCCCCIIIIIIIIIIIIIIIIIIII +
 2   + PPLLLLLLCCCCCWWWWWPPPPPPPLLLLCCCCCCWWPPPPPPPWWWWWWWWLLLLCCCCCCCCWWWPPPPPPPPOLLLCCCCCCCPPPPPOPPPLLLLLLLCCCCCIIIIIIIIIIIIIIIIIIP +
 3   + PPOLLLLLCCCCWWWWWWPPPOPPLLLLCCCCCWWWPPPPPPPWWWWWWWWWOLLLCCCCCCCWWWPPPOPPPLLLCCCCCCCCPPPPPPPPPPLOLLLLCCCCCIIIIIIIIIIIIIIIIIIP +
     ++----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+ +
     +    15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60 +
     +                   19                  20                  21                  22                  23                  24 +
     +                                                                                                                        +
     ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

                                                 TIME (MINUTES/HOURS)
```

C - COUPLING, D - DOUBLING, I - IDLE, L - LIGHT ENGINE MOVE, O - OTHER WORK, P - ENGINE PULL, HEAVY, S - ENGINE SHOVE, HEAVY
W - WAITING/CONFLICT

CONFLICT - DEMONSTRATION RUN

ENGINE ACTIVITY

ENGINE NO. 2

```
MIN ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
    +                                                                          +
 1  + IIIIICCCCCCWWWWWPPPPPPPLLLLLLOOOOOOOOOOCCCCCPPPPPPPLLLLCCCCCWWWWWWWWPPPPPPLLLLLCCCCCCCPPPPPPPPLLLLLCCCCCCCCWWWWPPPOPP +
 2  + IIIIICCCCCWWWWWWPPPPPPLLOLLLLOOOOOOOOOOCCCCPPPPPOPLLLLLCCCCCWWWWWWWWWPPPOPPLOLLLCCCCCCCPPPPPOPPLLLLLCCCCCCCWWWWPPPPPPP +
 3  + IIIIICCCCCWWWWWWPPPOPPLLLLLLLOOOOOOOOOOCCCCPPPPPPPPOLLLLCCCCWWWWWWWWWPPPPPLLLLLCCCCCCCPPPPPPPPLLOLLLCCCCCCCWWWWPPPPPPP +
    ++----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+ +
    +    15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60 +
    +                    1                   2                   3                   4                   5                   6 +
    +                                                                          +
    +                                                                          +
    +                                                                          +
    +                                                                          +
 1  + PWWWWLLLLLWWWWWWPPOWWWLLLLCPPPPPOLLLLCCCCWWPPPPPPLLLLLCCCWWWWWWWWPPPPOLLLLCCCCCWWPPPPPPPOLLLCCCCCCCPPPPPPWWPPPLLLCCCCCCCW +
 2  + LWWWWLLLLCWWWWWPPPPWWOLLLLCPPPPOLLLLLCCCWWWPPPPPPLLLLCCCWWWWWWWWPPPOPLLLLCCCCCWWWPPPPPPLLLCCCCCCCCPPPPPPWPPPOLLLCCCCCCCW +
 3  + OWWWWLILLCWWWWWPPPWWWLLLLLCPPPPLLLLLCCCCWWWPPPOPOLLLLCCCWWWWWWWWPPPPLLLLLCCCCCWWWPPPOPPLLLCCCCCCCCPPPPPOWPPPLLLLCCCCCCCW +
    ++----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+ +
    +    15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60 +
    +                    7                   8                   9                  10                  11                  12 +
    +                                                                          +
    +                                                                          +
    +                                                                          +
    +                                                                          +
 1  + WWPPPPWWPPOLLLLLCPPPPOWWWWWOLLLLCCCCWWWWWWWWWWWWPPPOPLLOLLLLCCCCWWWWPPPPPPOWWWWLLLLCCCCWWWPPPPPLLLLLCWWWWPPPOLLLCCCCCCCW +
 2  + WWPPPPWPPPLLLLLCPPPPPWWWWWLLLLLCCCCWWWWWWWWWWWWPPPPPLLLLLLCCCCCWWWWWPPPPPPWWWWLLLLLCCCCWWPPPPPPLLLLCCWWWWPPOLLLCCCCCCWW +
 3  + WPPPPOWPPPLLLLCPPPPPWWWWWWLLLLCCCCWWWWWWWWWWWWWPPPPPPLLLLLLCCCCWWWWWWPPPOPLWWWWLLLLCCCCWWWPPPOPOLLLLCWWWWPPPPLLLCCCCCCCWW +
    ++----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+ +
    +    15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60 +
    +                   13                  14                  15                  16                  17                  18 +
    +                                                                          +
    +                                                                          +
    +                                                                          +
    +                                                                          +
 1  + WWWWWWWPPPPPPPPPPPPPCCCCCCCCPPPPPOPPPWWWWWWWWWWOLLLLCCCCCPPPPPOPPLLLLCCCCCWWPPPOPLLLLLCCCCCWWWWWWPPPPPPOLLLCCCCCCCIIIPPWWW +
 2  + WWWWWWPPPPOPPPPPPPPPCCCCCCCCPPPPPPPPPPWWWWWWWWWWLLLLLCCCCCPPPPPPPPPLLLLCCCCCWPPPPPPOLLLLCCCCWWWWWWWPPPPPPLLLCCCCCCCCIIIPPWWW +
 3  + WWWWWWPPPPPPPPPPOPPCCCCCCCCCPPPPPPPPPPWWWWWWWWWWLLLLCCCCCPPPPPPPPOLLLLCCCCCWPPPPPPLLLLCCCCCWWWWWWWPPPOPPLLLCCCCCCCIIIIPWWWW +
    ++----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+ +
    +    15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60   15   30   45   60 +
    +                   19                  20                  21                  22                  23                  24 +
    +                                                                          +
    ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

                                TIME (MINUTES/HOURS)
```

C - COUPLING, D - DOUBLING, I - IDLE, L - LIGHT ENGINE MOVE, O - OTHER WORK, P - ENGINE PULL, HEAVY, S - ENGINE SHOVE, HEAVY
W - WAITING/CONFLICT

WEST CLASSIFICATION YARD CAR BUILD-UP MATRIX

TRK. NO.	TRK. INV.*	NUMBER OF CARS FOR HOUR BEGINNING AT 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	MAXIMUM FOR DAY
40	0	0	1	3	4	5	7	8	9	9	9	11	12	12	13	14	14	15	15	16	17	17	17	18	19	19
42	0	1	2	2	3	4	5	6	7	8	9	11	12	12	13	13	13	13	14	15	15	16	17	18	18	18
43	14	14	14	30	30	30	30	30	30	30	30	30	0	0	4	4	5	5	5	5	5	5	17	17	17	30
45	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
46	3	3	11	11	12	12	12	18	18	23	27	27	27	27	27	28	0	0	0	2	2	2	2	2	2	28
49	1	1	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
50	9	9	10	12	12	13	13	13	13	14	19	21	23	23	0	4	4	4	5	7	7	7	7	7	7	23
51	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1
52	26	26	26	26	26	26	26	2	2	2	6	7	7	7	7	7	8	8	24	24	24	24	24	24	24	26
53	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
54	23	23	24	24	24	24	24	24	24	15	15	15	24	24	24	24	24	10	10	19	21	22	22	24	24	24
55	5	5	5	5	5	5	6	6	6	6	0	0	0	0	0	0	0	0	0	0	0	2	6	6	6	6
56	35	0	4	9	11	23	23	23	31	32	33	33	34	34	34	34	34	34	34	34	34	34	34	34	34	34
57	27	27	29	29	0	0	0	4	10	11	15	15	15	15	15	16	17	17	17	17	17	29	31	31	32	32
59	7	7	26	0	1	10	17	28	29	32	32	32	32	32	32	32	32	32	32	32	32	12	12	12	12	32
60	10	10	10	14	15	16	16	16	16	0	0	0	2	2	3	3	4	4	1	1	1	9	9	9	9	16
61	20	20	25	27	29	31	31	31	31	31	8	8	14	14	14	15	15	15	20	21	21	23	23	23	23	31
62	0	0	0	0	0	0	0	6	6	6	6	6	18	18	18	18	28	28	28	28	28	28	28	28	2	28
63	0	0	0	0	0	0	0	12	12	12	12	12	28	28	28	28	28	28	28	28	28	28	28	28	28	28
64	33	33	35	36	49	50	51	52	52	52	52	19	20	20	20	21	22	24	25	27	27	33	34	36	38	52
65	30	30	36	38	39	44	44	50	52	52	52	27	43	43	52	52	52	52	52	52	47	52	52	52	52	52
67	37	37	14	26	45	50	50	50	50	34	41	41	50	50	50	50	50	50	50	50	50	50	50	50	50	50
68	38	1	6	23	25	36	43	46	12	17	21	21	48	48	48	48	48	48	48	48	48	48	32	46	48	48
69	42	43	48	48	48	48	20	20	28	33	39	39	48	48	48	48	48	48	48	48	48	48	48	48	48	48
70	16	16	20	22	32	33	34	35	36	47	47	47	10	10	10	11	12	14	15	16	16	23	24	25	29	47
71	2	4	10	16	20	28	38	40	45	47	47	47	47	47	47	47	47	47	35	41	47	47	47	47	47	47
72	45	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47

*INVENTORY AT START OF SIMULATION

L I N K   O C C U P A N C Y   R E P O R T

LINK NO.	NO. OF ENGINES	NO. OF CARS
43	1	30
45	8	240
46	1	28
49	1	2
50	1	24
51	1	1
52	1	26
53	1	1
54	2	48
55	1	6
56	2	69
57	1	29
59	2	56
60	2	20
61	1	31
62	1	28
63	1	28
64	1	52
65	2	104
67	3	137
68	4	152
69	4	192
70	1	47
71	1	45
87	12	210
88	13	211
89	14	339
90	10	310
91	9	207
186	18	270
187	16	240
188	2	28
189	14	102
190	14	102
191	4	26
192	10	75
193	4	27
194	6	49
195	16	130
197	18	270
198	18	270
199	16	130
200	16	130
201	30	681
202	6	166
203	24	525
204	6	137
205	18	366
206	14	296
207	4	92
208	4	92
210	5	75
211	15	166
212	13	137
213	4	58
214	9	79
215	6	61
216	3	28
217	20	241
218	20	241
219	44	400
220	66	641
221	30	681
222	26	613
223	42	28
224	42	1294
225	1	28
226	41	0
227	43	1322
228	67	1742
229	93	2130
230	68	1725
231	40	1047
232	20	427
233	2	45
234	2	45
235	1	45
236	161	3855
237	17	0
238	60	2533
239	58	0
243	14	0
244	16	681
245	17	1211

R O U T E   O C C U P A N C Y   A N D   C O N F L I C T   D E L A Y

ROUTE NO.	NO. OF ENGINES USING THE ROUTE	NO. OF CARS USING THE ROUTE	NO. OF CONFLICT DELAYS	TOTAL TIME OF CONFLICT DELAYS (MIN)
43	1	0	0	0
45	8	0	0	0
46	1	0	0	0
49	1	0	0	0
50	1	0	0	0
51	1	0	0	0
52	1	0	0	0
53	1	0	0	0
54	2	0	0	0
55	1	0	1	16
56	1	0	0	0
57	1	0	0	0
59	2	0	0	0
60	2	0	1	12
61	1	0	0	0
62	1	0	0	0
63	1	0	0	0
64	1	0	0	0
65	2	0	1	8
67	3	0	0	0
68	3	0	0	0
69	4	0	1	8
70	1	0	0	0
71	1	0	0	0
73	12	210	1	12
74	13	211	2	20
75	14	339	1	8
76	10	310	0	0
77	9	207	3	56
121	9	270	6	116
122	8	130	5	84
125	9	213	8	112
126	1	28	0	0
127	0	0	2	8
137	15	661	8	112
140	41	0	5	24
142	0	0	2	24
145	17	1211	0	0

T R A I N   D E P A R T U R E   R E P O R T

TRAIN NO.	SCHEDULED DEPARTURE TIME	ACTUAL DEPARTURE TIME	TRAIN DELAY TIME (MIN)	NUMBER OF CARS ON TRAIN	TOTAL DELAY TIME OF CARS ON DEPT. TRAINS (MIN)
1	300	305	5	75	375
2	315	316	1	35	35
3	500	501	1	55	55
4	500	630	90	90	8100
6	500	657	117	26	3042
5	500	700	120	96	11520
7	600	1112	312	74	23088
9	800	1305	305	88	26840
10	830	1331	301	99	29799
12	900	1616	436	53	23108
11	900	1700	480	90	43200
14	1100	1712	372	116	43152
13	1000	1758	478	28	13384
15	1300	2005	425	76	32300
16	1330	2021	411	52	21372
19	1800	2330	330	98	32340
20	1830	2341	311	60	18660
TOTAL 17			4495	1211	330370

AVERAGE DELAY TIME PER TRAIN IS 264 MINUTES
AVERAGE DELAY TIME PER CAR IS 272 MINUTES

CONFLICT - DEMONSTRATION RUN

WEST DEPARTURE YARD OCCUPANCY DIAGRAM

```
TRK NO  |-------------------------------------------------------------------------------------------------------------------------|
        |     2                                          9                                               16     3               |
    91  |     |==========|                               |================|                              |===|  |==============||
        |                      5               14                                                                19             |
    90  |                      |============|  |================================================|                |===========|  |
        |              4                                        10            11                                    20          |
    89  |             |==================|                      |===========| |==============|                      |========|  |
        |  1                                7                                               13              2                     |
    88  |  |=============|                  |=======================|                       |========|      |====================||
        |            3                 6                                 12                     18                              |
    87  |           |=============|    |==|                              |===============|      |===========|                   |
        |+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+|
         0    1    2    3    4    5    6    7    8    9    10   11   12   13   14   15   16   17   18   19   20   21   22   23   24
                                                              TIME OF DAY
```

```
===== S I M U L A T I O N   L O G =====
ENG  1  RT   0  LNK  88  STARTS COUPLING OPERATION                                                     D/T  0    0.00
ENG  2  RT   0  LNK  56  STARTS COUPLING OPERATION                                                     D/T  0   15.00
ENG  1  RT   0  LNK  88  ENDS COUPLING OPERATION                                                       D/T  0   17.58
ENG  1  RT   0  LNK  88  PICKS UP                         BLK  65 WITH  38 CARS       TRN  1           D/T  0   17.58
ENG  1  RT   0  LNK  88  RESERVES ROUTES                       88       137       0                    D/T  0   17.58
ENG  1  RT 137  LNK 238  ENTERS PULL-OUT LEAD                                                          D/T  0   26.24
ENG  2  RT   0  LNK  56  ENDS COUPLING OPERATION                                                       D/T  0   31.35
ENG  2  RT   0  LNK  56  PICKS UP                         BLK  22 WITH  35 CARS       TRN  2           D/T  0   31.35
ENG  2  RT 125  LNK  56  CONFLICTS WITH                   ENG   1   RT 137  LNK 224                    D/T  0   31.35
ENG  2  RT 126  LNK  56  CONFLICTS WITH                   ENG   1   RT 137  LNK 227                    D/T  0   31.35
ENG  2  RT   0  LNK  56  NO SUITABLE ROUTE FOUND                                                       D/T  0   31.35
ENG  1  RT 137  LNK 238  ON PULL-OUT LEAD, CLEARS         LNK 236                                      D/T  0   32.66
ENG  1  RT   0  LNK 238  RESERVES ROUTES                        0       127      74                    D/T  0   32.66
ENG  1  RT  74  LNK  88  ENTERS DEPARTURE TRACK                                                        D/T  0   33.00
ENG  2  RT 125  LNK  56  CONFLICTS WITH                   ENG   1   RT  74  LNK 229                    D/T  0   35.35
ENG  2  RT 126  LNK  56  CONFLICTS WITH                   ENG   1   RT  74  LNK 229                    D/T  0   35.35
ENG  2  RT   0  LNK  56  NO SUITABLE ROUTE FOUND                                                       D/T  0   35.35
ENG  2  RT 125  LNK  56  CONFLICTS WITH                   ENG   1   RT  74  LNK 229                    D/T  0   39.35
ENG  2  RT 126  LNK  56  CONFLICTS WITH                   ENG   1   RT  74  LNK 229                    D/T  0   39.35
ENG  2  RT   0  LNK  56  NO SUITABLE ROUTE FOUND                                                       D/T  0   39.35
ENG  1  RT  74  LNK  88  ON DEPARTURE TRACK, CLEARS       LNK 229                                      D/T  0   39.62
ENG  1  RT   0  LNK  88  SETS OUT                         BLK  65 WITH  38 CARS                        D/T  0   39.62
ENG  1  RT   0  LNK  88  RESERVES ROUTES                       74       140       0                    D/T  0   39.62
ENG  1  RT 140  LNK 239  ENTERS PULL-OUT LEAD                                                          D/T  0   39.84
ENG  1  RT 140  LNK 239  ON PULL-OUT LEAD, CLEARS         LNK 236                                      D/T  0   39.94
ENG  1  RT   0  LNK 239  RESERVES ROUTES                        0       144      67                    D/T  0   40.94
ENG  2  RT 125  LNK  56  CONFLICTS WITH                   ENG   1   RT 144  LNK 220                    D/T  0   43.35
ENG  2  RT 126  LNK  56  CONFLICTS WITH                   ENG   1   RT 144  LNK 220                    D/T  0   43.35
ENG  2  RT   0  LNK  56  NO SUITABLE ROUTE FOUND                                                       D/T  0   43.35
ENG  2  RT 125  LNK  56  CONFLICTS WITH                   ENG   1   RT 144  LNK 220                    D/T  0   47.35
ENG  2  RT 126  LNK  56  CONFLICTS WITH                   ENG   1   RT 144  LNK 220                    D/T  0   47.35
ENG  2  RT   0  LNK  56  NO SUITABLE ROUTE FOUND                                                       D/T  0   47.35
ENG  1  RT  67  LNK  67  ENTERS CLASSIFICATION TRACK                                                   D/T  0   49.60
ENG  1  RT  67  LNK  67  ON CLASSIFICATION TRACK, CLEARS  LNK 204                                      D/T  0   49.94
ENG  1  RT   0  LNK  67  STARTS COUPLING OPERATION                                                     D/T  0   49.94
ENG  2  RT   0  LNK  56  RESERVES ROUTES                       56       125       0                    D/T  0   51.35
ENG  2  RT 125  LNK 238  ENTERS PULL-OUT LEAD                                                          D/T  0   58.33
ENG  2  RT 125  LNK 238  ON PULL-OUT LEAD, CLEARS         LNK 236                                      D/T  0  102.40
ENG  2  RT   0  LNK 238  RESERVES ROUTES                        0       127      77                    D/T  0  103.40
ENG  2  RT  77  LNK  91  ENTERS DEPARTURE TRACK                                                        D/T  0  104.31
ENG  1  RT   0  LNK  67  ENDS COUPLING OPERATION                                                       D/T  0  107.11
ENG  1  RT   0  LNK  67  PICKS UP                         BLK   4 WITH  37 CARS       TRN  1           D/T  0  107.11
ENG  1  RT 137  LNK  67  CONFLICTS WITH                   ENG   2   RT 127  LNK 236                    D/T  0  107.11
ENG  1  RT 138  LNK  67  CONFLICTS WITH                   ENG   2   RT 127  LNK 236                    D/T  0  107.11
ENG  1  RT   0  LNK  67  NO SUITABLE ROUTE FOUND                                                       D/T  0  107.11
ENG  2  RT  77  LNK  91  ON DEPARTURE TRACK, CLEARS       LNK 232                                      D/T  0  110.42
ENG  2  RT   0  LNK  91  SETS OUT                         BLK  22 WITH  35 CARS                        D/T  0  110.42
ENG  2  RT   0  LNK  91  RESERVES ROUTES                       77       140       0                    D/T  0  110.42
ENG  1  RT 137  LNK  67  CONFLICTS WITH                   ENG   2   RT  77  LNK 236                    D/T  0  111.11
ENG  1  RT 138  LNK  67  CONFLICTS WITH                   ENG   2   RT  77  LNK 236                    D/T  0  111.11
ENG  1  RT   0  LNK  67  NO SUITABLE ROUTE FOUND                                                       D/T  0  111.11
ENG  1  RT 137  LNK  67  CONFLICTS WITH                   ENG   2   RT  77  LNK 236                    D/T  0  115.11
ENG  1  RT 138  LNK  67  CONFLICTS WITH                   ENG   2   RT  77  LNK 236                    D/T  0  115.11
ENG  1  RT   0  LNK  67  NO SUITABLE ROUTE FOUND                                                       D/T  0  115.11
ENG  2  RT 140  LNK 239  ENTERS PULL-OUT LEAD                                                          D/T  0  116.02
ENG  2  RT 140  LNK 239  ON PULL-OUT LEAD, CLEARS         LNK 236                                      D/T  0  116.12
ENG  2  RT   0  LNK 239  RESERVES ROUTES                        0       143      59                    D/T  0  117.12
ENG  1  RT   0  LNK  67  RESERVES ROUTES                       67       137       0                    D/T  0  119.11
ENG  1  RT 137  LNK 238  ENTERS PULL-OUT LEAD                                                          D/T  0  124.56
ENG  1  RT 137  LNK 238  ON PULL-OUT LEAD, CLEARS         LNK 236                                      D/T  0  128.86
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ENG	2	RT	59	LNK	59	ENTERS CLASSIFICATION TRACK										D/T	0	129.49
ENG	2	RT	59	LNK	59	ON CLASSIFICATION TRACK, CLEARS	LNK	213								D/T	0	129.63
ENG	1	RT	0	LNK	238	RESERVES ROUTES		0		127		74				D/T	0	129.86
ENG	1	RT	74	LNK	88	ENTERS DEPARTURE TRACK										D/T	0	130.20
ENG	1	RT	74	LNK	88	ON DEPARTURE TRACK, CLEARS	LNK	229								D/T	0	136.65
ENG	1	RT	0	LNK	88	SETS OUT	BLK	4	WITH	37	CARS					D/T	0	136.65
ENG	1	RT	0	LNK	88	RESERVES ROUTES		74		140		0				D/T	0	136.65
ENG	1	RT	140	LNK	239	ENTERS PULL-OUT LEAD										D/T	0	136.88
ENG	1	RT	140	LNK	239	ON PULL-OUT LEAD, CLEARS	LNK	236								D/T	0	136.97
ENG	1	RT	0	LNK	239	RESERVES ROUTES		0		141		45				D/T	0	137.97
ENG	1	RT	45	LNK	45	ENTERS CLASSIFICATION TRACK										D/T	0	149.90
ENG	1	RT	45	LNK	45	ON CLASSIFICATION TRACK, CLEARS	LNK	187								D/T	0	150.04
ENG	1	RT	0	LNK	45	STARTS COUPLING OPERATION										D/T	0	200.00
ENG	2	RT	0	LNK	59	STARTS COUPLING OPERATION										D/T	0	200.00
ENG	2	RT	0	LNK	59	ENDS COUPLING OPERATION										D/T	0	212.66
ENG	2	RT	0	LNK	59	PICKS UP	BLK	39	WITH	26	CARS		TRN	3		D/T	0	212.66
ENG	2	RT	0	LNK	59	RESERVES ROUTES		59		125		0				D/T	0	212.66
ENG	1	RT	0	LNK	45	ENDS COUPLING OPERATION										D/T	0	214.30
ENG	1	RT	0	LNK	45	PICKS UP	BLK	1	WITH	30	CARS		TRN	4		D/T	0	214.30
ENG	1	RT	121	LNK	45	CONFLICTS WITH	ENG	2	RT	125	LNK	220				D/T	0	214.30
ENG	1	RT	123	LNK	45	CONFLICTS WITH	ENG	2	RT	125	LNK	220				D/T	0	214.30
ENG	1	RT	0	LNK	45	NO SUITABLE ROUTE FOUND										D/T	0	214.30
ENG	1	RT	121	LNK	45	CONFLICTS WITH	ENG	2	RT	125	LNK	220				D/T	0	218.30
ENG	1	RT	123	LNK	45	CONFLICTS WITH	ENG	2	RT	126	LNK	220				D/T	0	218.30
ENG	1	RT	0	LNK	45	NO SUITABLE ROUTE FOUND										D/T	0	218.30
ENG	1	RT	121	LNK	45	CONFLICTS WITH	ENG	2	RT	126	LNK	220				D/T	0	222.30
ENG	1	RT	123	LNK	45	CONFLICTS WITH	ENG	2	RT	126	LNK	220				D/T	0	222.30
ENG	1	RT	0	LNK	45	NO SUITABLE ROUTE FOUND										D/T	0	222.30
ENG	2	RT	125	LNK	238	ENTERS PULL-OUT LEAD										D/T	0	224.91
ENG	1	RT	121	LNK	45	CONFLICTS WITH	ENG	2	RT	126	LNK	224				D/T	0	226.30
ENG	1	RT	123	LNK	45	CONFLICTS WITH	ENG	2	RT	126	LNK	227				D/T	0	226.30
ENG	1	RT	0	LNK	45	NO SUITABLE ROUTE FOUND										D/T	0	226.30
ENG	2	RT	125	LNK	238	ON PULL-OUT LEAD, CLEARS	LNK	236								D/T	0	227.96
ENG	2	RT	0	LNK	238	RESERVES ROUTES		0		127		73				D/T	0	228.96
ENG	2	RT	73	LNK	87	ENTERS DEPARTURE TRACK										D/T	0	229.62
ENG	1	RT	121	LNK	45	CONFLICTS WITH	ENG	2	RT	73	LNK	228				D/T	0	230.30
ENG	1	RT	123	LNK	45	CONFLICTS WITH	ENG	2	RT	73	LNK	228				D/T	0	230.30
ENG	1	RT	0	LNK	45	NO SUITABLE ROUTE FOUND										D/T	0	230.30
ENG	2	RT	73	LNK	87	ON DEPARTURE TRACK, CLEARS	LNK	226								D/T	0	234.19
ENG	2	RT	0	LNK	87	SETS OUT	BLK	39	WITH	26	CARS					D/T	0	234.19
ENG	2	RT	0	LNK	87	RESERVES ROUTES		73		140		0				D/T	0	234.19
ENG	1	RT	121	LNK	45	CONFLICTS WITH	ENG	2	RT	73	LNK	228				D/T	0	234.30
ENG	1	RT	123	LNK	45	CONFLICTS WITH	ENG	2	RT	73	LNK	228				D/T	0	234.30
ENG	1	RT	0	LNK	45	NO SUITABLE ROUTE FOUND										D/T	0	234.30
ENG	2	RT	140	LNK	239	ENTERS PULL-OUT LEAD										D/T	0	234.63
ENG	2	RT	140	LNK	239	ON PULL-OUT LEAD, CLEARS	LNK	236								D/T	0	234.72
ENG	2	RT	0	LNK	239	RESERVES ROUTES		0		143		57				D/T	0	235.72
ENG	1	RT	121	LNK	45	CONFLICTS WITH	ENG	2	RT	143	LNK	219				D/T	0	238.30
ENG	1	RT	123	LNK	45	CONFLICTS WITH	ENG	2	RT	143	LNK	219				D/T	0	238.30
ENG	1	RT	0	LNK	45	NO SUITABLE ROUTE FOUND										D/T	0	238.30
ENG	1	RT	121	LNK	45	CONFLICTS WITH	ENG	2	RT	143	LNK	219				D/T	0	242.30
ENG	1	RT	123	LNK	45	CONFLICTS WITH	ENG	2	RT	143	LNK	219				D/T	0	242.30
ENG	1	RT	0	LNK	45	NO SUITABLE ROUTE FOUND										D/T	0	242.30
ENG	1	RT	0	LNK	45	RESERVES ROUTES		45		121		0				D/T	0	246.30
ENG	2	RT	57	LNK	57	ENTERS CLASSIFICATION TRACK										D/T	0	247.58
ENG	2	RT	57	LNK	57	ON CLASSIFICATION TRACK, CLEARS	LNK	211								D/T	0	247.72
ENG	2	RT	0	LNK	57	STARTS COUPLING OPERATION										D/T	0	247.72
ENG	1	RT	121	LNK	238	ENTERS PULL-OUT LEAD										D/T	0	253.77
ENG	1	RT	121	LNK	238	ON PULL-OUT LEAD, CLEARS	LNK	236								D/T	0	257.28
ENG	1	RT	0	LNK	238	RESERVES ROUTES		0		127		75				D/T	0	258.28
ENG	1	RT	75	LNK	89	ENTERS DEPARTURE TRACK										D/T	0	258.67

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