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RAILROAD CLASSIFICATION YARD TECHNOLOGY
An Introductory Analysis of Functions and Operations

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Editor

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A review of the basic operating characteristics and functions of railroad classification yards is presented. Introductory descriptions of terms, concepts, and problems of railroad operations involving classification yards are included in an attempt to provide a "primer" on railroad yards. The report describes certain railroad operating practices and identifies problems that inhibit the efficient operation of railroad yards and the rail system of which they are a part. An extensive bibliography has been provided.

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PREFACE

Early in a study of railroad yards one is struck by the lack of basic, introductory descriptions of the terms, concepts, and problems of railroad operations involving classification yards. No "primer" on railroad yards exists. This report attempts to fill that void. The report is intended primarily for use by both government and non-governmental transportation and public planners, as well as the general public. The recent bankruptcies and Congressional actions relative to the railroad industry have generated renewed public interest in understanding railroad operations and the complex environment in which railroads function. An introductory report of this kind will hopefully be useful in providing that increased understanding.

The source data in this report came from various published reports and papers, from discussions with and correspondence from representatives of railroad companies and railroad suppliers, and from personal working experiences of the project staff. Descriptions of railroad functions and facilities included in this report do not necessarily characterize a particular railroad; they are intended rather as a general description.

This report was prepared by Raytheon Service Company for the U.S. Department of Transportation, Transportation Systems Center, which is conducting this research under the sponsorship of the Federal Railroad Administration. Members of the Raytheon staff who produced this report were Kenneth J. Belovarac, assisted by J. T. Potratz, Patrick O'Neil, and Artemis Kirk, bibliographer. Project manager for TSC was Kenneth F. Troup.

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1. INTRODUCTION

1.1 SCOPE

A railroad classification yard physically sorts, groups, and classifies railroad cars for purposes of train movements. Classification yards are also often the origins and destinations of freight shipments over the rail transport system. If a railroad is viewed as a network, classification yards would be nodes where trains entering from one link would have their cars resorted and grouped into trains moving over other links radiating from that node. An individual rail shipment may have to travel over a number of links and nodes, and on a number of different trains before reaching its destination.

From this simplified characterization of the rail transport system, it is clear that much handling of rail cars occurs. Railroads group cars into trains to utilize the inherent economic advantage of the rail mode – the ability to move large numbers of shipments as a single unit. Even though this is economically efficient, the necessary process of sorting and grouping cars into trains can negate this economic advantage by causing increased operating costs, lowering equipment utilization, prolonging transit time, and producing less than reliable transportation service.

This introductory analysis of railroad classification yards reviews many contemporary ideas about classification yards, especially instances where yards act as economical and physical bottlenecks to rail freight service. The basic operating characteristics and functions of classification yards are considered in the context of rail network operations over a wide range of conditions. An outline of the physical characteristics, operating procedures, and operating policies found in classification yards is also presented. Then, recognizing that it is futile to study classification yards out of context of the rail network, the effects of yard operations on network efficiency are reviewed. A summary of various operating schemes and methodologies to improve yard and network operating efficiency, improve equipment utilization, and provide for better quality freight service follows. Next, a case study review of the use of computer simulation modeling applied to the design of new yards and for improving the design and operating efficiency of existing yards appears. Following that, the issues involved in decisions to build new yards and to improve existing yards are examined. The issues covered include discussions of the economic criteria, industrial organization, and funding problems associated with such projects. Finally, a summary of the main points brought out in the paper are listed, followed by an extended bibliography of rail yard literature, which appears as an appendix.

1.2 SUMMARY OF STUDY

The major findings resulting from this effort are discussed in detail in the final section. Listed here in brief form is a summary of these findings:

1. The yard and network operating policies of a railroad can have as great an influence on whether a railroad yard becomes a bottleneck to operations as the physical and technological limitations of the yard itself.
2. Regular high-frequency train operation has significant potential for improving railroad freight service and improving yard efficiency.
3. Railroad yard simulation models are still in their infancy and only a small number of railroads have used or are using them.
4. The use of computers to aid in managing rail yard operations is still a new field, and only a small number of railroads are active in it. However, the use of computers in developing management information for rail yard operations has great potential for improving the efficiency of such operations.

5. There is a need for performance measures for assessing operations and economic effectiveness of yard and network operating efficiency and overall improvement alternatives.

6. New yards and yard improvements are mostly related to changes in traffic volumes and patterns, facility consolidation as a result of mergers, the maintenance of quality freight service and operating efficiency, and land-use development projects, especially in urban areas.

7. No new yards built or under construction significantly deviate from conventional yard design. Switching processes such as staged switching, which call for a non-conventional classification yard design, are not in common use.

8. The availability and overall cost of capital is a major constraint to new yard projects.

2. TYPES OF YARDS

2.1 INTRODUCTION

This section presents a brief review of the many types of railroad yards and terminals. Since the report as a whole will primarily focus on classification yards, a review of all types of yards will help clarify the role of classification yards among other kinds of yards in the context of a railroad network.

Railroad yards can be categorized in various ways: by operating function, by traffic and commodity flow characteristics, by size and capacity, by type of switching, by layout, and by their importance relative to flow characteristics of the network of which they are a part. Normally, railroad yards are categorized by the major operating functions. Seven types are defined here:

1. Classification Yards
2. Interchange Yards
3. Storage Yards
4. Local Switching Yards
5. Support Function Yards
6. TOFC/COFC (Trailer/Container on Flat Car) Terminals
7. Other Yards and Terminals

A review of the typical process of moving freight by rail will assist in understanding the functions of yards. This process is as follows:

1. The shipper places an order for a car with the railroad's agent. This may consist merely of a telephone call to the local freight station.
2. The yard office receives the order and selects the car. This again may result from a telephone call from the agent to the local yardmaster. (In a small-way station, the same man may fill both functions.)

3. The car is inspected for mechanical soundness by the car inspector. It must meet the special requirements of the shipper. (Grain cars, for example, must be clean and in first class physical condition, and there must be proof against rain leaking in and grain leaking out.)

4. The car is switched to the industry track. An industrial switch-run engine will take a group (cut) of cars covering a specified geographical portion of the industrial district. Loaded cars will be delivered to consignees for unloading. Loaded cars on shippers' tracks will be picked up for return to the yard. The empty car will be placed on the industry's tracks for loading.

5. The shipper loads his car and notifies the agent or yard office that it is ready for "pulling."

6. A bill of lading and waybill are prepared for the shipment.

7. A switch engine takes the car from the industry's tracks to the assembling or classification yard.

8. The car is classified into a train of cars having a generally similar destination.

9. After the train is completely built, the road movement begins.

10. During the road haul, the car may pass through one or more intermediate classification and interchange yards so that the car eventually is placed in a train going directly to its final destination.

11. On arrival at destination, the train is broken up in another classification yard, and the processes of steps 4, 7 and 8 are repeated in reverse until the car finally comes to rest on tracks of the consignee.

12. Consignee unloads car and notifies agent of its release.

It can be noted from this series of events that the classification yard is the key yard involved in car movements. The following sections describe classification and other types of yards, and the various functions they perform.

2.2 CLASSIFICATION YARDS

The most important function of a classification yard is to receive incoming trains and reassemble the cars into outbound trains that will take the cars closer to their destinations. Three major functions are performed in the classification yard: receiving, classification, and departure. The receiving function consists of an incoming train being placed in the receiving yard to await classification. The classification function is the breaking up of the train and placing each car onto a classification track corresponding to its general destination. The departure function is the making-up of a train comprised of one or more classification blocks according to destinations.

To carry out these functions, a modern classification yard complex is segmented into receiving, classification, and departure yards, as illustrated in Figure 1.

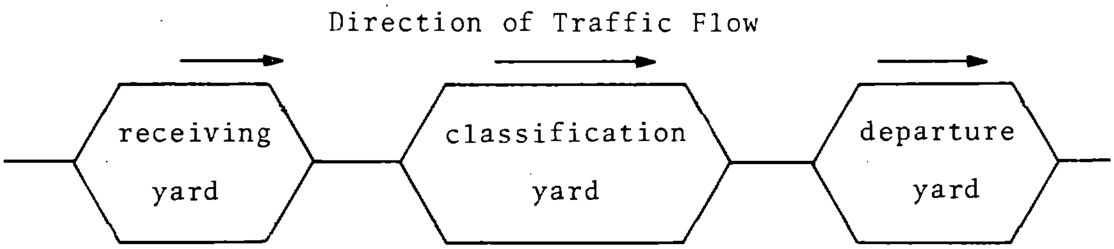


Figure 1. Schematic of Simple Modern Classification Yard Layout

The manner in which the receiving, classification and departure yards are physically laid out with respect to each other is a function of the availability of land, the predominating direction of traffic, the traffic volume, and local operating considerations. As a result, there are many types of layouts that a yard can have.

Sometimes receiving, classification, and departure yard segments are combined, as in Figure 2.

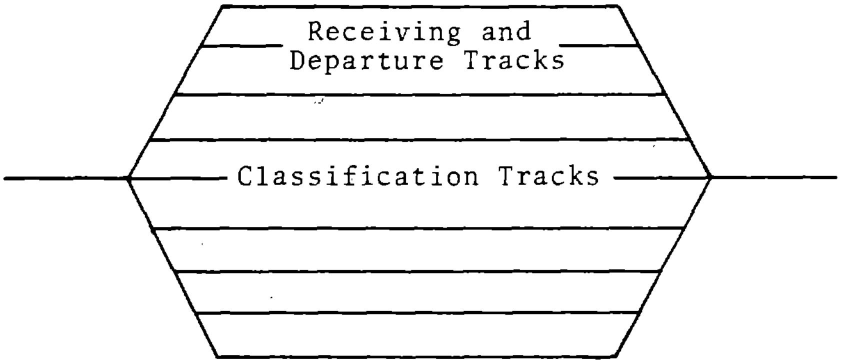
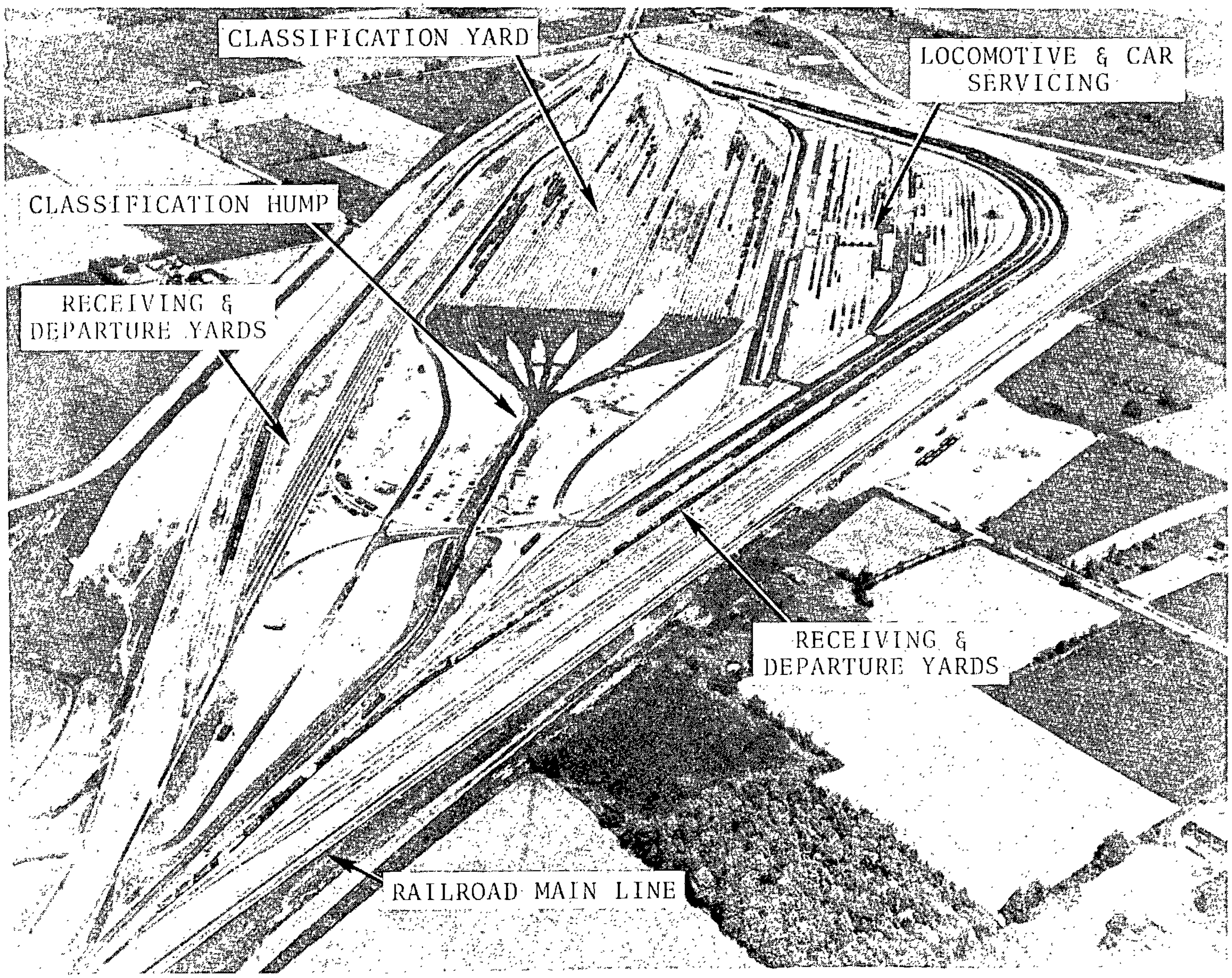


Figure 2. Schematic of a Small Classification Yard Containing Only One Body of Tracks Used for Receiving, Classification, and Departure Activities

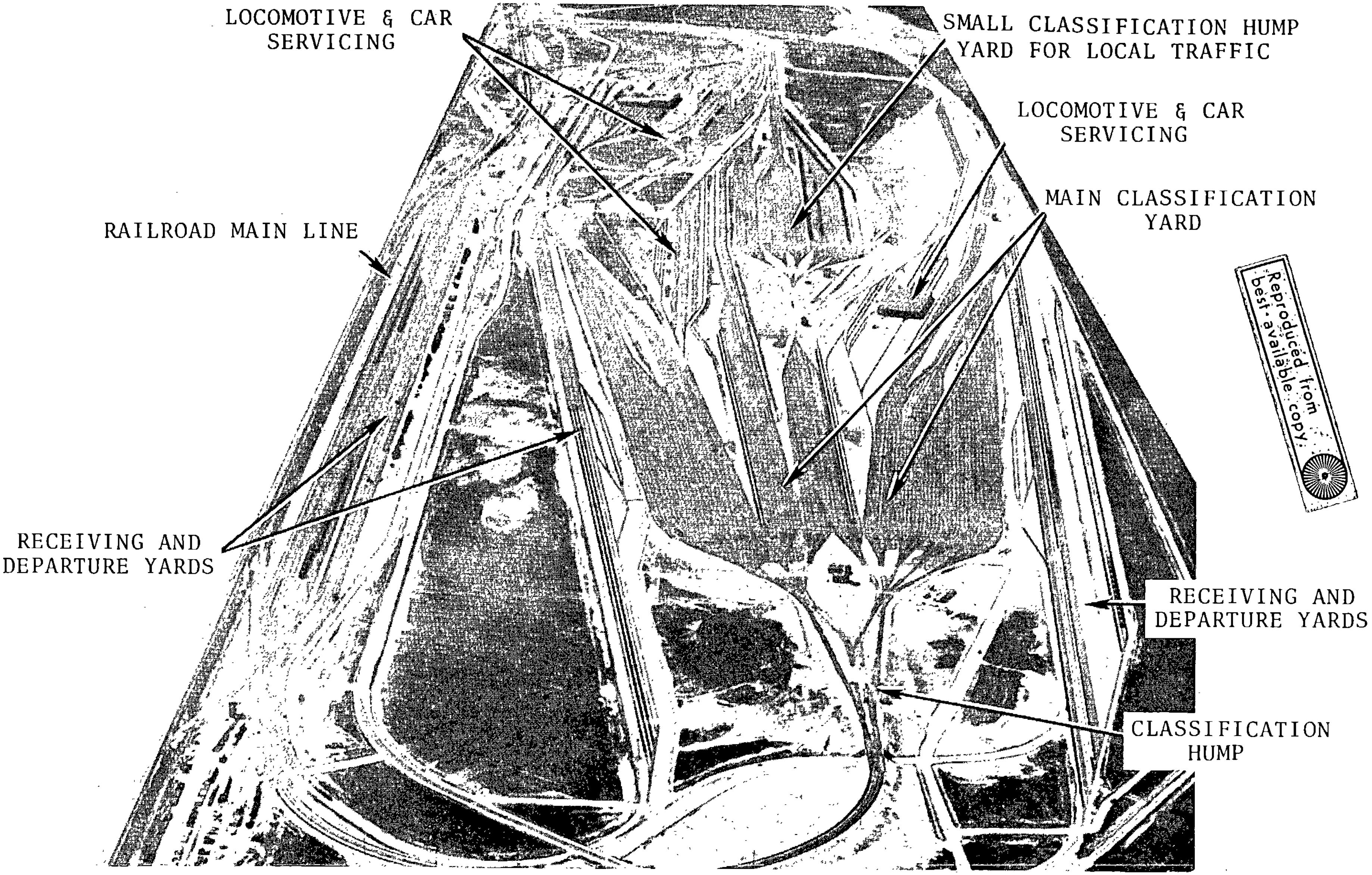
In other cases, a receiving and departure yard may be combined into one yard, or a classification and departure yard can be combined so that trains are assembled at the departure end of the classification yard and dispatched from that point instead of being assembled in a separate departure yard. (See Figures 3 and 4 for two examples of classification yard layouts.) Each yard layout has particular advantages and disadvantages that may affect intra-yard switching operations and must therefore be evaluated on a case-by-case basis by considering individual operating variables.

The classification segment of a yard may be either what is called a flat yard or a hump yard. Smaller yards such as that shown in Figure 2 are almost always of the flat yard type. The difference between a flat yard and a hump yard is that a flat yard is generally constructed on level ground or on a slight grade. Cars are pushed by a locomotive and then released, coasting to their



Courtesy of Westinghouse Air Brake Co.

Figure 3. Typical Modern Classification Hump Yard Layout



Courtesy of Westinghouse Air Brake Co.

Figure 4. Example of a More Complicated Classification Hump Yard Layout

respective tracks. (See Figure 5) In a hump yard, on the other hand, there is a steep incline or "hump" leading into the classification yard segment. Cars are pushed over the hump and roll freely downhill to their proper track, with their speed controlled by mechanical "retarders" built into sections of track to limit the car speed at coupling to four miles per hour. (See Figure 6.)

Virtually all new major classification yards being built are hump yards.[1] There are presently about 1500 flat yards and about 135 hump yards on the U.S. and Canadian rail system.[2] New hump yard construction will probably add another five to eight hump yards to this total.

The main advantage of a hump yard over a flat yard is that cars can be processed faster with fewer switch engine moves. However, the economic trade-off between flat yards and hump yards is not measured in car volume; rather, it lies in the balance between capital cost and operating expense. Hump yards are more expensive to construct than flat yards, but offer a lower cost per car handled. A hump yard can handle up to 3500 cars per day with an average hump rate of three cars per minute, some yards averaging as high as eight cars per minute. The maximum capacity of a flat yard is around 1000 cars per day with an average switching rate of one car per minute. However, some flat yards are now being upgraded with new automatic devices and process control systems which are designed to increase yard capacity significantly. One railroad reported that daily traffic volume of between 2000 - 2500 cars would be normal for a hump yard, and that some of these cars are likely to be humped more than once to obtain more classifications than there are classification tracks. Also,

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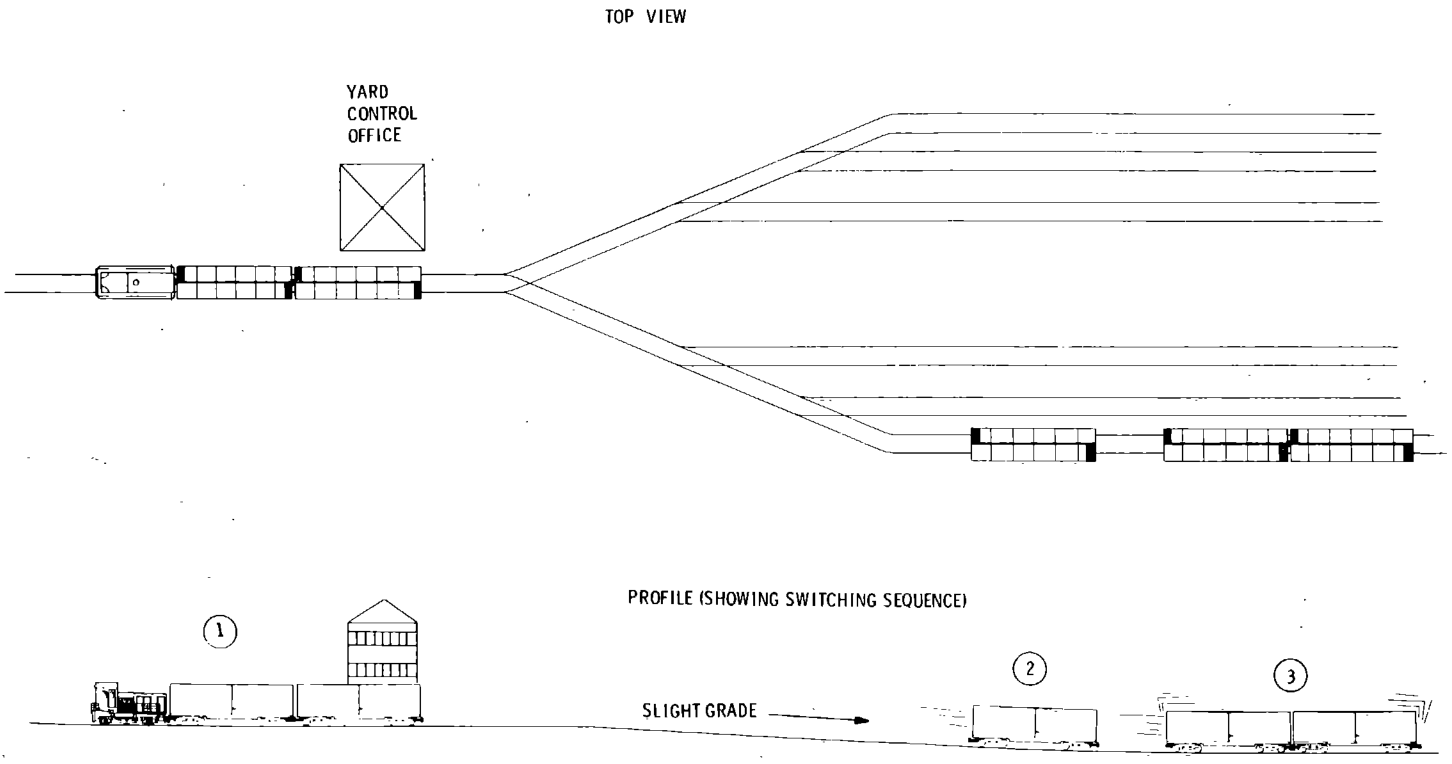
[1] WABCO Information Service, Classification Yard Installations - 1924-1972, Pittsburgh, PA: WABCO Information Service, February 1973.

[2] D.D. Huffman, "Railroading 1980 - Future Trends in Communications and Signalling," Railway System Controls (Nov./Dec. 1974) pp. 11-13. A more complete inventory for U.S. railroads is being identified by Stanford Research Institute.



1 CAR IS PUSHED BY ENGINE INTO YARD. (SOMETIMES ENGINE WILL TAKE CAR ALL THE WAY INTO THE YARD WITHOUT LETTING IT COAST, ELIMINATING STEPS 2 AND 3.)

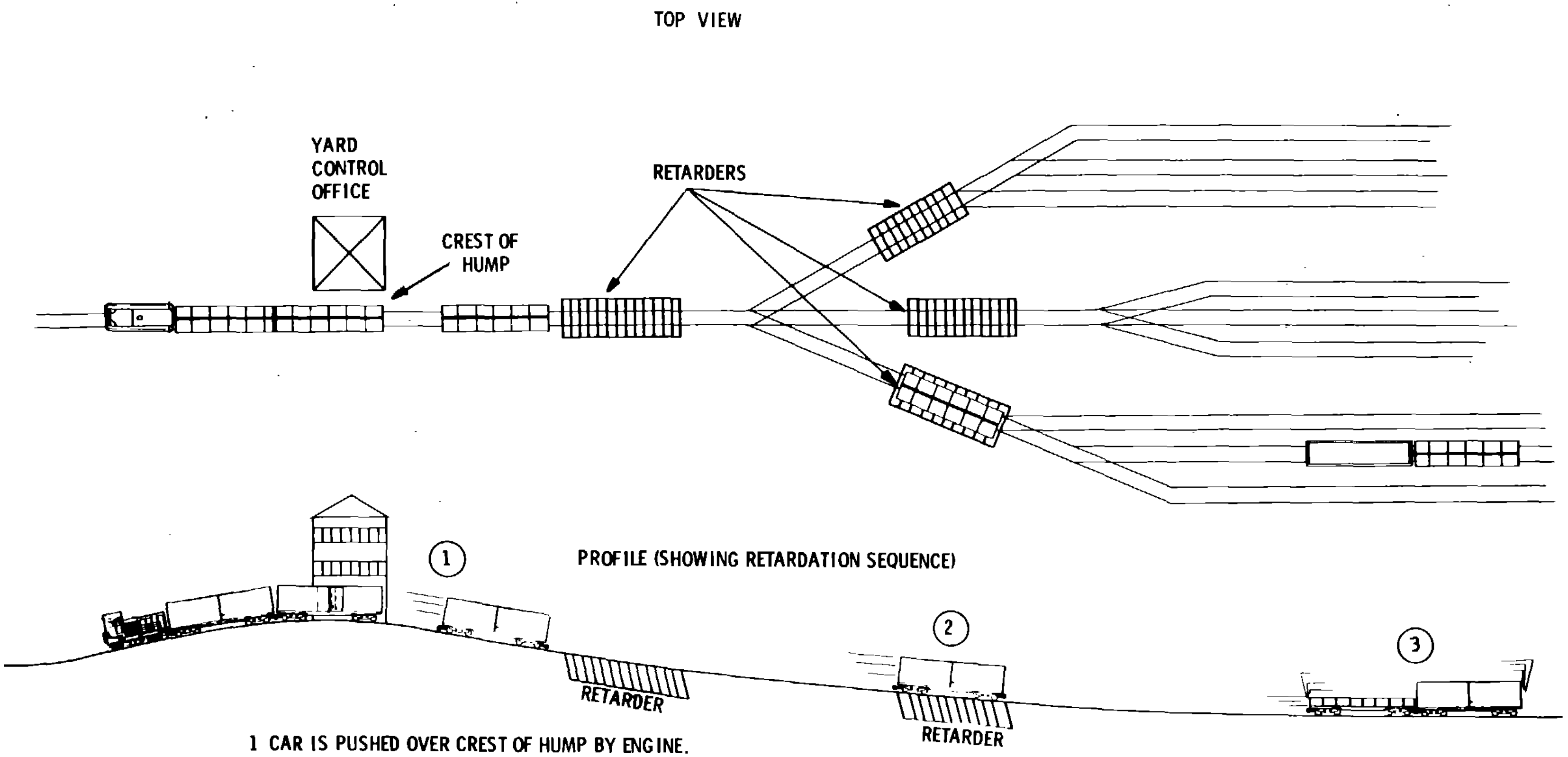
2 CAR COASTS DOWN SLIGHT GRADE AT ABOUT 4 MPH.

3 CAR COUPLES AT LESS THAN 4 MPH.

NOTE: APPROXIMATELY 1 CAR/MIN CAN BE SWITCHED IN THIS WAY.

A BRAKEMAN MAY SOMETIMES HAVE TO RIDE CAR DOWN THE GRADE CONTROLLING CAR SPEED WITH MANUAL BRAKE ON CAR.

Figure 5. Switching Scheme in a Flat Yard



1 CAR IS PUSHED OVER CREST OF HUMP BY ENGINE.

2 RETARDERS SLOW CARS TO 4 MPH.•

3 CARS COUPLE AT 4 MPH OR LESS.

NOTE: 3 TO 8 CARS/MIN CAN BE SWITCHED IN THIS WAY

- BEFORE RETARDERS CAME INTO BEING, BRAKEMEN WOULD RIDE CAR DOWN HUMP, CONTROLLING CAR SPEED WITH MANUAL BRAKE ON CAR.

Figure 6. Switching Scheme in a Hump Yard

some rehumping is always necessary on account of cars without waybills (no bills), cars needing repair (rips), or cars sent to the wrong classification tracks which must be reclassified onto the right tracks (misroutes). On the average about 10 percent of the cars in a classification yard must be reswitched for these purposes.

Classification yards are important yards in a rail network because most rail traffic at one time or another will stop at them to be redirected in the course of a journey. Sections 3 and 4 will present more information about the operations of classification yards. Other types of yards will be discussed in the following sections.

2.3 INTERCHANGE YARDS

Interchange yards are used to handle cars being transferred from one railroad to another. Usually, cars from one railroad destined for a connecting railroad will be placed on an interchange or connecting track. A locomotive from the receiving railroad will then pick the car up at that point, thus making the transfer.[3]

The interchange yard itself can be anything from a single track to a large classification yard where cars are blocked into trains at the transfer point.[4] An example of this type is the classification yard at Mechanicville, N.Y., which is a major connecting point between the Delaware and Hudson (D&H) and the Boston and Maine (B&M). At that point, eastbound traffic is transferred from the D&H to the B&M and is classified by the B&M into trains according to destination for various points in New England. Similarly, westbound traffic is handed to the D&H by the B&M.

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[3] By various agreements, some railroads both deliver and pull interchange cuts at specific locations.

[4] "Blocking" refers to arranging cars in groups according to their destinations.

2.4 STORAGE YARDS

Storage yards are yards where cars, generally empty, are stored until needed. Storage yards can also be used for storing old locomotives, cars in disrepair, unused rolling stock, and any other equipment. In some cases even loaded cars are stored. These are generally cars loaded with a commodity, such as coal or grain, that are being stored pending shipment on short notice. Similarly, loaded grain cars may have to be placed in a storage yard at a water port until a ship or grain elevator can be made ready to receive the cargo. In general, storage yards fulfill a variety of holding requirements in rail networks.

2.5 LOCAL SWITCHING YARDS

Local switching yards are small yards located in towns, industrial areas, junctions within a rail system, and large cities that are used for the handling, sorting, and storage of traffic related to local freight service for industries, interchange movements, large shippers, and general local car handling needs. Unlike classification yards, local yards are usually not used to assemble and break up main-line trains. Some branch-line local trains and local switching blocks may be made up in the local yards, but large scale classification activity there is unusual. Local yards are sometimes used in conjunction with classification yards for local car handling.

2.6 SUPPORT FUNCTION YARDS

Support yards serve such purposes as caboose storage, engine maintenance, storage for cars that need repair (bad order cars), and maintenance-of-way equipment storage and service tracks. Support yards are located at major junctions, local yards, interchange points, and classification yards, depending on the needs of the rail network they serve.

2.7 TOFC/COFC TERMINALS[5]

A TOFC/COFC terminal is a specially designed yard where truck-trailers are loaded and unloaded from flat cars. Trains of TOFC/COFC cars are often dispatched and received in these facilities, bypassing the usual classification yards most freight cars pass through. Otherwise, TOFC/COFC traffic is handled just like regular freight, depending on the TOFC/FOCC volume generated. Thus, TOFC/COFC terminals perform special functions for a specific type of rail service which is conducted differently from ordinary carload freight service.

2.8 OTHER YARDS AND TERMINALS

In addition to the yards listed above,there are also various yards and terminals oriented toward specific commodities. Examples of such facilities are special loading and unloading terminals for coal, ore, and automobiles. Although this study is concerned with classification yards, the importance of the many other kinds of rail yards and terminals mentioned above can not be ignored with respect to their roles in the operations and services railroads provide.

2.9 SUMMARY

In this section, the various types of rail yards and yard functions were described. First, the details of moving a freight shipment were outlined, followed by a brief discussion of classification yard functions, which are an important part of the freight movement process. It is important to realize that a rail yard may fulfill a number of functions. For example, a larger classification yard may not only serve the train make-up and break-up

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[5] TOFC (trailer-on-flatcar) and COFC (container-on-flatcar) are terms which describe intermodal service involving movement of highway trailers or containers without wheels on rail flatcars. Pickup and delivery of trailers and containers are performed by truck. The intermodal service makes most efficient use of the characteristics of both the rail and truck modes.

functions, but may also provide for interchange movements, local switching, and engine and car maintenance. Therefore, care must be taken when identifying a particular yard as an interchange yard, classification yard, etc., as it may well serve a number of functions.

3. OPERATING SCENARIO OF A RAIL FREIGHT CLASSIFICATION YARD

3.1 INTRODUCTION

This section presents a review of the operating functions in a classification yard by presenting an operating example of a typical yard in a simplified network. Later sections will present issues and problems related to classification yards; this introductory review provides a basis for the presentation of those issues.

3.2 CLASSIFICATION YARD OPERATING SCENARIO[1]

A simplifed example can show how a classification yard works. Figure 7 represents such a hypothetical railroad network.

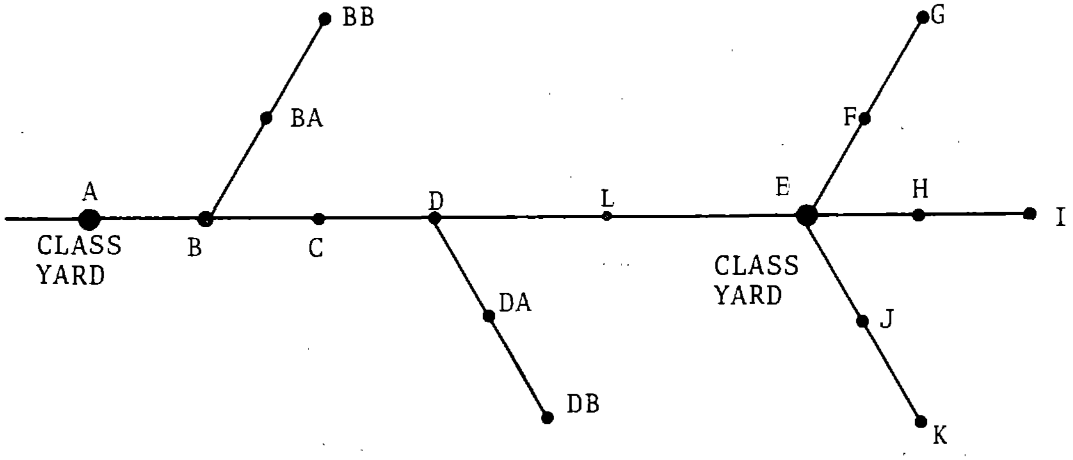

Figure 7. Schematic of Hypothetical Railroad Network

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[1] See M. Beckman et al., Studies in the Economics of Transportation (New Haven: Yale Press, 1959), Chapter 7.

Classification yards A and E are located within this network. Each network station point is identified by a letter code. Traffic from A destined for these various points will be classified into trains scheduled to service these stations on the network. The following trains dispatched from A:

TRAIN	CARRYING CARS FOR
1 (local)	DA, DB
2 (local)	BA, BB
3 (runthrough)	G
4 (local)	B, C, D, L, E
5 (runthrough)	K
6 (manifest)	E for points F, H, J, I

Trains 1, 2 and 4 are called local freights because they serve many stations and make frequent pick-ups and set-outs, generally for a small portion of a railroad or for particular branch lines. Trains 3 and 5 are called runthrough freights because they carry cars from origin to destination without making intermediate stops for reclassification purposes. Such trains may be operated "interline"; that is, over more than one railroad's lines. In such cases agreements between railroads are made for such service. Train 6 is called a manifest freight because it carries blocks of cars from one classification yard to another for further classification and does not stop for local service. However, runthrough and manifest freights sometimes will make a limited number of intermediate stops to pick up or set out a large or expedited block of cars.

Given the above train scheme, the classification segment of classifcation yard A will probably look like Figure 8. This labeling of the tracks is called a classifcation schedule. The classification schedule and the number of classification tracks are determined by the number of cars that accumulate each day at A for various destinations. An accumulation of at least 24 cars a day for any one general or specific destination may justify the assignment of a specific classification track for those cars.

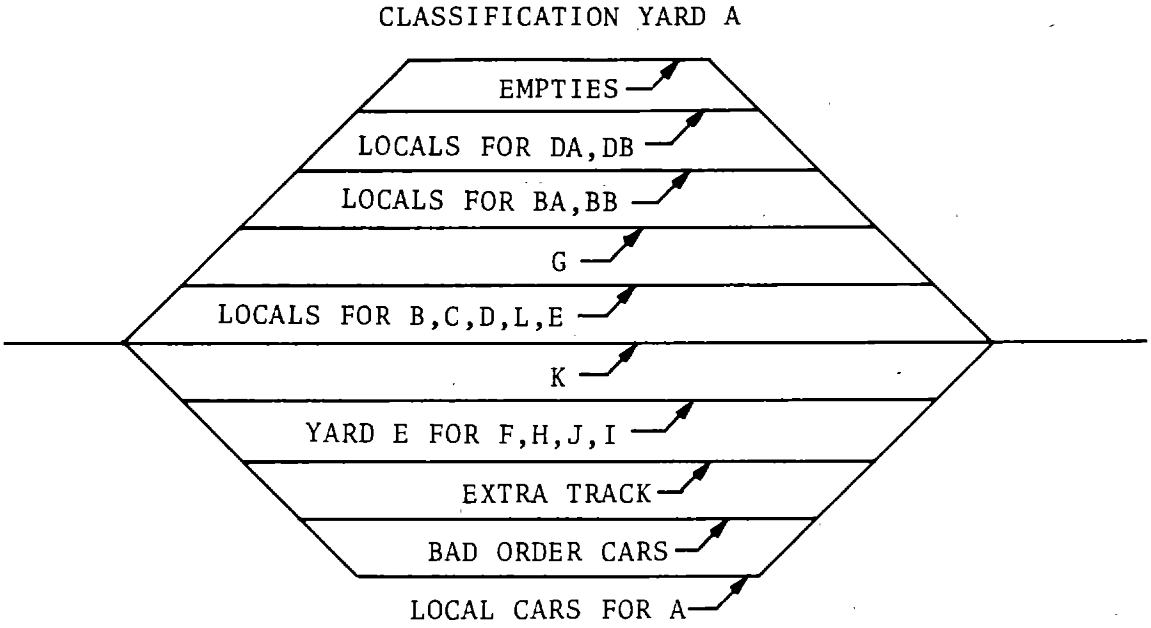

Figure 8. Schematic of Track Assignments in a Hypothetical Classification Yard

Note also that some tracks in the classification yard are reserved for extra cars, empties, bad order cars, and cars destined to local shippers at A.

When a train arrives at A, the following process will usually occur:

I. Receiving Process
   A. Train arrives in receiving yard.
   B. Engines and caboose are set out.
   C. Train is inspected.
   D. Train waits in receiving yard to be classified.

II. Classification Process
   A. Cars are taken to classification yard.
   B. Cars are classified onto their proper classification tracks.

C. If necessary, cars are preblocked and reswitched at this time to arrange them so that downline train pickup and delivery movements can be carried out in a more orderly fashion.

III: Departure Process

A. Blocks of cars from the classification yard segment are connected to each other to comprise a train.

B. Cars are taken to departure yard.

C. Caboose and engines are attached to train.

D. Inspection and air test of train is conducted.

E. Train proceeds out of yard.

Therefore, when a train arrives at A with cars destined for the many points beyond A, as listed, it will first arrive in the receiving yard where the engine and caboose will be taken off and the train inspected for bad order cars. Afterward it will be classified in the classification yard, where each car will be switched onto the track labeled for the car's general destination. The appropriate cuts of cars appearing in the preceding train list will then be periodically removed from the classification yard and assembled into trains.

Prior to train assembly, two processes may be performed: reswitching and preblocking. "Reswitching" refers to an operation where a train, say No. 2 destined for BA and BB, would have its cars blocked so that all the BA cars will be in one block and the BB cars in another block. In this way, the train crew can drop off the cars more easily. "Preblocking," on the other had, refers to an operation in which cars on a manifest train, like No. 6, are grouped so that the cars in No. 6 for F, H, J, and I can be handled as three integral blocks when they arrive in classification yard E. In this way, No. 6's cars will not all have to be switched separately when they arrive at E, greatly simplifying switching at that yard.

Reswitching and preblocking may save time and simplify operations at subsequent yards and stations, but more switching must be done in the original yard to reswitch or preblock the cars in the first place. The trade-off between preblocking and not preblocking is one of doing more switching in a preceding yard to simplify switching at a later one. In the case of large, highly automated hump classification yards, with humping rates up to eight cars per minute, preblocking done at preceding yards would not save any significant amount of time at subsequent hump yards. In addition, many automated humps are not designed for more than one or two cars at a time to be pushed over them, so that preblocked cuts would have to be broken up anyway. However, preblocking can save time at hump yards in certain cases. For example, preblocked TOFC/COFC cars at a hump can be switched by slowly moving them down the hump with an engine, or by sending them directly to a departure track. In flat yards, preblocking can save appreciable time, because the cars can be switched faster as blocks rather than as individual cars.

After a train has been made up in the departure yard, a caboose and engine are connected to it, the cars are inspected, and air brake tests are performed. The train is then ready to depart the yard and the classification process is completed.

After departing A, the various trains move over the network, each performing its assigned tasks as follows:

Train 1 – Local, departs A and sets out and picks up cars at DA and DB, then returns to A.

Train 2 – Local, departs A and sets out and picks up cars at BA and BB, then returns to A.

Train 3 – Runthrough train, departs A and runs through to G, bypassing yard E. Its counterpart may or may not operate runthrough from G to A.

Train 4 – Local, departs A and sets out and picks up cars at B, C, D, L, and E. Its counterpart performs similar operations on return from E to A.

Train 5 – Runthrough train, departs A and runs through to K, bypassing yard E. Its counterpart may or may not return as a runthrough from K to A.

Train 6 – Manifest freight, departs A with cars destined for yard E to be reclassified into trains for F, H, J, and I. Its counterpart may return as a manifest from E to A.

Trains 4 and 6 are the only ones that will be received at yard E from A. Train 4 arrives at E with cars terminating at E and with cars originating at B, C, D, and L destined to E and points beyond E. At yard E the local cars will be classified on a "locals for E" track or they will be dropped off at a local yard in the vicinity of E. In any case, a switch engine will eventually distribute them around E to their local destinations. The cars in train 4 for points beyond E will be classified and placed on trains going in the general direction of those destinations. The cars from train 6 destined to points beyond E will likewise be classified and placed on the appropriate outbound trains. Train 6 may or may not carry local cars to E from A, depending on various conditions including train length and the presence of high priority traffic.

Various railroad personnel are charged with managing these yard and network operations. The "yardmaster," as mentioned earlier, is responsible for the operations within the yard, including the receiving, classification, and makeup functions. The line-haul setouts and pickups that occur after a train has left a yard are under the control of the "trainmaster" charged with managing these activities along with other related moves. A "dispatcher" is responsible for governing line-haul train movements relative to train meets, passes, train orders, recording train movements, and any other duties related to safe, orderly train movement. These duties may be combined on small railroads; on larger railroads they may be augmented with assistant personnel for yardmasters, trainmasters, and dispatchers, each performing an array of specific duties.

3.3 SUMMARY

The classification yard example was presented to describe in a simplified manner the elementary functions of inbound train receiving, car classification, and outbound train makeup which are the primary functions of classification yards. The trains dispatched from the sample yard briefly characterized some of the train movements that occur over a network and on which classification yard activities must focus. Such a simplified network cannot represent rail operations such as interchange movements, TOFC/COFC operations, unit trains, empty car handling, and terminal railroads. The yard-network interface was presented through this example.

4. COMMON YARD OPERATING POLICIES

4.1 INTRODUCTION

In this section the receiving, classification, and departure policies that govern the execution of yard operating functions are presented. It will be seen that these not only govern the conduct of activity in the yard, but also affect network operations. The basic yard operating policies, usually termed the receiving, classification, makeup, and scheduling policies, are presented in detail below.

4.2 RECEIVING POLICY[1]

The receiving policy governs the conduct of activity in the receiving yard. This policy is comprised of decision rules that determine the order of classification of trains in the receiving yard. In small yards, where only a few trains a day are classified, there is no need for an explicit receiving policy. But in larger yards, where several trains may be in the receiving yard waiting to be classified, the yardmaster must have some criteria to help him decide what train should be classified next.

One policy is the "first-in, first-out" approach, where trains to be classified are chosen according to their arrival order into the yard. Another policy is the classification of trains based on the priority of the traffic they carry. Trains carrying perishables or shipments that must be expedited are given priority over other trains. There can also be a policy in which the trains chosen to be classified are chosen as to minimize the percentage of cars that miss their outbound connections. In other words, a train or train segment may be chosen for classification ahead of other trains because it contains many cars that would otherwise miss their outbound connections. In actuality, a combination of the above policies may be exercised, depending on traffic, management priorities, yardmaster objectives, etc.

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[1] Beckmann et al., op. cit.

4.3 CLASSIFICATION POLICY[2]

The classification policy in a yard determines the destination labeling given to each track. (See the example of the classification yard given in Section 3.) The classification scheme generally used depends on the number of cars originating each day for a given destination. One rule of thumb suggests that at least 24 cars a day originating for 1 destination would justify a classification track for that destination.

Classification policy is generally stable, but alterations are often made based on changing traffic patterns, changes in train assignments, traffic peaking periods, and varying traffic volumes. As a result, the yard must be amenable to such changes. For this reason, provision is usually made, especially in new yards, for expansion should it become necessary. In addition, there are usually extra tracks or "swing" tracks provided to allow flexibility for short term traffic changes.

4.4 MAKEUP POLICY[3]

The makeup policy is used to decide which cars will be placed on which outbound trains. In the example in Section 3, each classification track was filled with cars for one train. In actuality, a train may be comprised of a number of blocks from various classification tracks.

The decision to incorporate selected blocks of cars into particular trains is usually based upon the traffic requirements of the railroad and rests with the yardmaster. Yardmasters, within operating guidelines, can assign priorities to selected blocks and place them on the earliest appropriate outbound train. Also, if an outbound train is ready to leave but is of insufficient size, the yardmaster can take a prepared block and place it on that earlier train instead of holding that block for its later scheduled departure. Yardmasters must also decide where they will

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[2] Ibid.

[3] Ibid.

distribute surplus empty cars, and on what trains they will place them. The Association of American Railroads (AAR) car service rules provide guidelines for such decisions.[4] Yardmasters are also responsible for assembling extra trains during periods of heavy traffic in which published schedules could not be maintained. Therefore, it can be seen that train makeup policy is subject to many variables occurring at the yard level which can overstep the published or routine outbound makeup policies of the railroad company depending on day-to-day circumstances that the yardmaster must deal with.

4.5 SCHEDULING POLICY[5]

Scheduling or dispatching policy determines what time a train will depart. This is usually determined by timetable schedule subject to factors such as train length buildup, motive power availability,[6] train priority, crew availability, and lateness of inbound connection, plus any other associated conditions.

Many railroads have a minimum gross tonnage (for example, 2000 gross tons) below which they will hold or annul a train, feeling it is too short to justify operating it on economic grounds. Other railroads use minimum length criteria (such as 50 cars) for train origination. (These policies apply primarily to line-haul or road trains. Local trains involved in branch line pickup and delivery operations generally do not have minimum train size restrictions.)

In any case, when trains are canceled their cars are held and put on either a later train or their scheduled train for the following day. The canceling or "holding" of trains can produce traffic buildups in the yard. If outbound train departure frequency is low, large buildups are likely to occur, possibly resulting in oversized trains, extra trains, or portions of trains

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[4] Association of American Railroads, "Code of Car Survice Rules — Freight" <u>Car Service and Car Hire Agreement</u>, Washington, D.C.: <u>Association of American Railroads, issued</u> periodically). Circular No. OT-10-C.

[5] Beckmann et al., op cit.

[6] Motive power is the locomotive or group of locomotives needed to move the rail cars.

being left behind for lack of sufficient motive power. This can also cause congestion, filling, or "plugging of a yard," which hinders the yard's ability to function. In cases where outbound departure frequency is high, this buildup problem never becomes unwieldly because there are enough trains leaving the yard frequently enough to prevent buildups. However, if outbound frequency gets too high, there may be a problem with having enough available yard time to allow for the required switching between trains.

This timetable-tonnage departure policy can be presented graphically (see Figure 9). This policy, simply stated, tells how long a train will be held to wait for more cars, provided that by a certain time each day its length has reached a designated minimum number of cars.

The line XX' shows the actual car buildup as a function of time for a train. When XX' intersects ZZ' the train will be dispatched out of the yard. If line ZZ' is vertical, the policy

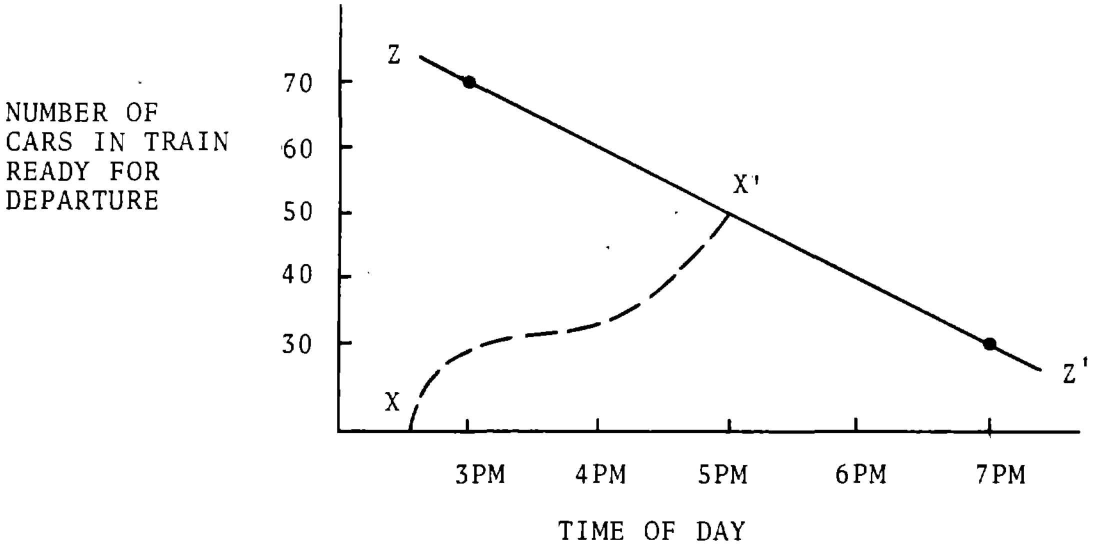

Figure 9. Graph of Departure Schedule Policy

is one of dispatching trains at a designated time regardless of length. A horizontal line ZZ' implies a policy of dispatching trains only when a certain length is reached, regardless of the time.

4.6 SUMMARY

This section presented a review of the receiving, classification, makeup, and scheduling policies used by yardmasters to manage the operations of classification yards. These policies are important in that they affect the operation of the yard iteself as well as the performance of the network of which it is a part. The receiving policy helps determine what trains will be classified first; the classification policy determines what classification tracks cars will be assigned to; the makeup policy determines which trains the cars will be placed on; and the scheduling policy determines the time a train will depart, oftentimes based on its tonnage or length by a certain time.

5. INTRAYARD OPERATING PROBLEMS

5.1 INTRODUCTION

This section reviews a number of problems occurring within the yard itself that can affect the efficient internal operation of the yard. Significant problems commonly occurring in yards include:

1. Unavailability of switch engine
2. Bad order cars
3. Reswitching
4. Equipment failures
5. Personnel problems
6. Effects of bad weather
7. Hazardous materials handling
8. Expediting priority shipments around other shipments
9. Paperwork problems
10. Derailments

It will be shown in Section 6.3 that these problems account in total for 3 to 13 percent of cars missing their connections. Even though this overall effect on yard performance would appear to be small, its importance to efficient yard operations should not be underrated. The awareness of these difficulties provides insight and appreciation of the complex workings of a yard.

5.2 UNAVAILABILITY OF SWITCH ENGINE

This problem occurs when a number of cars are available to be classified but the needed switch engine is working on another assignment. In large classification yards there is usually enough activity in the classification process to assign a full-time switch engine there. In smaller yards, switch engines may be assigned to industrial switching work when no cars are being classified. Also, the railroad may not find it economical to have an engine work the yard lead track all the time when traffic volumes fluctuate. In either case, cars in the receiving yard ready to be classified must wait until more traffic begins to arrive in the receiving yard before the yard engine is put to work. This may delay cars if they miss their outbound connections.

5.3 BAD ORDER CARS

Bad order cars have mechanical defects. These are usually discovered during the receiving or departure inspections. (Bad order reswitching is discussed in 5.4.) When the latter occurs, the outbound train is delayed until the bad order car can be "set out." K. J. Belovarac's work in the MIT/FRA study showed that for a sample of 442 train departures, bad order cars were responsible for 5.8 percent of the departure time variance.[1] While such delays appear to have a small effect on overall yard operating performance, bad ordering a car can lengthen the trip time of the shipment because the car must be held until it is repaired, reclassified, and sent out.

5.4 RESWITCHING

Reswitching occurs because some cars have to be classified at least twice. Cars that were routed to the wrong class track and must be pulled out and reswitched to the right track are one example of this. Another is bad order cars that have to be taken out of the class track bowl, repaired, and switched back into the bowl. Preblocking moves that use the classification leads and tracks can also be considered reswitches. Another case of reswitching occurs when there are more classifications than classification tracks, so that blocks of cars have to be classified more than once to refine blocking. Approximately 10 percent of the cars entering a classification yard will be reswitched.

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[1] K. J. Belovarac, "Determinants of Unreliability in Railroad Line-Haul Operations,"(unpublished Master's Thesis, Massachusetts Institute of Technology, May 1972), p. 65.

Reswitching is a problem to yard operations if it ties up traffic at the yard lead and ties up a yard engine that could be doing more productive work. Otherwise, its effect on yard performance is not great, particularly in light traffic yards or yards that do not experience peaks in traffic.

Bad order and misroute reswitching can be reduced in the following ways: First, computer and technological improvements can help reduce misroutes by processing switching information faster and more accurately. Second, bad order car reswitching can be reduced if bad order cars are found before being classified. However, because of human errors and the necessity for multiple classification, it is doubtful that all reswitching can be eliminated.

5.5 EQUIPMENT FAILURES

Common equipment failures are the breakdown of hump yard equipment such as retarders, switch machines, air compressors, and communication systems. Such failures can delay yard operations causing a tieup in traffic movement.

Retarder failure is one of the more common forms of this problem. Retarders are mechanical devices built into hump yard tracks. They control the speed of moving cars as they roll down the hump toward their proper track by retarding car speed through the application of friction against the wheels of the car (see Figures 10 and 11). If a retarder fails to slow a car, the car can collide with another car at too high a speed and cause extensive damage. An acceptable safe coupling speed is 4 mph. Furthermore, when retarders fail or need maintenance, involved tracks cannot be used until the retarder is fixed, causing minor congestion or delay. One railroad addresses this problem by closing the hump one day every week for three hours to perform preventative maintenance on the retarders. Other railroads have similar maintenance programs to suit the pattern of operation of each given yard.

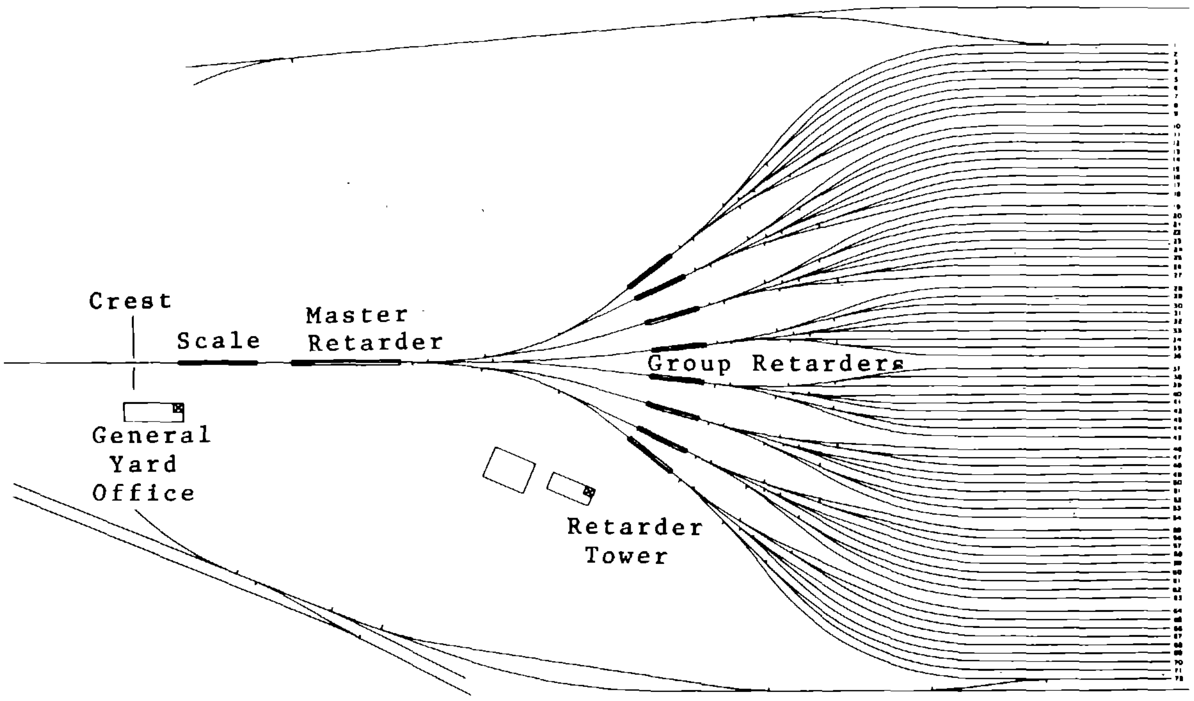

Figure 10. Typical Location of Retarders in a Hump Classification Yard

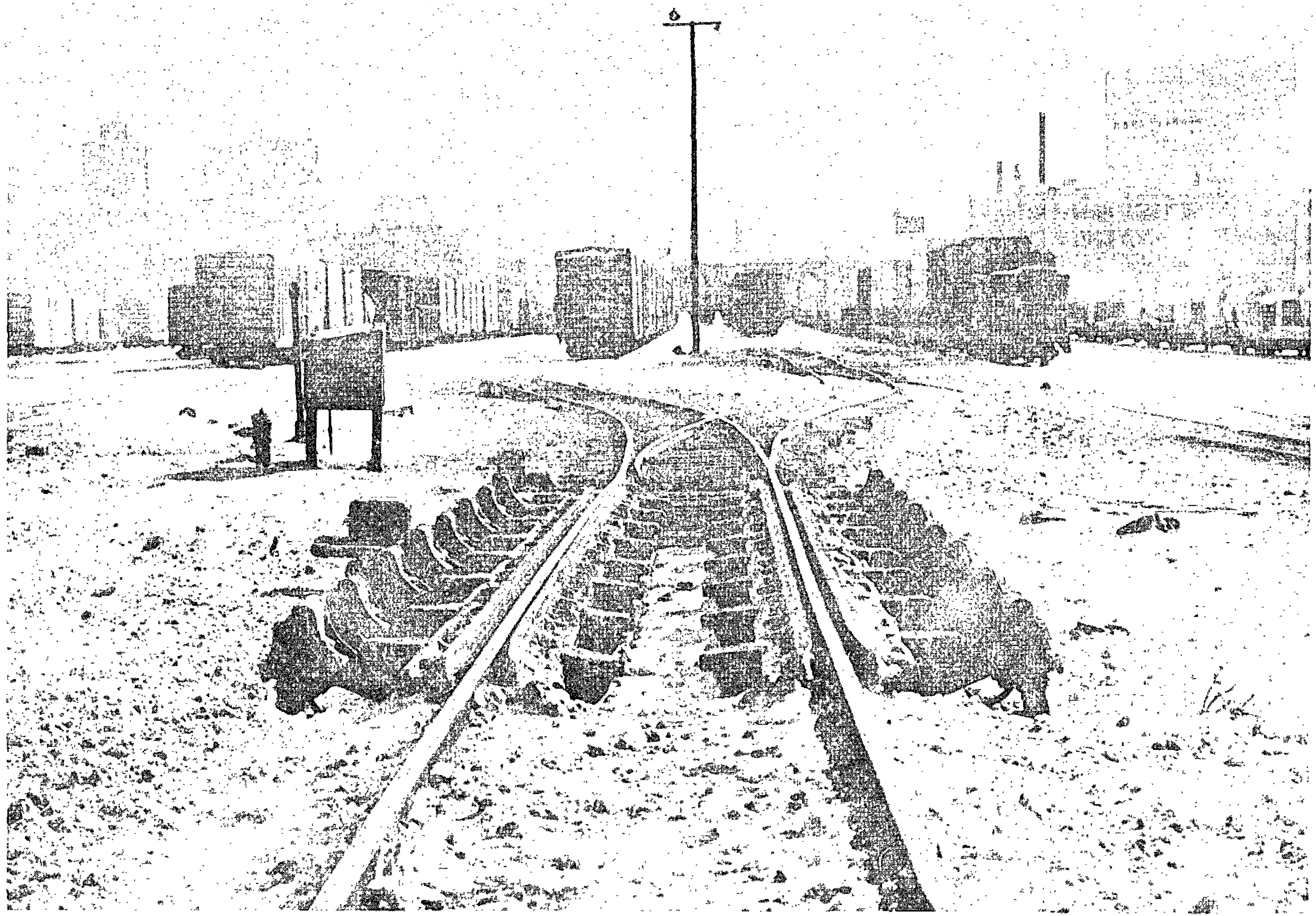

Figure 11. Example of a Common Track Retarder Used for Controlling Speed of Cars Released onto Classification Tracks

5.6 PERSONNEL PROBLEMS

The personnel situation in many yards, especially large ones near urban areas, gives rise to various employee failures, according to one railroad official. Employees with the most seniority and experience are most likely to win bids for a five-day, Monday-Friday work week and the most attractive first shift (8 a.m. to 5 p.m.). The peak traffic hours in the second and third shifts are left to the less-qualified, less-experienced workers. Furthermore, a 40 percent turnover in yard personnel within a year due to job changes, terminations, retirements, and transfers is often typical.

In smaller towns and rural areas the situation is different. Railroad pay in rural areas is high in comparison to other jobs. As a result, rural rail employees regard work as more than just a "job," unlike many urban rail employees. Moreover, the high costs of urban living can force urban rail employees to work a second job, making their rail job less important. The result is that employee performance in rural yards is likely to be higher than in urban yards.

No clear-cut solutions can be found to alleviate the problems of human nature that cause such situations in yards. In addition, various union work rules can sometimes affect yard efficiency.

5.7 EFFECTS OF BAD WEATHER

Floods, fog, snowstorms, tornadoes, and ice storms are weather phenomena that can disrupt and cripple rail yard operations. One seasonal weather problem in northern latitudes is snow. Snow in yards cannot merely be plowed aside, since yard tracks are so close together that plowing snow off one track usually means pushing it onto another. If cars are in the yard at the time, snow removal becomes even more complex, as the cars have to be pulled out and temporarily stored elsewhere before the snow can be removed.

Even though seasonal, the severity of this problem was demonstrated by a snowstorm in December 1969 which closed Penn Central's Selkirk, N.Y. Yard for several days, requiring personnel from as far away as Philadelphia to help remove the snow. Overall snow removal costs were about $8.5 million in January and February of 1970 on the Penn Central system; the Penn Central estimated the overall financial impact of the severe weather to be at least $20 million.[2]

Another cold weather problem is that cars have a higher rolling resistance to movement in low temperatures. The lubrication in the journal bearings of the cars has a high viscosity in cold weather, which adds to a car's starting resistance. A car may have to be moved back and forth a few times to "warm up" the journal bearings so the car will roll better. Cars have actually stopped on the hump due to the cold. Low temperatures can slow down yard operations and cause departure delays. Couplers, brake hose fittings and other mechanical parts can freeze; yard personnel must take the time to free the frozen components delaying proper classification of cars. Trains delayed by weather problems can increase yard congestion, which further slows yard operations.

Bad weather can affect yard operations in other ways. For example, fog, heavy snowfall, or heavy rain can hinder visibility, making it difficult for operators to identify cars, check car speed, notice misroutes, check switches, and communicate with other employees outdoors. Snow and ice can also jam switch points, necessitating cleaning delays, if not also producing misroutes or even derailments. Cold weather and heavy snowfall in particular make it difficult for employees to walk in the yard, creating unsafe situations, and otherwise affecting yard efficiency and reliability. Some of these problems can be alleviated with advanced technology, but in general, weather will remain a problem in classification yards.

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[2] J. R. Daughen and P. Binsen, The Wreck of the Penn Central, (Boston: Little Brown and Company, 1971), pp. 252-255.

5.8 HAZARDOUS MATERIALS HANDLING

Hazardous materials being carried in tank cars (propane or chlorine, for example) or in specially-equipped box cars (explosives for example) require special handling in a classification yard. Generally, such cars are not (nor should be) classified over the hump with other cars. Some yards even hold hazardous materials cars in special sections away from the main classification activity. Moving cars to and from these sections and placing them into their proper location in a train requires extra effort by switch crews. Given limited engine and crew resources, this reduces the railroad's overall efficiency in operating the yard. This is not to imply that such special handling should be eliminated or reduced in the interest of efficiency. The East St. Louis and Houston yard explosions in the last several years show what can happen with hazardous materials. The delays caused by such accidents are often on the order of one or more weeks.

5.9 EXPEDITING PRIORITY SHIPMENTS AROUND OTHER SHIPMENTS

Expediting priority shipments through a yard can temporarily disrupt regular yard operations.[3] At times this may be necessary if perishable traffic or other types of priority cargo are involved. Even though this problem does not appear to be a major cause of missed connections and disordered operations, it undoubtedly can result in the delay of other shipments. A method of expediting priority shipments without disrupting other movements by switching them around the classification yard would be appropriate in situations where such movements do cause congestion and delay to other yard operations.

5.10 PAPERWORK PROBLEMS

Considerable paperwork is involved at classification yards. The most important paper is the waybill, which contains information regarding the identification of a car, its contents, consignor,

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[3] Beckmann et al. op. cit., pp. 131-132.

consignee, origin, destination and routing. Each car must have a waybill. In classification yards, all the waybills for incoming cars must be resorted to match the same cars on outbound trains. Should the waybill become separated from its car, the car would be delayed indefinitely, misrouted, or even lost.

The occurrence of waybill separation is low, reportedly around one percent. Computers have helped decrease the occurrence of lost waybills considerably. One railroad official reported that computers have helped reduce waybill separation on his railroad from 10 percent to less than 1 percent. Another railroad estimates that the equivalent of 1 car in each of 500 passing through a terminal each day is misrouted.[4] Although the overall effect of waybill separation appears small, it is still a serious problem, since it can cause great expense in money and time searching for lost cars and waybills, and in the added switching and handling costs required to get the lost car back to its proper terminal. Administrative expenses associated with separated waybills usually exceed $5.00 per car. Lost or misrouted cars may cost a railroad in excess of $25.00 per car in penalties alone. This is without considering increased handling costs or the potential lost revenue from decreased car utilization.[5] Shipper dissatisfaction from late deliveries and lost shipments can result in future routing via a competing railroad, or worse yet, a modal shift to truck.

Computers and associated car identification devices are of some help in solving these waybill problems, but many systems are designed for network level control and car tracing rather than intraterminal management, and yard level systems are not in widespread use. Furthermore, waybills must be physically handled regardless of computers. Automated data exchange techniques are being evaluated and advocated, but currently are not widely employed.

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[4] See Association of American Railroads, Data Systems Division, Annual Papers and Committee Reports, 1973, pp. 181-182.

[5] Ibid. pp. 180-181.

5.11 DERAILMENTS

Derailments in yards are disruptive to yard operations and represent safety hazards to yard personnel. Because cars in a yard are only moved at slow speeds, yard derailments are rarely serious; but, nevertheless, much time can be required for them to be cleared. The process of clearing a yard derailment usually begins with switching any other cars on the same track where a car has derailed to other tracks. A crew then moves in to rerail the derailed car and repair the track. The clearing and repairing process can take a long time because of close track centers in yards and because adjacent tracks may be occupied. Modern yard design, however, calls for wider track spacing of alternate tracks to allow more room for yard inspection and maintenance.

The lack of sufficient ballast, tie, and rail maintenance is a major cause of yard derailments. Another factor is the accumulation of debris and car droppings that bury the tracks over a period of time, making the detection of track defects difficult. Yard derailments can also be attributed to car equipment failures, such as brake failures and dragging equipment, as well as rough car handling. Modern maintenance machinery, along with better enforcement of rules regarding car handling, can help reduce yard derailments.

5.12 SUMMARY

This section covered a wide range of problems affecting the internal operating efficiency of classification yards. Among these were switch engine unavailability, bad order cars, reswitching moves, equipment failures, personnel problems, bad weather, hazardous materials, expedited moves, paperwork problems, and derailments. This wide array of problems makes one appreciate the complexity associated with classification yards. These problems can affect network performance as well as intrayard performance.

6. NETWORK PROBLEMS RESULTING FROM RAIL YARD OPERATIONS

6.1 INTRODUCTION

This section considers some of the network problems that can be associated with rail yard operations. A key measurement of network performance is reliability.[1] Reliable railroad operations can benefit both shippers and railroads. It can benefit railroads through improved equipment utilization and by attracting more higher-valued, higher-rated traffic. Reliable rail service also benefits shippers in that they can schedule production and manage inventories more accurately.[2] Recent research efforts point to the importance of yards as a major factor affecting trip time performance. Therefore, it is especially important to consider yards in terms of their effects on network operations.[3] The MIT/FRA study done over the last four years presents interesting measures of rail service performance in this regard. The discussion in this section draws upon that study.

6.2 OVERALL INFLUENCE OF YARD OPERATING EFFICIENCY ON NETWORK PERFORMANCE

Yards can have a major influence on the overall level of service of a railroad network. A thorough study of yard effects on network rail freight service was done in the MIT/FRA study by C.D. Martland.[4] He carried out one of the more comprehensive

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[1] Task Force on Railroad Productivity, Improving Railroad Productivity Final Report to the National Commission on Productivity and the Council of Economic Advisors (Washington, D.C.: Council of Economic Advisors, November 1973).

[2] B. C. Kullman, "Choice of Mode Between Rail and Truck in the Intercity Freight Market," (Unpublished PH.D. dissertation, Massachusetts Institute of Technology, 1972).

[3] Massachusetts Institute of Technology, Studies in Railroad Operations amd Economics, Volumes 1-17, prepared for U.S. Department of Transportation, Federal Railroad Administration (Cambridge MA : Massachusetts Institute of Technology, 1970-1974).

[4] Carl D. Martland, Rail Trip Time Reliability - Evaluation of Performance Measures and Analysis of Trip Time Data, Vol. 2, Studies in Railroad Operations and Economics, (Cambridge MA: Massachusetts Institute of Technology, Department of Civil Engineering, Report No. R74-30, June 1972), p. 73.

measurements of the effect of rail yards on origin-destination service reliability by computing (for a sample of trips of over 134 origin destination (O-D) pairs) the statistical transit time variance of the origin yard, destination yard, and line-haul movement. Some of Martland's results are shown in Table 1.

TABLE 1. PERCENTAGE COMPONENTS OF ORIGIN-DESTINATION TRIP TIME VARIANCE FOR 134 O-D PAIRS[5]

Number of O-D Pairs	Segment Variance as a Percentage of O-D Variance		
	Origin Yard	Line-Haul Movement*	Destination Yard
134	34%	33%	35%

*Includes intermediate classification yard handling.
NOTE: These figures do not total 100 percent.

Notice that the origin and destination yards accounted for 69 percent of the average O-D trip time variance. Martland also developed time distribution histograms showing that interchange and intermediate classification yards increase the variance of the trip time as the number of interchanges and intermediate yardings increase. This variance would be included in the 33 percent line-haul variance remaining shown above. In other words, yards in total accounted for well over 69 percent of the O-D trip time variance in the sample.

Martland's work therefore demonstrated that rail classification yards, whether origin, intermediate, interchange, or destination, have a major effect on the level of rail freight service as expressed in terms of O-D trip time variability. Discussions of some of the yard problems that cause this high variance appear below.

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[5] Ibid. p. 73.

6.3 TRAIN CANCELLATIONS AND LATE DEPARTURES

Two yard-related network problems are cancellation and late departure of trains from yards. These can lead to unreliable service and long transit times.[6] Such events can also result in poor equipment utilization and missed connections.[7] R. M. Reid and J. D. O'Doherty's work in the MIT/FRA study presented data from three different yards showing how late arrivals and train cancellations cause freight cars to miss connections (see Table 2).[8] A car missing its connection in a yard must wait to be placed on another train, thus adding to its trip time and increasing the likelihood that it will not arrive at its destination on time.

TABLE 2. PERCENTAGE COMPONENTS OF MISSED CONNECTIONS IN THREE SAMPLE YARDS

Sample Yard	Percent of cars that missed connections	Cause of missed connections		
		% late inbound	% outbound cancellation	% other
Yard A (Hump)				
Loads	31	29	58	13
Empties	68	16	74	10
Yard B (Flat)				
Loads	25	20	76	4
Empties	36	19	73	8
Yard C (Flat)				
Loads	28	25	72	3
Empties	34	23	74	3

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[6] R. M Reid et al., The Impact of Classification Yard Performance on Rail Trip Time Reliability (Cambridge MA: Massachusetts Institute of Technology, Department of Civil Engineering, Report No. R72-39, June 1972) p. 5.

[7] Ibid., Chapter 2.

[8] Ibid., p. 38

These results show that train cancellations were the major cause of cars missing connections (58% to 76%), followed by late arrivals of trains into yards (16% to 29%) and other factors such as lost waybills, bad order cars, etc. (3% to 13%). In interpreting such results one must keep in mind that missed connections affect reliability only if they cause cars extensive delays. Delays due to missed connections are greater when outbound departure frequency is low. The results of Santa Fe's Regular High Frequency Train Service (RHF), which will be discussed later, attest to this.

Some of C. D. Martland's other results from the MIT study produced more sample data relative to the percentage of cars missing connections in hump yards, interchange yards, and flat yards (see Table 3). This table shows that missed connections varied from 8 to 21 percent in hump yards, 6 to 14 percent in interchange yards, and 6 to 30 percent in flat yards. Note that these estimates varied throughout the year and over varying car volume in each particular yard. The data sets in this and in the preceding table show that missed connections range from extremes of 8 to 31 percent in a variety of yards, with a midrange of 10 to 20 percent.

The MIT study also produced analysis concerning the relationship between missed connections and the policy of holding trains for reasons such as waiting for traffic to build up or lack of motive power. J. F. Folk developed a network simulation model in which he tested various "hold" and "no hold" policies. "Hold" means a policy in which trains are held late to wait for more cars, while "no hold" is the policy of not holding trains regardless of train size (assuming no problem with motive power, late crew, etc.). For a range of hold and no hold policies based on the length of time one should wait to reach a given train length (see Figure 1), Folk used his model to generate a plot of percentage of missed connections vs. various holding policies (see Figure 12).[9]

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[9] J. F. Folk, Models for Investigating Rail Trip Time Reliability Vol. 5, Studies in Railroad Operations and Economics (Cambridge MA: Massachusetts Institute of Technology, Report No. R72-40, June 1972), Chapter 3.

TABLE 3. SAMPLE YARD PERFORMANCE DATA USED IN MIT STUDY[10]

YARD	11/29/72-12/11/72	2/21/73-3/1/73	5/30/73-6/9/73	10/30/73-11/11/73
A CARS/DAY	2700	2400	2400	2300
HUMP MEAN TIME	21.8	21.9	18.0	19.6
MISSED CONNECTIONS*	21%	21%	11%	13%
C	2200	2000	2200	1800
HUMP	18.6	24.9	23.9	20.7
	14%	31%	28%	16%
D	1700	1600	1600	1600
HUMP	18.3	20.5	18.2	16.4
	11%	16%	10%	8%
E	1800	1600	1800	1900
HUMP	18.5	21.9	23.6	21.2
	12%	19%	25%	16%
F	700	700	800	700
INTERCHANGE	13.4	12.4	13.5	14.0
	3%	3%	5%	4%
H	400	400	500	400
INTERCHANGE	15.4	18.2	18.2	16.5
	6%	14%	12%	8%
G	400	300	NOT AVAILABLE	300
FLAT	15.8	14.7		15.6
	8%	6%		9%
K	NOT AVAILABLE	110	NOT AVAILABLE	140
FLAT		22.8		19.6
		30%		19%

*Missed connections are defined as all cars with yard times greater than 31 hours.

Source: Daily Yard Performance Report Data

(Yard Times Less Than 3 Hours Excluded)

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[10] Carl D. Martland, *Improving Railroad Reliability: A Case Study of the Southern Railway*, *Vol. 10*, *Studies in Railroad Operations and Economics* (Cambridge: Massachusetts Institute of Technology, Report No. F72-40, June 1972), Chapter 3

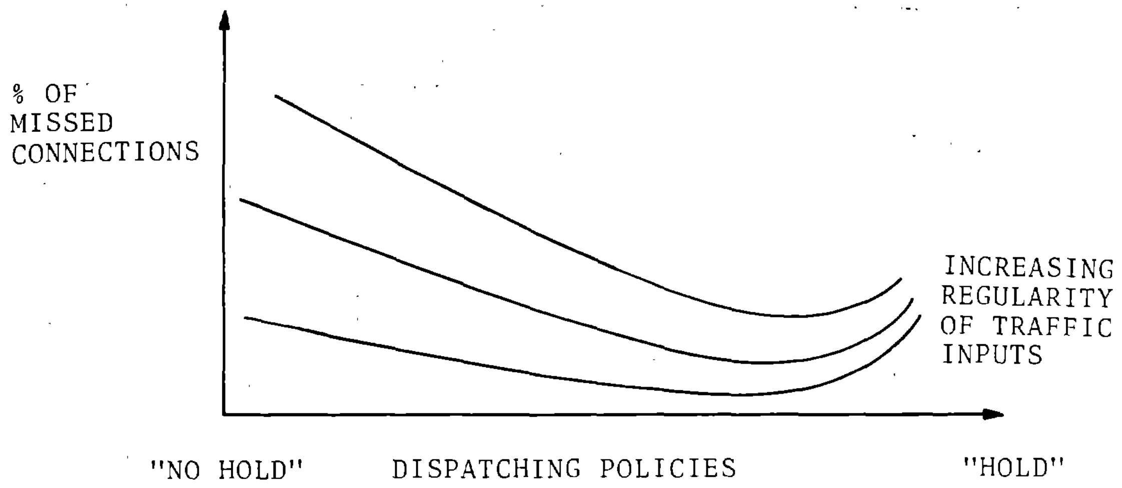

Figure 12. Systematic Effects of "Hold" and "No Hold" Policies on Missed Connections

This result shows that an absolute "no hold" policy does not minimize the percent of cars missing connections. This is because the late arrival of inbound cars necessitates the holding of outbound trains so that there is enough time to put the late inbound cars onto the outbound trains. Otherwise, outbound trains would depart with many of their scheduled cars left behind. Therefore, holding outbound trains for late inbound cars is sometimes necessary to avoid missed connections.

6.4 SUMMARY

This section presented a brief review of the effects of classification yard operations on network performance. Drawing upon the results of the MIT/FRA study, various measures were surveyed. Martland's work showed that yards could account for well over 69 percent of origin-destination trip time variance, depending on the number of yards a shipment was processed through. Reid and O'Doherty's analysis presented insight into causes of missed connections, revealing that train cancellations and late inbound arrivals caused the greater percentage of missed connections by a wide margin over internal yard problems. The MIT study also presented information showing that the number of missed connections in yards varies widely from 8 to 31 percent, with a midrange of 10 to 20 percent. Finally, one of J. F. Folk's results showed that holding trains in yards is sometimes necessary so late inbound cars would not miss their connections. The MIT study covered a wide range of other car movement reliability topics, most of which are not covered in this report.

7. PROPOSED SOLUTIONS FOR REDUCING YARD BOTTLENECKS IN NETWORK OPERATIONS AND FOR IMPROVING INTRAYARD OPERATING EFFICIENCY

7.1 INTRODUCTION

In this section a number of operating schemes and ideas are discussed which appear to have potential for reducing the bottleneck effect yards can have on networks as well as for improving reliability, decreasing transit time, increasing equipment utilization, and lowering various costs. These items are:

1. Improved Yard Design
2. Terminal Management Information Systems
3. Regular High Frequency Train Service
4. Preblocking
5. Runthrough Freights
6. Schedule Adherence
7. Geometric Switching
8. Staged Switching
9. Sweeper Train Service

7.2 IMPROVED YARD DESIGN

Some operating problems in yards can be relieved through improved yard design.[1] Many such design changes are related to increasing the capacity of yards. Argentine Yard, Kansas City, Kansas, on the Santa Fe Railroad is an example of the capacity of a yard being virtually doubled over that of an old yard.[2] Likewise, the Norfolk and Western expanded and rebuilt Luther Yard in St. Louis, enabling them to close Madison Yard and reduce operations in Brooklyn Yard, both also in the St. Louis area.

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[1] Martland, Procedures for Improving Railroad Reliability, op. cit., p. 52

[2] Santa Fe Railroad, Santa Fe Railway Argentine Yard (Santa Fe: Santa Fe Railroad, 1968).

Many yards are quite old; they were designed and built for traffic demands and flow patterns consistent with the era in which they were constructed. Changing markets, mergers, operating changes, new services, and economic growth or decline have resulted in periodic physical changes being made to yards. Typical yard improvements have included adding more classification tracks, building a hump, establishing better repair and servicing facilities, increasing track spacing to facilitate maintenance and inspection activity, and automating switches and retarders.

Railroad companies generally have the necessary talent to design yard improvements. Once the need for an improved design or layout change has been determined, the appropriate change is made, provided that sufficient capital and land are available. The Barstow, California, yard of the Santa Fe is a case in point. Here the railroad knew for a long time that such a yard was desired, but it could not really act on the matter until 1973 when the capital for a new yard became available.

Essentially, the new yard designs are not much different from the old. Receiving, classification, and departure yards are still necessary. No "new" rail yard design radically deviates from conventional designs; layout, shape, and size are variable, but the functions remain the same. Two exceptions to this are geometric and staged switching, which will be described later.

Foreign railways exhibit more diverse yard designs and operating schemes, as well as different kinds of hardware, than do American railroads. Two interesting variations in the retarder design concept are used in European railroads.[3] The German Federal Railroad (DB) employs an electrodynamic retarder which operates using magnetic forces in the opposite direction of the motion of the car. It has fewer moving parts than conventional U.S. retarders (see Section 5) and can be installed on a curved

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[3] K. Koehn et al., "European Retarder Systems," Railway <u>Management Review</u>, 72, No. 2 (1972), A7-A15.

track if necessary. British Rail employs an oil-pressure-operated cylinder type of retarder in which a series of cylinder units makes up a system equivalent to a U.S. retarder. This modularity improves maintenance and reduces complexity in retarder design. These retarders are examples of other technology available to American railroads for experimentation and application. The relatively small number of new yards being constructed, coupled with the cost and risk of experimentation, results in a conservative approach by the railroads toward changes from traditional hardware and design concepts.

7.3 TERMINAL MANAGEMENT INFORMATION SYSTEMS (TMIS)

The use of computerized terminal management information systems (TMIS) by American railroads to improve yard operating efficiency, a relatively new technological innovation, is growing. At least five major hump yards have TMIS systems: the Southern Pacific's West Colton Yard, the Southern Railway's Sheffield Yard, the Canadian Pacific's Alyth Yard, the Santa Fe's Argentine Yard, and the Norfolk and Western's Roanoke Yard. One major flat yard is also represented, the Kansas City Southern Yard in Shreveport, Lousiana.

TMIS systems supply yard personnel with information as to the status of events and activity in the yard. These systems can also speed up yard operations by keeping yard supervisory personnel up to date on activities in the yard, so that decisions can be made without the usual delay while yard personnel hand compile data and status reports. In fact, the system in Roanoke Yard on the Norfolk Western has added the capability to simulate the results of humping a selected track in the receiving yard.

The reliability of TMIS systems, however, is constrained by the fact that the data input is usually manual (unless electro-optical – Automatic Car Identifcation (ACI) – scanners are employed; television is occasionally used as a manual aid). In cases of manual input, errors as high as 15 percent have been reported. ACI holds the promise of eliminating such errors and has the added advantage of greatly speeding-up the entire process of car identification and control. The scanner automatically records all car movements past it. The car data (which includes equipment type, owner's code, and equipment serial number) are transmitted from scanner to computer, eliminating all manual intervention and associated errors. The speed and accuracy of acquiring data by ACI represent a significant opportunity to improve car throughput and eliminate costly and time-consuming errors at rail terminals.

Unfortunately, ACI has suffered from label readability problems resulting primarily from dirt and damage to the label. Label readability in recent years, as reported by the AAR, has decreased to about 80 percent. Improved label maintenance could increase ACI accuracy from 95 to 99 percent.[4] Various programs of label maintenance and other ACI improvement studies are underway within the railroad industry in an attempt to achieve these higher figures.

TMIS systems are capable of using sophisticated software packages to improve the accuracy of manual, ACI, and train list input information to a very acceptable level. These "data enhancement" procedures can help reduce the types of paperwork discussed in Section 5.

TMIS systems of contemporary design are well received by railway employees. The employee's involvement is made more interesting and less tedious through the use of remote computer terminals and other input-output devices. His contribution is recognized and visible. Experience has shown the power of the computer and ACI to the employee, and he associates this with progress and a strengthening of his job security.

Finally, the cost of TMIS systems is quite reasonable, approximately as low as 3 to 5 percent of the cost of the terminal itself. The investment in effective TMIS systems protects the investment in the terminal and will increase service levels, as much as 20 to 25 percent without additional investment in facilities and equipment.

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[4] K. F. Troup, Automatic Car Indentification - An Evaluation (Cambridge MA: U.S. Department of Transportation, Transportation Systems Center, Report No. DOT-TSC-FRA-72-3, March 1972).

TMIS systems have the potential to provide fast and accurate car data which can be used by management to make better decisions in less time, resulting in faster yard throughput, reduced transit time, and more reliable process control of yard operations. For example, one TMIS system incorporating ACI has been reported to have reduced labor costs by 50 percent, per diem costs by 60 percent, and yard time per car by 50 percent. It is reasonable to expect that computers will play an expanding role in the railroad system. In fact, it is evident that computer systems can be developed that will provide operating personnel faced with decisions with alternative courses of action from which they may choose.

7.4 REGULAR HIGH FREQUENCY TRAIN SERVICE

Regular High Frequency or "RHF" train service is an operating procedure whereby freight trains are dispatched from yards at regular frequency intervals of about two to four hours. This means that a train from one classification yard destined to another yard would depart, say, every three hours throughout the day, based on a minimum train tonnage requirement. By doing this, the network becomes "regularized" in the sense that operations occur expectedly, not erratically, and traffic queues are minimized.

A good example of actual RHF operation is found on the Santa Fe Railroad.[5] On the Santa Fe, RHF trains are operated from Argentine Yard, Kansas City, to the California coast. Trains run with a minimum of 2000 gross tons and horsepower-per-ton ratios of no less than 3, departing at intervals of about 3 hours. (Illinois Central Gulf Railroad also studied the feasibility of RHF service on its Iowa division; although the conclusions were favorable, the service runs were never implemented.)[6]

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[5] "Santa Fe Moves Traffic by the Clock," Railway Age, (March 25, 1974), p. 42.

[6] Illinois Central Gulf Railroad, The Iowa Experiment (Chicago: Illinois Central Gulf Railroad, 1972).

This operation benefits the Santa Fe system with better distribution and return of empty cars, more reliable service, better labor utilization, fewer traffic buildups and tieups in yards, and reduced yard throughput time. The average train weight is around 3000 tons, and since loads and empties are treated equally, empty trains are longer than loaded trains, allowing for a faster return of empty eastbound cars. The resulting regular traffic flow pattern has resulted in easier management of yard operations, since traffic is kept on the road and is not allowed to stay in yards just to wait for tonnage buildups.

The regular nature of this operation allows managerial and operating personnel to have a better idea of what is happening and what is going to happen, because the erratic nature of rail freight operation is reduced. This permits various departmental personnel to plan their work better. For example, yardmasters know what trains can be expected to arrive in their yards on an hour-by-hour basis, thus allowing them to prepare ahead of time for their arrival and handling instead of relying on random events to control activity in their yards.

The benefits and savings that RHF can bring to a network have not yet been measured. Some feel that RHF increases operating costs, but that has not been shown to date. The service is still new, and it may take a year or more before its costs and benefits can be accurately quantified due to the complexity of evaluating benefits, particularly of improved service.

It should be noted that RHF is not new. The Nickel Plate Railroad (now a part of the Norfolk & Western Railroad), which operated a main line from Buffalo to Chicago and other points in the Midwest, was known for its short, high frequency trains. In general, the steam locomotive technology of that day prohibited long trains, which was one reason why steam trains were short compared to the long diesel-electric drawn trains of today; e.g., an average train length of 48 cars in 1929 vs. 70 cars in 1970.[7]

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[7] Association of American Railroads, Yearbook of Railroad Facts, (Washington DC: Association of American Railroads, 1973), p. 41

The lower crew costs of those days also made short trains more economical compared to today's rates. The economics of the long tonnage train attracts railroad managements oriented toward goals of reduced operating costs, but the level of service can suffer from such a policy.[8]

Accordingly, the recognition of the system and level of service benefits of RHF should be weighed against any increased operating costs to determine the true costs and benefits of RHF vs. long tonnage train service. The Santa Fe experiment appears to point to RHF as being a possible solution to a number of operating and equipment utilization problems. RHF offers potential for improved service to customers and better operating efficiency while considerably reducing yard bottleneck problems.

7.5 PREBLOCKING

Recall that preblocking, described in Section 3, is a procedure whereby trains are blocked in a way which corresponds to the classification policy of a subsequent yard, so that when preblocked cars arrive at a subsequent yard they can be classified as blocks rather than as individual cars. This saves switching time in subsequent classification yards, but increases switching time at the preceding yards where the cars were preblocked.

Also recall that preblocking is of greater benefit to flat yards than to hump yards, since switching rates in hump yards are very high, and cars are usually not humped in blocks. In flat yards, on the other hand, cars can be classified faster if they are switched in blocks rather than as individual cars. Hence, preblocking is more effective in flat yards than in hump yards.

No substantive or quantitative research was found regarding preblocking costs and benefits. However, preblocking has the potential of providing a means of reducing classification switching time, particularly in flat yards.

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[8] Task Force on Railroad Productivity, op. cit., p. 304.

7.6 RUNTHROUGH FREIGHTS

Runthrough freights are freight trains made up of cars blocked for a single destination yard which do not generally stop at intermediate classification yards to be reclassified. Although runthrough trains may make intermediate yard stops to pick up and set off cars, the basic idea is to keep cars in the same train until they reach their destination yard without having to be reclassified onto other trains enroute. It is often necessary, however, for the locomotives to be changed enroute if the train is moving over more than one railroad. Many railroads, however, now "pool" their locomotives and let them run over other railroads associated with the runthrough train operation so locomotive changes will not be necessary. This operating procedure reduces transit time and increases the reliability of the car movement. It furthermore reduces the workload of the intermediate yards where the cars would normally be reclassified. In this way, runthrough freights can reduce yard congestion and improve service.

Runthrough freights are not the same as RHF trains. RHF trains depart yards at regular frequent intervals, whereas runthrough freights do not necessarily have to be run regularly or frequently.

The MIT/FRA study endorsed runthrough trains, noting that many railroad operating personnel agree that they can be a most cost-effective means of improving railroad reliability and that bypassing intermediate classifcation yards can save from a few hours to several days transit time.[9]

It must be noted, however, that runthrough trains are financially feasible only in cases where there is sufficient traffic between an origin-destination pair to justify their operation. A minimum train length of at least 50 cars or 2000 gross tons would be necessary to justify a runthrough service according to some railroads, while others would require more

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[9] Martland, Improving Railroad Reliability, op. cit., p. B-38.

traffic. Without runthrough service, a typical freight car may have to be classified two or three times as well as being interchanged with two or more railroads, thus lengthening its transit time and making its final arrival time more difficult to estimate.

In summary, runthrough trains minimize the use of yards, leaving yards open to handle originating and terminating traffic more efficiently, while raising the level of service by reducing origin-destination transit time and improving reliability.

7.7 SCHEDULE ADHERENCE

Trains can be dispatched according to a strict timetable, provided they are of minimum length at the scheduled departure time, even though more cars could be added if the train were held over. This makes train movements more predictable, because it allows yard supervisory personnel more time to plan their receiving, classifying, and dispatching work than they had under erratic operating conditions. This also results in better equipment use, since the location of motive power is known with more accuracy; thus, power availability for trains can be managed more effectively. The increased planning time helps avoid situations where motive power shortages occur in some parts of the system while other parts have excess power.

Reliability, both yard and line-haul, is improved by schedule adherence.[10] The MIT/FRA study, for example, showed that if trains depart from their originating yards on time they are more likely to arrive at their terminating yards on time.[11] Furthermore, if trains arrive at their terminating yards on time, there is a greater probability that their cars will make their outbound connections.[12] Thus, if schedules are adhered to, yard operation and efficiency will be improved.

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[10] C. D. Martland, Procedures for Improving Railroad Reliability, (Cambridge MA: Massachusetts Institute of Technology, Department of Civil Engineering, Report No. R72-37, June 1972) p. 46.

[11] Belovarac, op. cit., p. 24.

[12] Reid, et al., op. cit., p. 36.

In some cases, however, there is not enough regular traffic to justify scheduled operations. These are usually branch line districts where all trains are local and service is often provided on a "when needed" basis only. Most major rail trunk line routes, however, have enough traffic to justify scheduled operations.

7.8 GEOMETRIC SWITCHING

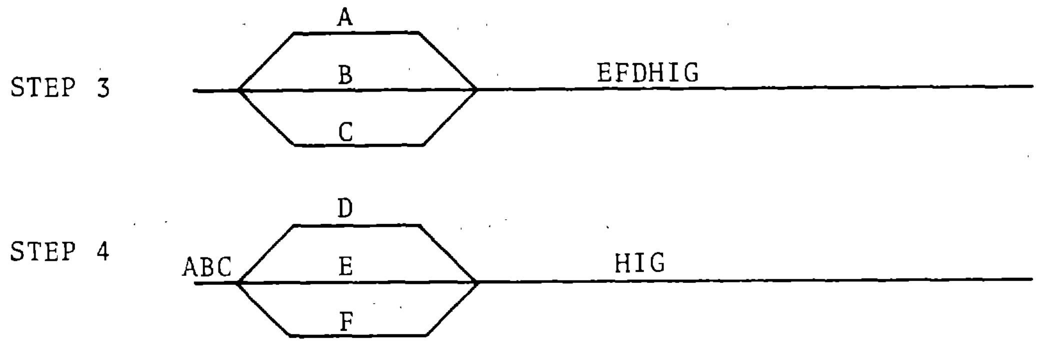
Geometric switching is a method of classifying cars into several classifications using only a few tracks. The following diagrams will be used to explain how this operation works.

Assuming that it is desired to classify the cut of cars CBEFAHDIG into three ordered trains: ABC, DEF, and GHI, using a three-track yard, the first step would be to classify the cars in the yard so that the ABC cars are on one track, the DEF cars on another track, and the GHI cars on the other track as follows:

STEP 1

STEP 2

The next step is to pull all the cars out of the yard and reclassify them to get them in their proper order, as illustrated here for cut ABC:



This process continues until cuts ABC, DEF, and GHI are completed.

The advantage of this type of operation is that many classifications can be obtained with few classification tracks. A common classification yard would require a classification track for each classification. In the above example, a nine-track yard would be needed to do what was done with only three tracks using geometric switching. Track requirements for geometric switching are generally the square root of the number of classifications, rounded to the highest integer. For example, 16 classifications require 4 tracks; 19 classifications require 5 tracks ($\sqrt{16} = 4$, $\sqrt{19} = 4.35$ or 5, the next highest integer).

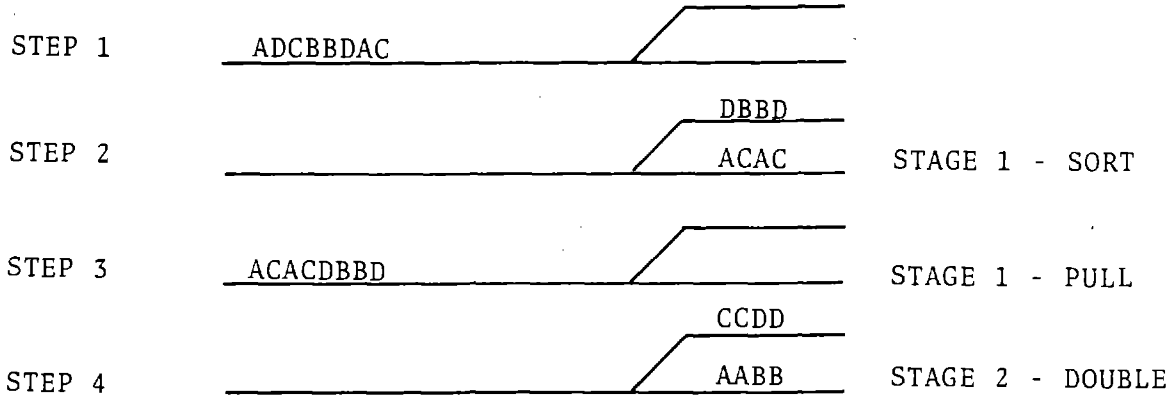
Geometric switching has various advantages and disadvantages. The advantages are that it requires less land and trackage than a regular classification yard, resulting in comparatively less property tax and track maintenance cost than a larger yard performing the same amount of work. One disadvantage of geometric switching is that each car must be classified twice. Also, the switching operation cannot accommodate the introduction of new traffic after the start of the second classification without confusion and disruption in the operation. In a regular classification yard new traffic can usually be introduced at any time without affecting the classification work already completed.

Geometric switching may not be feasible for large classification yard operations, but may have potential for smaller classification operations in local and other small yards. In addition, the smaller yard application would be desirable because of the savings in land use, taxes, and track maintenance costs which are more sensitive to the profitability of light traffic districts than in dense traffic areas. The procedure increases the classification potential of small yards.

Although not a major solution to yard problems, geometric switching offers potential as an economic car classification system which may help reduce yard costs, especially in relatively light traffic areas.

7.9 STAGED SWITCHING

Staged switching is related to geometric switching in the sense that cars are reswitched in the same yard or in an auxiliary yard to obtain more classifications than there are classification tracks. Given the following sequence of cars, ADCBBDAC to be switched into the ordered sequence AABBCCDD, the moves are as follows:



The scope of this report does not justify a detailed discussion of the theoretical technique involved. It is sufficient to point out that staged switching is a way of getting more classifications out of a smaller number of classification tracks by re-switching cars based on a track assignment algorithm in which the number of first-stage tracks times second-stage tracks equals the number of blocks that can be made. In the above example two stages were used, each with two tracks, enabling 2 x 2 or 4 blocks to be made.

H. B. Christiansen's paper is a good reference source on this subject.[13] According to Christiansen, the main advantage of staged switching is that it requires fewer switching moves than conventional switching. For example, in comparing switching moves among a three-track two-stage yard, a three-track conventional yard, and a nine-track conventional yard, the staged switching yard clearly requires the fewest number of switching moves, as seen in the following table:

Switching Moves	3-track 2-stage	3-track conventional	9-track conventional
Sorts	2	4	1
Pulls	1	3	
Doubles	4	5	8
TOTAL	7	12	9

Christiansen suggests that a feasible layout would require at least two connected hump yards, one for each of two stages, with the product of the yard tracks being the number of blocks that could be switched. For example, 2 connected 7-track yards could be used to make 49 blocks (7 x 7 = 49), or 2 connected 5-track and 4-track yards could be used to switch 5 x 4 = 20 blocks.

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[13] H. B. Christiansen, "Should Future Yards Classify Freight in Two Stages?" Railway Management Review, 72, No. 2 (1972), A20-A32.

The advantages and disadvantages of this system are similar to those of geometric switching described above. That is, fewer switch engine moves are required and more blocks can be switched with fewer tracks than in conventional switching, thus increasing the classification capacity of the yard. The disadvantage of this system is that it would be difficult to add cars arriving after the second stage switching had already begun. In addition, staged switching must be planned and carried out precisely. Its complexity might easily lead to confusion and disorganization.

Christiansen implies that such a technique might be impractical as a replacement for large classification yards but might be useful as a technique for making switching cuts to facilitate industrial switching. This technique also appears to be feasible for car sorting in branch line or light density traffic areas and in smaller yards.

7.10 SWEEPER TRAIN SERVICE

Sweeper train service is an operating scheme being tried experimentally on the Santa Fe Railroad's Texas lines. In this operation a train starts at point A destined for point B in a system. Enroute, the train makes numerous intermediate stops to pick up cars destined for point B only. It does not pick up any other traffic and cars are not reclassified enroute. In this way, cars are carried directly from their origin points to a destination point over that one railroad's network without initial or intermediate classifications. Note that this will not work for traffic to be interchanged unless there are interrailroad pooling arrangements.

The advantage of this operation is that it reduces car handling because it avoids the need for local trains to pick up cars at intermediate localities and take them to the nearest classifcation yard where they are placed on trains headed for the cars' destinations. It also reduces the yard workload at yards that would ordinarily classify such cars. It appears to have the potential to improve reliability and reduce transit time. Less car handling using this concept can also reduce the likelihood of loss and damage.

This method can also be used to deliver cars as well – a train leaving point A for point B can drop off cars destined for points between A and B.

The sweeper train concept essentially is an application of branch line district operating techniques applied to higher traffic density lines. The major difference is that local trains making intermediate stops pick up all cars at the intermediate points going toward any downline location, whereas sweeper trains only pick up cars headed for a particular destination, leaving other cars behind. The cars left behind are picked up by other sweepers or local trains headed toward the general respective destinations of those cars.

Sweeper train service reduces the amount of car handling in yards and thereby improves rail network operations and reduces the workload in yards. This allows more time for the yard to handle originating and terminating traffic, and it reduces the time normally required for classifying through traffic. Such a concept may have considerable application on eastern railroads where hauls are short and terminals close together. The Santa Fe Texas lines, for example, approxiate an eastern configuration. To date, Santa Fe operating personnel appeear pleased with this operating concept.

7.11 SUMMARY

In this section, nine different types of procedures were discussed related to improving rail operations by reducing the detrimental effects yards can have on network freight train service. Improved yard design and TMIS systems were presented as methods of improving internal yard operations. Geometric and staged switching are methods of increasing the classification capacity of yards without adding more tracks. Sweeper train service and runthrough freights were shown as methods of avoiding yard handling where possible and thus eliminating some yard delays. Regular high frequency trains and schedule adherence were discussed as methods of making yard operations more efficient and easier to manage by reducing erratic train operations and traffic buildups in yards. Preblocking was discussed as a method of making flat yard switching less time consuming.

8. RAILROAD SIMULATION MODELS

8.1 INTRODUCTION

In this section, computer simulation modeling, the most advanced tool for studying and analyzing rail yard operations, is reviewed. Two major types of railroad simulation models are discussed: yard models, in which the functions of a classification yard are simulated, and network models, in which the operating scenario throughout a railroad network is simulated. The most complex part of a network model is that part attributable to the classification yards in the network. Accordingly, the discussion that follows will deal with the simulation of yard behavior, even when speaking of network models.

The information in this section was derived from discussions with a sample of railroad simulation users. Many of the respondents used simulation models developed by their own staff or else have had experience with one very general model available from the Association of American Railroads (AAR).

8.2 SOME ASPECTS OF SIMULATION MODELS

A yard simulation model may be visualized as a description of the salient characteristics of a railroad yard, together with a computer program which uses this description to predict the behavior of the yard. Such a model is usually validated by comparing model projections of the yard performance against actual performance for actual traffic loads. It is important that the model predict accurately yard operating behavior after a change has been made in the yard layout or yard resource allocations. Note that if a model simulates the behavior of a yard accurately, it does not necessarily hold that minor changes in the model program will allow the model to predict the behavior of the same yard with the same accuracy after such seemingly minor alterations.

It is important that the model be written so that changes in the yard can be routinely incorporated into the program. To facilitate reprograming, a performance characteristic to be changed should be written as a subroutine rather than as a part of the major program emulating the yards. For example, a subroutine to represent waiting time in a yard can be more easily changed than an empirical probability distribution for waiting time which is a part of more general representation of the yard.

Two common uses of railroad simulation models are in improving existing classification yards and in designing new ones. The technique used is the obvious one of perturbation: the simulation model is developed and validated using real world traffic data gathered over a period of time from 10 days to 3 weeks. One aspect of the model is then changed to correspond to an alternate version of the yard being modeled, and the simulation is then rerun using the same data. The more efficient model (i.e., faster, less costly, etc.) is chosen to simulate the yard. Runs are made with yard design changed until simulated yard performance is satisfactory or no new variations on design seems to improve the network's performance.

The discussion in this section reveals that the value of a railroad simulation model is measured by how well it can be used to find ways to save money or generate more revenue. Any use made of a simulation model for railroad purposes derives its value from this measure. For example, a yard model owned by the Santa Fe railroad was redesigned to simulate the "regular high frequency departures" discussed earlier in Section 7. The simulation showed the high frequency schedule would be feasible even before the pilot project evaluation took place.

In all cases, the simulations being used are essentially elementary first cuts at railroad modeling; this is not to say that these models are not useful. Many of the models encountered were demonstratably valuable to the users. Indeed it would be surprising if even the most elementary simulation models were not useful, so long as they were developed to fill a specific need: to generate reliable data previously unavailable on which to base a management decision. Even estimates known to be slightly inaccurate are better than no estimates at all.

8.3 LIMITATIONS OF INSIGHT GAINED FROM THE USE OF RAILROAD SIMULATION MODELS

A question that may be asked by those unfamiliar with railroad simulation or with network models is how well the experience of using a simulation program can aid in developing insight into the problems of a railroad network or yard. The computer model itself provides no insight into the workings of a yard or the problems in a yard that can cause congestion, late departures, etc. If one were to examine the computer simulation output of a yard operation which showed that three days were required to process a car through that yard, it would be impossible to determine either from the structure of the model or the computer output why the yard process time was so long relative to some standard of, say one day's time as being a reasonable yard processing time. The only way to determine the cause of the long processing time in the above case is to "experiment" by running the model several times, each time with a change of some sort being made to the yard or train schedules until finding what "change" would satisfactorily reduce yard processing time. Of course, this solution is not unique; there are undoubtedly untested alternatives for reducing yard processing time. In addition, a different experimenter with a different model might arrive at a solution eliminated by the first experimenter. In any case, the model itself does not provide the answers to questions such as what makes a yard operate efficiently. The model is only a tool used by an experimenter who, after studying the results of a number of computer runs in which many alternatives are tested, can only speculate that in the final analysis such and such a change will produce stated results. And even at that point the experimenter can only speculate why a stated change will produce a stated result; for the model does not tell him why something works; it only tells him that it works. This is so because computer programs base their conclusions on a lengthy series of calculations, a method which a normal human mind would not emulate.

Accordingly, it must be understood that computer simulation models of railroad yards and networks can only be viewed as tools to help analyze, test, and study various alternative railway operating strategies. Similarly, the results are a function of the quality of the simulation programs, the input data, and the programmers.

8.4 ACCURACY OF SIMULATION RESULTS

In the development of a simulation model there is a tradeoff between accuracy of results and model complexity: the more complicated the model, the more accuracy can be expected in the simulation results. Conversely, where high accuracy is not required, the model may be be more simplified.

As this tradeoff became clear to the architects of the AAR simulation model, they decided that accuracy should not be sacrificed except in a few options which the user could choose. As a result, these programs are quite complex and demand a very large amount of accurate data concerning the networks they are made to simulate. Thus it is very time-consuming (on the order of one to two years) to bring the model to a state of usability on a new railroad network. At the time of this writing, the only successful application of the AAR model was its use in the St. Louis relocation study; in addition, the model was calibrated using data from the Chesapeake & Ohio/Baltimore & Ohio Railroads and validated by C&O/B&O who developed a mini network based on the AAR model. However, at least one new attempt is being made to use the model on the Southern Pacific.

The second point which should be made regarding the accuracy of simulation models is that in many situations it is impossible to achieve accuracy much closer than 10 percent. In J. F. Folk's thesis, "Models for Investigating the Unrealiability of Freight Shipments by Rail," identical input data with different random number sequences showed variations of up to 10 percent in simulated statistics, such as a number of car connections missed leaving a yard or mean departure time of trains.[1] The underlying lesson here

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[1] J. F. Folk, "Model for Investigating the Unreliability of Freight Shipments by Rail," (Unpublished Ph.D. dissertation, Massachusetts Institute of Technology, June 1972).

seems to be that the workings of a railroad network or yard cannot be predicted with much precision. For example, the same yard with almost exactly the same traffic two days in a row will not perform in the same way, because small variations may lead to larger ones. This would seem to indicate that one should not sacrifice the simplicity of a model for accuracy. How much accuracy one should strive for in the face of inherent inaccuracy is a question deserving more study.

8.5 TYPES OF SIMULATION MODELS

In the introduction differentiation was made between yard models and network models. There are a number of other important distinctions which define types of railroad simulation models. For example, models may be "data-driven" or "stochastic." In data-driven models each simulated train and its makeup arises from real-life data input into the model. Stochastic models, on the other hand, are those which receive real-life data which are then used by the model to generate random data. Such data are said to be "stochastically" or randomly generated. Almost all simulation models generate some data randomly. The dividing line comes between models which generate all their own data, stochastic, in one extreme, and models for which data are always abstracted from a real-life situation, data-driven, where this is feasible.

We now consider the distribution between "special purpose" and "general purpose" simulation models. The model supplied by the AAR mentioned earlier is a good example of a general purpose model in that it can be adapted to simulate any railroad network. A special purpose model, on the other hand, is built to simulate a particular railroad yard (or network); it is not easily altered to simulate a different yard of entirely different makeup.

In the discussion above, we have assumed that the model under discussion was "passive" in the sense that given the parameters of input such as layout design and resource allocation, output parameters such as speed, cost, and reliability are passively computed. Instead, the model might be of an "optimizing" type which calculates an optimum flow scheduling using specialized algorithms. The latter method is used by E. R. Peterson and H. V. Fullerton of Queens University, Ontario, in their Railcar Network Model being developed for the Canadian Institute of Guided Ground Transportation.[2]

One can also distinguish between models which consider each railroad car or block of cars as being distinct and pass them from function to function in a simulated classification yard, and models which do not treat cars at all, except to measure the rate at which they pass through various functions in the yard. In the second type of model, studies regarding bottlenecks and network flow are simplified, since the cars are not distinct but only act like a quantified fluid flow. This point of view is the one adopted by E. R. Peterson and H. V. Fullerton in the model mentioned above.

Finally, one can distinguish between simulation models which are meant to achieve solutions with one computer run (assuming no errors), and ones which are meant to interact with users. In the latter case a person with experience in running railroad yards may make suggestions for changes which can be estimated from readouts which the model gives of the state of the simulated yard. This type of model is called "interactive," while the models without this feature are called "batch" models.

Batch models, of course, are not really expected to arrive at the final solution in one computer run. Changes are made in the model following suggestions from the observers of the results of a run. The process lacks spontaneity, however, in that hours or days may intervene between runs of the program. A further handicap is that the suggestions and simulation results must be filtered through the programmer of the model.

With the interactive programs an operator who is not particularly experienced with computers can communicate with the system. This aspect can be important to operations personnel who will be

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[2] E. R. Peterson et al., Railcar Network Feasibility Report, (Kingston, Ontario: Queens University School of Business, March 1971).

the ones to implement any changes. They will be able to see what the simulated state of the yard would be as a result of various suggestions they might make, and they often have more confidence in a solution that they helped propose. The experience and common sense of yard operations people are necessary to make the best use of a computer in a rail yard.

On the basis of these two observations and the fact that many model makers perceive obtaining the cooperation of the operations personnel as their most important and difficult task, it would seem that interactive models are superior in performance to batch models, other things being equal. Information gathered by telephone interviews seems to confirm this.

8.6 DISCUSSIONS WITH RAILROAD SIMULATION USERS

The object of these discussions was to learn about the relative success or failure of various simulation models in terms of how often the models were used, whether the users were satisfied with the model results, and whether such results were used as a basis for implementing operating changes.

8.6.1 Association of American Railroads Network Model

The AAR model essentially is a network simulation package that the Association will rent to users along with assistance in its use. It is a data-driven, general purpose network model. The impact of the AAR model on U.S. railroads has been minimal due to the small number of users. It was used by the Illinois Central Gulf Railroad to simulate one division, but the model lost its attractiveness because of the complexity of input requirements. The Southern Pacific Railroad has spent over a year implementing use of the AAR model without reporting any results. The model was used in the St. Louis Terminal Relocation Study with rather interesting results now being documented by FRA. The model was refined during its St. Louis use; considerable time and expense was required to prepare the input for the model.

The AAR made the decision to make the model as accurate as possible, even if it may be hard to use or initiate because of complexity. As a result, the first problem has been to get the model set up and ready to operate; to do this, all the parameters of the appropriate network must be learned in a data gathering stage, which can be difficult and time consuming. Secondly, it has been perceived that those railroads managed by executives with operations department backgrounds are less likely to place much credence in the model, adding to its lack of use.

8.6.2 Illinois Central Gulf

This railroad was one of the first to use the AAR model. The problem was to find the manpower to set up the model without disrupting other projects which needed attention and without adding to the permanent staff for a one-time job. Therefore, a contract was given to the University of Illinois to collect initial data and set up program parameters.[3] Reportedly, some 20,000 data cards were needed. When the students finished the project and graduated there was a partial loss of continuity in the project. Furthermore, the Illinois Central's merger with the Gulf, Mobile, and Ohio changed the network structure. The project was subsequently terminated. In this study, the Iowa Division of the Illinois Central Gulf network was simulated to ascertain possible improvements in blocking policy. The suggested changes were used as part of ICG's Iowa Experiment study for regular high frequency service on that division; because of the labor union difficulties, this was never implemented.

8.6.3 Santa Fe Railroad

This railroad has a model constructed specifically for simulating hump yards. The model is quite complex and requires a great deal of computer memory. It also requires a large amount of

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[3] S. J. Kim et al., Application of the AAR Network Simulation System to the Illinois Central Railroad, Urbana IL: University of Illinois, Civil Engineering Department, September 1972).

computer time to run. It was used as an aid in designing a $40 million hump yard in Barstow, California. The amount of money saved due to using simulation in designing the yard is difficult to estimate but is judged significant by management. For example, the simulation allowed people to check variants on design and to reach agreements on various designs. It is hard to put a monetary value on this kind of benefit. The program can be adapted to other users. The concept of "regular high frequency" departures scheduling was simulated on an altered version of this program before the scheduling scheme was given a pilot test. This model is the only one encountered which seems an unqualified success and which was not of the interactive type.

8.6.4 Southern Railway

This railroad has used simulation for several years. In 1971, it developed a model to simulate a specific yard operation, with the twofold purpose of evaluating that one situation and evaluating the feasibility of developing this type of yard model.

The model dealt with the yard functions of train arrival, inspection, classification, car cleaning and repair, limited piggyback operation, and outbound train building and forwarding operations. It was used to help design improved physical characteristics of the yard under study.

Management is reportedly very receptive to using simulation models when they can add significant input to the decision making process. Southern's greatest problem has been the high computer cost involved in running some of their applications.

8.6.5 Southern Pacific

This railroad developed its own system simulation model in 1968. It was used to model the railroad, with the West Colton Yard included before it was built. It has also been used for blocking strategy. The Southern Pacific is currently in the process of preparing to use the AAR model.

8.6.6 Other Railroad Uses

AAR's Data Systems Division conducted a survey in 1974 of 45 major railroads and their uses of computer models. This survey showed the following:[4]

TERMINAL & YARD MODELS
ATSF - 2 Models (Active)
CO/BO - 2 Models (Inactive, As Required)
Southern - 1 Model (Inactive)
Burl Northern - 1 Model (As Required)
Rio Grande - 1 Model (As Required)
Union Pacific - 1 Model (As Required)
Total 7 Railroads

NETWORK MODELS
CO/BO - Active
CP - Active
L&N - Active
PC - 1 Active
  1 As Required
Southern - 1 Active
  1 As Required
SP - 1 Active
  1 Inactive
UP - Active
ICG - Inactive
Frisco - Inactive
Santa Fe - As Required
BN - As Required
CN - As Required
Total 12 Railroads

8.7 CONCLUSIONS

The responses of the various railroads discussed earlier indicate a diversity of viewpoints among the various railroads. Many railroads, as noted by the AAR survey, have never attempted any ambitious simulation modeling; others have tried it and failed, some with rented models and some with models they developed themselves. Finally, there is a small group which has had quite encouraging success.

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[4] Reports of the Data Systems Division's Standing and Ad Hoc Committees, September 1974, p. 10.

In response to their diversified early experiences with simulation the various railroads are destined for some time in the future to grow further and further apart in simulation capability. It will not be until the value of simulation models (when properly applied) has been completely established that some of the railroads which had bad initial experiences will turn once again to simulation. Information about successful simulation models should be disseminated as widely as possible to encourage more activity in the field.

Probably the most common complaint of the respondents was the lack of rapport between computer and operations personnel. It is not surprising that practical men, charged with the responsibility of running a railroad, are less than enthusiastic when research men, who have been conspicuously absent for several years communicating with computers, suddenly confront them with improved schedules difficult to implement in real life. If, as is almost sure to happen the first time, a mistake has been made and the new schedule actually makes matters worse, any future plans for changing the railroad will encounter strong opposition.

It is a mistake to exclude operations personnel from the simulation process, since involvement and interchange of ideas should be encouraged. An interactive model is the best type of simulation model to promote participation in all branches and levels of the railroad. It is probably not coincidental that most of the railroads which have had successful experiences with simulation models are using models of the interactive type.

With proper attention paid to the railroad simulation models developed, and with lessons taken from both the successes and failures, great strides should be made in this field in the next 10 years. With larger, less expensive computers on the market, and facilities being implemented for automatic real-time data gathering at classification yards, it will become possible to obtain more relevant data about yard movements merely by recording the real-time data transmission. With these data, modeling will become easier. The worst danger at present is that only the few railroads which have had success in the past will maintain any effort in the area of simulation, and that these will not experiment but will stick to their proven methods. This hardly seems a serious danger except in a scenario of very tight money and a highly depressed railroad industry. In any event, every effort should be made to encourage experimentation. Perhaps the most fruitful endeavor would involve crossfertilization. Railroads with real enthusiasm for a highly successful model seem to be willing to discuss the concept of their model, at least in broad outline. Mistakes made in model building should be identified, as has been attempted here.

More communication seems necessary for railroad simulation model growth. Furthermore, the standard meeting format – presentation of a model that never worked, without comment on its performance – should be avoided. The typical writeup of a model does not even give information by which a reader can judge if it has ever been used successfully. What is really needed is a meeting at which all performance (good points and bad) is discussed, with an attempt to identify model characteristics in their causal relationship to the good and bad points of the models under discussion. There is little danger that everyone will attempt to build the same model with the most desirable characteristics. Such a meeting would be stimulating and it is unlikely that an unqualified consensus would be reached; diversity of opinion is almost guaranteed, and from this diversity new and better simulation models can evolve.

The role of simulation and computers is that of helping management decide on new yard design and design improvements to existing yards as well as improvement to network operations.

9. NEW YARD PROJECTS

9.1 INTRODUCTION

This section reviews various issues related to new yard design and to improvements of existing yards. The information contained in this section is based on discussions and correspondence with railroad personnel whose work relates to new yard projects.

Railroad sources report that the basic flow of events in the development of a new yard project begins with a determination of the need for a new yard or yard improvement by the railroad company. This is followed by a yard study to determine the potential economic value of the idea. The next step is a design phase in which various company departments work out a physical design for the project. Then, providing capital is available for the project, the actual construction phase begins. This section will therefore present a detailed discussion of these issues, supported with examples derived from railroad interviews.

9.2 DETERMINANTS OF NEW YARDS AND YARD IMPROVEMENTS

Generally, the operating department personnel first perceive the need for yard or network improvements on the railroad. Such new projects or improvements usually result from any one or a combination of four general reasons:

1. Consolidation of facilities due to merger.
2. Changes in traffic patterns and volumes.
3. Improvement in internal operating efficiency and service.
4. External factors related to land use changes resulting in efforts to improve an urban or industrial environment; e.g., the St. Louis Terminal Project.

In the case of railroad mergers, there will usually be a resulting consolidation of selected yard facilities corresponding to planned shifts in traffic routing over the newly established network, as well as consolidation of facilities that are close together in one locality.

Two cases discussed in this regard with the Norfolk and Western Railway (N&W) were Bellevue Yard in Bellevue, Ohio, and Luther Yard in St. Louis. These are the largest yard projects undertaken on the N&W since the 1964 merger of the Norfolk and Western (N&W), Nickel Plate Road (NKP), Wabash Railroad (WAB), and Pittsburgh and West Virginia (P&WV).

The first of these was in Bellevue, Ohio, where a new 42-track automated hump yard was constructed as a result of traffic pattern changes in that area. This yard was built primarily to coordinate and integrate the merchandise traffic moving between the former N&W lines and lines of the former NKP, WAB, and P&WV. This yard became a symbol of unification because it physically connected the traffic flows of the four roads at one yard.

The other case was Luther Yard in St. Louis, an example of consolidating merged facilities in one location. Luther Yard was a former Wabash Railroad yard which handled traffic to and from Kansas City and other points west of the Mississippi River. The WAB also operated Brooklyn Yard in East St. Louis and the NKP operated Madison Yard in the same general area. The rebuilding of Luther Yard enabled N&W to close the NKP Madison Yard and to reduce substantially operations at Brooklyn Yard. The result was a significant decrease in operating costs and an improvement in service in the St. Louis area.

An example of a yard project based on the need to improve internal operating efficiency and service is the Santa Fe's Barstow Yard project in southern California. The Santa Fe plans to open a new classification yard in Barstow to classify eastbound traffic now being classified in two yards, Los Angeles and Bakersfield. The opening of this yard will enable the Santa Fe to reduce work at those two yards by consolidating the work at Barstow. It will help increase efficiency by permitting the consolidation of traffic at Barstow, and the dispatching of larger blocks of cars for eastern points, instead of running shorter eastbound trains out of Los Angeles and Bakersfield.

The St. Louis Terminal Project, on the other hand, is an example of a case where yard changes are being proposed for a number of yards so as to improve the land use characteristics of the St. Louis area. At present there are about 60 rail yards in the 4,500 square mile St. Louis area. It was felt that many of these yards could be consolidated, thus releasing railroad land for other types of development.[1] In consolidating these yards many factors must be considered, such as the fact that many railroads are involved and the complexity of yard consolidation of multiple operations. Furthermore, any consolidations would have to include technology that would result in improved efficiency over the present yard configuration.

Many more examples similar to those stated above could be added, but these examples are sufficient to demonstrate briefly the usual reasons why new yards or yard improvements are made. Various economic criteria are considered relative to new yard projects and improvements; these will next be considered.

9.3 ECONOMIC CRITERIA FOR NEW YARD PROJECTS

Once the need for a new yard or a new yard project has been identified, a study is often performed by the company to determine the economic feasibility of the idea. Among interviewed railroads, the most important criterion for new yard projects was the net rate of return on investment as a measure of economic effectiveness. Railroad personnel interviewed in this regard reported the following net rate of return estimates as in the acceptable range for the projects indicated:

Road Name	Project	Est. Net Annual Return on Invest.[2]
Illinois Central Gulf	Fulton Yard	24% - 28%
Santa Fe	Barstow Yard	20% - 30%
Southern Pacific	West Colton Yard	28%

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[1] East-West Gateway Coordinating Council, St. Louis Region 1971 Annual Transportation Report, March 1972.

[2] An official of the Illinois Central Gulf Railroad has pointed out that recent inflation would cause these ROI estimates to drop somewhat.

Accordingly, a 20 to 30 percent net rate of return on investment seems to be the range within which a new yard project can be justified.

In selecting a yard project, as well as a particular design for a chosen yard project, the respondents indicated that a number of alternatives are evaluated before a final choice is made. The Illinois Central Gulf, for example, evaluated four different designs for Fulton Yard, taking into consideration such factors as savings in switching costs, savings resulting from reduced car time, and savings from improved train running times. In another case, the Southern Pacific analyzed and compared system impact of six alternative yard projects, including West Colton, before committing capital to West Colton Yard. The economic analysis on West Colton Yard was complete and included system revenue, system switching costs, system train costs, system car utilization, system locomotive utilization, system switching damage, system mechanical costs, land use potential, and other items.

One official from a midwestern railroad pointed out that new yard studies are often challenges to hypothesis of yard improvements usually suggested by the operating department. He also pointed out that a railroad must have sufficient manpower and computer resources to perform useful evaluations of alternative yard projects. Another official, from a major eastern railroad, felt that there was a need for improved methods of measuring operating performance in yards and terminals to study new-yard economics and to evaluate present terminals. He noted that on many railroads the emphasis is on train and engine crew minimization, which is easy to measure. Few railroads have attempted to measure facility utilization - locomotives, cars, etc. Operating performance is most frequently measured at individual terminals in very general terms, with each manager responsible for determining the capabilities of his facility. The respondent foresees future use of more quantitative production measures, but has been unable to develop measures which both local operating personnel and top management find suitable.

In conclusion, it was apparent that the railroads interviewed were doing relatively thorough and sophisticated economic analyses of railroad yard projects. In so doing, the rate of return on investment was a major determinant of project justification. Several other performance measures were also used to study the impacts of alternative yard projects and yard designs on the network as well as in the terminal being studied. Some of the respondents felt that more resources and better measuring techniques were warranted in such analyses. From this it may be concluded that system analysis work of this type is a growing concern with railroads and that this work will probably become increasingly sophisticated in the future, resulting in better analyses of network needs and improvements.

9.4 CORPORATE ORGANIZATION OF NEW YARD PROJECT ACTIVITY

The identification of new yard needs, once justified by estimates of economic feasibility, are placed into a design phase, which determines the physical and operating characteristics of the new yard undertaking. Accordingly, the work involved in designing a new yard or a yard improvement can vary considerably as a function of the size of the project and the railroad organization responsible for its development. For example, in the simple case of making a yard improvement by adding a few more tracks to a classification yard, a common procedure would be for the operating department to request that the engineering department make the required changes, after having cleared it through appropriate coporate channels. At the opposite extreme, the design of a major new classification yard could conceivably involve a four-year program involving many departments acting jointly. As a result, the quality of the final design will depend somewhat upon the structure of the organization given the responsibility of developing the design. In general, it was felt that most large railroads had the in-house capability to perform yard design work.

The primary organizational activity within a railroad company relative to major new yard projects usually rests jointly with the operating and engineering departments. The operating department defines the operating requirements of the yard and specifies the traffic routing and traffic flows into and out of the yard. The engineering department uses these requirements to design the physical yard itself. Such design includes factors like the number of tracks and track length, the yard layout, engine and car servicing facilities, amount of track material, switch machine and retarder requirements, and cost estimates for the required material. They are also responsible for administering the actual yard construction work among their own forces and those of any contractors.

Other departments are also involved with new yard projects from other than design points of view. For example, the real-estate department must concern themselves with acquiring any new land that may be required as well as ensuring that the project falls within local zoning and land use ordinances. In addition, the mechanical department must set the requirements for any car and engine servicing facilities in the yard. The purchases and stores department, on the other hand, must order the materials needed for the project. Furthermore, the finance department must administer the capital that is spent on the yard.

Accordingly, depending on the size of a new yard project, many suborganizations within the railroad company can become involved. The actual design of a new yard, however, still rests with the operating and engineering departments, with the operating department dominating because they generally set the requirements of the new yard. Other departments are more or less concerned with the myriad of details associated with the actual construction of the yard.

Many railroads have "systems planning" departments which also play a role in this scenario. From the respondents that were contacted regarding new yard projects, it appeared that "systems" people within the firm usually provided support service for the economic analysis of the project and for the design phase; i.e., computer analysis support and simulation, among others.

An interesting example of the organization structure for the design of a new yard was seen in the West Colton Yard Project of the Southern Pacific Railroad. Colton Yard is located in southern California and was built, among other reasons, to combine the workload of several smaller yards in that region that handled traffic to and from southern California. The Southern Pacific (SP) appointed a representative from their operating department to coordinate the design and implementation of that project. What was interesting about this design was the great extent to which this individual had his staff acquire input from many different departments and individuals within the firm as a basis for developing what would be considered a nearly optimal yard design. This activity went beyond the involvement process mentioned above.

This SP yard staff began their design work by embarking on a very thorough search for the best technical design possible within the state-of-the-art of yard technology. First of all, their representatives visited several railroad yards in the United States and some in Japan to obtain a comprehensive view of various types of operating strategies and design innovation that could be incorporated into West Colton. They then identified constraints which could prevent a yard design from being effective and then incorporated their knowledge into the design parameters. In doing so they attempted to identify situations that might make the yard a bottleneck, and proceeded to build in ways of avoiding such occurrences. For example, certain tracks of the classification yard are extended beyond the classification area and are used as train makeup and departure tracks. This facilitates train makeup and increased production rates by minimizing needed car movement, thus helping avoid a possible bottleneck caused by humping cars faster than they can be departed.

After the design work has been completed, the construction project usually begins. The engineering department oversees the construction and maintenance of the new yard. The key factor that can delay a project or prevent it from being carried out is the unavailability of capital. This factor is discussed in the next section.

9.5 CAPITAL CONSTRAINTS ON NEW YARD PROJECTS

The capital constraint problem regarding new yard projects is significant in that it can prevent yard projects from being carried out. For example, the Barstow Yard Project on the Santa Fe was reported to have been in a "ready-to-go" state for quite some time, but the Santa Fe was unable to implement the project until the capital became available.

There are two main reasons why capital is not readily available for new yard projects. First of all railroads seldom generate enough internal capital for multimillion dollar yard projects; most railroads have capital sufficient only to cover the costs of higher priority items such as rolling stock and maintenance. As a result, railroads must borrow money. Financial institutions, however, regard most railroads as high risk investments, especially in light of the recent Northeast rail crisis, and are unwilling to lend them money. Furthermore, should a railroad go into receivership or have financial difficulties, it would be almost impossible for creditors to recover their loan principal on an item such as a railroad yard because there is little that can be recovered except the material salvage, which would be far below the cost of the yard. A railroad yard, therefore, cannot be used as good collateral for the loan used to pay to build it. Besides, government regulation would most likely prevent railroad facilities from being dismantled to pay off unpaid loans. Railroads do not, on the other hand, have this much trouble obtaining capital to make equipment purchases because cars and locomotives are easily salvageable and resaleable in case a railroad defaults on the loan used to purchase the equipment.

Therefore, it is important to realize that capital for new yard projects is difficult to raise and this can restrain their construction. However, smaller yard projects do not usually encounter the capital problem because they are usually small enough for the company to use internal funds for their implementation. It is only the multimillion dollar projects that require debt financing from outside institutions if the company does not have the money available from within. This availability of capital problem is being addressed by Congressional legislation in the form of the Rail Reogranization Act of 1973 and various loan guarantee proposals which would provide as much as two billion dollars in loan guarantees, not only to bankrupt railroads but also to any railroad needing capital for internal improvements.

Another alternative to the yard capital problem is to implement operating changes that make capital-intensive yard expansion projects unnecessary. One way of doing this is to reallocate classification work to other less congested yards where feasible. An official of the Missouri Pacific Railroad pointed out that his railroad has been doing this for many years, especially in the vicinity of yards operated at near capacity that could not be expanded anymore due to land constraints. The MoPac respondent also pointed out that his railroad has been increasing the number of interline runthrough agreements with connecting railroads, thus reducing intermediate classification yard work and helping to hold down the need for more yard space while improving service. Other operating schemes listed in Section 7, such as sweeper trains and RHF service, may also have potential for providing alternatives to yard expansion in addition to service and efficiency improvements.

9.6 SUMMARY

In this section, a general discussion was presented relative to new yard projects. The determinants of new yard needs were discussed and were seen to be mostly related to traffic changes, service improvements, and improved operating efficiency, all as a result of external factors, internal changes, or mergers. Some common economic criteria that were used to justify new yard projects were also presented. It was seen that the dominant criterion is the net rate of return on investment. The need for better performance measures and data for evaluating operating investment alternatives was also mentioned. This was followed by a review of the organizational structure within railroad companies that are assigned the task of developing new yard designs and projects. The West Colton Yard Project on the Southern Pacific was given as a major example in this regard. It was seen that new yard design organization is primarily comprised of the operating and engineering departments, with other departments providing support and serving secondary functions. Finally, the capital constraint issue was presented. It was seen that capital for new yard projects is difficult to obtain and that the unavailability of capital can, therefore, be a major roadblock to new yard projects. In this regard, it was mentioned that techniques of reducing car handling in yards may be useful in lieu of building new yards. At the same time, reduced car handling could also provide for improved rail freight service as well as reducing yard needs.

10. SUMMARY

This introductory analysis of railroad yards reviewed a wide spectrum of issues, including yard operating functions, simulation, new yards, operating improvements, and various operating problems. The conclusions that are stated below were derived from this study, based on information contributed by various interviewed railroad officials, as well as items in research literature. These findings are by no means definitive and are not based on quantitative analysis. They nevertheless provide a degree of insight into railroad yard and railroad network issues, both operating and academic.

The basic conclusions are:

1. The operating policies of a railroad with respect to yards and networks can have as great an influence on whether a railroad yard becomes a network bottleneck to operations as the physical and technological characteristics of the yard itself. Furthermore, intrayard operating problems may not affect network operating efficiency as much as makeup and scheduling policies within a yard that result in train cancellations and late departures. The MIT/FRA study presents a quantitative study of this problem.

2. The Santa Fe Railroad's regular high-frequency train service and sweeper train service has significant potential for improving railroad freight service on both long haul and short haul networks, as well as providing for reduced car handling in yards. This can result in less yard congestion and can therefore lower the likelihood that a yard will become a bottleneck. The improved equipment utilization that Santa Fe reported is another benefit that this type of operation can provide.

3. Yard simulation models are still in their infancy and very few railroads have had success with them. They are especially useful in new yard design and yard design improvement studies. Related network models are not in wide use by railroads primarily due to difficulty in developing the data and getting the cooperation of the operating personnel to implement suggested operating changes. The consequently low financial return of computer modeling rail operations may also be a reason why the industry has not been very enthusiastic toward them.

4. Terminal Management Information Systems (TMIS) are still in the early stages of development; however, operating TMIS systems in a select number of yards do exist. These systems can offer potential for facilitating intra- and interyard operating decisions and generally appear to be in a slow yet persistent growth phase.

5. The need for developing effectiveness measures seems to grow larger year after year as railroads attempt to develop better management information systems, to obtain a better grasp of the effects of projected operating improvement changes, to develop better economic criteria for new yard projects as well as other types of internal improvements, and to measure operating efficiency more reliably.

6. New yards are usually built for reasons related to changes in traffic flow volume and patterns, consolidation of facilities as the result of mergers, maintenance of an acceptable level of service and operating efficiency as defined by the given railroad, and for projects related to local land use development.

7. No new yard design concept appears to deviate significantly from the conventional railroad yard design setup of a receiving, classification, and departure yard. Different switching techniques, such as staged switching

and geometric switching, may allow for less yard space for smaller yard operations but may have limited feasibility in large classification operations. European and other foreign railroad experiences offer examples of different design and operations in yards.

8. The design of new yards and yard improvements is basically a joint effort of the engineering and operating departments. However, the operating departments may dominate this relationship somewhat, as they are the ones who usually determine the operating requirements for the new yard or yard improvement. Other departments within the companies fulfill necessary auxiliary functions related to such projects. Furthermore, in the case where a major new yard is being designed, a special task force within the company may be set up to manage the project, such as was the case with the Southern Pacific's West Colton Yard.

9. The availability of capital is a major restraint on new yard projects. This in itself can provide the motivation for railroads to discover additional ways of reducing car handling, because the prospects of railroads obtaining the capital for new yards and yard improvements are not encouraging. Furthermore, an effect of reduced car handling can be improved service, from which the railroads may benefit financially in the long run. For example, the MIT/FRA study showed that service reliability could improve if cars are classified less and if operating procedures such as runthrough trains are implemented.

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APPENDIX - SUPPLEMENTARY

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