CONCLUSIONS

Redevelopment of Thornton Yard presented many planning challenges. The need to greatly increase capacity contrasted sharply with the limited property available for expansion. This contrast heightened the need to investigate a wide range of plant and operating alternatives, select the one that best balanced capital and operating requirements, and further test and refine the chosen alternative. The TRIM simulation model was the only way of ensuring that these needs would be realistically met within a reasonable time frame. CN's Transportation Planning Department is confident that through the use of TRIM, an excellent yard design has been developed. This belief is shared by senior CN management and executives, who have approved the proposed flat plan 1 design as the basis for long-term expansion at Thornton Yard.

Engineering Design and Operational Study of Coyotepec Yard

SANTIAGO CARDOSO-CONTRERAS AND PETER J. WONG

Coyotepec Yard, near Mexico City, is being designed to handle 6,000 cars on a peak day. The basic design and the results of computer evaluation studies are presented. Topics addressed include trim-end design; capacity of the yard; humping rate; size of receiving, classification, and departure yards; and number of inspection and yard engine crews.

National Railways of Mexico has planned a large hump yard, Coyotepec Yard, with a capacity of 6,000 cars per day, the largest in the Western Hemisphere. Supplementing an existing, obsolete facility north of Mexico City, the new yard will become a key point for the country's rail network. The design of such a high-capacity facility required departures from conventional practice. In final form, the design represents a collaboration of the efforts of railroad representatives and consultants from Mexico, the United States, and Canada. When the yard has been completed, service will be improved and efficiency increased on the Mexican rail network.

Mexico has a large railway system in place today, which consists of 15,850 miles of track (1,000 miles under construction), 50,000 freight cars (plus 10,000 foreign cars on line at any given time), and 1,400 diesel-electric locomotives. This system handles 70 million tons of freight annually. Freight traffic is expected to grow at 6.8 percent annually through the year 2000.

A large percentage of the country's rail freight traffic must pass through Mexico City; not only do the routes of many cars terminate there, which serves the needs of the city's 16 million inhabitants (projected at 25 million by the year 2000), but all lines between northern and southern Mexico pass through the city as well. The burgeoning freight traffic threatens to overwhelm the existing Terminal Valle de Mexico (TVM) facility. Additional capacity is required, and it was decided not to expand the existing facility but to design a completely new yard to be located astride the new Mexico-Queretaro Main Line currently under construction. Several benefits will result from the new facility:

1. Reduction in transit time,
2. Reduction in operating costs,
3. Improvement in customer service,
4. Reduction in freight-car cycle time, and
5. Technology transfer.

Technology transfer has acquired great importance. The economic recession and tremendous inflation that have wracked Mexico recently have made it almost impossible to contract a large project such as Coyotepec to a foreign enterprise.

DESIGN PROCESS AND SPECIFICATIONS

The overall yard design was divided into the following categories:

1. Yard layout,
2. Yard data system,
3. Process-control system (PCS),
4. Trim-end design,
5. One-spot system and engine facilities,
6. Operating philosophy,
7. Operating management control points,
8. Key operating buildings,
9. Communication and signals (intrayard communication, interlocking design, and control of yard movements), and
10. TV monitoring system.

The purpose was not to complete a design in final detail but to develop each of the foregoing items in sufficient detail to know how these systems should work so that necessary performance specifications could be prepared for the invitation of bids. An exception was made for the critical crest and switching portions, for which a detailed design was made from the outset.

Yard Layout

The most important part of a yard project like Coyotepec is probably the yard layout, which consumes the most time in the conceptual phase of a large yard. Many days and weeks were spent on yard layout by the planning team for the Coyotepec Yard.

Three major constraints had to be considered in working on the yard layout. First, there were those imposed by the boundaries of the land site selected for the yard. Second, there was the division of the whole terminal into two phases, each of which would be able to handle 6,000 cars in the year 2000. The first is the North-South Phase (receiving yard, hump, classification yard, trim end, departure yard) and the second the South-North Phase. The third constraint was the preconceived notion of yard design imposed by the previous operating experience of National Railroads of Mexico personnel. Through many meetings and discussions some of the preconceived notions about yard design and operation were abandoned. This process consumed about 6 months. The main issue of discussion was the advantages and disadvantages of two basic yard layouts: an in-line yard in which cars are pulled from the classification yard to the departure yard and a shove-back yard in which cars are pulled from the classification yard and then shoved into the parallel departure yard.

The result of this long process was six possible layouts of both types of yard. The one selected was a compromise that had both in-line and shove-back departure yards operating through a single multitrack pulling throat that will be able to work five engines at the same time under ideal conditions. Subsequently, one of the advisors, Bill Williamson, submitted another design similar to the one selected but with three multitrack pulling throats that can work six engines under most conditions. This submission of a seventh layout raised considerable controversy with respect to how the yard would be operated.

The controversy led to a decision that simulation was the only way to make an evaluation of the two alternatives. Consequently, a contract was made with SRI International in August 1981 to undertake the simulation of these two alternatives with SRI's CAPACITY and CONFLICT models, so that an evaluation and choice could be made. Various members of the technical team were observed at work in the simulation project, and it became obvious that much had been learned in the past months, because this complex process was handled well. Because of their experience in working on the Coyotepec Yard, the technical team was well qualified for another project, and a set of alternatives for a yard in Monterrey has been drawn up.

Approval was obtained from the Ministry of Communication and Transport for the final layout of Coyotepec Yard with the following specifications:

1. Receiving yard;
2. Hump with a capacity of 6 cars/min;
3. Classification yard with 64 tracks in 8 groups of 8 tracks (the first 8-track group will receive cars for TVM yard only), a master retarder, 8 group retarders, and another group retarder for 6 tracks to the one spot (each of the 64 tracks on the bowl will have tangent-point retarders and inert retarders at each end); coupling speed will be controlled at 4 mph by a double radar measuring device;
4. Two trim-end designs, one with a single key and one with three keys;
5. One on-line departure yard;
6. One parallel departure yard;
7. One transit train yard (relay yard);
8. One minihump with 5 tracks of 35 cars each;
9. One transfer yard; and
10. Two support yards.

Besides all the yards, there are support facilities: a one-spot repair facility and a servicing and repair facility for electric and diesel-electric locomotives.

Dual servicing facilities are necessary because there will be an electric double-track main line beside the yard. Allowance for future electrification has been made in the receiving and departure yards as well. Furthermore, 43 different types of buildings have been designed--for example, the main control tower and administration building, the trim-end tower, the receiving-yard crew building, the departure-yard crew building, the shops for work on electric and diesel-electric equipment, car facility, caboose office, hospital center, and fire center.

Yard Data System

The computerized yard data system is a relatively new phenomenon in the railroad industry. It was not invented; it evolved. Before the use of the computer, yard data were collected manually. Required information was passed from location to location in the form of switch lists, hump lists, consists, and so forth. The user then read, manipulated, and interpreted these data for his own use. This process was slow, inefficient, and incompatible with the needs of a modern, high-technology railroad yard. Consequently, data systems used by two modern U.S. railroads were examined--the Missouri Pacific System (MoPac) at St. Louis, Missouri, and the Southern Pacific System (SP) at San Francisco, California. MoPac built the switch system and SP built its transportation commodity classification system. Both railroads spent a number of years and millions of dollars in developing the individual systems.

Coyotepec Yard will need systems like these in order to operate. The question is to decide what kind of data system to use. Both MoPac and SP submitted proposals to supply their respective systems to the Coyotepec Yard project. These proposals have been evaluated and submitted to the Ministry of Communication and Transport for action.

When a specific system has been selected, it will be necessary for representatives from the operating computer systems, signals, and communications to go over the system in detail with the vendor to ensure that the capabilities for the job are available. Knowledge of yard operations should be reviewed from the flow of yard data and the information requirements of Coyotepec. This process will be a tremendous learning experience for those involved and the required knowledge cannot be gained in any other way. The technical group will then become the core of expertise that will be necessary to further expand, develop, and use efficiently the data system selected. During this third step of detailed activity it will also be necessary to work with the PCS suppliers to design an operating interface between the two systems.

PCS

One of the most important elements in a modern railroad hump yard is the PCS and the humping function it serves. If the Coyotepec Yard is examined, it is easy to see that the hump is a center of great activity and also that many functions support the hump work. Furthermore, the sorting process done by the hump has a strong and direct bearing on the capacity and efficiency of the whole yard and, in this case, the whole railroad. Because of this, the efficiency of hump support functions must be proportional to humping capacity or the inherent capacity of the hump is restricted. This is the reason for careful study of the specific data interface between the management inventory system (MIS) and the PCS, the weigh-in-motion scale (ahead of the hump), and the specialized design of the pull-out end of the classification yard, which will be discussed later.

The stated goal for the first yard at Coyotepec was 6,000 cars per day at the peak. Observation of the SP West Colton Yard near San Bernardino, California, in which cars are humped by using the PCS, gave evidence that this humping rate was economical and safe on a regular, ongoing basis. Therefore, a recommendation to the Ministry of Communication and Transport was made without hesitation that the West Colton system be used at Coyotepec if anticipated humping levels were to be achieved. However, it was necessary to review in detail how the system works and its many features and components such as retarders and electrical supply systems. The ability of various suppliers to produce this kind of PCS was also discussed. Project team members and Mexican railroad personnel must now review and evaluate each proposal. If possible, the vendors should make an exhaustive presentation of their products. Important items include data flow from inbound trains and return of individual car data from the PCS to the MIS for inventory updating. Data needed by the PCS to hump cars include such problems encountered during humping as the wrong list, catch-ups, stalls in the switching section, and breakaway of uncontrolled cuts.

Trim-End Design

If the PCS is one of the most important elements in a modern railroad hump yard, what about the trim-end design for this project? Once a hump had been developed to handle 6,000 cars per day, a trim-end design with at least the same capacity became necessary. The first step was to translate into Spanish the section on hump yard trim-end design of SRI's Railroad Classification Yard Technology Manual (1), in which a manual procedure to evaluate engine conflicts and interferences at the trim end is described. This was used to simulate the pullout end. A matrix with the number of classification and departure tracks (on-line and parallel departure yards) was constructed. In one layout (1:2000 scale) all the switches were shown that the trim end needed to permit any car in any classification-yard track to pass through the throat to the departure tracks (both on-line and parallel yards). The switches were all numbered and values were given to the parameters describing various engine movements.

The manual simulation was used to screen many different alternatives, one of which was the alternative presented to SRI. With the help of Peter J. Wong and Masami Sakasita, some changes were made and further simulations were conducted. The three-key design by Bill Williamson was simulated as well. Both plans proved to be good designs. Williamson's is more expensive in its construction and maintenance, but it has more capacity (7,200 cars in a peak day). However, it also needs personnel with advanced knowledge of yard operation, which is a type of expertise not available on this project.

Although this is a satisfactory design with a new layout and a new trim-end design, there are many unknown factors. Theoretically, this project will be able to handle 6,000 cars in a peak day, but it may not. The quality of work by contractors and construction supervisors will have an impact on the eventual performance as well. Only when such a yard is actually in operation, such as the new Queensgate Yard in Cincinnati, Ohio, will it be known whether the projections for Coyotepec Yard are correct.

One-Spot System and Engine Facilities

An efficient car repair facility is essential to the operation of a large yard because of the anticipated 2 percent bad-order rate during normal operations. If the bad-order (defective) cars are not handled consistently, their backup and consequent storage and switching requirements can soon have a detrimental effect on the entire yard operation. Moving bad-order cars by means of "mechanical rabbits" into the repair shed has been considered. The repair building is equipped with stationary hydraulic jacks, small retarders, all necessary tools, car parts, wheel sets, blue flag systems, and so on.

The specifications of the facility are standard; the location of the one spot is important. It must be placed so as to minimize handling of cars to and from the shop. That is why it will be located in the middle of the yard between the North-South Phase (first phase) and the South-North Phase (second phase). The car repair facility will have the capacity for 61 light repairs and 120 on the one spot (four tracks). It will also be able to wash and supply 100 cabooses, to repair 5 cabooses, to wash 20 tanks, and to transfer freight loads between two tracks.

The facilities for electric engines will have the capacity to handle washing, travel inspection, and sanding of 121 engines. For diesel-electric engines the facility will have the capacity to handle washing, fueling, and light repair of 181 engines (capacity, 12 per day).

Blue-flag systems are the means by which mechanical and locomotive department employees are protected from injury while they are working on or under engines, cars, or other rolling equipment. Performance specifications for the various blue-flag systems to be used in the yard have been supplied. This includes those to be used in the one-spot facility along with other protective devices required and operating restrictions to be observed in moving cars through the one spot.

Operating Philosophy

Because of the many new concepts that were being explored, it was felt that a document was needed that would help explain how the new yard should operate. Consequently, early in 1982 an extensive document was prepared that discusses in considerable detail the main functions, processes, and systems involved with moving cars into, through, and out of Coyotepec Yard. This document also contains discussions and recommendations concerning the importance of the main lines at each end and how Coyotepec Yard should accommodate the flow of trains to and from these lines. This document provides a good overview of the kind of yard Coyotepec will ultimately become and of the kind of operating problems that will be faced.

Operating Management Control Points

Because of the high throughput expected of this yard, it was not feasible to design it without exploring as many of the common weaknesses found in existing yard operations as possible. A great deal of time was spend discussing with operating personnel the need for coordination and control in a yard expected to handle 6,000 cars per day. This problem was addressed not only in the document on operating philosophy but also either directly or indirectly during the entire project. Every track layout and system recommended inherently contained the elements needed to control and coordinate the operation at Coyotepec. Detailed recommendations were made for two operating control points--the crest tower and the trim tower. These are the two points from which all activities in the yard are directed, from the arrival of trains to their departure, as well as all related processes. The actual design of these towers reflects the many discussions on this important subject.

Key Operating Buildings

Considerable time (about 6 to 7 weeks) was spent working on the key operating buildings to be included in Coyotepec. The largest of these is the main administration building, to be located near the crest of the hump. This building will include administrative offices, the main yard office for clerical functions, the main operator tower, and the process-control computer room. If the management computer system is to be located at Coyotepec, its computer center could be in this building as well.

The second most important building is the trim tower, to be located at the pull end of the classification yard. All train makeup activities will be directed and monitored from this point. The remaining buildings to be designed were the mechanical and locomotive force buildings. In this process drawings made by the coordinator of each building were reviewed in terms of the functions it was to support. After two or three iterations of this process, concept drawings of these key operating buildings were made. The drawings were then sent to the architects for preparation of the final plans.

Communication and Signals

Signals and communication are involved in almost every element of yard operation. A few of the more important topics discussed are mentioned here.

Intrayard Communication

The major portion of oral communication within the yard would be via telephone and intercom systems; there would be minimum use of two-way speakers. This follows recent trends in other yards.

Interlocking Design

There was considerable discussion about whether the yard should have direct contact with the dispatcher when trains move into and out of the yard or whether it should be surrounded by an independent interlocking system. In other words, should trains move from central traffic control (CTC) directly into yard territory or from CTC territory interlocking into yard territory? This was studied carefully. After two or three meetings with the operations personnel it was decided to install a manned interlocking system because it is less restrictive. Moving the trains, cuts, and engines into and out of a yard through a local interlocking system is much more flexible and efficient than operating directly into a CTC system.

Control of Yard Movements

In a large yard such as Coyotepec there is always substantial movement. Trains are arriving and departing, road locomotives are moving from trains to the servicing facilities and from the servicing facilities to trains, and light yard engines and yard engines with cars are moving about in and between various sections of the yard. In many yards this profusion of movement generally results in significant confusion and delay, particularly when there is a large work load and decreased efficiency. To avoid this problem, it is necessary to establish a central control over routes and signals in order to coordinate them. This will be done by the wide use of power switches and various signals controlled from two points, the hump operations tower and the trim tower. This system was thoroughly discussed with operating, signal, and communications personnel and advisors, and visits to existing yards made it possible to see the system and its components in operation. Signals and communications personnel worked with the advisors to lay out a centralized control system for yard movements at Coyotepec.

TV Monitoring System

One item discussed in detail was the possible use of a TV system for monitoring inbound and outbound trains. Because of the success of this type of system in yards in which it has been installed, it was recommended that such a system be used at Coyotepec.

It is not possible to mention all the activities and details covered in such a complex project as this. Nevertheless, some of the more interesting aspects of design concern the physical layout of the tracks. A more detailed discussion of this part of the design process follows.

COMPUTER SIMULATION OF YARD DESIGN

Background

Because of the shape of the available land, the basic design of Coyotepec Yard will have an in-line receiving yard, a classification yard with 64 tracks, an in-line departure yard for trains departing to the south, and a parallel (pullback) departure yard for trains departing to the north. This basic design is called the one-key design (Figure 1). A proposed modification of the basic one-key design was to subdivide the in-line departure yard into three in-line departure yards; this design is called the three-key design. One of the important issues in this project was to decide which of the two designs could better meet the projected needs of Coyotepec Yard.

The other design and operational questions to be resolved for Coyotepec Yard were the following:

1. How many cars can Coyotepec Yard classify?
2. How many trains can Coyotepec Yard process?
3. What should the humping rate be?
4. How many tracks should there be in the receiving, classification, and departure yards?
5. How many inspection, hump-engine, and trim-engine crews are required to operate the yard?

Evaluation Methodology

SRI International developed the computer simulation models CAPACITY and CONFLICT to aid in the design and operational evaluation of railroad classification yards. These two models were used to simulate various aspects of Coyotepec Yard.

The CAPACITY model represents the entire yard, whereas the CONFLICT model focuses on the trim end of the classification yard. The CAPACITY model estimates the requirements for and use of the receiving, classification, and departure tracks; the hump; and inspection, hump-engine, and trim-engine crews. However, in many situations, especially in large hump yards, the trim end of the classification yard can be a bottleneck. Consequently, examining the trim end in more detail than is provided in the CAPACITY model is often useful; this is accomplished in the CONFLICT model. The CAPACITY model uses the average rates of work in the performance of tasks, but in the CONFLICT model the work of each trim engine is monitored and evaluated in detail.

These yard models enable the user to operate the yard in the computer in much the same manner as in the real world. Performing operational experiments in the computer, however, is much more practical and efficient than performing the experiments in the real world. To run the models, the user must develop a detailed train schedule and operational scenario for each case to be studied. Specifically, the data include inbound and outbound train schedules and consists, instructions for the order of humping inbound trains, classification-track assignments, instructions for the order of making up out-

Figure 1. Approximate schematic of one-key design.

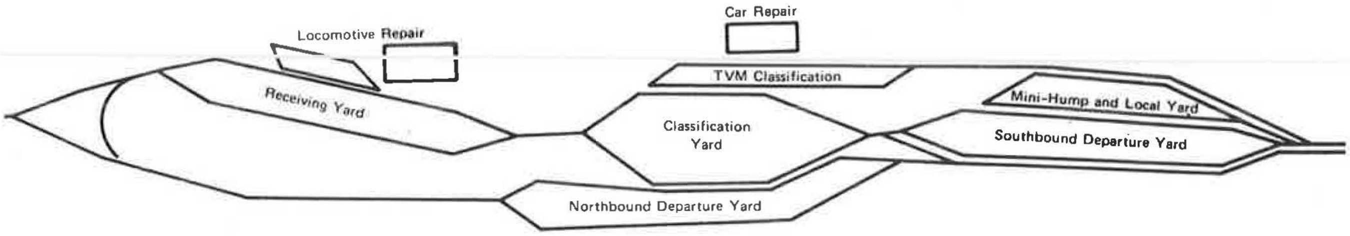
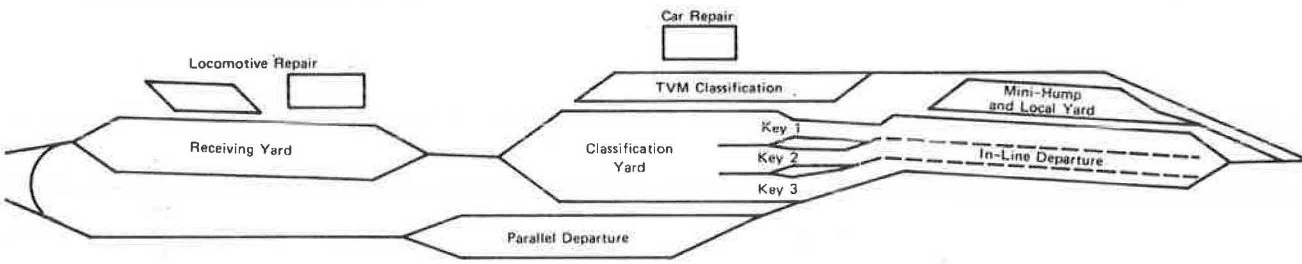


Figure 2. Approximate schematic of three-key design.



bound trains, assignment of inbound and outbound inspection crews, and the allocation of work to hump- and trim-engine crews.

Thus the preparation of input data for the models requires considerable thought to properly plan the yard operations. This is especially true for examining projected scenarios for which no data or experience exists. Consequently, on the basis of projected traffic data provided by INPLAN, the joint INPLAN-SRI team created realistic train schedules and operational scenarios for the years 1985, 1990, 1995, and 2000.

One of the fundamental tasks of this study was to evaluate the one-key and three-key designs and select the better alternative. Because the designs are essentially the same except for the trim end, the CONFLICT model was used to quantitatively evaluate the trim-end capacity of the two designs.

Then the CAPACITY model was used to estimate the overall capacity of the design alternative selected and the track and crew requirements for the years 1985, 1990, 1995, and 2000. A base-case scenario was developed for each year, and then a sensitivity analysis was performed to test the ability of the yard to respond to changes in the base-case scenario. For example, the hump rate was varied, arriving trains were concentrated into a 2-hr period, and outbound trains were delayed on the departure tracks. In this manner, the sensitivity of the yard to normal operational disruptions could be analyzed.

Selection of One-Key Design

SRI analyzed the basic one-key Coyotepec Yard design, shown in Figure 1. It consists of an in-line receiving yard, a main classification yard adjacent to the TVM classification yard, an in-line departure yard, a parallel (pullback) departure yard, and a minihump yard.

SRI also examined a modification in the trim end of the basic design, which is called the three-key design. As indicated in Figure 2, the three-key design is essentially the same as the one-key design. The difference is that the main classification yard is subdivided into three classification yards that are connected to three in-line departure yards via three segregated sets of trim-engine routes called keys. The three-key design concept is a variation of SP's West Colton Yard trim-end design. The purpose of the three-key design is to provide as many segregated routes as possible from classification yard to departure yard so that as many trim engines as possible can be used without conflict and interference.

However, the segregation of routes between the classification yard and the in-line departure yard makes it difficult to pull a cut of cars from the classification yard to tracks in a departure yard not in the same key. This geometric restriction constrains operations in the yard because cars assigned to classification tracks associated with a given key must be made up on trains in the departure tracks associated with the same key; that is, crossovers from one key to another are virtually impossible. This operating restriction profoundly limits the yard's flexibility in responding to daily changes in outbound train schedules and makeup instructions and in the inbound traffic level and mix of cars. For example, changing the classification-track assignment for a group of cars to either a longer or a shorter track to fit the expected volume is more difficult because the yardmaster must ensure that the train carrying that group of cars departs from the departure track corresponding to the changed classification-track assignment. Similarly, if a classification track overflows, the overflow cars must be put on an empty track on the same key. Also, if on a particular day it is necessary for a departing train to have a different consist mix, the only cars that can be assigned to the departing train are those from classification tracks in the same key.

The detailed CONFLICT model analysis indicated that for a given classification-track assignment and a specified departing-train schedule and consist, the capacity of the one-key design is slightly greater than that of the three-key design. The layout and operations of the three-key design dictate that all southbound trains and a significant portion of the northbound trains depart to the south from the in-line departure yard. (Note that the north trains departing to the south reverse direction before entering the main line via a balloon track.) The analysis also revealed considerable congestion

Table 1. Recommended minimum requirements: one-key design.

Design Feature	1985	1990	1995	2000
No. of tracks				
Receiving yard	14	15	18	22
Departure yard				
North	7	9	10	12
South	7	9	10	12
Minimum hump speed (cars/min)	4.0	4.0	5.0	6.0
Crew[a]				
Inbound inspection	4, 4, 4	4, 4, 4	5, 5, 5	7, 7, 7
Hump-engine	2, 3, 2	2, 3, 3	3, 3, 3	3, 3, 3
Trim-engine				
North departure yard	2, 2, 1	2, 2, 2	2, 2, 2	3, 3, 3
South departure yard	2, 2, 2	3, 3, 3	3, 3, 3	3, 3, 3
TVM yard	1, 1, 1	1, 1, 1	1, 2, 1	2, 2, 2
Outbound inspection				
North departure yard	1, 1, 1	1, 1, 1	2, 2, 1	2, 2, 2
South departure yard	2, 2, 2	2, 2, 2	2, 2, 2	3, 3, 3

[a]The group of three numbers indicates the size of crew for the first, second, and third shifts.

and a crossing conflict between northbound and southbound trains leaving the in-line departure yard for the main line.

An analysis of the layouts in the three-key and one-key designs indicated that the three-key design has 30 percent more tracks and switches. Therefore, the three-key design will be substantially more expensive to build and maintain.

Compared with the three-key design, the one-key design has slightly lower capacity, is less expensive to build and maintain, and is more flexible in responding to changes in traffic and operating conditions. Consequently, SRI recommended the adoption of the one-key design.

Capacity of Coyotepec Yard

Coyotepec is expected to have a peak capacity of approximately 6,000 cars and 70 trains per day. To achieve this peak capacity in the CAPACITY model analysis, it was assumed that the hump engines worked at rates slightly faster than normal. The normal rates of work were conservative estimates; the INPLAN coordinators believe that the higher rates of work can be sustained for short periods. Therefore, it was estimated that the peak capacity can be sustained over a period of several days but that the long-term steady-state capacity will be approximately 5,500 to 5,600 cars per day.

Major Design Recommendations

SRI recommended that Coyotepec Yard ultimately have 22 receiving tracks, 12 northbound departure tracks, and 12 southbound departure tracks. In Table 1 the increased track requirements for the years 1985 to 2000 are given.

It is also indicated in Table 1 that Coyotepec Yard must be designed to hump 6 cars per minute by the year 2000. Although the minimum hump speeds for the years 1985 to 1995 are lower, the rate of 6 cars per minute must be designed into the yard at the beginning because the humping rates are fixed by the hump grades and retarder placements.

To facilitate the humping activity, SRI recommended that a hump-engine escape route be designed so that once an engine has finished humping, it can quickly clear the hump by going onto an escape track. The escape track should be so constructed that the hump engine can return to either side of the receiving yard via a tunnel under the hump.

Overpasses may be desirable at both ends of the yard so that trains entering and leaving the yard from one main-line track can cross above the traffic on the other main-line track. This will prevent congestion from trains entering and leaving the yard from the main line.

To allow flexibility for the TVM classification tracks to handle transfer traffic when needed, SRI recommended that a reasonably short and conflict-free route exist from the TVM classification tracks to the minihump yard.

If a peak humping rate of greater than 6,000 cars per day is desired, INPLAN should consider the possibility of constructing a dual-lead hump with scissors crossovers down the hump grade to support simultaneous humping operations. However, for dual-humping operation trains arriving in the yard must be blocked by the outlying yards so that they carry cars for only one side of the classification yard; this ensures that no cars cross over during simultaneous humping operations.

Yard-Crew Requirements

The minimum yard-inspection and engine-crew requirements for the years 1985 to 2000 are given in Table 1. The sets of three numbers (for example, 2, 3, 2) indicate that there are two crews on the first shift, three crews on the second shift, and two crews on the third shift. The translation of crews into actual personnel is as follows:

1. One inbound inspection crew, six persons;
2. One hump-engine crew, five persons;
3. One trim-engine crew, five persons; and
4. One outbound inspection crew, three persons.

The minimum crew levels recommended can produce a considerable operational cost saving at Coyotepec Yard. Also, staffing the yard initially at the minimum crew levels is wise because extra crews can be added when the need arises. If too many crews are planned initially, eliminating crews later may be difficult because of established labor agreements. If Coyotepec Yard is operated at minimum crew levels, the crews will become used to working at high efficiency, even with low traffic levels; otherwise, when the traffic levels rise to those anticipated for the year 2000, the workforce will not be efficient enough to handle 6,000 cars on the peak days.

Coyotepec Yard has been designed to allow a specified maximum number of hump and trim engines to work productively without conflict. Consequently, in the year 2000 the Coyotepec crews must be capable of working efficiently because inefficiency cannot be compensated for by the addition of extra yard engines, which will begin to interfere with each other and decrease operational efficiency.

CONCLUSIONS

Coyotepec Yard is approximately twice the size of large yards in the United States. It has been designed with the best technology and methods available. The ability of the yard to meet its peak capacity potential, however, will be determined not only by its physical design but also by the efficient coordination of train schedules with other outlying yards and the efficient management of engines and crews within the yard. To achieve long-term goals, the planning of operations for the successful opening of Coyotepec Yard in 1985 is critical because a number of labor practices will be established that will be difficult to change later.

The most visible results of this project are as follows:

1. The array of yard designs was narrowed to a choice between two specific, new yard designs.
2. The yard was designed to handle 6,000 cars on a peak day.
3. The classification yard was designed to work together with the TVM yard and was dedicated to serve only a group of eight TVM tracks.
4. A trim end was designed with a capacity equal to that of the hump and with great flexibility, few conflicts, and low cost.
5. The minihump was designed with the trim end east of the on-line departure yard and later changed to be beside the classification yard west of the TVM group. With this change there will be fewer conflicts at the trim end.

Employee acceptance of the new yard and its new systems may pose problems when the yard is opened. It is not too early to start a program of familiarization for the employees. First, sessions could be held with union leaders and their local representatives to tell them what is being planned and why and invite their cooperation and suggestions. Second, when possible, some of the new devices and systems could be set up in a demonstration mode so they could be tried. Third, comprehensive training programs could be offered before the yard is opened. The training sessions should feature hands-on training by using actual devices and procedures. A program along these lines will help to overcome possible problems of nonacceptance.

ACKNOWLEDGMENT

In order to design the Coyotepec Yard, an interdepartmental group was set up as follows: Vicente Ortego, planning; Jaime Hueso, signals; Antulio Morgado, communications; Miguel Ruiz, locomotives and cars; Roberto Castellanos, systems; Ignacio Salaza, track and structures; and Manuel Gonzalez, operations.

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A Modular Approach to Classification Yard Control

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A design is described that focuses on existing yards. It provides basic control functions and is cost-effective, expandable, and maintainable. The distributed system provides natural partitioning, expansion, system flexibility, and modularity through the use of microprocessors. Hierarchical relationships of each function within the yard are explained and illustrated. Suggested hardware for the system includes racks, chassis, and power supplies. Estimates of facility requirements such as power, floor space, and heating or cooling are also provided.

In late 1979 the need became apparent for a yard-control system with characteristics somewhat different from those of existing computer-based control systems. Most new control system development had been targeted for new yards designed for increased levels of automation and functional capability. These systems provided a level of control that could not be obtained by using previous technologies. However, these systems did not lend themselves to applications in existing yards where a high degree of automation was impractical either because of existing field conditions or the configuration of the yard. Therefore a project was launched to analyze existing control systems and determine whether a system could be developed that would provide basic control features in a configuration more applicable to an existing yard facility.

DEFINITION OF FUNCTIONS OF A YARD-CONTROL SYSTEM

The first step in the project was to identify and define those functional features that might be required in the target system. The track and equipment layout of a yard is shown in Figure 1. A list and brief description of each function required of the control system follow:

1. Cut detection: The control system must detect a cut after it has been separated from the train. The presence of the cut must be detected soon enough to allow characterization of the cut (see item 2).
2. Cut characterization: Each cut must be characterized with respect to length, axle count, number of cars, weight, and rolling resistance. Characterization must be complete before the cut enters the master retarder.
3. Cut tracking: The system must track the movement of cuts through the control area. If a cut proceeds on a path other than the intended path, an alarm should be generated. The track on which the cut leaves the control area should be recorded for reporting purposes.
4. Switch control: The system must provide for automatic switch movement to ensure that each cut is routed to the requested classification track.
5. Distance to couple (DTC): The system must maintain a record of distance from tangent point to standing cuts on each classification track. This information is derived from a car-count algorithm or from electronic hardware measuring distances.
6. Exit-speed calculation: Given the cut characteristics, cut destination, curves, grades, elevation drop, distance to go on the classification track, and target coupling speed, the system must