RAILROAD CLASSIFICATION YARD DESIGN METHODOLOGY STUDY

ELKHART YARD REHABILITATION: A CASE STUDY

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16. Abstract

This interim report documents the application of a railroad classification yard design methodology to CONRAIL's Elkhart Yard Rehabilitation. This case study effort represents Phase 2 of a larger effort to develop a yard design methodology, and to document the methodology in the form of a yard design manual.

The application of the yard design methodology to Boston and Maine's East Deerfield Yard is described in a separate interim report.

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PREFACE

This report documents the application of a railroad classification yard design methodology to CONRAIL's Elkhart Yard Rehabilitation. The work was performed by members of the Transportation and Industrial Systems Center (TISC) of SRI International for the Department of Transportation's Transportation Systems Center (TSC), Cambridge, Massachusetts. Dr. John Hopkins, from the TSC, was the technical monitor of the project (under contract DOT-TSC-1337). The effort was sponsored by the Office of Freight Systems, Federal Railroad Administration, as part of a program managed by Mr. William F. Cracker, Jr.

Mr. James Wetzel of CONRAIL was responsible for the overall Elkhart yard rehabilitation program. Dr. Peter J. Wong of SRI was the project technical leader and principal investigator for applying the newly developed yard design methodologies. The SRI team consisted of:

Ms. C. V. Elliott--Developed computer program for trim-end conflict evaluation and performed analysis of trim-end alternatives.

Dr. M. Sakasita--Responsible for the analysis of trim-end alternatives.

Dr. W. A. Stock--Developed computer program for hump profile design and assisted in the analysis of hump profile alternatives.

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ELKHART YARD REHABILITATION: A CASE STUDY

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1.0 Introduction

CONRAIL operates over 17,000 miles of line and over 300 yards where one or more crews report for duty. Many of these lines and yards, including 18 hump yards, are redundant, serving traffic routes of previously competitive railroads.

One of the primary targets of CONRAIL and the United States Railway Association (USRA) is plant rationalization: the elimination of redundant facilities, lines, and functions. Currently, traffic routed via the Chicago and Kankakee Belt may move over one of four lines and may be classified at one or more of eight major yards. Elkhart Yard is in a key location to consolidate traffic routes although it does not have the capacity to handle all of the traffic potentially available to it. About 3,600 cars per day are potentially available for classification at Elkhart, but of these, 850 cars now bypass Elkhart via other routes and are switched at other yards.

Consolidating CONRAIL's Chicago gateway traffic into one primary route and through one major classification yard--Elkhart--will lead to economics of scale, better network traffic-blocking efficiency, and improved route utilization. Consolidation of this traffic will also permit the elimination of some intermediate handlings and duplicate operations, and will provide a more efficient interface with western connections.

Figure 1 shows CONRAIL's western gateway routes, Elkhart Yard, and the terminals that will be affected by the expansion of the Elkhart Yard operation.

Elkhart Yard's present capacity constraints are:

(1) Short tracks in the classification yard.

(2) Single track pullout lead on westbound yard side.

(3) Excessive distance between the classification yard leads and westbound departure yard.

(4) Excessive curvature and distance between the hump crest and class yard clearance point.

(5) An obsolete retarder control system.

Items 1, 2, and 3 above are related to the classification yard and the westbound trim-end geometry, and items 4 and 5 are related to the hump-end geometry. Both westbound trim-end (including the classification tracts) and the hump-end geometry improvement plans were generated and examined using the SRI yard computer programs. The work involved in evaluating the improvement plans is an iterative process. The SRI yard programs, i.e., PROFILE (for hump profile design) and CONFLICT (for trim-end geometry analysis), were proven to be extremely useful analysis tools.

This paper consists of three major parts. The first part describes the existing yard geometry and proposed plan. The second part describes the hump grade modification plan. The third part describes the trim-end geometry modification plan.

2.0 Existing and Proposed Yard Description

2.1 Existing Yard Description

Elkhart Yard, built by the former New York Central in 1957, is a first-generation computerized hump yard with an in-line receiving yard, a hump with electronic retarder controls, a classification yard with a fishtail configuration, and two parallel departure yards. Figure 2 is a sketch of the present facility.

2.1.1 Receiving Yard

The receiving yard includes fifteen tracks for inbound trains. Track capacities range from 45 to 120 cars in length with adjacent running tracks for through movements of trains and locomotives. The receiving yard switches are power-operated and controlled from the main hump tower. The hump is in-line with the receiving yard, which allows trains to be shoved directly from the receiving yard to the hump.

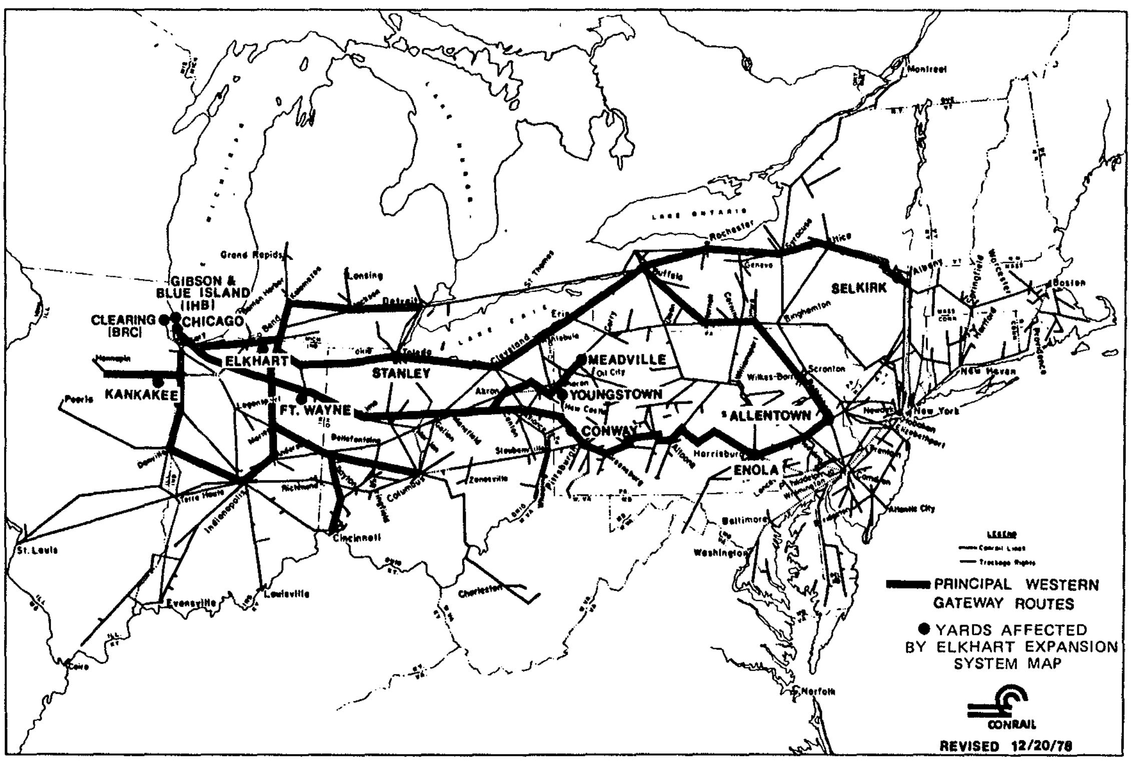

FIGURE 1 CONRAIL'S PRINCIPAL WESTERN GATEWAY ROUTES

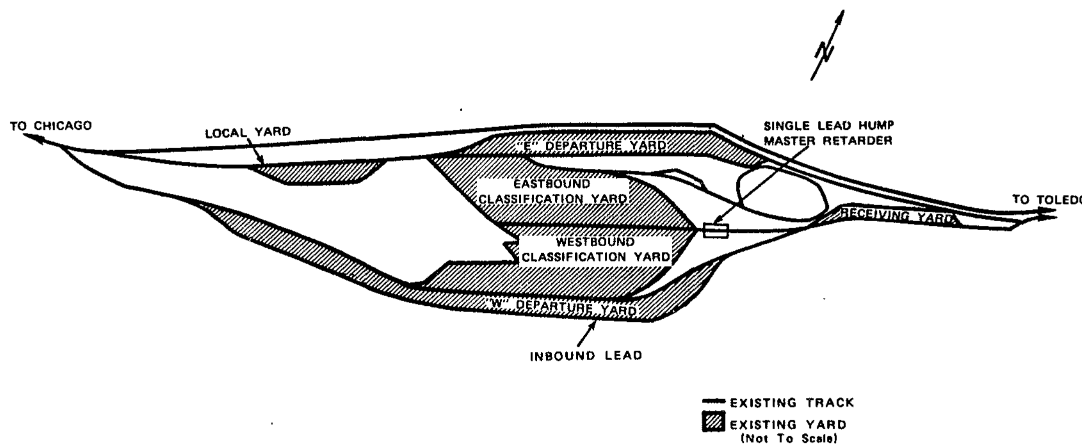

FIGURE 2 PRESENT CONFIGURATION OF ELKHART YARD (CAPACITY AT 2,600 CARS/DAY)

2.1.2. Retarder Controls

Two sets of retarders are used in this control process. A master retarder, 198 feet long and located about 250 feet from the crest, controls the speed of all cars. This hump control is activated by an analog computer programmed to release cars when their velocity has been reduced to a predetermined value. A series of switches beyond the master retarder splits the hump lead into eight group routes, each of which ultimately divides into nine tracks for a total of 72 classification tracks. The group retarders are also controlled by the analog computer. Velocity calculations for the master and group retarder controls are based on a series of values, which include a car's rolling resistance, weight, length, speed, track destination, and distance to coupling as well as wind velocity, direction, and other weather characteristics.

This computerized retarder control system is an example of a "first-generation" analog computer. It has a limited capacity to measure and analyze rollability variables. It is necessary, therefore, to employ a retarder operator for monitoring the operation and, when necessary, overriding the programmed commands. In modern yards, this need has been made obsolete through the use of advanced digital computers.

2.1.3 Classification Yard

The present classification yard (72 classification tracks) is split into two parts. For eastbound classifications 39 tracks are retained, and 33 tracks are retained for westbound classifications. The tracks, varying in length from 1,440 to 3,180 feet, are capable of holding between 24 and 53 cars, 60 feet long. The short tracks are in the center, and the longer tracks form the outside groups, creating a V-shaped configuration. The unique shape is the source of the general design term, fishtail.

2.1.4 Departure Yards

The two departure yards are located on either side of the classification yard. The eastbound departure yard contains six tracks, each with the capacity to hold 112 cars 60 feet long. The westbound departure yard contains five tracks with the same capacity of 112 cars each. Cars pulled from the classification yard are shoved into one of the departure yards according to their destinations. In the case of eastbound trains, cars may be moved directly from the classification yard to the departure yard with a series of sequential moves and coupled to another block already on the departure tracks.

The design of the westbound departure yard produces a less efficient operation than that of the eastbound yard because the westbound track configuration was originally modified to provide an in-bound route for trains coming from the west and destined for the receiving yard. This construction required a 2,000-foot extension of the westbound departure yard beyond the end of the classification. The cars to be moved from the classification yard to the westbound departure yard must be handled by a series of intermediate switches or over the additional distance of the extension. The time consumed in moving cars this excessive distance is double the standard time required for similar moves to the eastbound departure yard. All switches in the trim end of the classification yard, as well as those in the departure yard, are manual. They slow the operation further and restrict the yard capacity.

In addition to the principal components previously described, Elkhart also has auxiliary facilities for car repair and cleaning and locomotive service and repair, and an 11-track local yard to serve local industry.

2.2 Proposed Improvement Plan

Various designs have been engineered to improve the operation and to increase the yard's capacity. They range from a plan to rebuild the fishtail into a teardrop configuration with two symmetrical departure yards with wide track centers to a plan for constructing a modified westbound departure yard with power-operated crossovers at the approximate intersection of the classification yard lead and departure yard body. Plans to rebuild the receiving yard with wide track centers and extend the tracks to hold 150 or more cars were investigated. Designs were also analyzed for a double lead and fully automatic computer control including a management information system and for a single hump lead with tangent point retarders on each track.

Each variation of design was evaluated by a simulation to determine its capacity. Then the operating improvements were measured against costs. The yard capacity alternatives ranged from a "do-nothing" alternative, with the present capacity of 2,600 cars per day average with a peak of 2,900 cars per day to an alternative increasing production to a maximum of 4,200 cars per day by using a double lead hump.

In August 1979, CONRAIL's Board approved an expenditure of $1.75 million for engineering and the initial year's work. The yard modification project is estimated to cost $18 million. This expenditure will provide an added throughput capacity of about 500 cars per day with a peak capacity of 3,200 cars. A plan for the modified yard is shown in Figure 3.

The improvements to be made include the following:

(1) Extending 21 classification tracks to hold 40-50 cars each.

(2) Adding two departure yard tracks to the westbound departure yard.

(3) Constructing two parallel pullout leads with power-operated crossovers.

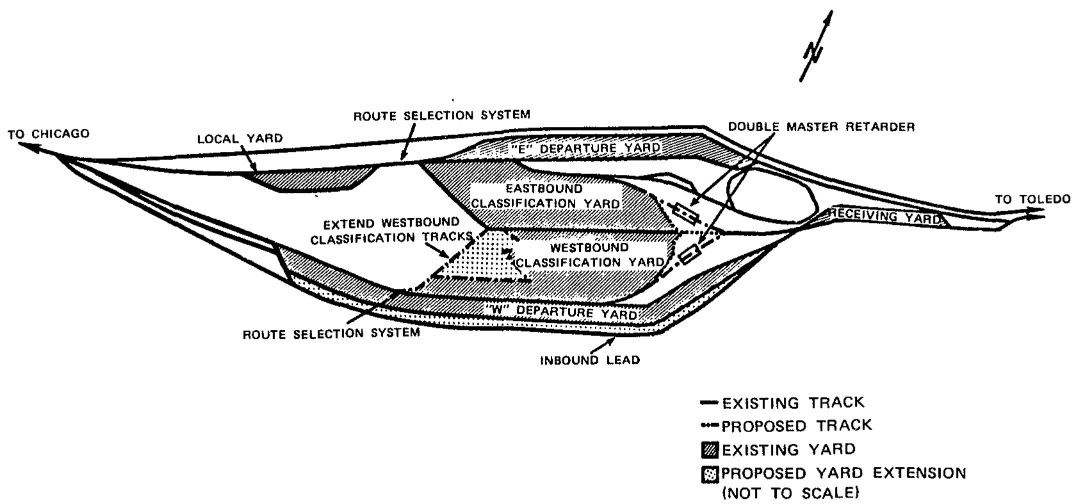

FIGURE 3 PROPOSED MODIFICATION TO ELKHART YARD (CAPACITY AT 3,200 CARS/DAY)

(4) Modifying the hump track configuration by installing two master retarders.

(5) Installing automatic retarder control with automatic self-tuning.

3.0 Hump Grade Modification

3.1 Objectives and Constraints

The maximum humping rate at a yard is governed by many variables, including car rollability, weather, the track configuration, and hump profile. The present sustained humping rate at Elkhart yard is 1.8 miles per hour. Although cars may be humped at higher speeds, the result is an increase in adverse events such as misswitches, corner impacts, catch-ups in retarders, and overspeed impacts. The required humping rate in the proposed plan for providing a switching capacity for 3,200 cars per day (each 60 feet long) is 2.5 mph. The objective of this analysis is to find a design that meets this hump speed goal with as few adverse humping events as possible and at minimum cost.

Due to budgetary considerations, the range of design alternatives that can be considered is highly constrained. It is very desirable that the current scale be maintained in its present location on its present grade.* This permits little flexibility in the location of the hump crest. Escape tracks on the outside of the outermost groups must also be maintained, which restricts the configurations that can be considered on the bowl end of the hump grade. To reduce rehabilitation costs, it is desirable that the present grade (0.0%) from the group retarder to the tangent point be maintained. Finally, the present low hump speed of the existing design primarily appears to be due to the extreme curvature and the long distance to the clearance point of the outermost groups. Proposed designs should include a reduction of the curvature and distance.

3.2 Existing Design and Proposed Design Alternatives

The existing design consists of 72 classification tracks arranged into 8 groups of 9 tracks each. There is a single master retarder consisting of two control sections. There are 8 group retarders, one to each group, varying in length and number of control sections. Immediately after the hump crest is a 105-foot scale on a 3% grade. Maintaining this scale in its present configuration is desirable for any rehabilitation of the hump grades. After the group retarder, the grade decreases to zero. At the tangent point, it becomes 0.15% (the proposed designs all maintain this profile in this area although their horizontal layouts differ).

Eight alternate designs were developed in an effort to meet the above objectives and constraints. Of these, five were retained for later study and designated Alternatives 4 through 8. The designs all modify the present Elkhart hump grade geometry in the area between the hump crest and the tangent point; no modifications to the bowl tracks themselves were considered. The designs reduce the excessive track curvature in the outer groups from 15° to 12°30'. To reduce the total central angle and reduce the distance between the hump crest and clearance point, the designs call for a turnout before the master retarder, thus dividing the yard into two equal parts. After examining several alternate schemes, a design was developed that fits a number-eight equilateral turnout below the existing hump scale. It locates the proposed master retarders in a position that requires only minor track changes in the center groups, and no change in groups two, three, six, and seven. These modifications decrease the degree of curvature and the total central angle, reduce the distance from the crest to the clearance point from 1,344 feet to 1,259 feet, and permit retention of the scale. No other design alternatives could be generated, due to the constraints of simultaneously flattening the outermost group curvature, while keeping the scale in its present location. In each design, each master retarder consists of two control sections separately controlled to reduce the likelihood of two cars being in the retarder at the same time (denoted as catch-up in a retarder). This event is more likely to occur in a single unit retarder. The group retarders consist of single control sections.

It should be noted the Elkhart retarder system has recently been upgraded from 100 tons to 160 tons capacity. As a result of the added retarder capacity, a reappraisal of the retarder requirement for handling an easy-rolling car (2 lb/ton), permitted reducing the master retarder from an effective length of 192 feet to 177 feet.

The profile geometries of the present design and the five proposed designs are summarized in Table 1. A schematic view of the horizontal layout of the five proposed designs shown in comparison to the present design is given in Figure 4. The horizontal layouts of the five designs coincide (with the exception of the deletion of the scale in Alternative 8). In the horizontal layout, Alternative 8 coincides with Alternatives 4 through 7 virtually everywhere except in the location of the hump crest. The differences between the plans are seen in the different profiles summarized in Table 1.

A problem inherent to the present hump profile is the crest vertical curve. When this yard was built in 1957, the average car length was only 45 feet. Today the average car handled

*Primarily for purposes of comparison, one design reported herein was tried that eliminated the scale. However, because one of the designs with the scale was a better performer and because retaining the scale is so desirable, further designs without the scale were not pursued.

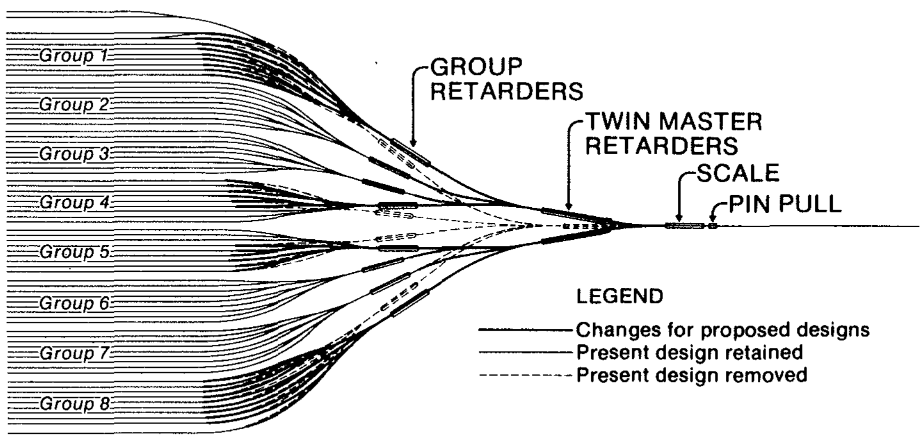

FIGURE 4 SCHEMATIC HORIZONTAL LAYOUT OF PRESENT AND PROPOSED HUMP GRADE DESIGNS

Table 1

SUMMARY OF THE GEOMETRIES AND SIMULATED PERFORMANCE
OF PRESENT AND FIVE PROPOSED HUMP GRADE DESIGNS

Profiles	Present Design	Alternative 4	5	6	7	8
Grade						
End Vertical Curve to Scale	3.00%	3.19%	3.19%	3.19%	3.19%	3.19%
Scale	3.00%	3.00%	3.00%	3.00%	3.00%	Scale eliminated
Scale to Master Retarder	3.00%	4.00%	4% decreasing to 3%	4.00%	4.00%	5.00%
In Master Retarder	4.15% decreasing to 3.9%	4.00%	3.00%	3.00%	1.75%	5.00%
Master to Group Retarder	0.93% increasing to 1.18%	0.50%	1.50%	1.50%	1.75%	0.50%
Group Retarder	1.39%	1.18%	1.35%	1.00%	1.40%	1.18%
Group Retarder to Tangent Point	0%	0%	0%	0%	0%	0%
In Bowl	0.15%	0.15%	0.15%	0.15%	0.15%	0.15%
Crest Location	Unchanged	Moved 10 ft toward bowl	Moved 10 ft toward bowl	Moved 10 ft toward bowl	Moved 10 ft toward bowl	Moved 115 ft toward bowl
Crest Vertical Curve Length	80 ft*	80 ft	80 ft	80 ft	80 ft	80 ft
Distance, Crest to Clearance Point	1,344 ft	1,259 ft	1,259 ft	1,259 ft	1,259 ft	1,154.1 ft
Location Where Collision Occurs According to Simulation	1,230.3 ft	1,207.1 ft	1,162.7 ft	1,173.1 ft	1,168.6 ft	1,077.7 ft
Distance Before Clearance Point Where Collision Occurs	113.7 ft	51.9 ft	96.3 ft	85.9 ft	90.4 ft	76.4 ft

*For comparison purposes, the crest vertical curve was lengthened from 50 ft to 80 ft. This change is contemplated, regardless of any other changes that may be made, to better accommodate long-wheelbase cars.

through Elkhart is over 60 feet long. In 1957, a 50-foot vertical curve was desirable for faster separation, but switching longer cars today over a 50-foot vertical curve creates a problem with binding knuckles and stuck pins. The solution to the stuck pin problem is a longer vertical curve (80 feet); however, with a flatter hump and longer cars, separation is decreased. To compensate for the slower breakaway, the hump crest was moved 10 feet toward the bowl, and the grade between the crest and the scale was increased from 3.00% to 3.56%.†

The crest vertical curve was used in each proposed design. Because even a minimum upgrade of the existing Elkhart hump necessitates lengthening the hump crest, this one improvement was also included for comparison in the test of the present design.

3.3 Evaluation Procedure

Each of the five proposed designs was evaluated using the SRI PROFILE hump gradient simulation model. Because PROFILE is a one-route

†The 3.19% grades reported in Table 1 are effective grades traversed by the center of gravity of a 60-foot car. Because of the car's wheelbase, its center of gravity will never actually experience descent on a 3.56% grade.

simulation, only the outermost track (this being the worst case) of the outermost group was evaluated. This track is the worst case because it has the most curvature and the longest distance from crest to the clearance point.

The evaluations were performed based on hardest- (slowest) and easiest- (fastest) rolling cars. Only velocity-independent (static) rolling resistances were considered. The hardest-rolling car was assumed to have an 18 lb/ton initial resistance, dropping to 15 lb/ton after the group retarder. The easy-rolling car was assumed to have a resistance of 2 lb/ton throughout. The worst situation considered was a triplet where a hard-rolling car was followed by an easy-rolling car, which was followed by another hard-rolling car traveling to the last switch on the farthest outside track. The hard-rolling cars were retarded as little as possible to achieve maximum penetration into a class track assumed to be empty. The easy-rolling cars were retarded to maintain 4 miles per hour at the clearance point since they were assumed to be targeted to an adjacent class track nearly full. In addition, each car was retarded to limit its speed to at most 15 miles per hour at all facing point switches. The additional losses taken for all simulated cars were:

- On curves--.04 foot of velocity head/degree of central angle (without curve oilers) or .025 foot/degree of central angle (with curve oilers).
- On switches--.025 foot of velocity head/switch traversed.

All car lengths were taken as 60 feet, and in all cases, a 2.5 mile-per-hour hump speed was used.

Under these assumptions, the easy-rolling car tends to overtake the hard-rolling car approximately up to the area of the group retarder. In the group retarder, however, the easy-rolling car must be retarded so severely that after this point the hard rolling car is the one that tends to overtake the easy-rolling car.

The target speed for the easy-rolling car (4 miles per hour at the clearance point) is an extremely taxing trial for any design. Usually, the target will be 4 miles per hour at the tangent point. However, the clearance point was used in this study because it is the most extreme case any design will be asked to handle. (Occasionally, under extremely heavy traffic conditions it will be necessary to back cars around the curved track upstream from the tangent point.) If a design works for the 4 miles-per-hour target speed at the clearance point, it should certainly perform adequately when the target is 4 miles per hour at the tangent point. If a design does not work for the 4 mile-per-hour clearance point target speed, but does perform adequately for a 4 mile-per-hour target speed at the tangent point, it can still be considered when no better design is available because loading the class tracks upstream from the tangent point is comparatively rare. In such designs, however, adequate performance with a 4 mile-per-hour target speed at the tangent point is a must. The performance in such a case can be verified through a separate PROFILE run.

Only the overall results from the design evaluations done by PROFILE will be summarized here. The usual evaluation procedure for one design requires at least two and often more runs by the PROFILE model. In the first run, the hard- and easy-rolling cars are simulated without any retardation to obtain the speeds they would attain if allowed to roll freely. Examining speeds at switches and at other target speed points such as the clearance point or tangent point allows simple energy calculations to be performed yielding the excess velocity heads that must be extracted from the cars by retardation. A second PROFILE run is then made with these values as the retarder settings. Sometimes this second run is sufficient to evaluate a design's performance; however, often headway problems will be discovered between cars, and further runs will be necessary to revise the retarder settings to obtain the best possible performance for which the design is capable.

3.4 Results of Evaluations

Over 100 separate iterations were made analyzing these designs with the SRI-PROFILE model. These analyses revealed that none of the designs could satisfactorily separate the two cars prior to the clearance point. In fact, the headways were so close that in none of the designs could the cars be separated at the last switch (thus the catch-up preceding the clearance point was only a misswitch, not a cornering). However, as previously stated, retarding the easy-rolling car to achieve 4 miles per hour at the clearance point is an extreme trial for any design. Indeed, all of the proposed designs are far better performers than the existing design.

Under these assumptions, design Alternative 4 performed the best, with the cars coupling 51.9 feet before the clearance point. In a separate run, when the easy-rolling car was retarded to achieve the less severe target of 4 miles per hour at the tangent point, design Alternative 4 performed well, with headways sufficient for switching being maintained through the last switch, and no catch-up prior to the clearance point. Based upon these series of runs, design Alternative 4 was chosen as the basis for the rehabilitation of the hump end of Elkhart Yard.

Finally, a limited sensitivity analysis regarding car length was performed on the Alternative 4 design. The final Alternative 4 PROFILE run was rerun changing only the car lengths involved. Two such runs were made; one with all cars of 45-foot length, and one with all cars of 86-foot length. The results of these sensitivity runs are summarized in Table 2. As expected, there are some slight differences in the location where the coupling collisions occur. However, with the short cars, two cars were found to be in the same retarder control sections in both the master and group retarders; this despite there being two control sections for the master retarder.

Table 2

LIMITED SENSITIVITY ANALYSIS WITH REGARD TO CAR LENGTH FOR ALTERNATIVE 4

Car Length (feet)	Collision Point Distance from Crest (feet)	Distance Before Clearance Point Where Collision Occurs (feet)	Other Events of Note
45	1,187.3	71.7	Catch-up in master and group retarders
60*	1,207.1	51.9	None
86	1,231.1	27.9	None

*Normal run previously reported.

Therefore, on the basis of these runs, the Alternative 4 design was revised to have three control sections for the master retarder, and two control sections for the group retarder.

3.5 Detailed Examination of a PROFILE Simulation Run for Alternative 4

This section presents a typical PROFILE model simulation output, and at the same time provides a more detailed look at design Alternative 4. A partial PROFILE output, summarizing most of the important portions of the output, is shown in Figures 5 through 9. The run presented in these figures is the "normal" run for design comparisons reported in Table 1.

First, the model prints an "echo-back" of the input parameters. Certain model control parameters comprise the first part of the "echo-back"; these are shown in the top portion of Figure 5.

The specified track geometry comprises the next portion of the "echo-back"; this geometry comprises the bulk of Figure 5 and indicates the nature of the track geometry input required by the model. The entire profile grade is represented as a series of track sections of uniform characteristics. As can be seen in Figure 5, these charactersitics include such features as section length, grade, car rolling resistances (since these can change section-by-section), curve resistance, switch loss, and retarder characteristics. Of course, certain parameters (such as curve resistance, switch loss, and retarder characteristics) may not be applicable in all track sections, in which case they are set to zero by the user when preparing the input. The details of the Alternative 4 design are evident in Figure 5; for example, the two control-section master retarders (as originally envisioned when running the normal Alternative 4 design) can clearly be seen.

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. The data that must be entered by the user to describe the cars is evident in Figure 6.

Immediately after the car data (on the same page) is found a list of undesirable events that may have occurred during the course of the simulation. This information comprises the first part of the simulation output proper. For example, in Figure 6 the report on the collision before the clearance point, which was alluded to earlier, can be seen.† Other events which may be reported here could include a car stopping, or a catch-up within one control section of a retarder.

The primary numerical output of the PROFILE simulation is a table giving 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. An example of this table is given in Figure 7. 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 velocity and velocity head, and the track section of the location of the car's center of gravity.

†The collision distance reported in Table 1 was the location of the couplers at the impact point, while the distances reported in the output shown in Figure 6 are the locations of the centers of gravity of the involved cars. Hence, the distance in Table 1 is, for example, the location of the trailing car plus half its length.

SRI HUMP PROFILE SIMULATION - ALTERNATIVE 4 - 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

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)	D E S C R I P T I O N
1	5.0	0.0	.95	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	CREST TO EVC
2	7.0	5.0	1.47	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	VC1 TO VC2
3	10.0	12.0	2.20	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	VC2 TO VC3
4	18.0	22.0	3.01	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	VC3 TO VC4
5	10.0	40.0	3.19	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	VC4 TO EVC
6	10.0	50.0	3.19	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	EVC TO SCALE
7	105.0	60.0	3.00	2.00	18.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	SCALE
8	10.0	165.0	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
9	1.0	175.0	4.00	2.00	18.00	-0.00	-0.00	10.81	.03	-0.00	-0.00	-0.00	-0.00	KING SW
10	42.0	176.0	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
11	8.0	218.0	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
12	50.0	226.0	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
13	34.0	276.0	4.00	2.00	18.00	-0.00	-0.00	8.55	-0.00	-0.00	-0.00	-0.00	-0.00	HC1 TO BVC2
14	10.0	310.0	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
15	66.0	320.0	4.00	2.00	18.00	-0.00	-0.00	-0.00	-0.00	4.61	4.62	4.61	4.62	MASTER 1
16	115.5	386.0	4.00	2.00	18.00	-0.00	-0.00	-0.00	-0.00	1.43	5.78	1.43	8.40	MASTER 2
17	29.0	501.5	2.25	2.00	15.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	MASTER TO SW2
18	1.0	530.5	.50	2.00	15.00	-0.00	-0.00	12.55	.03	-0.00	-0.00	-0.00	-0.00	SW 2
19	50.0	531.5	.50	2.00	15.00	-0.00	-0.00	12.55	-0.00	-0.00	-0.00	-0.00	-0.00	SW2 TO ESW2
20	134.0	581.5	.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
21	50.0	715.5	.50	2.00	15.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	EHC2 TO TANESW
22	68.0	765.5	.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
23	1.0	833.5	.50	2.00	15.00	-0.00	-0.00	-0.00	.03	-0.00	-0.00	-0.00	-0.00	ESCAPE SW
24	15.0	834.5	.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
25	10.0	849.5	.75	2.00	15.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	BVC3 TO GP 6 RET
26	115.5	859.5	1.18	2.00	15.00	-0.00	-0.00	-0.00	-0.00	0.00	7.62	0.00	8.40	GROUP RET.
27	10.0	975.0	.50	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
28	1.0	985.0	0.00	2.00	12.00	-0.00	-0.00	7.84	.03	-0.00	-0.00	-0.00	-0.00	SW 3
29	50.0	986.0	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
30	45.0	1036.0	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
31	1.0	1081.0	0.00	2.00	12.00	-0.00	-0.00	14.64	.03	-0.00	-0.00	-0.00	-0.00	SW4
32	42.0	1082.0	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
33	46.0	1124.0	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
34	1.0	1170.0	0.00	2.00	12.00	-0.00	-0.00	6.76	.03	-0.00	-0.00	-0.00	-0.00	SW 5
35	42.0	1171.0	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
36	46.0	1213.0	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
37	314.0	1259.0	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
38	2500.0	1573.0	.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

FIGURE 5 EXAMPLE OF ECHO-BACK OF SIMULATION PARAMETERS AND TRACK GEOMETRIC DATA — NORMAL RUN OF ALTERNATIVE 4

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	30.00	1.00	-0.00	-0.00
2	1	60.00	70.00	1.00	-0.00	-0.00
3	2	60.00	30.00	1.00	-0.00	-0.00

```
A COLLISION OCCURRED AT TIME  104.67 SEC. BETWEEN
CAR  2 - VEL =     4.30 MPH, DIST =  1237.07 FT., TIME ON TRACK =    88.31 SEC.
CAR  3 - VEL =    11.66 MPH, DIST =  1177.07 FT., TIME ON TRACK =    71.94 SEC.
```

FIGURE 6 EXAMPLE OF ECHO-BACK OF CAR DATA AND SIMULATION PREDICTION OF AN UNDESIRABLE EVENT – NORMAL RUN OF ALTERNATIVE 4

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	56.124	5.349	3.667	2.500	.212	0/ 1	****TRACK SECTION BOUNDARY****
.636	17.000	2.388	61.659	5.715	3.838	2.617	.232	1	CREST TO EVC
1.301	17.665	5.000	67.609	6.091	4.018	2.740	.254	1/ 2	****TRACK SECTION BOUNDARY****
1.636	18.000	6.371	70.662	6.276	4.164	2.839	.273	2	VC1 TO VC2
2.636	19.000	10.752	79.921	6.808	4.599	3.135	.333	2	VC1 TO VC2
2.904	19.268	12.000	82.440	6.945	4.715	3.215	.350	2/ 3	****TRACK SECTION BOUNDARY****
3.636	20.000	15.629	89.337	7.304	5.203	3.547	.426	3	VC2 TO VC3
4.636	21.000	21.165	98.612	7.751	5.869	4.002	.543	3	VC2 TO VC3
4.777	21.141	22.000	100.154	7.811	5.963	4.065	.560	3/ 4	****TRACK SECTION BOUNDARY****
5.636	22.000	27.462	108.290	8.146	6.756	4.606	.719	4	VC3 TO VC4
6.636	23.000	34.680	117.644	8.479	7.680	5.236	.929	4	VC3 TO VC4
7.302	23.666	40.000	123.814	8.669	8.296	5.657	1.084	4/ 5	****TRACK SECTION BOUNDARY****
7.636	24.000	42.825	126.906	8.756	8.624	5.880	1.171	5	VC4 TO EVC
8.432	24.796	50.000	134.270	8.939	9.406	6.413	1.393	5/ 6	****TRACK SECTION BOUNDARY****
8.636	25.000	51.940	136.156	8.981	9.606	6.550	1.453	6	EVC TO SCALE
9.442	25.806	60.000	143.599	9.128	10.398	7.090	1.703	6/ 7	****TRACK SECTION BOUNDARY****
9.636	26.000	62.036	145.391	9.160	10.577	7.211	1.762	7	SCALE
10.636	27.000	73.073	154.628	9.300	11.497	7.839	2.082	7	SCALE
11.636	28.000	85.030	163.790	9.408	12.418	8.467	2.429	7	SCALE
12.636	29.000	97.909	172.665	9.488	13.339	9.095	2.802	7	SCALE
13.636	30.000	111.708	179.698	9.545	14.259	9.722	3.202	7	SCALE
14.636	31.000	126.427	184.596	9.585	15.180	10.350	3.629	7	SCALE
15.636	32.000	142.068	187.397	9.613	16.101	10.978	4.083	7	SCALE
16.636	33.000	158.629	189.272	9.632	17.021	11.605	4.563	7	SCALE
17.007	33.371	165.000	189.881	9.637	17.362	11.838	4.748	7/ 8	****TRACK SECTION BOUNDARY****
17.573	33.937	175.000	190.695	9.644	17.973	12.255	5.088	8/ 9	****TRACK SECTION BOUNDARY****
17.629	33.992	176.000	190.767	9.645	17.988	12.265	5.096	9/10	****TRACK SECTION BOUNDARY****
17.636	34.000	176.140	190.777	9.645	17.997	12.271	5.101	10	KSW 1 E SW1
18.636	35.000	194.670	191.844	9.654	19.063	12.998	5.724	10	KSW 1 E SW1
19.636	36.000	214.266	192.424	9.658	20.130	13.725	6.382	10	KSW 1 E SW1
19.821	36.185	218.000	192.478	9.658	20.326	13.859	6.507	10/11	****TRACK SECTION BOUNDARY****
20.210	36.574	226.000	192.524	9.656	20.808	14.187	6.819	11/12	****TRACK SECTION BOUNDARY****
20.636	37.000	234.986	192.461	9.651	21.336	14.547	7.170	12	BHC1 TO EHC1
21.636	38.000	256.941	191.838	9.626	22.574	15.391	8.026	12	BHC1 TO EHC1
22.462	38.826	276.000	190.761	9.571	23.597	16.089	8.769	12/13	****TRACK SECTION BOUNDARY****
22.636	39.000	280.132	190.468	9.548	23.789	16.220	8.913	13	HC1 TO BVC2
23.636	40.000	304.472	188.010	9.341	24.891	16.971	9.758	13	HC1 TO BVC2
23.857	40.221	310.000	187.281	9.275	25.135	17.137	9.950	13/14	****TRACK SECTION BOUNDARY****
24.251	40.615	320.000	185.804	9.136	25.622	17.470	10.340	14/15	****TRACK SECTION BOUNDARY****
24.636	41.000	329.791	184.299	8.982	25.244	17.212	10.036	15	MASTER 1
25.636	42.000	354.542	180.890	8.647	24.259	16.541	9.269	15	MASTER 1
26.636	43.000	378.310	178.229	8.415	23.275	15.870	8.532	15	MASTER 1
26.969	43.333	386.000	177.510	8.359	22.948	15.646	8.294	15/16	****TRACK SECTION BOUNDARY****
27.636	44.000	401.234	176.177	8.268	22.714	15.487	8.126	16	MASTER 2
28.636	45.000	423.773	174.278	8.175	22.364	15.248	7.877	16	MASTER 2
29.636	46.000	445.961	172.495	8.131	22.013	15.009	7.632	16	MASTER 2
30.636	47.000	467.799	170.829	8.127	21.662	14.770	7.391	16	MASTER 2
31.636	48.000	489.266	169.282	8.147	21.312	14.531	7.153	16	MASTER 2

FIGURE 7 EXAMPLE OF CAR HISTORY TABLE: PARTIAL OUTPUT FOR CAR NO. 2 (EASY-ROLLER) — NORMAL RUN OF ALTERNATIVE 4

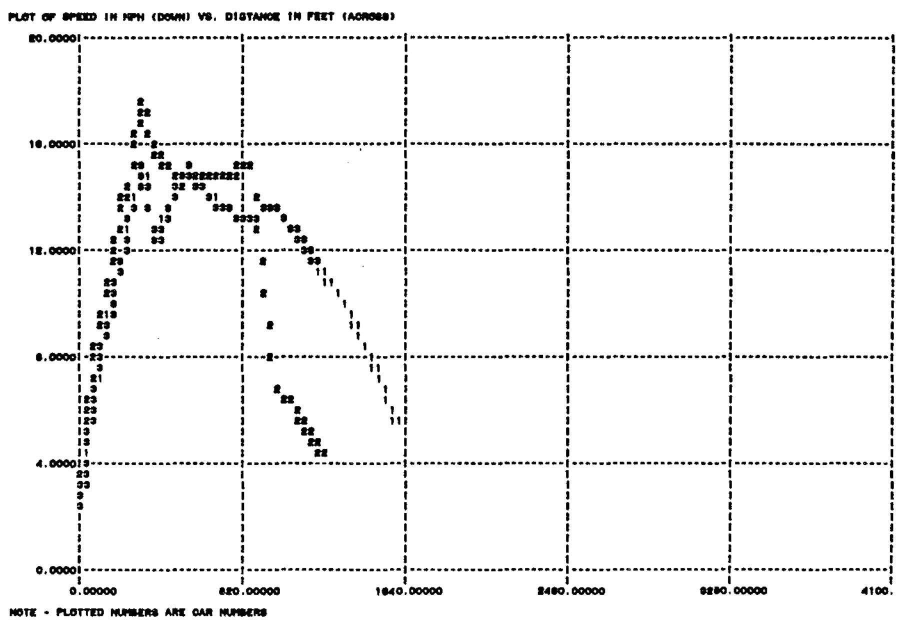

FIGURE 8 PLOT OF SPEED VERSUS DISTANCE – NORMAL RUN OF ALTERNATIVE 4

Finally, PROFILE gives certain optional graphic outputs generated on the line printer. Examples of two of these graphs are given in Figures 8 and 9. Figure 8 shows a plot of the speeds of the simulated cars versus distance, and Figure 9 shows distance headway of the simulated cars versus distance.

3.6 Final Proposed Design

The design referred to as Alternative 4 has been adopted as the final proposed design for the rehabilitation of Elkhart Yard. This design significantly outperformed the present Elkhart design in the PROFILE simulation runs and performed the best among all proposed designs. While this design, as all the others, fails the extreme test of having no couple-up prior to the clearance point when the easy-rolling car must be retarded to 4 miles per hour, it performs admirably in the more usual circumstances when the easy-rolling car must be retarded for 4 miles per hour at the further downstream tangent point. This final design has two master retarders, each consisting of three control sections, and eight group retarders each consisting of two control sections. Except for the revision increasing the number of control sections in the master retarders from two to three, the design is summarized in Figure 4 and Table 1. Somewhat more detail is also given in the PROFILE "echo-back" output in Figure 5.

4.0 Trim-End Design Alternatives Evaluation

4.1 Objective

Approximately 1,100-1,200 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 contains yard capacity for moving over 1,200 cars per day through the westbound departure yard. This capacity, however, is insufficient. The capacity problem is caused by factors such as: (1) the long travel distance for the trim engines between the classification yard and the departure yard, (2) the 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 SRI 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.

4.2 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 long. Figure 10 shows that only one pullout lead exists for trim-end maneuvers. 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 11, the classification tracks in the middle of the yard are extended by 1,000 to 1,500 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 11) 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. The departure yard has five tracks ranging from 107 to 112 cars long. Two additional tracks 112 cars long are adjacent to the existing yard. Dead excess 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 12, the westbound class tracks in the middle of the yard are extended to 1,500 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

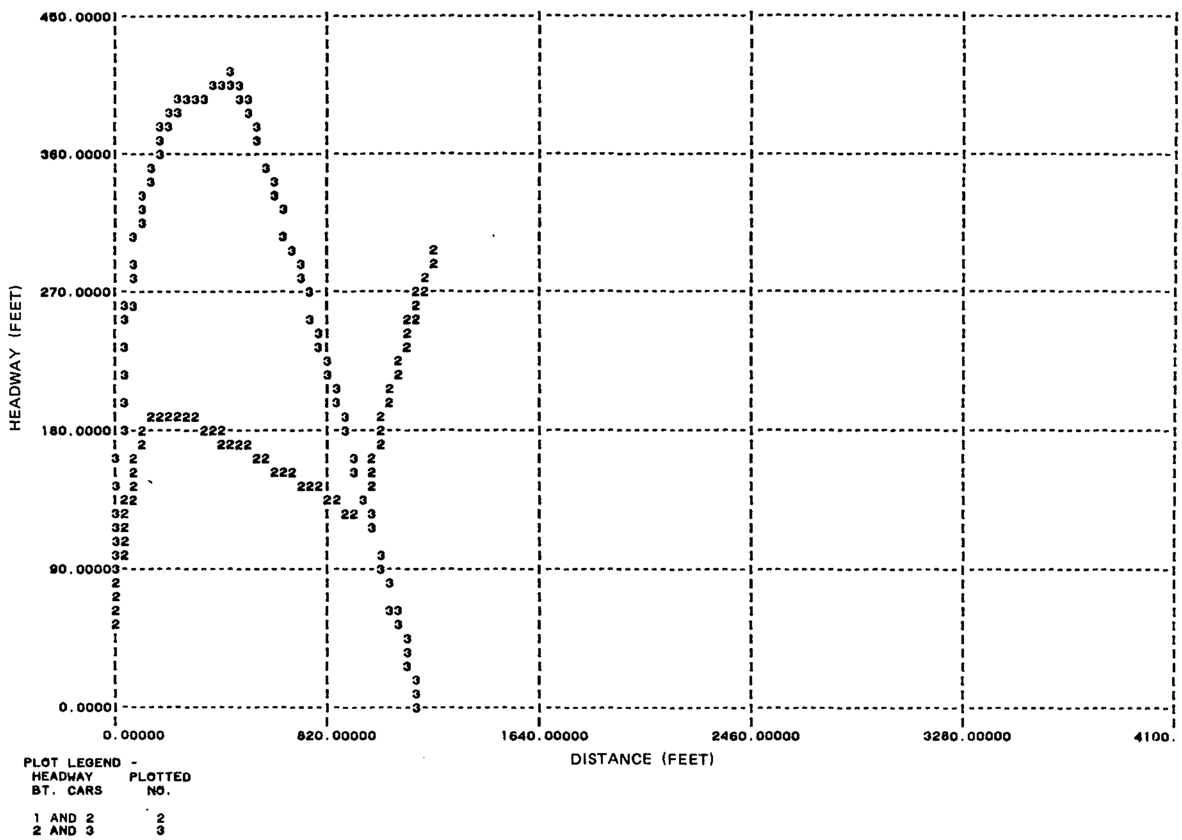

FIGURE 9 PLOT OF DISTANCE HEADWAY VERSUS DISTANCE – NORMAL RUN OF ALTERNATIVE 4

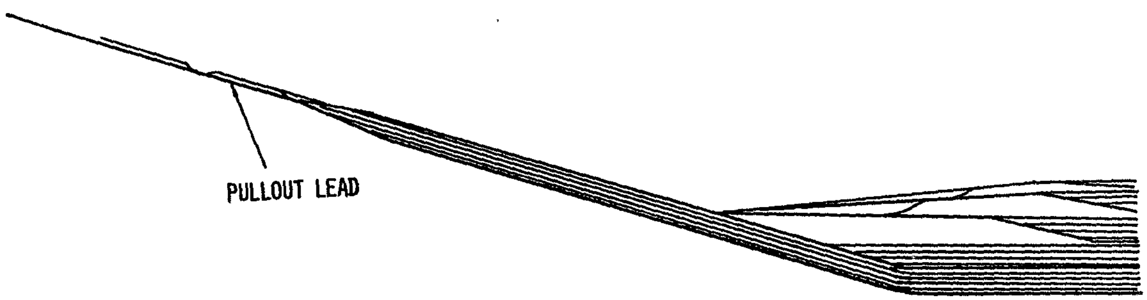

FIGURE 10 EXISTING TRIM-END DESIGN

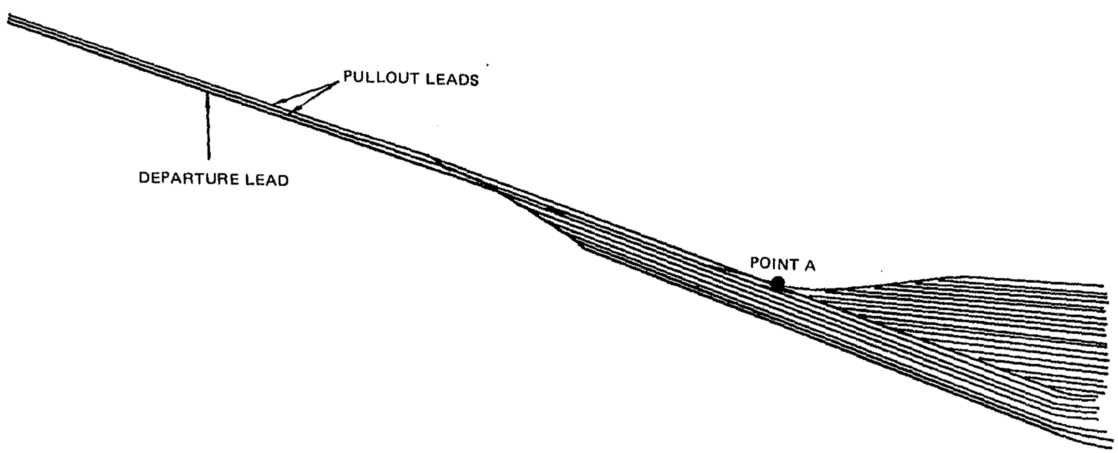

FIGURE 11 TRIM-END ALTERNATIVE 1: EXTENDED CLASSIFICATION TRACKS WITH DUAL PULLOUT LEADS

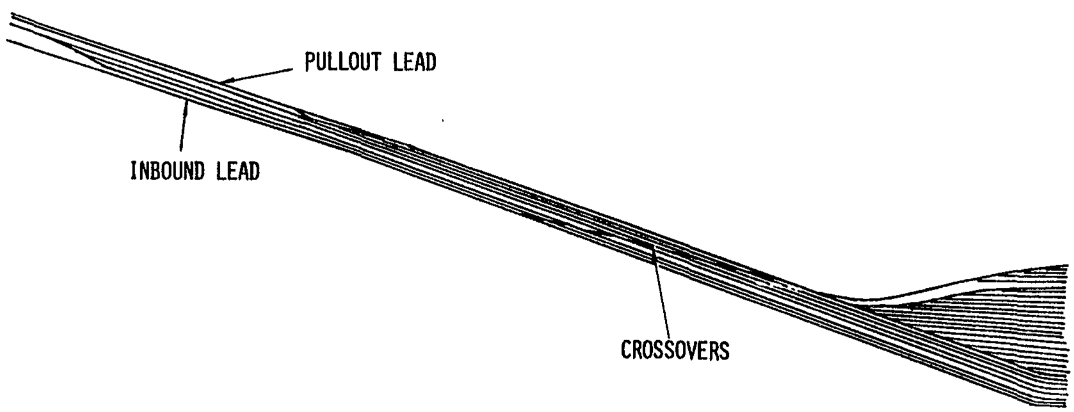

FIGURE 12 TRIM-END ALTERNATIVE 2: EXTENDED CLASSIFICATION TRACKS WITH CROSSOVERS IN THE DEPARTURE YARD

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 when eastside and westside are combined. When a train exceeds the length of the eastside 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, westbound classification tracks in the middle of the yard are extended by 1,000 to 1,500 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.

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.

4.3 Operational Parameters and Assumptions Used for 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 operational parameters and assumptions:

- The input traffic level is set at an inflow of 1,800 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-ups; a train is built by one engine only.
- Track overflows on classification tracks are prevented by limiting the flow of cars onto a classification track 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.

4.4 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 hours to 2400 hours (military time). During this time period, 17 trains out of 19 trains scheduled were built, carrying a total of 1,211 cars (Table 3). The trim engines moved a total of 1,370 cars during this period. The number of trains processed in a 24-hour period is much less than the total number of trains planned for departure and much less than the total input flow to the yard. This implies that the yard is over-saturated. Therefore, the amount of delay for both trains and cars will increase indefinitely as the simulation time grows. The total train departure delay time was 4,487 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 1,800 cars per day and any level higher, 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.

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

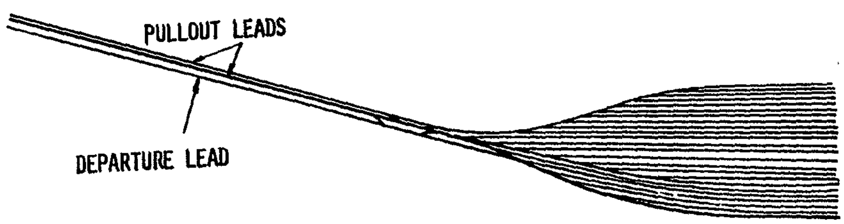

FIGURE 13 TRIM-END ALTERNATIVE 3: EXTENDED CLASSIFICATION TRACKS WITH DUAL PULLOUT LEADS AND RELOCATED DEPARTURE TRACKS

Table 3

TRAIN DEPARTURE REPORT FOR THE EXISTING YARD

Train Number	Scheduled Departure Time	Actual Departure Time	Delay Time (min)	Number of Cars on Trains	Total Delay Time for Cars on Departure Trains* (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.

train departure delay time amounted to 3,780 minutes (Table 4). The delay time per train was 199 minutes. There were a total of 1,456 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 at 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. This is 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 by the two trim engines is 1,597 cars within 24 hours; (2) one trim engine was left idle from 2130 hours to the end of the simulation at 2400 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 2400 hours. During the simulated time frame, 18 scheduled trains were built. Total departure delay time was 3,751 minutes (Table 5) with an average departure delay time of 208 minutes per train. The 18 trains moved 1,332 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 is 90 percent higher than the low of 20 minutes per train seen with the first alternative. It is 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, is the point where the classifications' 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 are 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.

Table 4

TRAIN DEPARTURE REPORT FOR ALTERNATIVE 1:
EXTENDED CLASSIFICATION TRACKS WITH DUAL PULLOUT LEADS

Train Number	Scheduled Departure Time	Actual Departure Time	Delay Time (min)	Number 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 5

TRAIN DEPARTURE REPORT FOR ALTERNATIVE 2:
EXTENDED CLASSIFICATION TRACKS WITH CROSSOVERS IN DEPARTURE YARD

Train Number	Scheduled Departure Time	Actual Departure Time	Delay Time (min)	Number 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.

In this design the trim engines moved 1,567 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 2115 hours to the end of the simulation.

4.5 Evaluation of Alternatives

The results of the simulation of the existing design and the two alternatives (Alternatives 1 and 2) are summarized for comparison in Table 6. Alternative 3, which is considered to have the largest capacity (in terms of number of cars handled in a time unit), is not considered for evaluation because of its exceeding the target budget of capital improvement for this yard.

Table 6 indicates that 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: Alternative 1 handles 19 trains with the least delay (199 min/train). The two trim engines move the largest number of cars, 1,597 cars versus 1,567 cars in Alternative 2. Departing trains leave with a total of 1,456 cars. 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 of 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) will perform significantly better than the crossover design (Alternative 2) because the crossover tracks may frequently be blocked, causing delay for trimming operations.

Table 6

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.