THE ELIMINATION OF RANDOM CAR SEQUENCE IN TRAINS

Herbert Trask Landow

A Thesis
in Transportation
Presented to the Faculty of the
Graduate Division of the Wharton School,
University of Pennsylvania, in partial fulfillment of the requirements for the degree of
Master of Business Administration

1961

L. H. T.

1961 G. University

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

INTRODUCTION

It is the nature of railroads that an economic advantage may be secured through the operation of groupings of cars rather then cars individually. These groupings, or trains, permit the railroad to specialize the propulsion vehicle and reduce manpower requirements. Propulsion and crew costs are thereby far less than would be required were the railway freight car to be the unit of operation.

Freight cars can be assembled into series and operated as a unit because they share many features. Standardization of gauge, flange, coupler height and surfaces, underly the high productivity of freight train operation. This productivity manifests itself in long freight trains of low horsepower-weight ratio. The basic five man crew is more than adequate to operate and control freight trains of one hundred and fifty cars. Such length is not at all uncommon. Extreme lengths of up to two hundred cars are attained by some roads but the law of diminishing returns takes effect in this region. Delay in brake reation time makes such trains difficult to control. Slack action becomes unweildy with increasing train length and pulled drawbars become increasingly common.

The economies resulting from such fantastic production, however, are ephemeral. A considerable price must be paid to attain the prerequisite conditions under which such operation occurs. This price takes several forms. They are primarily the costs of assemblage and disassemblage of trains and the time costs (delays) incurred in the process. The adverse effects of these two factors upon sales through upward rate pressures and long in-transit times are considerable. They combine to seriously hamper the railroads competitive battle against other modes of transport.

The freight yard is the scene of the creation of freight trains and the subsequent revisions of their consists. The yard may take many forms. It is defined as a system of tracks in which terminal functions are performed. Each form adapts the system of tracks, as a tool, to the character of the terminal at hand. Terminals vary widely in terms of the traffic flow and in the degree of switching work that they are required to perform. These varying jobs, however, are performed upon a small number of basic track patterns.

It is the purpose of this paper to explore several of these basic designs and their limitations. One of the most severe of these limitations is the inability of contemporary yard designs to satisfactorily remove randomness in car sequence in the trains it creates. As will be demonstrated, a train is more than a series of cars hauled by a locomotive. Over the road train performance is only one step in an overall production process. By ordering the sequence of cars, train operation more perfectly meshes into succeeding stages of production. Thus the efficiency of terminal and road operation may be considerably enhanced.

The failure of modern yard design to order car sequence sufficiently is the basis for the presentation in this thesis of a design that may accomplish this desirable goal. This design will create trains or car sequences by individual car selection, thus insuring that the sequence may be as ordered as desired. It will be known as the ICS design. In order to illustrate the usage of such a technique and indicate the broad outlines of the economic advantages of such an application, a comparative study will be made.

The terminal problems of St. Louis will be reviewed and will be the base of a comparative study. The basis will not be the cost of operation and performance of the present fixed plant in St. Louis. This plant is generally recognized to be cumbersome in operation and costly in performance. The comparative base will be a design which has been specifically recommended to solve the St. Louis problem. This design is the most advanced possible within the limitations of existing technology. It is an"automated" hump yard.

Automation is a much misused concept, but it is in fact correctly applied here. Unfortunately it is only one stage of the terminal functions that is automated. This stage is classification. In the critical function of train assemblage, wherein yard output is determined, more conventional methods persist. Consequently a residual randomness of car sequence exists within the blocks of cars which then compose the train. This disorder is costly. Through the greater use of automation, the ICS design is intended to remove this residual randomness and its consequent costs.

CHAPTER ONE

THE TERMINAL PROBLEM

It is the purpose of this dissertation to explore a basic physical fact, which is the essence of railroading, and its relation to the everpresent railroad problems.

The fundamental datum from which we must begin is that the unit of revenue and sales in railways is the car, whereas the unit of operation is an aggregate unit, the train. The dichotomy of car and train is both created and resolved in the terminal of the railway. Thus it is that this paper focuses on the relation of car and train, i.e., the "terminal" problem.

The dimension of the terminal problem is sufficiently vast to be reflected in the overall railway problem. The competitive pressures on the railways during an automotive revolution are certainly largely responsible for the railway decline. The terminal problem is the principle channel through which these competitive pressures became effective. Without the burden of cost and delays resulting from terminal operations the railroads would not have been so severely handicapped.

This chapter will first examine the effects of this handicap in terms of the growth of other transport media. Then the burden itself will be examined together with a look at the terminal functions and costs. Finally, the interrelationship of yards in a railway system will be examined to establish a basis for an analysis of classification techniques to follow.

A: THE PROBLEM DEFINED

1: The Decline of the Railroads in the Transport System

In order to document the presence of a problem facing the railroads, we may take note of several facts.

The percentage of total intercity ton-miles carried in the United States by the railroads has declined continuously over the past twenty-five years. The only exception to this decline occured under the stresses of the second World War.[1] Traffic on the Great Lakes has shown relative stability since 1940. Other modes, however, have experienced a mushrooming growth which appears to be a postwar phenomenon. Indices of this growth are given in Table 1.

TABLE 1

Distribution of Intercity Freight Traffic
by Modes (Ton-miles) Index 1944=100

Year	Rail	Great Lakes	Inland Waterways	Motor Trucks	Oil Pipeline	Air
1944	100.0	100.0	100.0	100.0	100.0	100.0
1945	92.5	95.2	94.7	114.9	95.2	128.2
1946	80.6	80.8	89.1	140.7	72.0	131.0
1947	89.0	102.9	110.1	175.2	79.1	222.5
1948	86.7	99.9	137.4	119.2	90.0	314.1
1949	71.6	82.1	133.5	217.3	86.5	313.0
1950	79.9	94.0	164.6	296.7	97.2	447.9
1951	87.7	101.0	198.3	322.7	114.5	533.8
1952	83.5	88.0	203.4	334.0	118.5	584.5
1953	82.2	107.3	239.1	372.7	127.9	581.7
1954	74.5	76.8	262.9	368.4	134.9	559.2
1955	84.5	100.1	311.2	388.2	153.0	677.5
1956	87.8	93.2	348.3	435.5	173.1	793.0
1957	83.8	98.7	365.0	447.7	175.1	846.5
1958	74.8	71.6	337.7	446.2	167.8	915.5

Source: Exhibit accompanying the testimony of James M. Symes before the Subcommittee on Transportation, House Committee on Armed Services, at the Hearings on Adequacy of Transportation in the Event of Mobilization, July, 1959. p. 73.

The growth indicated above has continued apparently independent of the variations in aggregate traffic volume of the period. Consequently the proportion of the aggregate carried by rail has consistently declined. The decline, expressed as a percentage of the aggregate is exhibited in Table 2.

TABLE 2

Percentage Distribution of
Total Intercity Freight
Traffic By Modes

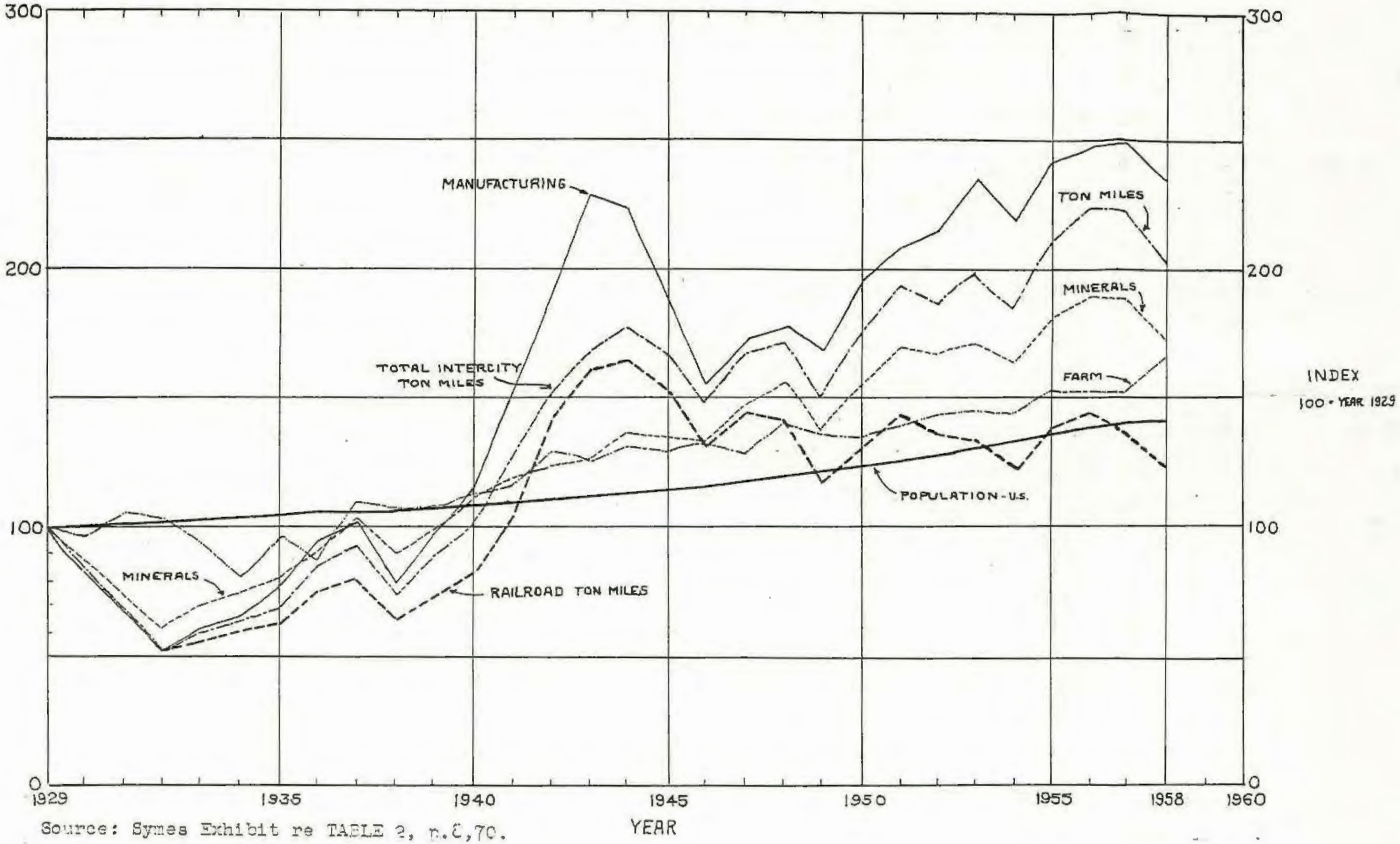
Year	Rail	Great Lakes	Inland Waterway	Motor Trucks	Oil Pipeline	Total
1934	70.8	12.5	2.4	5.4	8.9	100.0
1939	62.4	14.0	3.7	9.7	10.2	
1944	68.6	10.9	2.9	5.4	12.2	
1945	67.3	11.0	2.9	6.5	12.3	
1946	66.6	10.6	3.1	9.1	10.6	
1947	65.5	11.0	3.4	10.0	10.3	
1948	61.9	11.4	4.1	11.1	11.5	
1949	58.4	10.6	4.6	13.8	12.6	
1950	56.2	10.5	4.9	16.3	12.1	
1951	55.6	10.2	5.3	16.0	12.9	
1952	54.5	9.1	5.6	17.0	13.8	
1953	51.0	10.6	6.2	18.1	14.1	
1954	49.5	8.1	7.4	19.1	15.9	
1955	49.4	9.3	7.7	17.7	15.9	
1956	48.2	8.2	8.0	18.7	16.9	
1957	46.3	8.7	8.5	19.3	17.2	
1958	45.3	6.9	8.6	21.1	18.1	

Source: Exhibit accompanying testimony of James M. Symes, before the Subcommittee on Transportation, House Committee on Armed Services, at the Hearings on Adequacy of Transportation in the Event of Mobilization, July 1959. p. 72.

Another striking characteristic of this shift of traffic among the modes is the background against which the shifts took place. The aggregate ton-mile output increased almost uniformly since the depression year of 1932. Population

FIGURE 1

Indices of Economic Activity, U.S.
1929-1958



Source: Symes Exhibit re TABLE 2, p.8,70.

growth was also undisturbed except minimally during the war years. The country has experienced expansion of its output in manufacturing, farming and minerals. This economic growth of the nation is expressed graphically in indices in Figure 1. The year 1929 is presented as the index level 100. Also in this exhibit are curves depicting variations in intercity ton-miles.

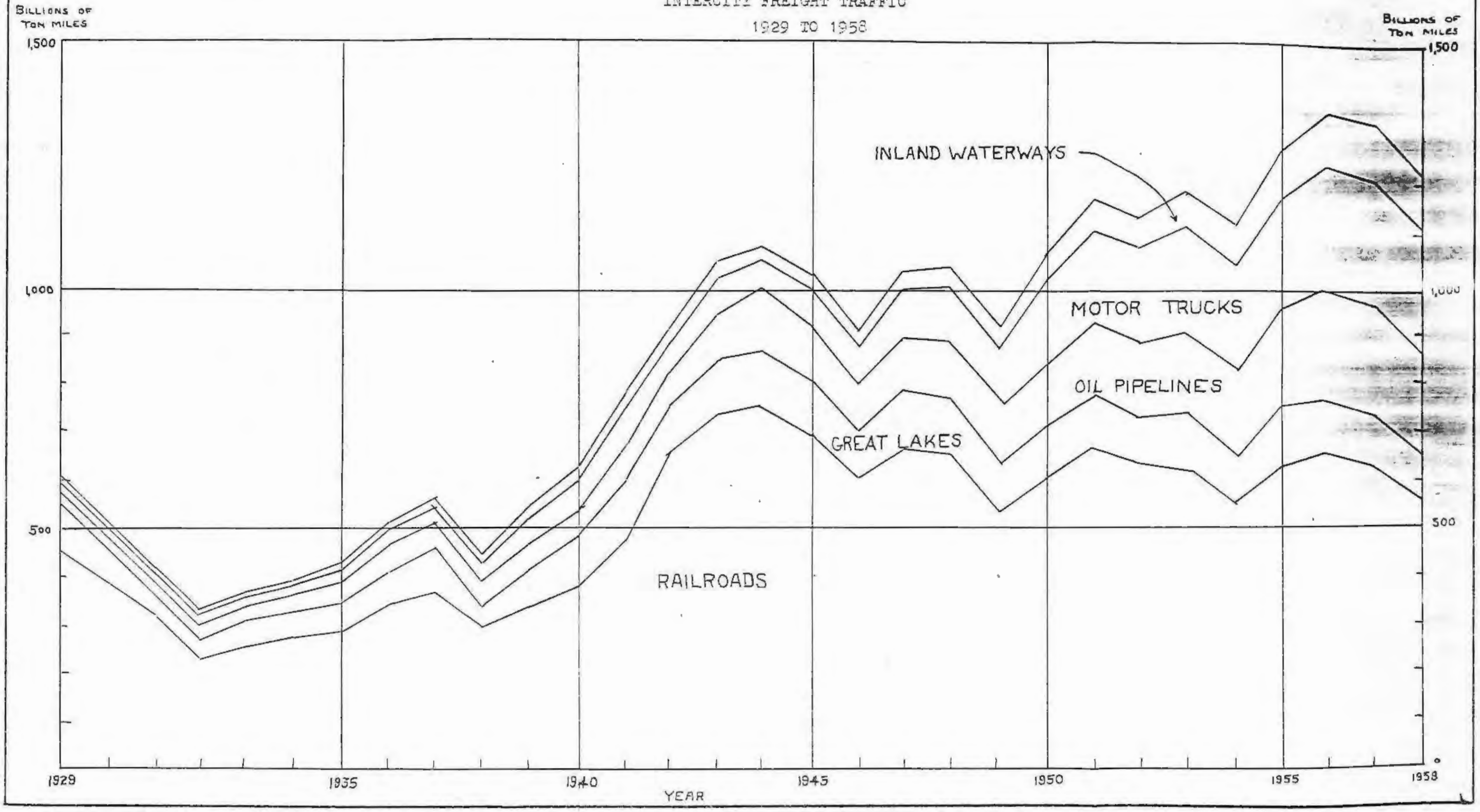
It is not suprising that the newer modes of transpotrt should carve for themselves an increasing proportion of the transport market. What is suprising, however, is the extent to which they have done so and the fact that in so doing they have virtually denied to the railroads any portion of the increase in aggregate ton-mileage. Railroad output has not only declined asa percentage of total output, but has failed to increase in absolute quantity in a market for transport which has increased markedly in the postwar period. This fact can be seen easily in Figure 2.

The "railway problem" has long been with us. A manifestation of the problem is the level of the rate of return of the carriers. A study, comparing this rate of return with other regulated industries concluded, "...the comparison in each instance indicates clearly the abnormally low rates of return realized by the railways, year by year". [2] The railway rate of return has not improved since the period of that study (1921-1948). It has in fact deteriorated since 1948, never having returned to the level established in that year. In 1948, the rate of return upon net property investment

FIGURE 2

INTERCITY FREIGHT TRAFFIC

1929 TO 1958



Source: Symes Exhibit re TABLE 2, p.71.

was 4.31 %. In 1958 it had declined to 2.76%.[3]

A low rate of return in a particular industry is not necessarily, of course, a sign that the public welfare is endangered. In the decade since 1948 competing carriers have siezed vast portions of the total traffic. The less traffic that the railways carry of the total the less essential to the public welfare they appear. Indeed, it may be that the railway is victim to economic Darwinism and that steps such as nationalization may only preserve an anachronism at public expense. Such a conclusion is not intended here. Rather, it should be noted that private interest is not identical with the public welfare.

2: The Terminal as a Factor in the Railway Decline

Relevant, from the standpoint of the public, are the causes for the railway decline. The decline is indicative or symptomatic of the presence of a problem, at least to the rail carriers. The problems may be categorized into three groupings; technological, governmental or managerial. Each may contain a key or critical factor. Necessarily acting within the limits of a given technology, neither government nor managers should impede the use of the economic potential of a mode contrary to the public interest. Some restraints, however, may be established for the general welfare. Such restraints prevent a mode from reaching the upper limit of its economic potential. They cannot do otherwise, as the limit of a mode lies within the technological characteristics of that mode. Thus the technological problem is a fundamental one. It stands logically apriori to the problems incurred from the mismanagement by government or private executives of the potential that lies within a technique of transport.

If the public is to obtain dependable, safe, economical transport it is necessary to accomplish several things. Each mode must absorb and apply from the sciences the knowledge which it can use to improve its technological formula. Further, each mode must be free of the human errors that diminish the efficacy of that formula. Failure to do so transforms the decline of an industry sector from a private to a public concern.

In the belief that the technological problem is logically apriori and significant, this paper undertakes to examine the basic principle of the railway formula. It is within this basic principle of railway carriage that a critical problem may be found.

The railway may be defined in several ways. In striking toward the essence of railroading we must eliminate those characteristics which are supplementary or derivative. The use of the flanged wheel is such a supplemental device. More complex guidance systems are tchnically possible and are actually contemplated for highway use. Steel rails and wheels provide additional economic advantage by offering low rolling resistance and high axle loadings. Standardization of gauge and fittings among the various firms insures wider distribution of the advantages of the railway formula. Underlying all of these, however, is the economic advantage of mass production of transportation derived of the dichotomy of car and train. Were it not for this advantage, conventional highway transport would probably be the equivalent of the railway. No difference in principle would remain between these modes of transport.

The essence of the railway is that the unit of production output is the train, whereas the inputs to prodution are individual cars. The question which faces railroading is this. Are the costs of the prerequisite conditions of mass production (terminal operations) together with the costs of the road haul, significantly less than the cost of any alternate method of creating space utility? The railway decline suggests that this difference is a quanta induffícient to stem the growth of other modes of transport.

The key opportunity for the railway lies in the control of the costs of terminal operations. It is in the terminal that the railway both creates and desassembles the trains. The terminal problem is a production problem. The yard is the basic tool of the terminal productivity. It is a physical entity and defined as follow: "The yard is a system of tracks within defined limits provided for the making up of trains, storing of cars and other puposes, over which movements not authorized by timetable, or by train order, may be made, subject to prescribed signals and rules, or instructions".[4]

3. Terminal Services and Functions

Not all terminal services utilize the yard as the final instrument of production in accomplishing a terminal service. These services are manifold and necessitate special facilities in addition to the yard for their creation.

Such services include;

1. the spotting of cars at specified points,
2. trap or ferry car service,
3. plant switching,
4. the icing or heating of cars,
5. storage of freight,
6. grain elevation,
7. weighing of freight, and,
8. loading and unloading services.

The physical facilities devoted to these services include;

1. running tracks from yards to industries,
2. sidings from running tracks to plants, piers, and warehouses,
3. team tracks,
4. storage facilities for merchandise traffic,
5. grain elevators,
6. bulk freight loading facilities,
7. freight stations, and,
8. transfer houses.

The primary function of these facilities is to provide some service necessary to complete the servicing of some commodity movement. They are distinguished as a group from yard activities per se in that they are not conducted for the convenience of the railroad. They are part, rather, of a service for sale. Conversely, the assemblage and disassemblage of trains is strictly a production activity, unrelated to sales except through its consequences upon price and quality of the service. As will be shown, these consequences are severe but the railroad chooses to incur these consequences rather than to move cars as individual vehicles.

The operation of yards entails the generation of two types of cost. They are monetary costs and time costs. The latter is usually recognized in the form of unusual delays but yard timecosts are properly a function of all time spent in yards. Time consumed in the yarding process is a function of yard design and the amount of work to be performed in that yard.

4. Terminal Delays

The road movement of cars can be performed with reasonable dispatch. Average freight train speeds have reached a new high at 19.2 miles per hour.[5] This figure is a national average of all freight trains and is based upon the aggregate mileage performance in any given year, divided by the total time that trains required from origin to final terminal. These data include all time required to pick up and set out cars on line and at intermediate terminals.

Train speeds have increased almost without pause since 1926. Grouped five year averages of freight train speeds are given in Table 3.

TABLE 3

Average Freight Train
Speed-5 Year Grouped Averages
And Selected Years

Years	Av. Speed
1926-30 Av	12.8
1931-35 "	15.5
1936-40 "	16.4
1941-45 "	15.8
1946-50 "	16.3
1951-55 "	18.0
1956	18.6
1957	18.8
1958	19.2

Source: Eastern Railroads Presidents Conference, Yearbook of Railroad Information, 1959.

Train performance has improved in other respects as well. Tonnage per train has increased considerably in the last decade.[6] Performances are not uncommon today which would have seemed sensational fifteen years ago. Merchandise traffic now moves from Chicago to the West Coast in sixty hours for third morning delivery.[7] Boston is second morning to and from St. Louis and Chicago.[8] The key to such performance, however, lies in the fact that such trains have little or no work performed on them at intermediate points. Their performance is not downgraded by the necessity of participating in the routine intermediate yardings that most trains undergo,

Train performance and car performance are interrelated. Car performance is based upon the former but cannot exceed it. Train performance is only one factor in determining car performance. The car spends only a fraction of its total time in trains. A study of this relationship was made by

Mr. L. F. Loree, an eminent operating officer of the Delaware and Hudson Railroad. His work, published in 1922, found that 14.9 days were required for the average freight car trip from placement at the loading point until release after unloading. The time during this interval was distributed as follows.

TABLE 4

Distribution of Time of an Average
Freight Car Trip

Event	Time in Days	Percent
Road Movement	1.49	10.0
Delay in road movement	.15	1.0
Interchange	2.48	16.6
Intermediate Yardings	1.55	10.4
Storage Tracks Movement to and delay on	.75	5.0
Repair tracks Movement to and delay on	1.34	9.0
Loading and unloading	5.74	38.5
Reconsignment delays	.50	3.4
Delays loading and unloading due to weekends and holidays	.90	6.0
Total	14.90	100.0

Shippers or consignees had the freight cars in their possession or control 36.3% of the above total time, while the railroad had possession or control for the balance, 63.7% of the time of the average trip.

Switching and interchange operations accounted for 60.4% of the time that the car was in carrier possession or control.[9] It is this fact which accounts for the vastly slower car movement than that of the trains in which the car moves.

Car speed, measured from consignor's release to consignee's placement, is difficult to estimate. It is derived and subject to considerable error. It is based upon a figure for average daily car mileage. This, in turn, is based upon total loaded car mileage per day divided by the size of the serviceable car fleet on that day. The denominator includes all cars serviceable but for which no loads were available and cars that were being loaded and unloaded. The size of the car fleet and the turnaround rate thus influences this statistic. During the peroid 1943-58 the car fleet has been erratic in size, but shrinking slightly over the entire period.[10] Car daily mileage has not moved upward during this period. To the contrary, it has declined. This movement may be seen in Table 5.

TABLE 5

Average Daily Car Mileage

Year	Miles
1943	51.0
1944	51.9
1945	49.3
1946	45.2
1947	48.8
1948	47.2
1949	42.9
1950	46.5
1951	47.2
1952	46.2
1953	46.5
1954	43.8
1955	48.2
1956	48.3
1957	47.0
1958	43.6

Source: Eastern Railroad Presidents Conference, Yearbook of Railroad Information, 1959.

The latest statistic (1958) indicates a mileage of 43.6 per day.[11] This is approximately 1.8 miles per hour over a twenty-four hour period. When correction factors are applied to measure car speed for loaded cars only, from release by shipper to the consignee's docks, a current estimate of five miles per hour seems reasonable. It is not surprising that the Federal Coordinator (FTC) reports described such service as "sluggish".[12] In the Freight Traffic Report of 1935 the data is summed as follows:

> The highway motor vehicle at present provides the speediest overall land transportation - on the whole averaging 15 MPH between consignor and consignee, compared with 5 MPH by railway, 3 to 10 MPH by waterways and 1 to 5 MPH by pipe lines. The relatively poor showing of the rail carriers was due in part to low speed limits imposed on train crews,... but chiefly to the fact that over two thirds of the carrier time is consumed in terminals and yards ...[13]

Evidence concerning car performance in the 1950's is available from a study by the American Railway Engineering Association (AREA). This study, issued in 1956, was based upon data collected from a 495 car sample. It was concluded that the average freight car spent 82.9% of the time of its movement (under railroad control) standing in some yard or terminal facility awaiting road movement. Only 17.1% was spent in actual train movement.[14] In 1933, the corresponding percentages were 69.6% - 30.4%.[15]

When a car is standing it is performing a warehousing function, not a transportation function. It can earn no revenue while awaiting movement. The motionless freight car therefore constitutes a liability to the carrier. The problem of terminal delay is commonly accepted as one of the most serious single problems that the carriers face. The competitive environment in the transportation industry today finds the railways effectively handicapped by their inability to provide a service as fast and reliable as that provided by the highway.

The Loree, FCT and AREA studies have concurred on three points. 1. Freight car movement is slow. 2. The freight car spends only a small fraction of its time in trains, the balance being spent motionless waiting for movement to destination to occur. 3. Terminal handling costs cannot be measured by the accounting records alone. The element of delay in terminals consumes vast unmeasured resources.

No evidence is known to exist which may contradict these concurrent views. They are the views of the industry and the supporting data are presented here in concise form to indicate the dimension of the problem. In summary, it can be stated that the railways have not succeeded in developing a yard design capable of performing the yard function without entailing the monetary and time costs presently incurred. Yard designs have been improved during the century. They have been better adapted to a wide variety of local yard requirements. During this era of refinement however, no change has occurred in the fundamental principle of yard operation.

5. Terminal Costs

This cost category includes all costs incurred within the physical limits of the yard. It excludes the time costs inherent in the yard operation.

Terminal costs include the costs of all terminal services and thus exceed yard cost alone. The bulk of these costs are yard costs, however, and are incident to the creation and dissolution of trains.

The Freight Traffic Report of the Federal Coordinator in 1935 contains a thorough analysis of the yard expenses. The data are not necessarily identical to that which would be based on present conditions. However, no current studies are existent on this subject. Further, it seems a reasonable assumption that there has been no significant changein the structure of railway operations or costs in the interim period. Therefore we may use the Coordinator's findings as an index to the existing structure of railway costs, road and yard.

The Coordinator concluded that yard operations were responsible for 54% of total railway costs. Road haul costs absorbed the balance of 46%. In 1932 the total number of switch engine hours was 50% greater than the number of road engine hours. In the same year the mileage of yard tracks exceeded that of all railroad branch line tracks and were half as great as the total mileage of main line trackage.[16] Terminal activity dominates the railroad in other ways as well. Exclusive of industry trackage, the yard system was found to have sufficient capacity to hold at one time over three and one quarter times the freight car fleet of the nation.

The Coordinator studies found the impact of terminal costs to be so great that it estimated road haul costs for a rather interesting situation. It hypothesized the existence of a solid commodity movement from siding track at point of origin to final destination without a single break in the train line. The train line is the air brake line which must be separated is any change in consist is made en route. Thus the train was to incur absolutely no terminal expense responsibility during its trip. In such a case, the study found that the movement of a full tonnage train could be conducted at a cost of less than 2 mills per net ton.[18] The revenue per ton-mile (average) paid the railroads during the five year period, 1931-35, was 1.013¢.[19] The level of 2 mills per net ton mile, the study noted, was below the then existing level of average costs for pipe line transportation.

The conventional car undergoes several yardings during its journey however. The study found that 37% of rail costs were to be found in the terminal and destination area yards. Intermediate yarding operations constituted 16% of total rail costs.[20] The impact of such costs on the railroad cost structure is considerable. Any improvement in yard operation or technique may become a highly significant element of cost reduction. Unless some fundamental revision of yard practice is undertaken, however, there is little hope that any real progress in yard costs reduction can be made.

B: THE HISTORY OF YARD INADEQUACY

1: World War I Congestion

Transportation requires resources both material and intellectual. Physical plant must be organized to function efficaciously. Order must be superimposed upon an otherwise discoordinated set of entities. This disunity of plant and organization was manifested by the transportation crisis of 1917.

The first World War was responsible for a surge of shipments to the East Coast of the United States for export at that time. The railroad system, then under private executive direction, failed to absorb this rush volume. From 1915 to 1917 the United States exported vast quantities of freight to the rest of the world. In 1917 the advance war materials for the United States Expeditionary Forces were added to this volume. The freight shipments of private, governmental and allied institutions competed for a place in line for export movement.[21]

Consequently the Port of New York, whose potential flow with proper control was of millions of tons of freight annually, proved ineffective. It and other North Atlantic ports became blocked. Despite an almost universal desire to ship from these ports in volume, their output was far below capacity. The reason for the jam was organizational. No single central institution was responsible for controlling the flow of export materials to the ports. As each shipment came into the port area it constituted a marginal private product far greater than the marginal social product it created through its consequences.

The jam was caused by mutual interferences of traffic. Ports and their piers can only function effectively when a delicate balance of inbound and outbound movements prevails. There is little storage space at the port. Freight must arrive just prior to loading and the empty car promptly switched out of the way of additional traffic. Coordination requires a consolidated institution for its guidance.

The immediate result of the uncoordinated flow to the ports was that railroad freight yards, in approach to the ports, became storage points. It is at this point that the problem mushroomed in dimension. The problem had been organizational. But here it took on a technological aspect. The freight yard whether flat, hump or gravity, is a production tool that must be lubricated. The storage of cars in yards reduces the ability of the yard to do its job, i.e., classify cars. The inverse relation between the car storage function and the performance of work in terms of switching of cars is a technical characteristic of yard design. The organizational problem had manifested itself through the physical limits that yard design imposed upon its output.

In addition to the jamming of yards, there occured the issuance of many priority orders for movement in a vain attempt to insure movement. This necessitated the performance of extra switching work in lining these priority cars for outbound trains. Conventional yard design is such that much time is required to extract a car from the middle of a cut of cars. During this time the yard leads are jammed and other work cannot proceed.

As yard output fell, so also trains could not run, for fewer could be created. The paralysis spread inland from the Atlantic coast ports.

> For example, on a typical day in December, 1917, 12,500 carloads of freight "on wheels", about 8,000 more on railroad piers, and some 22,4000 in ground storage were held at the port of New York alone. In addition, an estimated 25,000 carloads on wheels were held out of port on sidings all along the main lines as far West as Pittsburg and Buffalo and even beyond.[22]

Thirty-seven thousand, five hundred cars were unavailable for loading and useful movement. Rigid embargoes against the movement of export freight became necessary. It was not until March of 1918 that a free flow of traffic resumed. By this time the railroads had been siezed by the government in an attempt to resolve the crisis.[23]

The Second World War export traffic was controlled far better. The underlying limitations of the yards, however, was attacked as well as the organizational problem. This was done by providing special holding and reconsignment yards where goods could be held in covered and open storage until the ports were ready. By so doing the other yards were free to act in their classification function. Yard trackage was not used for storage per se.

Consequently, although the rail system in World War II transported 746.9 billion ton-miles in the 1944 peak year as compared to the 408.8 billion in World War I (1918) the system remained fluid. This does not mean, despite the 1958 output of only 557.0 billion ton miles[24] that out yards are adequate to present needs. Adequacy must be measured in terms of costs of output and the ability of the yards to remain fluid. Only the fluidity problem was attacked and resolved by the Office of Defense Transportation.

2. The Development of the Long Train

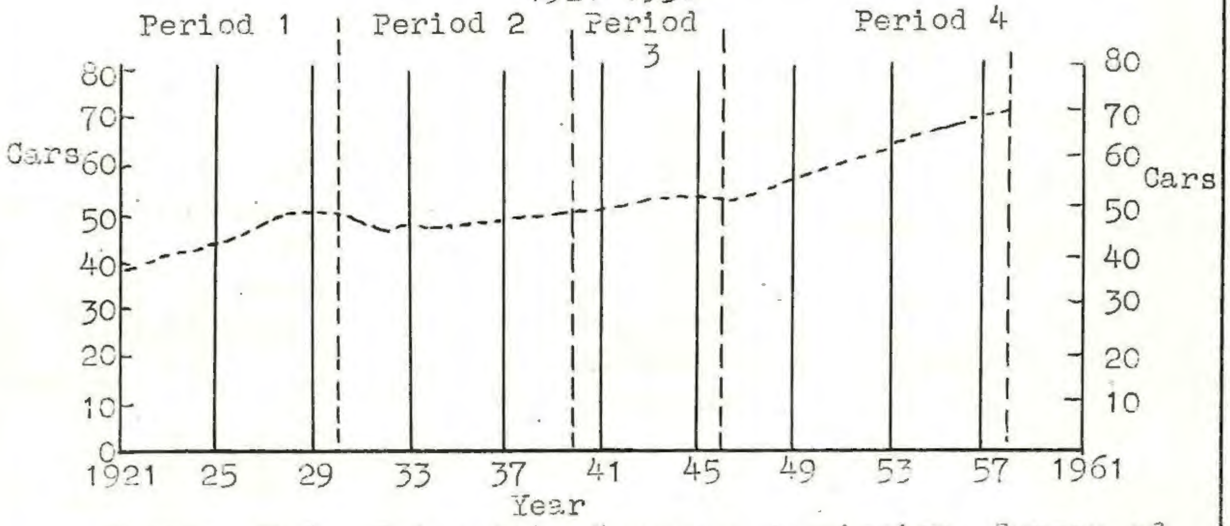
Yard capacity has always been adapted to some degree to the general pattern of railway operations. Often this was not accomplished through conscious design. The basic yard pattern of trackage is quite flexible. The uses to which it can be put are many, given a particular layout. A group of parallel tracks, simply interconnected, can be used for storage, classification, departure, inspection, and receiving of cars. Additional costs are incurred when these many functions are permitted to interfere with one another. Yard design in some locations became quite sophisticated to avoid these costs. By the addition of spedial facilities as icing platforms, scales, etc., a general purpose track could be used for specific functions in addition to its more generalized use.

Frequently, however, the sophistications of separate yards exclusively devoted to storage and other functions were not attained. Yard trackage can match the requirements of local conditions due to its inherent plasticity. There is one limitation, however, to this general adaptability of yards. This lies in the length of the yard tracks. Length controls the capacity of the yard to hold an uninterrupted group or string of cars on one track. As the train must arrive or depart from the yard in a continuous unit, the yard must be of sufficient length to hold a full train. Classification can be performed upon shorter than train length cuts of cars. In the conventional yard, however, where all functions take place upon one set of trackage bundled by a common track, if train length does not match yard length the entire yard is of disproportionate size.

Prior to this century trains were commonly limited to twenty-five cars. The cause of this limitation lay in train brake design. Until the automatic air brake became universal in application longer trains were impractical. Violent slack action accompanied a brake application on a long train by straight air.[25] The automatic air brake was quicker in response and was instrumental in permitting the growth of longer trains as motive power was developed.

Statistics on train length are distorted by the inclusion of branch line trains whose length is determined by traffic rather than by technological factors. While recognizing the existence of this downward bias, the growth of train length can be seen in Figure 3.

FIGURE 3
Average Freight Train Length
1921-1958



Source: U.S., Interstate Commerce Commission, Bureau of Statistics, Statistics of Railways in the U.S. 1921-58

The periods indicated in Figure 3 are characterized by the influence of the following factors:

Period 1. 1921-1930. Improved motive power.

Period 2. 1930=1940. Low or moderate traffic levels. No significant change in motive power.

Period 3. 1940-1946. High traffic volume. Some superpower steam locomotives. Increased proportion of mainline trains to the total.

Period 4. 1946-1958. Motive power revolution- dieselizarion. "Normalized" traffic levels. Fewer trains.

The downward bias of branch line trains became more pronounced in the last period as trains became fewer in the aggregate. In spite of this the trend toward the long train is pronounced. Multiple unit operation of diesel-electric units permitted the diesel to become everyman's superpower. It allowed roads with limited clearances, sharp curves and light axle loadings to indulge in high horsepower locomotives whose forte is pulling power in the low speed ranges. It was, in fact, the series wound direct current traction motor (the diesel's transmission) which revolutionized the freight train in America.

Labor and material costs were captured in an inflationary spiral in the decade from 1946 to 1955.[26] The long train made possible by the diesel-electric's tractive effort was the answer of the railways to this problem. Basic in consequence was the fact that the yards of the nation were simultaneously outmoded. They no longer were matched in design to the characteristics of their input and output.

3: Today's Situation Summarized

Train length on the main line of American railways is now commonly in the 125-175 car range. A 150 car train is approximately one and one-quarter miles long. Such length is a postwar phenomena. As trains enter or depart from old yards they tend to hang over onto the mainline, or at a minimum, block the yard approach leads from which the switching work must be performed.

"Doubling" and "tripling" are the practice commonly used to create long trains of short segments. In this practice the locomotive will couple to a first group of cars, pull forward, and "double" back for a second cut on an adjacent track. It backs until the coupling is made; train brake air lines are then joined. If a third cut is to be added, the now combined two sections are moved forward and backed (tripled) against the third cut of cars.

Recently, Mr. Perlman, President of the New York Central Railroad, inquired about the operating practices at one of NYC's Chicago yards. Two hundred forty cars were moving East per day in three trains.

> He adked why a gradeless road couldn't run a pair of 120 car trains and save a crew, was told that yard switches would permit doubling over to make up a train ... but not tripling. A simple trackwork change soon updated the yard to diesel length trains.[27]

Presumably the trackwork change was an extended yard lead. Tripling could then occur without blocking the main line. Such a change would not eliminate the need for doubling and tripling moves themselves, however. It only permits the railroad to live with an outmoded facility for a while longer.

Outmoded and inadequate yards are commonplace. Mr. John Barriger reviewed the present day situation in American railroading and wrote as follows:

> Technical, economic and commercial obsolesence is the outstanding characteristic desclosed in the operation of most railroad yard and terminal facilities. These are most generally less representative of modern engineering and operating technologies than any other important feature of railroad work ...
>
> Modernization of the freight yards and terminals of the United states and the subsequent more effective utilization of them represents an immense undertaking, but it is essential to avoid continued excessive costs and car detentions ...
>
> There are probably as many as 500 freight yards in the United States which could be modernized or revised for more effective use. After this is done, probably half as many others can be closed. The cost of transportation and equipment for the former will run from $50,000 to $20 million each and will average about $6 million. The total cost of these improvements will be about $3 billion.[28]

Today's system of yards is costly and burdensome. Improvements are needed acutely.

C: THE YARD IN THE RAILWAY SYSTEM

1: Randomness

The product of the yard is the train. Technically the train is a "locomotive or locomotives coupled, with or without cars, bearing markers".[29] For our purposes the presence or absence of classification lights (markers) on the cars is immaterial. The above definition is established in order to facilitate control of road movements. Yardmen have a different perspective. To them the train has a more common sense definition, i.e., a car or sequence of cars arriving or leaving the yard.

Apart from any storage function which the yard may perform, the yard output is that which constituted the input. The same cars which flow inward later flow out. The apparent input and output do not differ to the casual observer.

Yards create order. This is their function. Their input must be less ordered than their output for the yard to have contributed to the railway operation. The input cars must be handled in accordance with the individual characteristics of each car. The characteristic most frequently controlling in nature is the destination of the car. The car must be forwarded from the yard with other cars toward its destination. Although the cars in the output group do not have identical final destinations they may share a routing to some common advance point. It is the fact that there is a possible movement in common that underlies the existence of train operation.

The order that the yard superimposes upon its input may only be to select the cars with common routing to the next yard. It should be noted that this procedure, however, does not necessarily create an ordered sequence in the cars of the output train. Rather it creates a train which itself is a unit of order insofar as all the elements within itself have been selected by a common criteria. Within the aggregate unit of order,i.e., the train, it is possible that there may be no order.

The obverse to the concept of order is disorder. Disorder of car sequence will be known as <u>random sequence</u>. By random sequence is meant that, if a selection process were undertaken, any car of a sequence of cars would have an equal chance of being selected from the group. Also, any prediction of car position would be limited to an apriori probability in which chance is the sole determinant of car position.

This statictical use of the concept of randomness is not fully applicable to our case. Occasionally the timing of inputs to the yard may follow some pattern and the input itself may be consistently of certain commodities in known movements. This may induce some residual degree of order into an otherwise truly random car sequence. Consequently, the term random will not be used here in its full statistical sense. To so use it would be to overstate car sequence disorder. It is an appropriate term, however, when used in its generic sense. Car sequences are said to be random, for our purposes, when no conscious design or order has been imposed upon the sequence. The sequence is one of chance and haphazard in nature.

2: The Theory of Yard Interrelationships

The yard prepares sequences of cars for road haulage. The road movement must terminate at a point at which the cars in the train no longer have some criteria for inclusion in the train. If such cars are randomly distributed in the train the entire train must be terminated. Road movement, therefore, links the output of one yard to the input of the next. Road movement occurs when a yard can generate a car sequence based upon the selection criteria of movement to some common point. As soon as road movement has occurred yarding must be repeated. A new criteria of common movement must be found and used to create a train. If the yard orders car sequence, as well as merely producing any haphazard sequence, it is establishing order internal to the train.

The train, as an aggregate unit, is a unit of ordered yard output. However, when the train arrives at the next yard it has consumed this unit of order. A unit of order has been expended in the sense that it is no longer in the stock of consumable resources. As the train enters the second yard it constitutes an input which has no more order than exists in the car sequence alone. If this sequence were truly random the order in the input would be nil. To the extent that the sequence is ordered the yard input is ordered. The first yard will have performed some of the work that the second yard could have been called upon to accomplish.

Yards are thus linked together in a railway system in two ways. First, the sum of the outputs of all yards must equeal the sum of all yard inputs. The term sum is used here to mean a cumulative count of the physical units (the cars). Second, the internal train order created at yard A becomes an input to yard B.

If yards can, to some degree, substitute for the activity of other yards, the following question arises. In what manner should work be allocated to yards in a system so as to minimize the total costs? This is a complex subject.

The variables are many and interdependent. Restraints must be placed upon the possible values which the variables might take in order to establish a realistic model. This is the type of problem well suited to the methodologies of operations research. It is not the purpose of this paper to explore the structure or mathematics of these relationships.

The New York Central Railroad faced such a problem during the last few years. The Central recognized the need for a new yard of high capacity in its Southern District, but did not know where to locate the yard. St. Louis, Toledo, Cleveland, Bellefontaine, Columbus, Indianapolis, and Cincinnati were possible sites. The operations research study gave recognition to the fact that an optimum solution could not be found by examination of local savings alone. The effect of a yard is felt systemwide.

> In addition to purely local savings, there are also potential district or system savings. If a new yard permits finer classification than an old facility, classification than an old facility, classification cost can be cut in other yards.[30]

By "finer classifications" are meant, a higher degree of order in car sequence than previously existed. The performance of this work in one location spreads its effect to other yards. The remaining yards have less work to perform and are therefore less costly to operate.

3: Maintracking

The theory of yard interrelationships has been presented. This relationship manifests itself in a practice known as maintracking.

This practice consists of the creation of trains at yards of origin which are composed almost exclusively of cars for some destination terminal. The destination in question is separated from the point of origin by several intermediate terminals. These intermediate yards are bypassed. The train remains on the mainline at these points. In essence, the criteria used in train formation has been selected in such a way as to minimize the work performed on a set of cars and lower the total costs of operation.

Previous to the 1920's, prevalent operating practice dictated the movement of trains from one yard to the next closest yard. Little attempt was made to study the yard in the system.[31] Under such practice each individual yard performs a minimum of work. It merely assembles trains for movement to the adjacent yard. Almost all cars handled move on to the next yard; therefore very few switching moves need be made to prepare such a train. Only a few need to be handled individually for local movement. Yet the sum of the individual "minimized" yard costs may be far greater than a policy whose focus is system wide operations.

The practice of maintracking sprang up extensively in the 1920's. The experience of the Rock Island Railroad will be described below to illustrate the practice, its purpose, and the results.

Each yard is assigned a pattern of classification to perform. The pattern of classification work is the set of groupings into which the yard sorts cars. This set is established in order to minimize costs for the system as a whole. Classification policy had been established on the Rock Island prior to the systemwide study of 1925. Classification policy was designed by local supervision for the apparent needs of their division. Systemwide policy, however, was an unknown dimension. The Rock Island undertook a traffic study previous to establishing a systemwide classification policy. The traffic study undertook to learn the volume of traffic from each yard, the territories to which dispatched, the nature of the traffic and the trains in which it was then being dispatched.

The classification policy study was an attempt by the Rock Island to solve congestion and cost problems without expending capital on new yard facilities. Therefore, the classification policy had to be formed in such a way as not to overburden any one existing facility. If possible it would reduce peak loads at some yards. There were severe limits on the advance work that an individual yard could accomplish prior to dispatching a maintracker.[32]

Such trains were composed of not one but several groups or "blocks" of cars. Each block was prepared for a specific destination. Within each block, car sequence was random. At a limited number of intermediate yards the train would have a block for that yard removed. An additional cut of cars would be added if desired. This added cut would be composed of cars moving to the final destination. During this train recomposition, the body of the train would remain on the maintracks adjacent to the intermediate yard. This form of maintracking is most common. It insures the advantages of maintracking without incuring costs for higher train miles than would otherwise be necessary.

The principle which underlay the classification policy was simply systemwide optimization of costs and train performance.

> As was determined by the preparatory efforts the work which is done in one yard has a direct bearing on each yard into or through which traffic passes, so it was desirous and necessary that the influence of each yard in the operation of other yards by carefully determined and taken advantage of.[33]

The results of the new operation were favorable. Terminal costs did not increase.

TABLE 6

Traffic Volume and Yard Engine Hours
Percentage Change
1926 From 1923

Yard	Traffic	Yard Engine Hours
Silvis	+15.6%	-11.6%
Kansas City	+20.0%	- 1.2%
El Reno	+19.4%	- 0.5% *
Nine intermediate yards from Silvis to Fort Worth	+20.1%	-2.0%

* Reduction in spite of local oil field switching undertaken since 1923.

Source: Railway Age, vol. 82, no.8, p. 520.

The speed of movement was increased as well. For example, the run from Little Rock, Arkansas to Chicago, Illinois was speeded as follows. In 1923 only 2% of the cars would arrive at destination within five days. An additional

8% would arrive within the sixth day. In 1925, after the system classification plan was functioning, 25% of the cars arrived within five days and another 26% within six days.[34]

The evidence verifies the theory of yard interrelationships. The railway freight yard does not exist merely in a local dimension, but rather in a systemwide dimension. The benefits of an excellent yard design will spread to other portions of a system. The criteria of excellence in yard design is the ability of the yard to minimize total system costs by creating internal train order.

The following chapters will explore the production techniques possible by which random car sequence can be minimized where it is an economic liability.

Footnotes

Chapter 1

1 Eastern Railroad Presidents Conference, Yearbook of Railroad Information (New York: Eastern Railroad Presidents Conference, 1959), p.4.

2 Sidney L. Miller and Virgil D. Cover et al., Rates of Return Class I Line-haul Railways of the United States, 1921-1948 (n.p.; University of Pittsburgh Press, 1950), p.121.

3 E.R.P.C., op. cit., p.72.

4 Delaware, Lackawanna & Western Railroad Company, Rules of the Operating Department, effective April 27, 1952 (n.p.;n.p.,n.d.), p.17.

5 E.R.P.C., op. cit., p.45.

6 Ibid., p.43.

7 Railway Age, June 15, 1959, p.9.

8 Railway Age, November 30, 1959, p.80.

9 L. F. Loree, Railroad Freight Transportation (New York; Appleton, 1922), p.263-4.

10 E.R.P.C., op. cit., p.40.

11 Ibid., p.11.

12 U.S., Federal Coordinator of Transportation, Freight Traffic Report (Washington, D.C.; 1935), v.1, p.113.

13 Ibid., p.23.

14 American Railway Engineering Association, Proceedings, (Chicago; American Railway Engineering Association, 1956), v.57, p.321.

15 U.S., Federal Coordinator, op. cit., v.2, p.71.

16 Ibid., v.1, p.95.

17 Ibid., v.1, p.95.

18 Ibid., v.1, p.103.

19 E.R.P.C., op. cit., p.49.

20 U.S. Federal Coordinator, op. cit., v.1,p.98.

21 Russell W. Humphreys,"U.S. Army Control of Port-bound Traffic During World War II" (unpublished Master's thesis, Wharton School, University of Pennsylvania, 1948), p.5.

22 Joseph R. Rose, American Wartime Transportation (New York; Crowell, 1953), p.74.

23 Ibid., p.75.

24 Exhibit accompanying testimony of James M. Symes,president, The Pennsylvania Railroad Company, before the Subcommittee on Transportation, House Committee on Armed Services, at the Hearings on Adequacy of Transportation in the event of mobilization, July 1959, p. 70.

25 C.M. Drennan, ABC's of Air Brakes (New York; Simmons-Boardman, 1954), p.14.

26 E.R.P.C., op. cit., p.90.

27 Trains, June,1957, p. 17.

28 John W. Barriger, Super-Railroads for a Dynamic American Economy (New York; Simmons-Boardman, 1956), p.51-2.

29 D.L.&W.RR. Co.,op. cit., p.17.

30 Railway Age, February,24,1958,p.14.

31 Ibid., v.76,no.38, p.1817.

32 Ibid., v. 82,no.8, p. 519-522.

33 Ibid., p. 518.

34 Ibid., p. 521.

CHAPTER TWO

THE FLAT YARD

It has been shown that the freight yard is a production tool. This tool establishes the prerequisite conditions essential to economic road haulage. It is the purpose of the following chapters to examine this production tool in its many forms. Each form or yard design has advantages and disadvantages. By studying these we will be led to a better understanding of a particular design's suitability and limitations. Where possible, recommendations will be made to overcome these limitations.

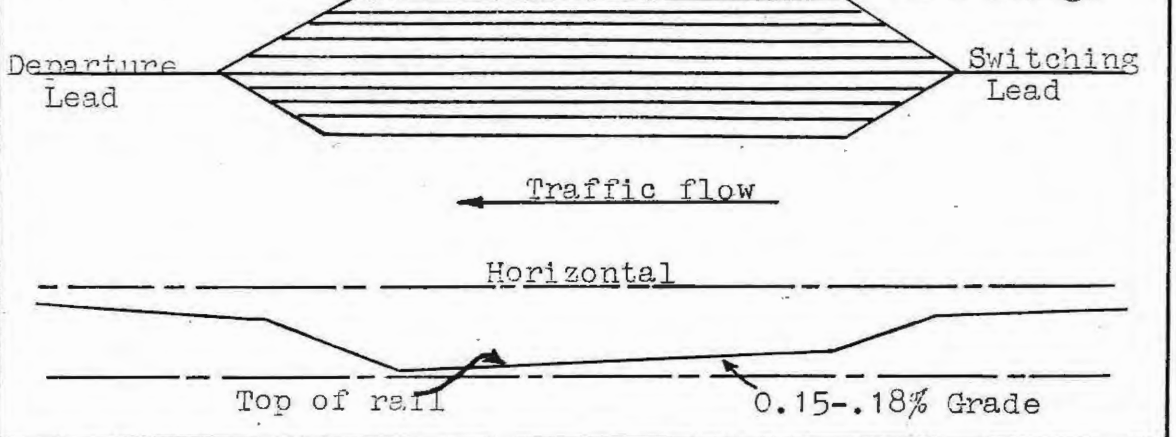
A: PHYSICAL CHARACTERISTICS

The "flat yard" is named for its cross section elevation characteristic. The section is longitudinal, i.e., parallel to the yard tracks and through the length of the yard. The adjective "flat" would suggest that all such yards are absolutely horizontal in elevation. The yard is rarely perfectly flat. It may be built on a slight incline. It may rise and fall in elevation with the peak at almost any point in the yard. Yards have often been placed with little concern for the difficulties that gravitational forces may have upon the yard operation. In the Erie Railroad yard at Salamanca, New York, for example, switchmen find it necessary to apply hand brakes on the cars after they have been placed upon some of the classification tracks. Failure to secure the car might result in a runaway car and possible derailment.

Gravitational forces on a car may be a help in the right place in a flat yard. If the yard gradually slopes downward, away from the switching leads, cars shunted to a track will have a tendency to continue rolling until they are in the clear and couple to standing cars much farther down the track. In such a case, the switch engine will have to work less hard. Less initial momentum will have to be supplied such a car in switching. Similarly, gravity may be used to stop a car in a flat yard. If the class tracks, at the end farthest from the switching lead, were to incline upwards, cars switched to these locations on their own momentum would stop as they gained potential energy. It is therefore unnecessary for the switch engine to accompany such a car to the far end of a class track and make an affirmative stop. Considerable time can be saved by this technique. A yard which declines fom the switching lead to the class tracks and then inclines at the end of those tracks is known as a saucer shaped yard. The cross section is illustrated in Figure 4. The St. Louis-San Francisco Railway built such a yard in the post-war period in Tennessee.

The flat yard is, therefore, not necessarily flat. An accurate definition must be negative in this instance. The flat yard is one in which the accelerative impulse to motion for classification is not provided by gravity. Yards are thus primarily defined as gravity and non-gravity (or flat) yards. In the flat yard gravity may be used for control purposes but not as a power source.

Figure 4
Cross Section Elevation & Diagram of Saucer Yard Design



Frequently, the flat yard is a creature of the desire of the railway to perform the yard function at minimal capital cost. As has been pointed out, this type of yard has great plasticity of function. The fact that it can be constructed with little concern to land elevation and a minimum of grading keeps cost under control while creating a tool which is simple, durable and flexible in use.

D: OPERATING PROCEDURE

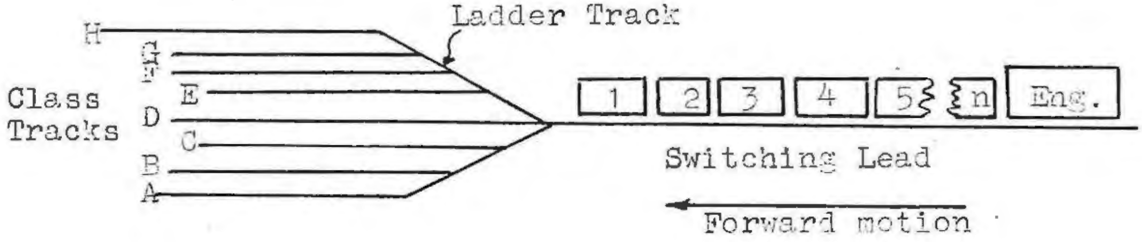
Two techniques have been used in flat yard operation for classification purposes. The function of both is to move cars from some common track (the lead) to a specific classification track. In both techniques, the criteria of car movement is most commonly the routing of the car. A track corresponding to a frequently used routing from the yard receives all cars which share that routing. Class tracks are assigned routing significance rather than destination definition because of the multiplicity of possible destinations. Routings are fewer and correspond more closely with an economically possible number of class tracks.

1: Tail Switching

This technique is the most commonly used method of classification in the world. It requires no special investment for grading of land or supplementary trackage. Prior to actual classification, a sequence of cars to be switched is placed on a switching lead. We shall not the sequence as 1,2,3,...n. Car 1 is defined as that car nearest the class tracks, cars 2 through n being succesively farther away. Last in the sequence is the locomotive (next to car n).

FIGURE 5

Position of Cars and Engine
During Tail Switching



Within this sequence (1...n, locomotive) every car or group of cars to be sent to one classification track as a unit is known as a cut. A cut is an uninterrupted sequence of cars of the same category. Several cars, sharing the same routing to some advance point may be in a cut.

Switches on the ladder track which control the routing of the cars into the class tracks are usually operated manually by menbers of the five man switch crew. This crew consists of two enginemen, a foreman and two switchmen.[1] The foreman has two sources of information upon which he bases his switching moves. First, he has a list of the cars 1...n on the lead track. The destination or route of each loaded car is on this list. Empty cars are classified according to car service rules.[2] Secondly, he knows which tracks in the yard are to receive cars of certain routings. He might, for example, direct that cars 1...n be distributed to class tracks a, b, ...z in the following possible pattern.

TABLE 7

Switching Problem

Car Sequence	1	2 3 4	5	6 7	8	9...n
Cut Number	1	2	3	4	5	6...m
Track Assignment	A	D	E	A	D	C...Z

Foreward motion of a locomotive, for our purposes, is motion toward the class tracks. Given the above pattern to be executed, the foreman would command "one for A". A switchman would line the switches and a highball would be given the engineer. The cars 1...n are then accelerated toward the class track. When the coupling pin is "free" and sufficient momentum attained the switchmen signals for a stop. The forewardmost car will continue to track A on its momentum. As soon as the car clears the switches the field switchman will follow the second command of the foreman, "three for D". Switches will be relined as necessary and foreward motion again begun. The coupler pin will be lifted between the cars numbered 4 and 5 in the notation of Table 7. This three car cut will then be set free to drift into track D.

When the commodities in the cut are of an exceptionally fragile nature the switching crew is expected to follow a more controlled proceedure. The fragile cut will be shoved to its proper position on the class track while still coupled to the other cars and locomotive. Car speed is thereby controlled by the engineman during the entire classification move. The cut is released only after it is in its proper position. Then the engineman backs up to the lead track to resume the normal "kicking" of cars to the class tracks. Controlled placementis more time consuming and less efficient than the "kicking" method.

In 1958 the railroads paid $108,552,818 in damage claims.[3] A large portion of this is due to the shocks received by ladings during classification. Some portion may be attributed to normal slack action which occurs in road movement. Attempts of the railroads to reduce these payments have had little success. Only a basic revision of classification techniques could lead to a permanent improvement in this situation.

As cars are classified, the foreward motion of the sequence, i.e., cars and locomotive, carries it farther forward then desired. It becomes necessary to move the entire sequence of cars backward to the lead track in order to unblock switches to the class tracks which became occupied due to the cumulative forward motion. The backward motion is wasteful of time and fuel. The frequency with which it is necessary to undergo this reversal process is indicated by the fact that this technique is known as "push-pull" switching.

Tail switching is, therefore, characterized by a high incidence of shock action on the cars. These shocks occur whenever the car sequence is started or stopped suddenly. Motions tend to be sudden in switching moves, furthermore, because of the slack action which exists and the need to prevent forward creepage by strong braking action.

The cars 2...n, of the original sequence 1...n, undergo two shocks (runs of slack) with the release of each cut. The number of shocks delivered to cars in their cut groups varies from 3 per car for cut number 2 (N_2) to $3+2(m-2)$ for cars in cut m. The number of shocks received by all the cars 1...n is equal to the sum of the series:

$$N_1+3(N_2)+5(N_3)+7(N_4)+\ldots(3+2(m-2))(N_m) .$$

where N_2 is the number of cars in the second of m cuts. Where n=25=m, N=1 and the summation equals 625 car shocks. This is an average of 25 car shocks per car. The number of cuts in the sequence m, therefore, also equals the average number of shocks received per car. This average can be kept low by classifying cars with a low number of cuts per series. The number of shocks any car in a cut will receive is equal to twice the cut number less one.

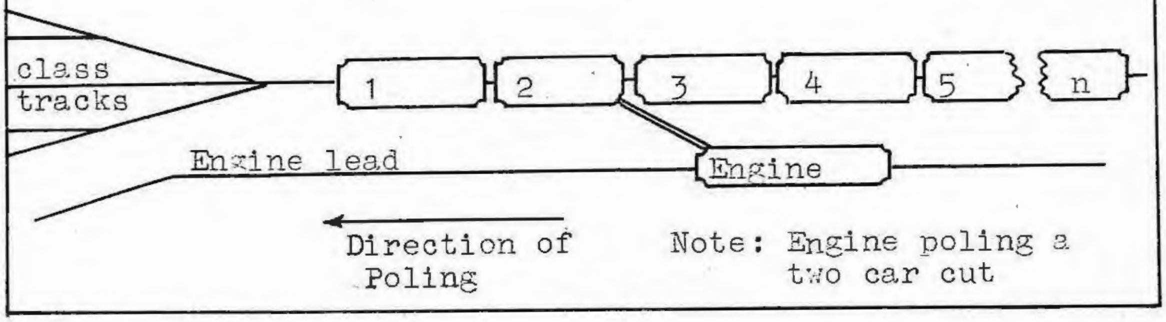
Minimizing cuts per series reduces damage but tends to slow the switching process. The yardmaster is, therefore, caught in a vise of costs pressing from either direction. Most commonly the pressure of time wins out. Damage costs tend to be regarded as a necessary part of railroading, an irreducible sum.

2: Pole Switching (Poling)

The major disadvantages of tail switching for moderate volumes of traffic (500-1000 cars a day) are the damage entailed and the time consumed in moving cars other than the one to be classified in making a single move. The most direct method to avoid these disadvantages is simply to accelerate each cut toward its class track successively without moving the cars behind the forward cut until they in fact become the forwardmost cut. In pole switching the rear cars remain motionless until propelled exclusively to their own class track. Motion is imparted only to the forwardmost cut.[4]

The engine cannot transmit power to a cut through the medium of other cars of only the forwardmost cut is to be moved. Also, the engine cannot be placed directly behind each cut to be moved without engaging in an unduly complex set of movements. The simplest method to permit the movement of one cut at a time is to place the locomotive behind and slightly to the side of the cut to be moved. The locomotive moves on a track parallel to the lead track and transmits power through a pole forward and laterally to the rear of the cut to be moved. A transverse vector of force is transmitted to the car but this does not impair the operation. The operation is illustrated in Figure 6. The forces transmitted to the cars are not delivered to the center sill through the coupler and draft gear. They are delivered directly to the underframe at the corner of the car. Each corner of the car has a socket to receive the pole which reduces the chances of slippage and accident. The socket is known as a poling socket.

FIGURE 6
Position of Cars and Engine
During Poling



Note: Engine poling a two car cut

The operating procedure of the poling yard is similar to that of the tail yard with the exception of the method of application of power. Usually a special purpose car was built to precede the engine. From this car there were four poles, two on each side, one of which worked forward, the other to the rear. This technique gave better control over the positioning of the poles and enhanced the speed and safety of the operation.[5] The poling technique, which is an anachronism now, was refined to such a point that two cuts would be started at once. The two cuts, coupled, were released from succeeding cars and propeled by a pole on the rear car of the first cut. When rolling at a speed proper to the second cut the coupling between the cuts would be broken. Then the engine would again accelerate, moving the first cut far enough ahead of the second to enable proper throwing of the switches between the cuts.

Poling is no longer used in the United States, as far as can be determined. Although it was superior to flat tail switched yards for medium traffic volumes (500-1000 cars per day) the gravity yard proved even more advantageous. The pole yard was therefore displaced by a superior design.

The poling technique necessitated the free motion of cars after being kicked by the pole toward a class track. Cars with fragile lading could not be easily controlled as they moved to the class track. In order to insure, therefore, that the cars did not contact other cars on the class track at excessive speeds, car riders were frequently employed in poling yards. These riders climbed aboard the moving cars and controlled their free speeds with the hand brake.[6]

As poling proceeded along the sequence 1...n the distance traveled from the point of release to the class track increased. To overcome correspondingly increasing frictions, speeds of release from the pole must increase. In order to compensate for the increased power requirements called from the locomotive, a descending grade toward the class tracks was sometimes utilized. When the yard had a horizontal elevation and high volumes of traffic, a second locomotive placed behind car n of sequence 1...n could shove the sequence forward as poling proceeded. If the grade in the lead track was favorable and sufficient the cars might be brought forward by gravity under hand brake control.

The poling yard was an attempt to avoid the wasted energy and time consumed by switching a forwardmost cut through the medium of other cars. It applied impetus exclusively to the cut requiring it and thrust that cut toward destination without reversal of cars and shock to lading. It thus sought to be a continuous motion process.

The pole yard had advantages over tail switching by having a higher capacity. More cars could pass through this poling process per day than in a tail switch yard of similar track layout and elevation.[7] The engine had better control over initial car speed than in tail switching. This resulted from the fact that the engineman did not have to accelerate a large body of cars, but only a limited cut. In cases where a strong kick was required, as in cold weather with a hard rolling car, the engine could provide sufficient initial speed to the car in a short distance. This was due to a relatively high power-weight ration as compared with tail switching.

C: FLAT YARD OUTPUT, COST AND EFFICIENCY

Yard output, it has been noted, is an ordered car sequence. This can take two forms. First, the train per se and secondly, internal train order. The latter becomes an input to some advance yard to which the train moves. The work of the yard is to create order. The measurement of order is difficult at best however. Further, its measure is of consequence to us through its effect upon the cost of transportation. As the optimum condition of production is minimum cost, we will define the optimum degree of order as that which results in lowest system costs.

In measuring yard efficiency we must first measure the output, i.e., the useful work performed. This can be measured, by the number of cuts made. The volume of cars per se is not as significant a measure of work.

Each classification requires cuts to be made upon the input sequence. The number of cuts varies with the degree of order imposed upon the input. This can be seen in the case where there are three class tracks and an input of cars "perfectly blocked", i.e., only two cuts need be performed upon the input to break it into three groups, one for each track. Each cut in a perfectly blocked train contains all the cars of the sequence for any one track. If the inputs were disordered, up to as many as one cut per car would have to be performed.

The number of cuts per car relates input to output. The less order in the input the higher the number of cuts per car becomes. Further, the more ordered the output, the more classifications (cuts) that will have to be performed. Again the number of cuts per car increases. Cuts per car are directly proportional to order desired in output, and inversely related to order of the input. This corresponds with the earlier assertion that work at yards was interrelated. The ordered input for a yard diminishes the work to be performedat that yard.

The measure of work we have choosen for the flat yard corresponds logically with our analysis. It also, however, has empirical verification. The greater the amount of order created, the higher the cost. In the railway flat yard, variable costs are a function of the time required to perform various classifications. The more time required for a task, the more fuel, engine maintenance and crew time is assignable to that task. By measuring time therefore we can couple cost to output.

A recent study demonstrated the following relation between time required to switch a cut and the length of the cut.

TABLE 8

Calculated Decrease in Yard Engine-minutes per Car, as Size of Cut is Increased

Number of cars in a cut	Engine-minutes per cut (x_1-a)	Average engine-minutes per car	Per cent average engine-min. per car
1	3.16646	3.1665	100.00%
2	3.45606	1.7280	54.57
3	3.74566	1.2485	39.43
4	4.03526	1.0088	31.86
5	4.32486	.8650	27.32
6	4.61446	.7691	24.29
7	4.90406	.7006	22.13
8	5.19366	.6492	20.50
9	5.48326	.6092	19.24
10	5.77286	.5773	18.23

Source: Walter B. Wright, "How Cars in Multiple Cut Costs", Railway Age, January 4,1960,p.24.

A regression analysis of the original data was used to derive the formula on which the above table was based. The following notation was used in defining these relationships:

X_1 = yard engine hours per day in classification

X_2 = cuts of cars per day

X_3 = cars per day in excess of one per cut

a = yard engine hours independent of cars or cuts switched

b_2 = yard time per cut

b_3 = yard time per car in cuts greater than one car.

They are interrelated as $X_1 = a + b_2X_2 + b_3X_3$ which simply states that the yard engine hours are equal to a sum of the values:

1. time independent of switching (a),
2. time per cut multiplied by the number of cuts,
3. additional time per car for cars in a cut in excess of one multiplied by the number of such cars.

The first car in the cut was found to take 3.16646 minutes (X_2). Each additional car in a cut (X_3) took 0.2896 minutes further. Each day, 808 minutes at the yard studied were independent of the volume of business (a). The last factor includes time for lunches, handling cabooses and merely waiting for cars to accumulate prior to switching them. The above formula values[8] fit the data with a coefficient of correlation of).83.

The additional time and cost required to switch the second car in a cut is very small. Only a 7% increase is required by the presence of a second car in a cut. This percentage is derived of the ratio $X_3/X_2 = 0.2896/3.16646$. Time and variable costs in yard operations are therefore related closely to the number of cuts made rather than the number of cars handled through the flat yard.

Yard efficiency can be best understood, therefore, in terms of the relation of cost to the order created by the yard. This order is measured by the number of cuts performed. If work measurement concerned itself with the physical volume of movement through the yard it would miss the essential nature of yard operations, i.e., its order creating function. Physical volume is important but of secondary importance.

Costs in a flat yard tend to be variable with changes of traffic volume. Few elements of fixed plant are required other than trackage. Thus, variable costs become a large portion of total expenditure in an active yard (500 to 2000 cars per day). The variable costs are a bit lumpy, that is, quite discontinuous. A crew and engine trick must be assigned by eight hour units and considerable variation in traffic (approximately 500 cars per day) will occur before more or less tricks can be economically operated at new traffic levels. Fuel and engine maintenance are the most continuously variable expenses of flat yard operation. This general variability of costs is in contrast to the cost behavior of gravity yards which will be discussed in the following chapter.

Footnotes

Chapter 2

1 Agreement between the New York Central Railroad Company, Western District, and the Brotherhood of Railway Trainmen, Cleveland, Ohio, December 1, 1955.

2 The Official Railway Equipment Register, October 1959, LXXV, no.2 (New York, The Railway Equipment and Publications Company Agent), p.777.

3 U.S., Interstate Commerce Commission, 72nd Annual Report on Transportation Statistics in the United Ststes for the year ending December 31, 1958.

4 John A. Droge, Freight Terminals and Trains, (New York, McGraw-Hill Book Co., 1925), p.63.

5 Ibid., p. 64.

6 Ibid.

7 Ibid., p.65.

8 Walter B. Wright, "How Cars in Multiple Cut Costs", Railway Age, January 4 1960, p.24.

CHAPTER THREE

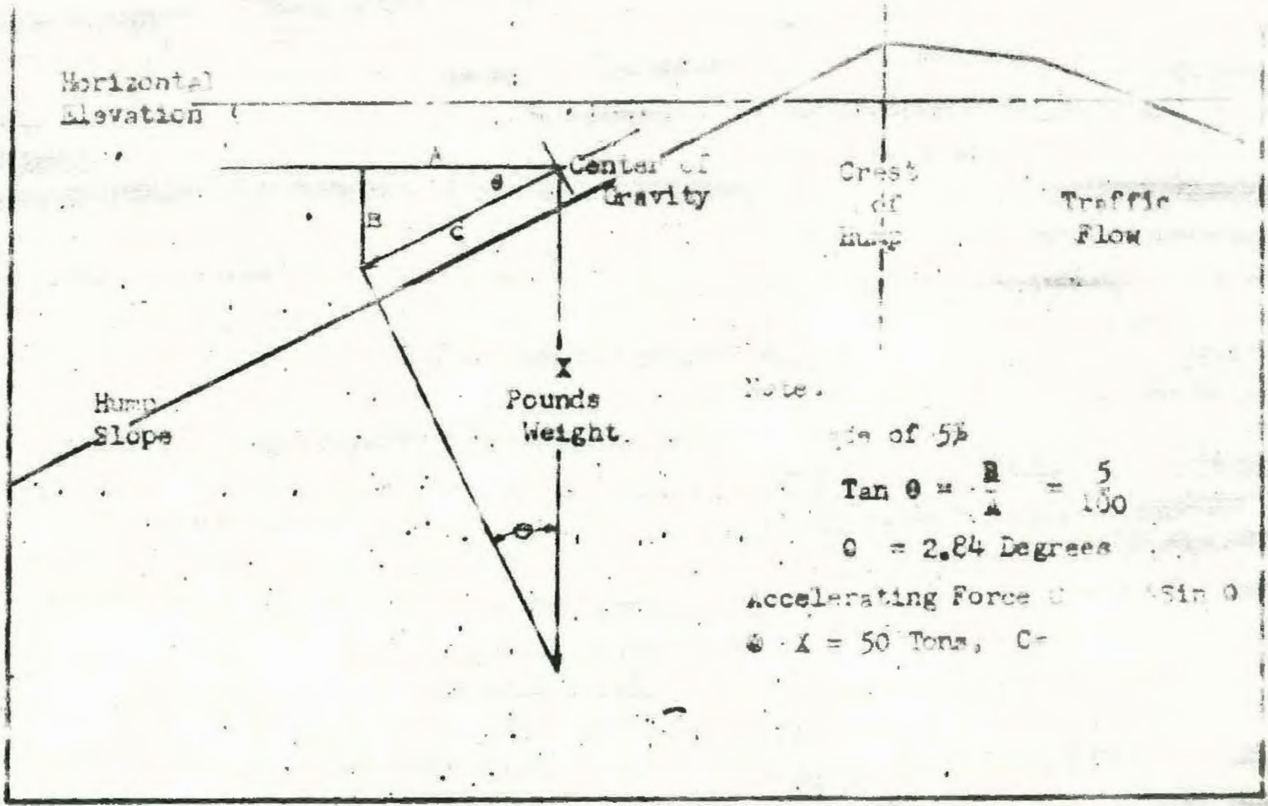
THE GRAVITY TYPE YARD

Flat yards were defined in a negative manner as being nongravitational. By this was meant that the accelerative impulse to motion received by a car in classification was by forces other than gravitation. Gravity yards are the converse side of this concept and it is to them that we now turn our attention. The propulsion of a car by utilizing the gravitational attraction of the car and earth is not new. In 1846, in Dresden, Germany, a yard was operated which used gravity.[1] It was 1882 before a gravity yard was operated in the United States, however.[2]

The gravity yard has found extensive use in this country. By 1917 eighty such yards were operating.[3]

A: PRINCIPLE OF OPERATION

In principle the yards are simple. The cars are pushed to a summit or arrive at the edge of a downward sloping grade. In either case the cars are placed at some elevation higher than that of the classification tracks. The cars therefore have potential energy, i.e., energy of position, and can exchange this form of energy for kinetic energy. The cars are successively pushed toward the downward slope and permitted to accelerate as the gravitational forces develop



Note.

Grade of 5%

$$\text{Tan } \theta = \frac{B}{A} = \frac{5}{100}$$

$$\theta = 2.84 \text{ Degrees}$$

Accelerating Force C [illegible] Sin θ

@ X = 50 Tons, C=

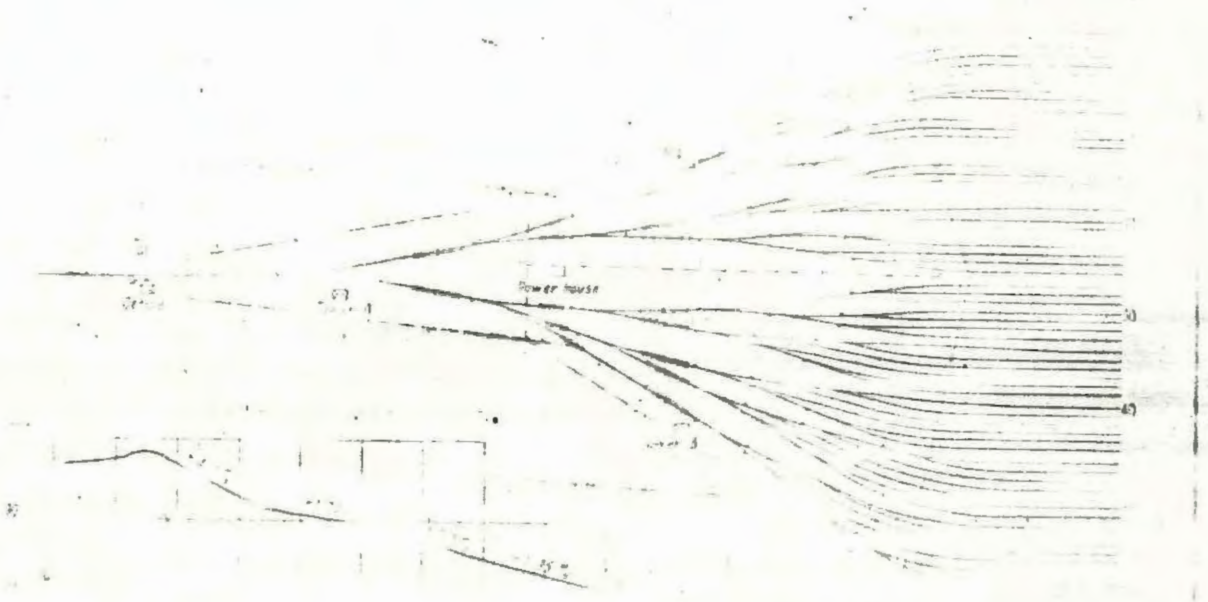


Figure 8
Elevation and Track Diagram of
Hump Yard

a propulsion vector. It is this vector (see Figure 7) and not the shoving locomotive which propels the car forward to the class tracks.

The basic physics of the matter are no different than the release of a child's sled on a snowy slope. Acceleration forward is a function of the loss of height and very soon stopping becomes a problem. The relation between velocity (V) and loss of height (H) is expressed in the formula $H = .0334 \cdot V^2$.[4]

1: Method of Operation of Gravity Yards

In the gravity yard today, an artificial hill or hump is built to provide the necessary height. The cars are placed on a lead track which suddenly shoots upward in the direction of traffic flow. Cars acquire the necessary potential energy as they are shoved to the summit or hump crest. As they are pushed forward they enter the downward grade portions of the hump and are accelerated by gravitational forces. The locomotive shoves cars forward in order to feed cars across the hump. The elevational cross section and track diagram of a typical yard is described in Figure 8. The engine does nothing to separate the cars as in tail switching with all its stopping and starting. In hump yard operation the cars become separated at the crest where the coupler pins are lifted. The separation is due to the acceleration of the forward cut prior to the acceleration of the next cut. The existence of separation between cuts moving down the ladder tracks makes it possible to sort the cuts onto their proper class track as the cars go over the hump in a continuous motion. This type of switching is characterized by an absence of backing up moves and intermittent thrusts forward to the class tracks. The operation is best described as a single smooth motion, giving the appearance of the greatest ease.

2: Retardation

Each car has a different distance to roll to other cars standing on the class tracks. As it is desireable that the cars should couple gently to the others standing on the class track, it is necessary to control the speed with which the car leaves the hump area. Failure to introduce such control will permit the car, a free rolling object, to collide with other cars with high impact and damage to both cars and lading. If the height of the hump is lowered to reduce car exit speeds some cars will fail to move to the end of a class track on a cold day when journal lubricants do not wick properly. Individual car speed control becomes imperative therefore for economic operation of hump yards.

Such control, or retardation of speed, must occur prior to car coupling on the class track in order to avoid impacts on full tracks prior to retarding action.

In current practice rolling motion is impeded by a pair of brake shoes attached to the track structure. These shoes are longitudinal to the rail and grip or squeeze the car wheel between their two opposing surfaces. Such devices are known as retarders and their use is common.

For many years retardation was accomplished manually by men riding the cars who operated the hand brake. The cost of wages to these persons and the associated liabilities for injury combined to make remote controlled retardation the more efficient of the two methods.[5]

Retarder operation has become not only remote controlled but completely automatic. Operators who formerly controlled the setting for each car at every retarder are now displaced by electronic gear which measure all the relevant factors and make the proper settings.

Some of the facotrs that such equipment must evaluate are the following:

1. distance the car has to roll to its coupling point on the assigned class track,
2. rolling resistance of a particular car,
3. amount of curvature en route to class track,
4. winds and temperature, and
5. car weight.[6]

The rolling resistance of the car varies with each car and is measured by its degree of acceleration as it comes down the hump. The acceleration is measured by radar instruments. A radio beam of fixed frequency is focused at the car coming down the hump. The echo return frequency is distorted by the car acceleration and becomes a measure of that acceleration. This information together with other data is evaluated by an analogue computor which determines the exact amount of retardation required by each particular car.[7]

B: PROBLEMS IN HUMP YARD DESIGN

Despite the automatic retardation features of some hump yards, such yards are far from having evolved to their highest state of advancement possible. One fundamental problem remains in existing hump yard design. That is the limited rate at which cars can be sent across the hump and be classified.

1: Disuse of the Hump

The speeds with which cars are fed to the hump and the consequent humping rate per hour and day are given in Table 9.

TABLE 9

Humping Rates at Varying Speeds

MPH	(1) Feet per second	(2) Cars per hour	(3) Cars per day	(4) Actual cars per day @ 40 min. use per hour
2.0	2.93	263.7	6328.8	4177.0
2.5	3.66	329.4	7905.6	5218.0
3.0	4.40	396.0	9504.0	6273.0
3.5	5.13	461.7	11080.8	7313.0
4.0	5.86	527.4	12657.6	8354.0
5.0	7.33	659.7	15834.8	10450.0
6.0	8.80	792.0	19008.0	12545.0
7.0	10.26	923.4	22161.6	14627.0
8.0	11.73	1055.7	25336.8	16722.0
9.0	13.20	1188.0	28512.0	18818.0
10.0	14.66	1319.4	31665.6	20900.0

Actual humping rates are lower, as given in column 4, than the potential rate, column 3. This is caused by periods during which the hump is not in use, in spite of the presence of cars awaiting humping. The hump is not in use for twenty minutes of the hour on an average. The causes of this disuse are many. The necessity of waiting for the arrival of cars at the yard is one cause. This factor is usually negligible due to congestion at the hump caused by limited humping speeds.

The main cause of disuse is the need to correct errors in humping proceedures. This is known as"trimming". It is done by an engine whose crew shoves cars in the clear when they stop too soon and respots misclassified cars. During the period of trimming, the trackage between the hump and class tracks is occupied and cannot be used.

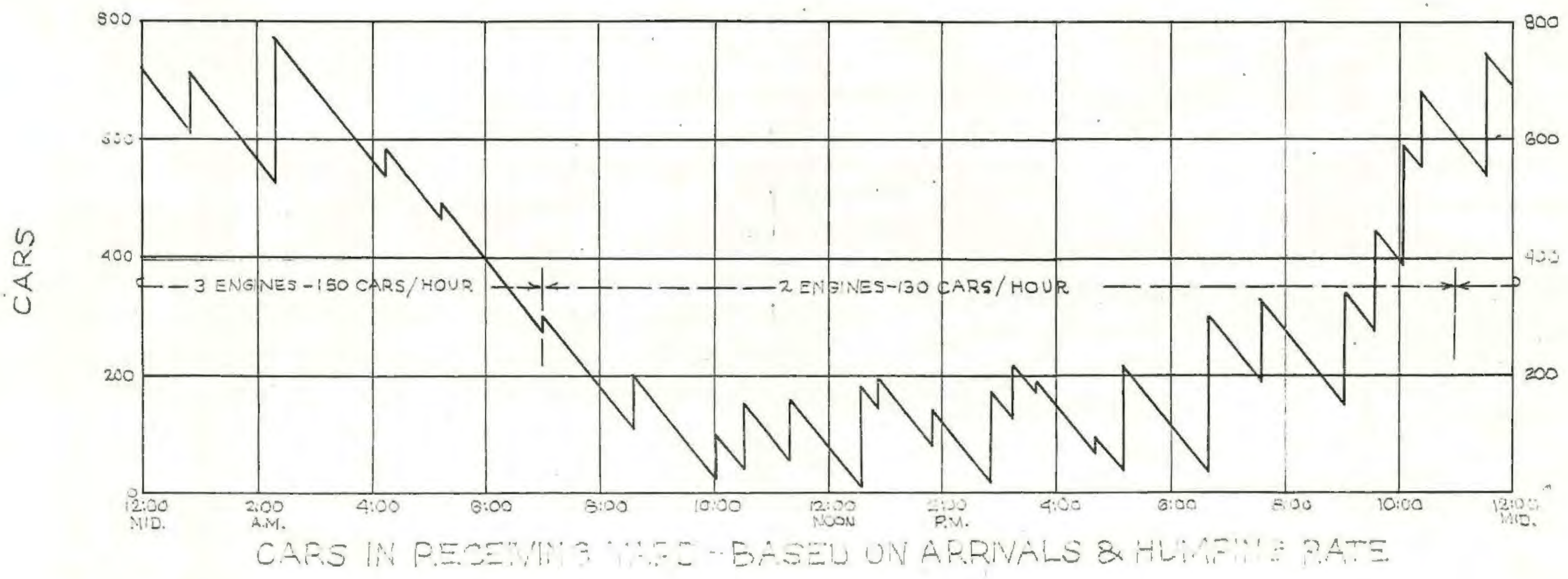
2: Receiving Yard Congestion

If cars arrived at a hump yard in a steady flow totaling 4000 cars per day there would be no congestion at the hump. Trains, however, are scheduled to meet the needs of commerce and arrive bunched in groups. To illustrate the bunching effect Figure 9 shows the anticipated fullness of a receiving yard at Youngstown, Ohio during periods of the day. It should be noted that this yard was equipped with the most advanced control devices and yet the humping rate did not exceed 150 cars per hour. During the full twenty four hour cycle the receiving yard would fill to a maximum of almost 800 cars. The arrival of only three short trains during a six hour period gives the yardmaster the opportunity he needs to catch up on a backlog of traffic.

At the close of the business day, the rush begins, and the backlog swells from a 100 car level toward 800, necessitating delay to cars. In a highly competitive environment the railroad is penalized by these delays.

FIGURE 9

Receiving Yard Occupancy, Youngstown, Ohio



Source: Youngstown Yard, Analysis and Recommendations
New York Central System, March 31, 1956.

There are costs associated with slow delivery schedules. Slow car speed necessitates high car ownership in relation to car loading. If the road is supplying the shipper with a car fleet to meet his needs, perhaps ten cars must be supplied per carload. This is because, as one is loaded, many others are simultaneously moving toward destination, being unloaded or returned.

This relationship is illustrated by car ownership by the New York Central Railroad of 110,615 cars at the close of 1959.[9] Average car leadings per day during that year were 8,915 cars.[10] This is a ratio of 12.41 cars per load per day.

The cost of such car fleets is considerable. The New York Central had to pay a 5% rate on equipment trust certificates in 1957, the last date car financing was undertaken.[11] At an average value of $5,000 per car the NYC would pay, at the 1957 interest rate, $27.6 million annually as the cost of capital. This figure is considerable when compared to the $8.4 million net income the road earned in that year.[12]

3: Closure Rates

We can conclude that the limitation on flow rates over the hump is the primary problem affecting hump yard design. In order to increase the flow rate we need first to understand the factors which create this limitation.

Disuse of the hump is organizational in nature. Physical causes lie in the acceleration of one cut toward another cut as the cuts roll toward the class tracks. The velocity of the first car in any sequence may be slower than that of the second. As a result there occurs a closure in the space between the cars. Loss of this space necessitates slow hump speeds. If a cut catches up with another, it will not be possible to throw the switch points after the first cut has passed and route the second cut toits proper class track. The method used to insure ample spacing to counteract this effect is the slow hump speed. Low flow rates permit a cut to get a long headstart prior to the acceleration of the following cut.

Closure is caused by two factors. The first factor is the difference in the natural acceleration of two cuts on the same grade. This results from the various rollabilities of the cars due to various types of bearings, rolling resistances as a function of bearing temperature, wheel surfaces, alignment of wheels and axles (skewness), dragging brake shoes and wind resistances.

The second factor is the introduction of external control over car velocity. The use of car retarders introduces differences between cut velocities. These are the most marked variations that can be introduced. The master retarders have the cars while they roll off the hump on the initial grade. This grade is the steepest in the yard, frequently of 4%.[13] Although unable to stop a car which normally enters this retarder at 12.5 to 15 miles per hour it can slow it to four miles per hour.[14] A difference of car velocities between cars can, therefore, be introduced by the master retarder of as much as eleven miles per hour.

The group retarders receive the cars at slower speeds and on more moderate grades. They are placed just prior to the class tracks, a group of which lead from a single group retarder. These retarders are able to bring a car to a dead stop. Velocity increments between cuts may, therefore, be as much as the maximum speed of a following cut.

The master retarder is usually used to release at some pre-established speed. By so doing it brings the cars within a speed range that the group retarders can then adequately handle. When necessary, it can release at higher speeds to permit a light car to roll onto a long track without further restriction from the group retarder. As existing design places the retarders <u>between</u> the hump and the class tracks, there is no method of obtaining the proper spacing of cars consistent with high flow rates across the hump.

C: RECOMMENDATIONS

In order to increase the flow rate, without diminishing the ability of the yard to perform a high number of cuts per train, several steps must be taken.

First, artificially induced closure rates must be avoided. These are derived of the actions of group and master retarders. The retarders must be removed from their present location and placed in the bowl at the end of each class track. By so placing the retarders they will be eliminated as a source of velocity variations between cuts. The retarders should be deep enough on the class tracks (three car lengths) to avoid slowing cuts which are still on the ladder track. The economics of such placement will be discussed in Chapter Six.

The only velocity variation remaining between cuts would be introduced by winds, rollability and track curvatures for any routing. Two successive cuts destined for different class tracks will share a routing for some part of their free roll journey. To the extent that they share a routing, they will be subject to the same curvature resistances. Retardation and closure effects from this source will be avoided, by eliminating retarders at their conventional position on ladder tracks.

The remaining resistances of wind and car rollability are nominal near the hump. As the two successive cuts move father from the hump these resistances have cumulative effect and may again present a closure problem. Because of these factors a second and third step are necessary.

The second recommendation to avoid closure problems depends upon a change in the switch control circuits.

Cuts roll through sections of track known as track circuits as they go down the hump. The rails are one element in an electrical circuit which detects the presence of a car on a section of track. Detection is accomplished by the shorting of the circuit by the car wheel and axles. This occurs when current flows from one rail to the adjacent rail. The track circuits are used in the classification process to inform automatic devices of the proper time at which a switch can be thrown to line up the track for the next cut. These circuits are often as long as the switch, from switch point to clearance point. Therefore, although a cut has passed the switch points and they are physically capable of movement they are locked in position until the track circuits no longer detect the presence of the cut at some farther point toward the class tracks.

The lock up period of the switch presents a barrier to the following car, if the switch is to be relined for classification of that car. It is as if the first car had suddenly stopped dead in its tracks for several seconds and the closure rate was thereby increased. It is possible to do two things to avoid this closure effect.

First, one can change the time required for point movement. Switch points can be moved in 0.6 seconds in most designs today. A new design switch machine has reduced this time to 0.4 seconds.[15] This is advantageous. However, the greater part of the lock up time is caused by the length of the track circuit.

Second, the length of the track circuit can be shortened, thereby shortening the time of occupancy of the circuit. The ideal circuit should lock up the points from movement only during the period during which the wheels are on or about to pass over the switch points themselves. For a description of a circuit proposed to accomplish this see Appendix One.

The faster the rolling speed of the cars the greater the separation needed to allow ample time to throw the points. The minimum separation is a function of the length of the length of the switch point (commonly ten feet) and the speed of the approaching cut. Table 10 below gives a possible set of such spacings where 0.5 seconds is allowed for point movement. Such spacings do not exceed one standard car length of forty feet. As closure rates will be modest it is unlikely that even high humping speeds of ten miles per hour would fail to allow sufficient spacing.

TABLE 10

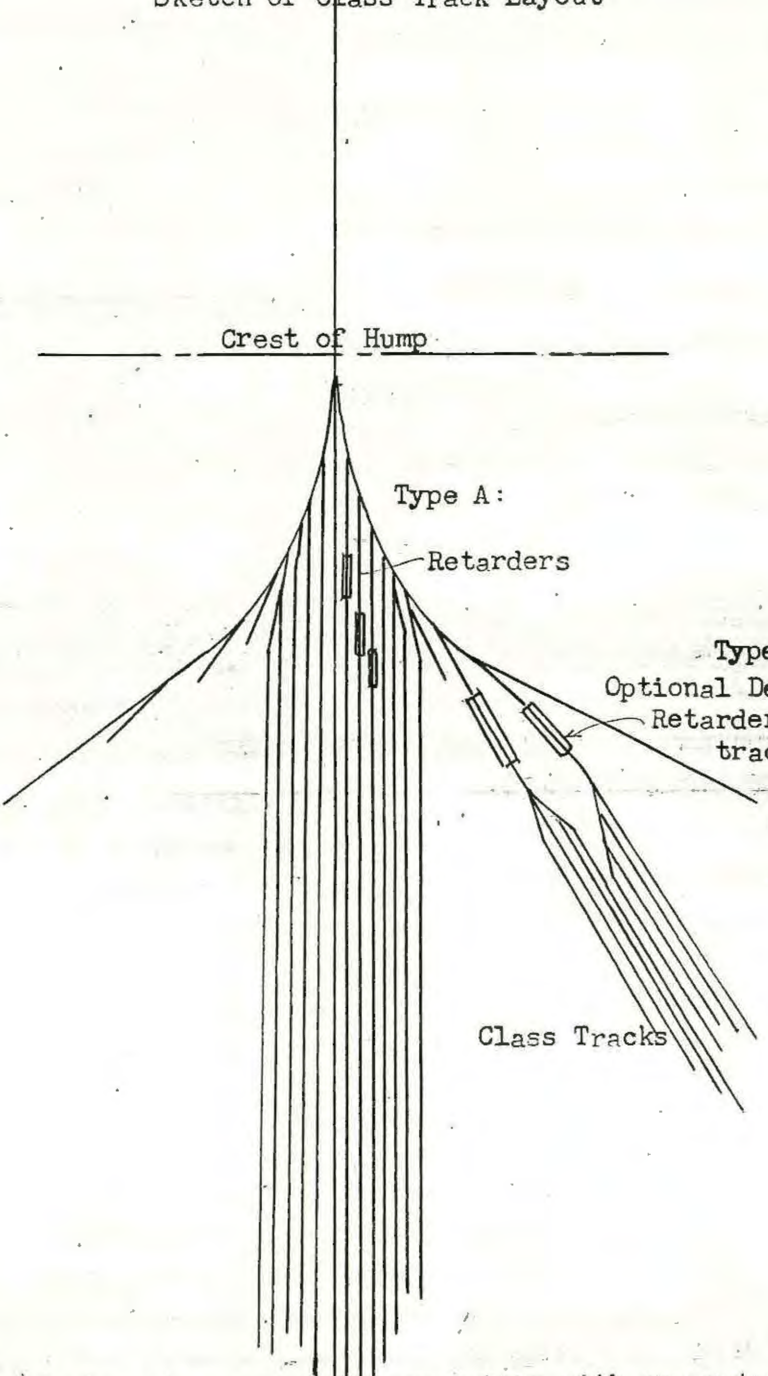
Minimum Allowable Distance Between Cuts

1 Speed of approaching cut (V) mph	2 Feet traveled in 0.5 seconds at V	3 Length of point (Q) in feet	4 Minimum separation (2+3)
5	3.66	10	13.66
10	7.33	10	17.33
15	11.00	10	21.00
20	14.66	10	24.66
25	18.33	10	28.33
30	22.00	10	32.00

The final method of controlling spacing is more abstract. Spacing can be created by alternating the tracks to which cars are distributed so that few cars in immediate succession share a routing. The input of cars is less than perfectly random, but the cuts are mixed none the less. It will be possible to avoid shared routings of successive cars if the switches which create separate routings are brought closer to the hump and made more numerous. Existing practice places the hump tracks as in Figure 8. I propose that instead the switches be brought toward the hump as shown in Figure 10. This is feasible if the retarders are relocated toward the class tracks and the master retarder is eliminated.

Figure 10

Sketch of Class Track Layout



Note: Type A design stresses early separation with one retarder per class track.
Type B utilizes group retardation, early separation.

For example, in a sixty-three class track yard, rather than have seven groups of nine class tracks each, twenty-one groups of three tracks each could be used. In such a layout, a cut in the input has a chance of one in twenty-one of being assigned to a particular group. The probability that the next cut of a random sequence of cuts is for the same group is the product of the separate probabilities, or one in 441.

Disregarding end effects, therefore, it is probable that only one cut in 441 cuts will share a routing with the immediately following cut. When the following cut is sent to another group, a period of free time is thereby created behind the first cut, during which time switch points may be thrown and closure rates may develop harmlessly.

Perfectly random distribution of cuts to class track groups would insure the efficiency of high flow rates until the improbable sequence occurred. At an average of two cars per cut and 100 cars per train, the improbable match would occur once in 8.8 trains. As actual cut mixtures are less than random, successive cuts to the same class track group will be more frequent than the above figure. The degree of frequency will vary with the number of track groupings prior to retardation and the track assignments of cuts of inbound trains.

Hump rate can be high during the period of classification of successive cuts which share no route to a retarder, where closure rates will be a problem. Alternating routes can be detected by a machine which correlates the track pattern with the input switching data. Failure of cuts to satisfactorily alternate could signal the hump locomotive to temporarily slow the humping rate.

By a combination of any or all of the above techniques, the problem of closure rates and spacing of cars may be resolved. Car flow rates across the hump will thereby be freed to attain the high volumes of traffic which hump yards are eminently suited to receiving.

D: ECONOMIC CHARACTERISTICS OF HUMP YARDS

The hump yard is a fixed plant of high volume capacity. Within the volume range for which it is designed the total yard costs will tend to be very static. The variability of costs should be minor. At present, rail out-of-pocket cost studies regard yard costs as 100% variable.[16] While this percentage is a moot point at best, the hump yard presents a situation completely anamalous to the generally accepted percentage. The recognition of this fact in railway cost study cases would considerable reduce the average variable cost level.

Variability of cost is limited by the necessity of operating such large facilities on a twenty-four hour basis. Once committed to operation, personnel and plant can accept a broad range of possible traffic volume.

The increase of flow rates across the hump will permit an even higher capacity than exists at present. Hump yards may become joint facilities in major terminals. In so doing they will be called upon to handle far greater numbers of cars than at present. In Chapter Six we will explore such an actual situation and apply the ideas presented above.

Footnotes

Chapter 3

1 John A. Droege, Freight Terminals and Trains (New York, McGraw-Hill, 1925) p.69.

2 Ibid.

3 Railway Age, May 24, 1954, p.16.

4 American Railway Engineering Association Proceedings, 1917, vol.18 (American Railway Engineering Association, Chicago, 1917) p.283.

5 Railway Age, August 1, 1931, Operating Economy Series, no.4, vol.91, no.5.

6 Railway Age, October 5, 1953, p.20.

7 Ibid.

8 New York Central Railroad, Form T-13 a, Comparative Summary of Operation of Yards, January, 1960.

9 Annual Report of the New York Central Railroad Company to the Interstate Commerce Commission for the year ending December 31, 1959, Schedule 541, line 960, column J.

10 Ibid., Schedule 417, line 36, column J.

11 Ibid., Schedule 118, line 22, column D.

12 Ibid., Schedule 300, line 64, column B.

13 John A. Droege, op. cit., p. 82.

14 Ibid., p. 75.

15 Railway Age, October 19, 1959, p.42.

16 New York Central System study CF-60-1, Development Of Out-Of-Pocket Unit Costs From Operating Expenses And Statistics As Regularly Compiled For The Year 1959 And Marked Up For Estimated 1960 Unit Costs, April 13, 1960, p.6,8.

CHAPTER FOUR

THE YARD AS A TOOL

The primary objective of the railway is to create space utility. All activities not directly involved in the creation of movement are secondary and supporting in nature. Terminal activities are certainly of this latter category.

The freight yard is an instrument with which we create economic conditions for road haulage. It accomplishes this by assembling trains with or without internal order in the consist. Having explored the forms which the yard takes at present, it is proper to ask the question, what might be an ideal design. Both flat and hump yards create order. Do they represent a final answer in the methodology of this activity? It is the purpose of this chapter to answer this question in the negative and to propose another entire set of methods by which order could be created in train car sequence.

A: THE OPTIMUM IN YARD DESIGN

1: The Criteria of the Optimum

To maximize railway road haulage efficiency, order is superimposed upon train car sequence. The optimum yard design, in turn is a function of the amount of order to be created in the train consist. If only moderate traffic volumes are existent then a flat yard may be suited to the job. Conversely, if order is to be created in high volume situations, the hump yard design becomes the desireabletechnique. But this relates yard design to traffic volume conditions alone.

The key question left out of this argument is the question of the amount of order to be created. Yards are interrelated in their performance in a railway system. The internal train order (yard output) becomes an input at the next yard. Consequently the order desired at any one yard is dependent upon the total work to be done in a railway system and can not be determined properly in isolation from this broad context.

The amount of order created in any railway yard may vary between two limits. The extreme cases of this variation are the complete absence of internal train order versus the placement of each car in the train consist in some sequence considered desireable. The criteria of desireability here is economic, i.e., what combination of locally created train sequence will result in minimized work and costs systemwide. Yard construction must therefore wait upon the answer to the optimization problem.

At present, yard construction and location have been predicated upon presumed answers to the optimization problem. This has not been unreasonable, however, in light of several limiting factors. The roads have established patterns of traffic flow which define the high volume yard points. These locations are necessitated by corporate dimensions. Also, the traffic originating and arriving to or from some community determines the number of trains needed to serve the point and the switching to be performed. By adding facilities to the essential local yards, in order to create a non-local functioning yard, the marginal costs of the additional investment can be kept to a minimum. Such has been the pragmatic theory of yard location.

Yard types have been predicated upon the decision as to yard location. Location has determined volume and the amount of order to be created in internal train order. Location plans have had to be made under a limitation, however. This limit is the inability of flat and hump yard designs to create highly ordered car sequences in trains simultaneously with high volume situations. If a system of yards has low internal train order output capacity, the amount of work required of the system may rise. The reason for this is that yards are failing to create high order inputs for other yards, some particular combinations of which may be more economic than many yards which tend to create trains in isolation.

In order to gain maximum efficiency in yard operations it is first necessary to have available a tool of maximum production. The yard tool reaches its peak of output when it can create trains of completely ordered car sequence at economic cost levels. Completely ordered car sequence necessitates, by definition, a train output whose blocks are of single shipment dimension, usually one car length. Existing designs produce trains composed of blocks of cars of multiple car length. Within the block, car sequence is random. The maximum possible output of a yard must be trains of non-randomized car sequence.

Maintracking is the most extended use of internal train order creation open to the railroads given existing yard design. The economic potential of a yard which can perform to the upper limit of classification has always been out of reach. It is the purpose of the following section to point out that such a yard is no longer inconceivable or necessarily impractical.

2: The Method of Solution

The problem posed is to conquer the limit imposed upon classification ability of contemporary yard design. This limit is, in light of present technological levels, a self imposed one.

The goal is to place cars economically in highly ordered train sequences and thereby reap potential economies.

The method is to select and place cars individually and sequentially in desired train order.

The instrument of the method is a "Skewed" track pattern. The basic change is in the track pattern of the yard and its use. Present design calls for classification track lengths suitable to receive long blocks of cars. Long block length is the antithesis of our goal as the degree of internal train order and block length are inversely related.

The proposed design is actually a family of designs characterized by the ability to select individual cars or short cuts of cars for train position placement. It will therefore be called the Individual Cut Selection or ICS design.

B: THE ICS DESIGN

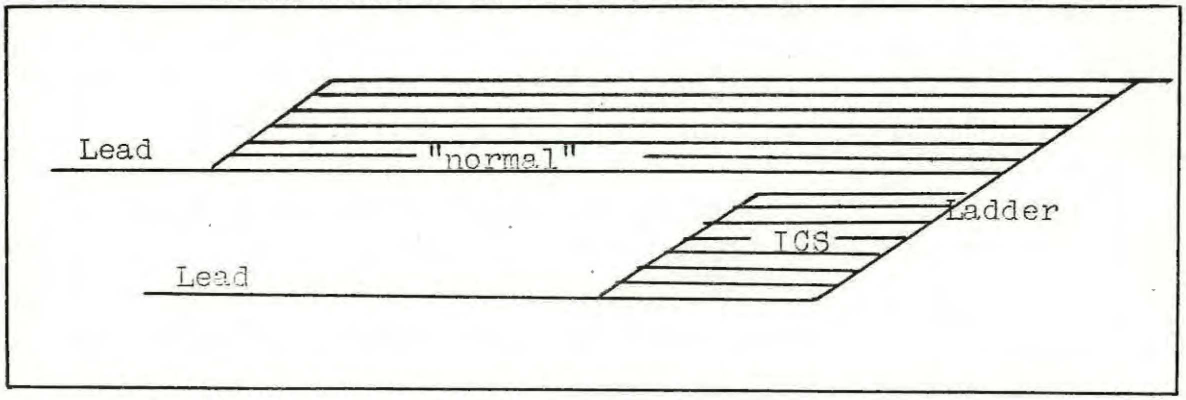
Placing cars in train order position, unit by unit, may prove desireable in some cases and not in others. No greater amount of order could be imposed upon a train than such sequencing. However, as an upper limit, we can see that it is unlikely to be the economically desireable activity. It is more probable that optimum performance conditions at some specific locations in a yard system will call for short cuts of cars to be created at that point. When trains are to be forwarded to some classification point where work must be done in any case, prior classification, however crude, would only create order that is not needed or used and would be an economic waste. The yard design under study here is of its nature a high internal train order design. It is to be used at some central point and will be most effective when given disordered inputs and required by the system to deliver a highly ordered output. Exact cut length of the output cannot be predicted a priori but must await analysis of a specific system. Specific applications can only be made after the present limits on creating internal train order are surpassed.

1: General Description

The ICS design will be characterized by an ability to create extremely short cuts in large number, and to place these sequentially in desired train order. Conventional design fails to offer the needed opportunity to develop short cuts because the number of class tracks is badly limited. Cars are placed next to one another, coupled, and therefore, inaccessible to economical selection for train placement.. Physically, high internal train order conditions are possible in present design, but economically it is not feasible.

To be economically accessible, cuts must be isolated from other cars. This fact, together with the desireability of having many such short cuts awaiting assemblage into trains, gives the yard its "skewed" characteristic. The ladder tracks are elongated and the class tracks shortened, as in Figure 11.

FIGURE 11
Illustration of ICS and Normal Grid Track Pattern



The problem in utilizing this pattern is the development of economic techniques for feeding and emptying these short class tracks.

A yard composed exclusively of such short grids would occupy considerable land. However, just as yards are today specialized into subsections, so also with the ICS design. The entire yard need not be built in this fashion, as will be seen later. The relative land use factors are explored in Appendix 2. The gridiron tends to require 3.15 times as much land as a conventional pattern of identical standing capacity.

2: Input Techniques.

The use of the familiar five man crew and locomotive for the assemblage of short cuts is uneconomic. High volume conditions, in which we are interested, prohibit the use of flat yard classification techniques. They are expensive, as demonstrated in Table 11. Less expensive techniques of classification are essential in a high volume, short block yard.

TABLE 11

Expenses per Switch Engine
Hour, N.Y.C.R.R., 1958, Accounts 377-89

Yard payroll (non-operating)	$ 6.29
Yard payroll (operating)	15.64
Yard fuel	.95
Other yard engine expense	1.45
Total	$24.33

Source: Annual Report of NYC RR Co. to the ICC for the year ended Dec.31, 1958. Schedule 320, Accounts 377-89 inclusive, p.308 divided by 1/6 (Schedule 531, col.b, line 11.)

Among the possible methods are gravity feed and special motive power. Gravity feed techniques are familiar, refined and useful. By utilizing the high flow capacity of this design, especially as enhanced in Chapter 3 above, we can classify high volumes into fine classifications. The short class tracks present us with the problem of retardation at the end of the track, however. This problem may be resolved by the use of inert retarders. This is a spring loaded retarder which has a constant pressure applied to the retarding brake shoes. Upon entering the retarder, the car is slowed and stopped. The car can be removed by a locomotive whose power is sufficient to overcome the "drag" of the retarder. No personnel are required for the operation.[1] It is necessary also to slow the car prior to entry to the class track if more than one car is to be placed on the short class track. Power retarders are the proper instruments for this job. Their economic use becomes more difficult however as the class track is shortened. We can see, therefore, that if the yard is to make extensive use of the short track pattern, or utilize it as the sole storage point for cars in the classification bowl, the hump feed method may be costly.

An alternate technique for feeding cars to short class tracks economically abandons the gravity technique. Rather than permit cars to become free rolling we can place them in a fully controlled manner with locomotives.

The work to be done here occurs in a very limited geographical space of several acres of land. The work is highly routine, consisting of the separation of cars from trains and their haulage a minor distance to the class tracks. Such a situation permitting tight control of a routinized function is an excellent prospect for automation.

Any automated instrument must transmit, to an agent of control, information about the conditions relevant to its operation. Such information would include data of horsepower output, location, and brake air pressure at any instant. The control unit in turn must be designed to relate this data to prescribed criteria of the desired conditions. Differences between input data and prescribed criteria are used to generate command information which will bring the difference to zero (create the desired condition). This command information must be transmitted to the locomotive and used as the basis for action. The cycle of automation is then complete. All the essentials are present, i.e., a criteria of action, knowledge of existing conditions, a decision making process, and a unit to execute decisions, each coupled into a complete cycle of information flow.

The probable characteristics of such an engine are not of overwhelming importance to this paper. It seems probable that the function of the locomotive could be best accomplished by a 200-300 horsepower diesel propelled vehicle mounted on two axles coupled, driven through proven hydraulic transmissions. Design details more debatable in nature, such as brake design, bearings, and coupling mechanisms are better left to the responsible engineers.

It is appropriate to note at this time, however, the essential practicability of such design. Remote control of vehicles via radio is not new or strange. Military applications are familiar.

In the railway industry, such remote control of operations has already begun. In 1956, the German Federal Railway experimented with a radio controlled electric switch engine. This engine has been operating in the Munich east yard, powering strings of cars as they go over the hump. Thirteen different types of commands can be issued to this engine. These commands control throtle settings, brake settings, and safety devices.[2] Control of humping operations is more fully placed in the hands of the hump conductor by this technique. To increase or decrease hump speeds he has only to throw a switch rather than to wait upon the reaction of an engineman to some visible or audible signal.

In 1955, the French National Railroads operated an electric train by radio control at speeds up to 74 miles per hour. In 1958, they revealed an experiment with a switching locomotive. The remote control operation is controlled by carrier wave bearing three submodulations. Carrier signals are interpreted electronically and act through servogear on the brake control and diesel engine regulator control.[3]

Domestically we have seen experiments by the New Haven Railroad in the remote control operation of suburban multiple unit equipment.[4] Recently the Southern Pacific is reported to have successfully controlled a road diesel unit by radio in pusher service. In this instance the controlled unit was cut into the middle of the train ascending a long grade. Power and braking outputs were controlled from the leading locomotive unit.[5]

Although more visionary ideas abound in quotations from the manufacturers, our concern is with the immediately applicable.

The application of such vehicles to yard operation will entail several problems. In the specific yards, however, where conditions of volume and internal train order demands are sufficient, they will be an economic tool of yard design.

3: Output Techniques

The classification of freight cars is only the first stage of a two stage process. The second stage is the assemblage of trains. Only if the train is to consist of just one block of cars and have no internal train order, do the two stages become identical.

We are considering yard designs suitable to create high internal train order conditions, however, and must consider the train assemblage problem. Having classified trains into blocks of cars we must reassemble the blocks to again create a train. If the blocks are few in number, five or less, this is not a difficult job. It is economical for a conventional locomotive and crew to do this work.

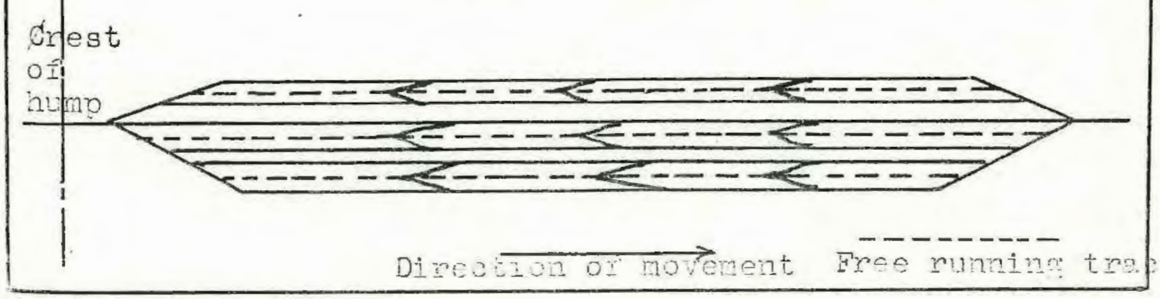
The method employed is to couple the engine to the block to be first in train order, pull and double it against succeeding blocks, until the train is completed. The procedure is not regarded as unduly time consuming or expensive.

If, however, instead of less than five blocks we wish to assemble more short blocks, the conventional tools are increasingly uneconomic. Two methods are available to fill this gap in technology. The first method is gravitational. The class tracks could be placed upon a slope (either graded or natural) so as to impart accelerating forces to the cuts when released. Grading is expensive, however, and natural locations for such work are rarely found.

The second method, the use of remotely controlled locomotives, is more promising. Once again we have a geographically limited situation and a routinized function susceptible to automated control. These locomotives are best adapted to shoving cars rather than pulling. The latter requires preliminary coupling testing to see that all couplers are locked. Shoving at slow speed into protected areas where inert retarders can provide braking from the forward end is safer and simpler. Remote controlled locomotives could shove blocks onto departure tracks, in sequence, and return for more blocks. The economics of the yard as determined by volume and work to be done will extablish the number of such engines needed and the control techniques used.

An interesting attempt to solve the departure yard (train assemblage problem was devised by George Billmyer, then with the New York Central Railroad. In order to create train order in the departure track, he proposed to extend the classification ladder track the full length of a train.[6]. Cars were initially classified over a hump according to a train membership criteria. The free rolling car rolled onto the ladder track parallel to the track of its train assignment. Upon reaching proper train position it was deflected from the ladder track by a crossover to its train. A diagram describing this traffic flow is given in Figure 12.

FIGURE 12
" Trainmaker" Yard



This yard design was an attempt to create high internal train order conditions by simultaneously performing both stages of work, i.e., classification and train sequence creation. To do this the departure yard becomes absorbed into the classification bowl. Short class track sections are set end to end for ease of train assemblage. The yard, designed to hold full length trains on the segmented class tracks, becomes elongated and narrowed.[7]

The designer suggested the use of a remote controlled trimmer locomotive similar to one actually built for the New York Central at the Elkhart yard. The final job of train assemblage is done by the road locomotive which merely backs onto its train, coupling up the several blocks that had been prepared in line by the classification process. Variants on this design involve the number of blocks to be created and the number of cars assigned to each block.[8]

This yard would eliminate the departure yard as a separate entity, create more blocks per train than now possible and do so while handling the cars only once, in a forward flow motion. The design is at a disadvantage, however, because of the extremely long ladder tracks it requires. Cars rolling on such a ladder would be subject to impacts from following cars due to the existence of a natural closure rate between cars. The unique shape of the yard would necessitate extensive grading and many crossovers. Installations would require rebuilding or new constructions. Further the ability to classify a car to train position presumes knowledge of the desired train position. Such knowledge is not available until all the cars for any train are either present or known to be available in time for inclusion within that train.

In essence, the design, known as the Trainmaker yard, incorporated an ICS principle. Cuts were isolated from one another on short class tracks. These trakcs were arranged in sequence so that train assemblage was vastly simplified. The several problems of such a yard remained unsolved, however, and physical construction of such a yard was never undertaken.

In the post-war period the railroads began an extensive yard modernization program. This program was designed to improve service and cut costs through yard consolidation at major terminals. Yard "automation" was the goal and many millions of dollars were spent. In noe of these yards were ICS design principles incorporated, however. In fact, the track patterns and methods used refinements of designs employed in the 1920's. Most of the yards built were high volume hump yards at central locations. At some of these yards high internal train order output certainly would have been desireable.

C: APPLICATION OF THE ICS PRINCIPLE

The critical situation in yard design is one in which extremely high volume conditions now necessitate yard operations of extremely low train order output. Far too many yards of recent construction have been built which consolidated facilities, lowered costs per car handled and ignored the need for internal train order in the output. In order to conquer this problem we can choose those variables of yard design whose combination may surpass these limits.

Among the possible variables of yard design are class tracks varying from one car length to train length. Also, as has been seen, the departure yard may be moved into the class tracks. Classification and exit from class tracks can be by conventional locomotive and crew, remote control or gravity. All of these variables may be utilized in a vast number of possible combinations.

The specific requirements we must meet are conditions of 3000 cars per day or more, transformed into trains of fifteen blocks. Such conditions preclude the possibility of performing both classification and train creation at the same time. Rather, the two stages must be performed separately in order to permit the high volume conditions we have postulated. The isolation of the yard function into two stages will permit specialization within the stages. Stage one (classification) can classify by train membership criteria. Train membership as distinguished from train position can be known simultaneously with the presence of the car. The trains created in stage one are random sequences of cars. The hump technique is eminently suited for such volume conditions, especially when modified to limit closure rates to a nominal amount. The second stage will use as its input the output of the first stage, a random sequence of cars. Continuous high volume input into stage one will necessitate an input technique of equivalent capacity to stage two. Consequently a gravity feed to stage two is dictated. In order to create internal train order conditions, the random input must be classified by train position. This is the ICS portion of the yard. Stage two is the classification of cars to a short track grid which will facilitate movement of cars or cuts in sequence to the departure track.

The ICS design has been described as a skewed track pattern. By this is meant that the conventional ratio of ladder track length to class track length is changed considerably. If trains of fifteen blocks are to be created, class tracks of one car length will be far too short. Assuming train length of 150 cars maximum, the ICS grid must have a capacity of at least 150 cars. Such a train would have an enforced block length of ten cars maximum. As this block length may be unduly short for a long train, the ICS grid should be expanded to a capacity of approximately 300 cars. We now have the conditions for which we have planned, that is a number of blocks per train commensurate with the minimization of total yard costs in the system.

Having classified a train into the ICS grid we must now empty that grid of its blocks into train position in the departure yard. Access to individual cuts is available. The movement of these cuts, sequentially, can most economically be accomplished through the use of remote controlled locomotives. This is dictated by the volume conditions which require rapid clearing of the ICS grid prior to the classification of the next train into that grid.

A wide variety of actual track patterns could incorporate these two stages of activity. Two separate humps, for example, could be used, one for each stage. Or, if volume conditions permit, one hump may be utilized alternately by the two operations. A more specific design must await more specific information about the job to be accomplished at any location.

Footnotes

Chapter 4

1 Modern Railroads, Vol.XIV (July,1960), p.50.

2 John Broadbent, "Beyond the Atlantic", Trains, VolXVII (March,1957),p.12.

3 John Broadbent, "Beyond the Atlantic", Trains, Vol.XIX (April,1959), p.10.

4 "Signalling... a look ahead", Railway Age, Vol.CXLI (Centennial Issue, Spetermber,1956), p.265.

5 Railway Age, January 25, 1960, p.22.

6 George W. Billmyer,3rd, "The Trainmaker Yard", Trains, Vol. XVIII (December,1957), p.50-53.

7 Ibid., p.51.

8 Ibid., p.53.

CHAPTER FIVE

ST. LOUIS TERMINAL PROBLEM

The critical limitation upon contemporary yard design, is the inability to create highly ordered trains under high volume conditions. This problem becomes critical because of the numerous high volume locations in this country at which work must be performed.

Yard design, it has been shown, may incorporate varying ratios of class and ladder track lengths, together with gravity or locomotive feeds. Out of this variety of techniques we must pull at least one combination which can conquer the existing limitations on yard design. By so doing we may demonstrate that existing design suffers from a self-imposed limitation which can be economically surpassed.

The terminal problem at East St. Louis, Illinois, is a useful battleground for this attempt. The aforementioned high volume conditions exist there. Also, there has been an attempt to solve these problems within the framework of conventional design. The limitations of this design will prove apparent.

A: DESCRIPTION OF THE PROBLEM

The dimension of the terminal problem at this location stems from the dimensions of its traffic. St. Louis is known as the gateway to the southwest. Twenty-three lines were built into St. Louis. These are operated by nineteen companies and provide twenty-eight routes to this gateway. Each line attempted to bring its rails as cloas as possible to the commercial center of St. Louis. This center is a short distance from the Mississippi River. This river presented an almost impassable barrier to traffic until the opening of the Eads Bridge in 1874. The multiplicty of interchange moves, occuring over crowded trackage ultimately forced the formation of the Terminal Railroad Association of St. Louis (TRRA) in 1889.[1]

The TRRA is the largest of the jointly owned terminal companies in the United States. The St. Louis gateway which it serves is the second largest rail center of the nation. Its vast traffic volumes are handled in a maze of thiry-nine interconnected yards within the terminal district.[2] The advantages of yard consolidation have long been recognized, as for example, in the Federal Coordinator Reports of 1934.[3] Joint facilities, however, bear a burden in that there is diffused resposibility for changes and modernization. Consequently, St. Louis has not been the scene of yard construction so prevalent in other parts of the country.

The specific dimensions of its traffic flow have been revealed by a study performed by the Terminal Modernization Committee (TMC) of the TRRA in 1956. This study took a sample of traffic of an eleven day period, June 11 to 21, 1956 inclusive. During the test period, all traffic in the gateway was analysed for its volume, its routing through the terminal, and the time required en route. The volume of traffic approached a peak of 10,000 cars daily, This volume moved over an intricate pattern of routes within the gateway. For the route analysis, the industries, freight houses and team tracks for each road-haul carrier were defined as a single group. Between the many such groups, there existed 5,223 separate routes which were actually utilized by trains of more than one car length. In addition, 2,765 separate routings were utilized by cuts of one car length but these moves were of unusual nature and are not part of the usual pattern of operations. The average length of the train movement over any of the 5,223 routes was sixteen cars.[4] This short average length is derived of the multiplicity of routings, each covered by a switch or transfer run.

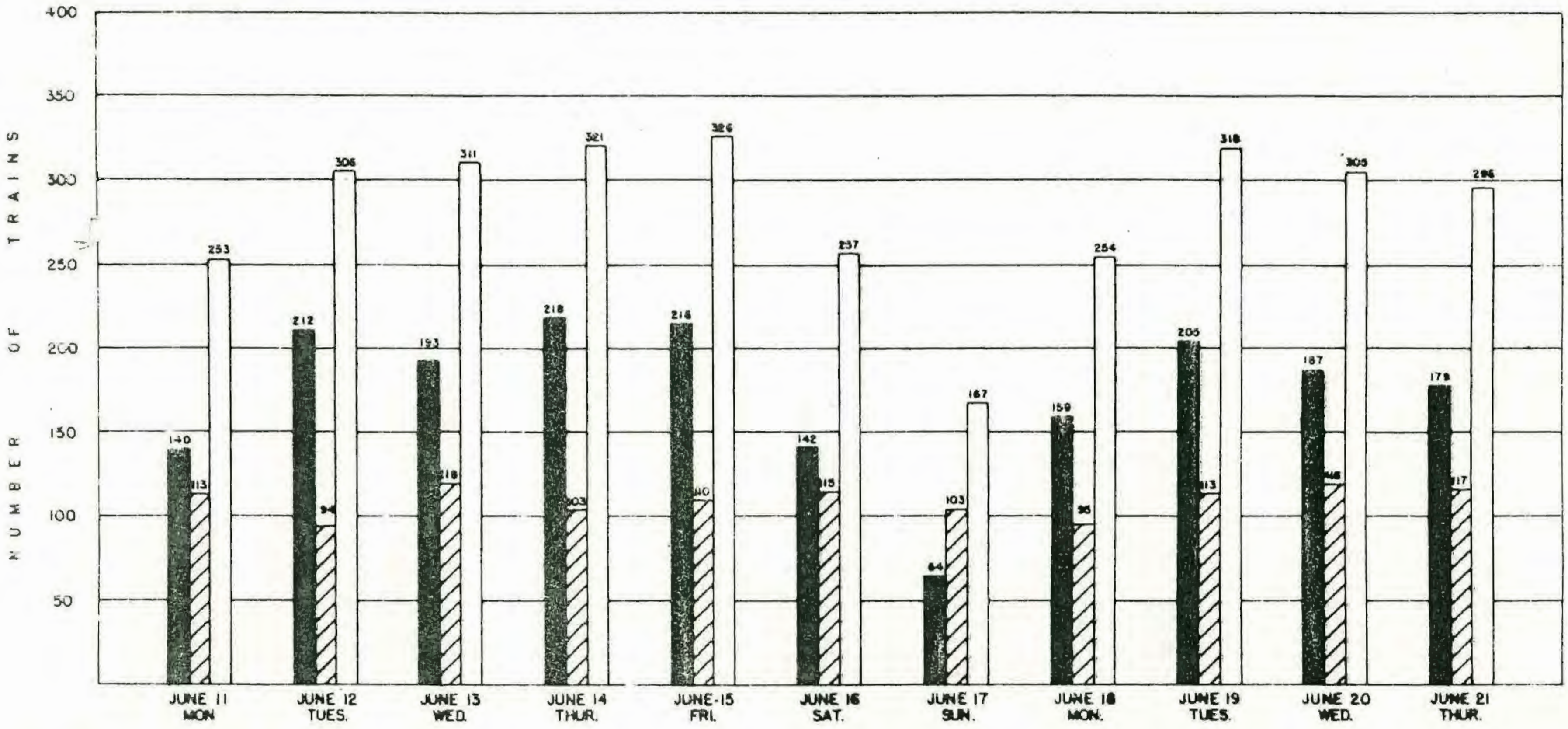
Daily train arrivals reached a peak of 326 from an average level of 283. Corresponding departures reached a peak of 292 trains from an average level of 261. (Figures 13 and 14). Within these trains, average train length was sixty-one cars for road trains and thirteen cars for switch runs.[5] The term switch runs includes runs from freight houses and team tracks but excludes all transfer runs which could be excluded under a centralized yard operation. Car arrivals during the test period roase from an average of 8,815 to a peak of 9,657 daily. Corresponding departures averaged 8,316, peaking at 9,454 cars.[6] (Figures 15 and 16). Due to the short train elngth of switch runs, the inbound road trains supplied 75% of the car input to the St. Louis district in only 39%

FIGURE 13

TMC CHART NO. I-A

DAILY TRAIN ARRIVALS IN SAINT LOUIS GATEWAY

(INBOUND ROAD FREIGHT TRAINS AND INDUSTRIAL SWITCH RUNS)



THIS CHART REPRESENTS TRAINS OF ALL RAILROADS IN SAINT LOUIS GATEWAY FOR THE STUDY PERIOD, JUNE 11, 1956 THROUGH JUNE 21, 1956
SOLID BLACK COLUMNS INDICATE INBOUND INDUSTRIAL SWITCH RUNS AND SIMILAR SERVICE FOR FREIGHT HOUSES & TEAM TRACKS BUT EXCLUDES ALL OTHER TRANSFER RUNS
HATCHED COLUMNS INDICATE INBOUND ROAD FREIGHT TRAINS
SOLID WHITE COLUMNS INDICATE TOTAL TRAINS

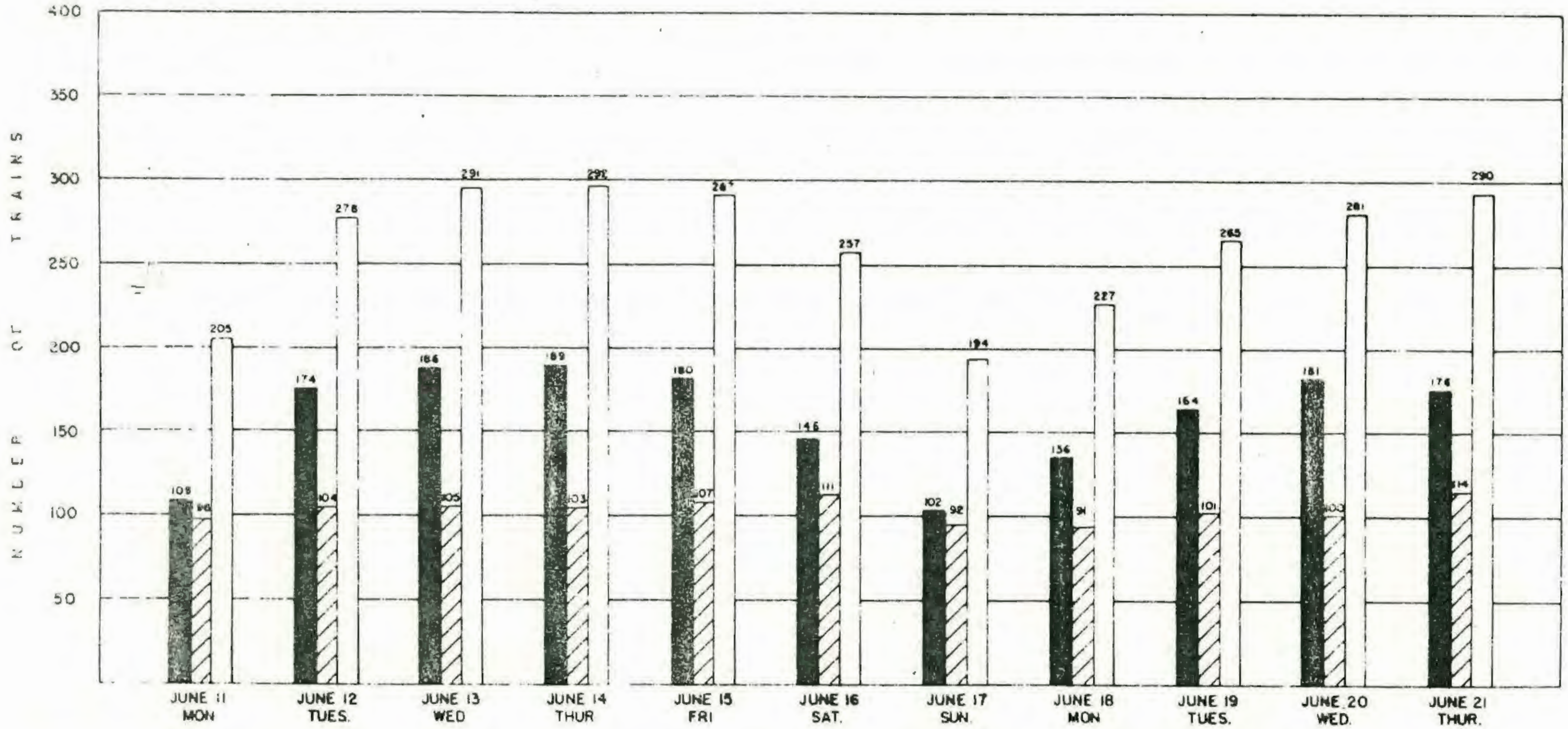
T.R.R.A. ENGR DEPT MAR 15, 1957

FIGURE 14

TMC CHART NO. 2-A

DAILY TRAIN DEPARTURES FROM SAINT LOUIS GATEWAY

(OUTBOUND ROAD FREIGHT TRAINS AND INDUSTRIAL SWITCH RUNS)



THIS CHART REPRESENTS TRAINS OF ALL RAILROADS IN SAINT LOUIS GATEWAY FOR THE STUDY PERIOD, JUNE 11, 1956 THROUGH JUNE 21, 1956
SOLID BLACK COLUMNS INDICATE OUTBOUND INDUSTRIAL SWITCH RUNS AND SIMILAR SERVICE FOR FREIGHT HOUSES & TEAM TRACKS BUT EXCLUDES ALL OTHER TRANSFER RUNS
HATCHED COLUMNS INDICATE OUTBOUND ROAD FREIGHT TRAINS
SOLID WHITE COLUMNS INDICATE TOTAL TRAINS

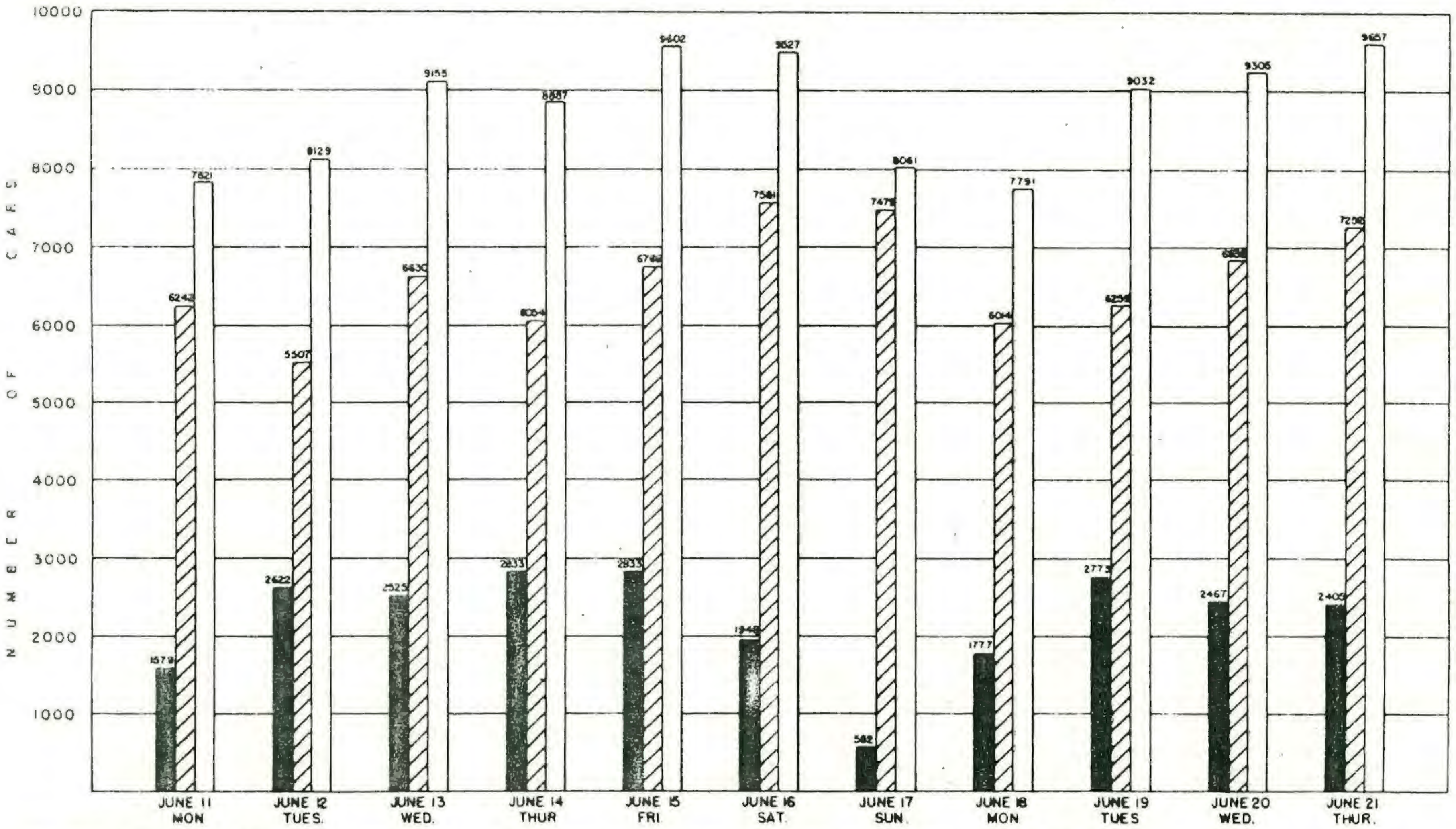
TRRA ENGR DEPT MAR. 18, 1957

FIGURE 15

T M C CHART NO. I-B

DAILY FREIGHT CAR ARRIVALS IN SAINT LOUIS GATEWAY

(FROM INBOUND ROAD FREIGHT TRAINS AND INDUSTRIAL SWITCH RUNS)



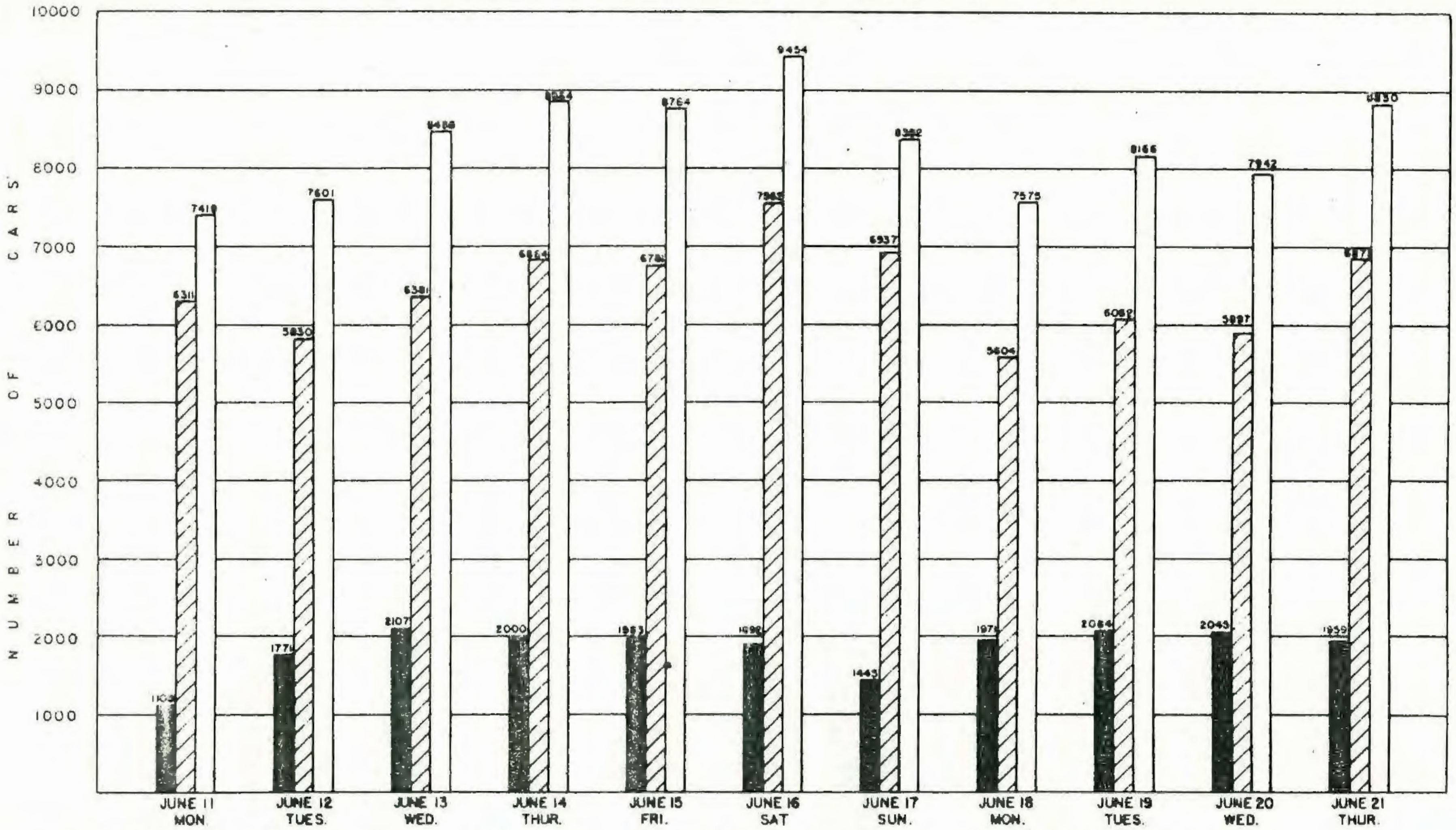
THIS CHART REPRESENTS CARS OF ALL RAILROADS IN SAINT LOUIS GATEWAY FOR THE STUDY PERIOD, JUNE 11, 1956 THROUGH JUNE 21, 1956
SOLID BLACK COLUMNS INDICATE CARS FROM INDUSTRIAL SWITCH RUNS AND SIMILAR SERVICE FOR FREIGHT HOUSES & TEAM TRACKS BUT EXCLUDES ALL OTHER TRANSFER RUNS
HATCHED COLUMNS INDICATE CARS FROM ROAD FREIGHT TRAINS
SOLID WHITE COLUMNS INDICATE TOTAL CARS

T.R.R.A. ENGR. DEPT MAR. 18, 1957

FIGURE 16

TMC CHART NO. 2-8

DAILY FREIGHT CAR DEPARTURES FROM SAINT LOUIS GATEWAY
(IN OUTBOUND ROAD FREIGHT TRAINS AND INDUSTRIAL SWITCH RUNS)



THIS CHART REPRESENTS CARS OF ALL RAILROADS IN SAINT LOUIS GATEWAY FOR THE STUDY PERIOD, JUNE 11, 1956 THROUGH JUNE 21, 1956
SOLID BLACK COLUMNS INDICATE CARS IN INDUSTRIAL SWITCH RUNS AND SIMILAR SERVICE FOR FREIGHT HOUSES & TEAM TRACKS BUT EXCLUDES ALL OTHER TRANSFER RUNS
HATCHED COLUMNS INDICATE CARS IN OUTBOUND ROAD FREIGHT TRAINS
SOLID WHITE COLUMNS INDICATE TOTAL CARS

T.R.R.A. ENGR. DEPT. MAR. 15, 1957

of the total trains.

Although the daily average and peak volumes of the St. Louis terminal activity vastly excede the levels of operating conditions at other terminal centers, the daily activity is only one dimension. An analysis of hourly peaking of activity shows that the terminal problem is far worse than daily activity levels would indicate.

Although train arrivals averaged approximately twelve per hour, a peak of thirty-eight trains per hour was experienced. This peak occurs at 7 p.m. as industrial switch runs terminate their days activity. Train departures averaged eleven per hour during the day but reached a peak of twenty-eight trains at 9 a.m. This peak reflects the movement of local trains outward from the yards for the days work.[7] (Figures 17 and 18).

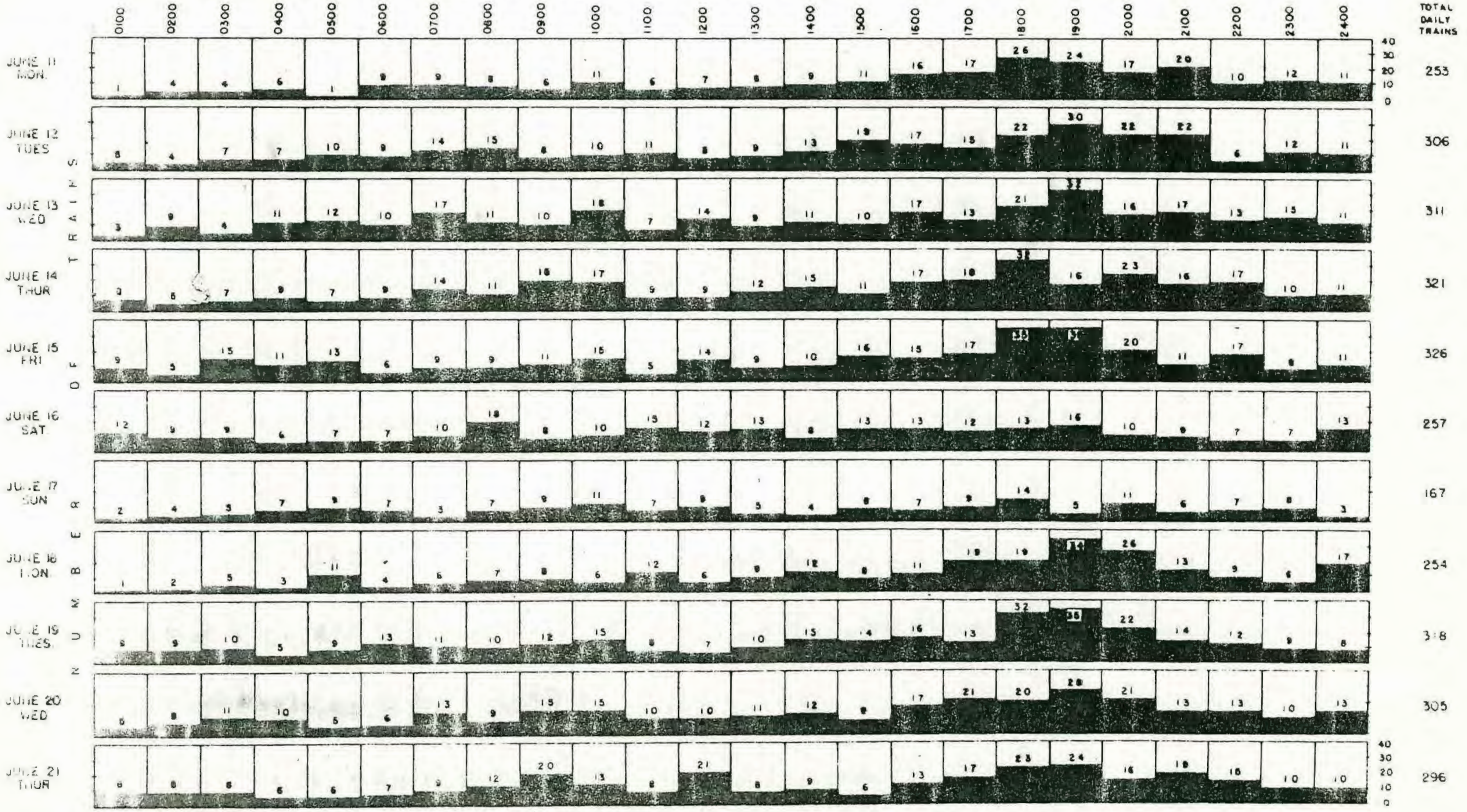
Due to the disparity of train lengths by different train type (road vs. transfer) we must examine this daily peak of traffic in terms of car volumes. Car departure peak activity occurred at 9 p.m., a shift of twelve hours from the train departure peak. A peak of 1,000 cars in one hour was experienced. Maximum arrival activity reached 900 cars at 7 p.m. (Figures 19 and 20).

The St. Louis terminal suffers, therefore, from the acceptance of vast volumes of traffic into a system of yards not suited to such volume. This fact is demonstrated by the fragmentation of the traffic into thirty-nine yard facilities, diffused through out the St. Louis area.

FIGURE 17

T M C CHART NO I-C

FREIGHT TRAIN ARRIVALS IN THE SAINT LOUIS GATEWAY DAILY BY HOUR OF ARRIVAL



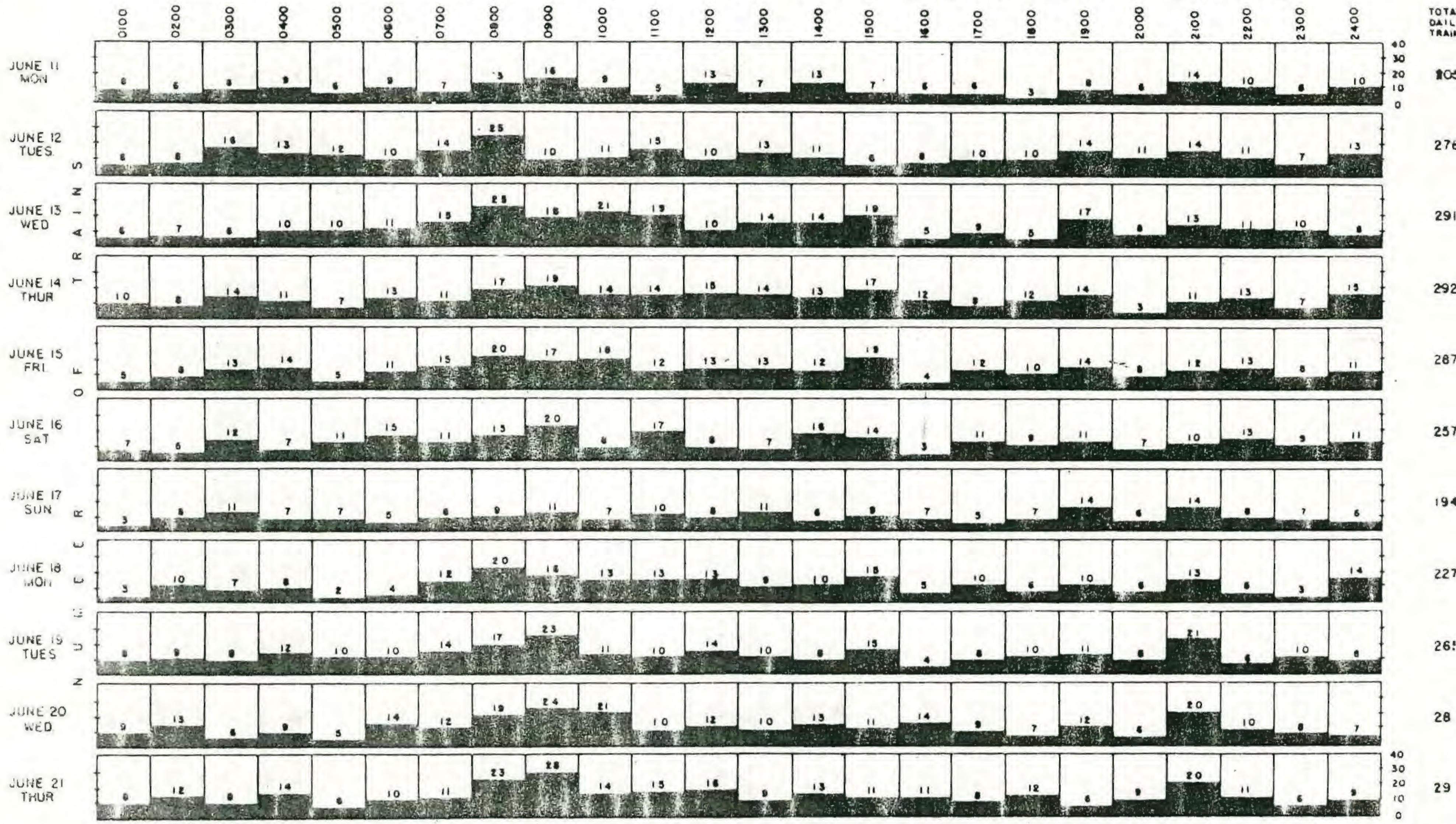
THIS CHART REPRESENTS TRAINS OF ALL RAILROADS IN SAINT LOUIS GATEWAY FOR THE STUDY PERIOD, JUNE 11, 1956 THROUGH JUNE 21, 1956 CONSISTING OF ROAD FREIGHT TRAINS AND INDUSTRIAL SWITCH RUNS

T R R A ENGR DEPT MAR 15, 1957

FIGURE 18

T M C CHART NO. 2-C

FREIGHT TRAIN DEPARTURES FROM THE SAINT LOUIS GATEWAY DAILY BY HOUR OF DEPARTURE

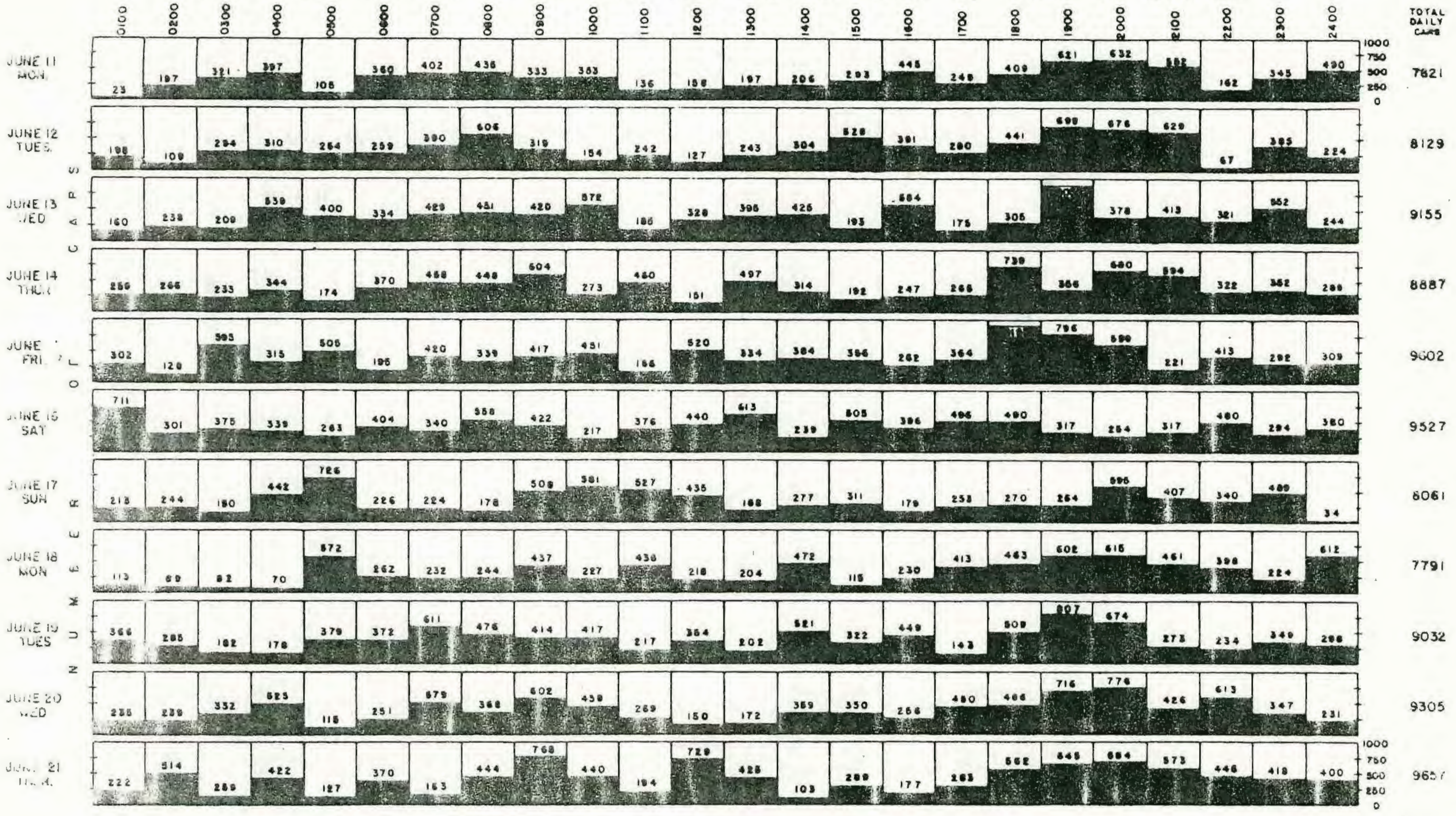


THIS CHART REPRESENTS TRAINS OF ALL RAILROADS IN SAINT LOUIS GATEWAY FOR THE STUDY PERIOD, JUNE 11, 1956 THROUGH JUNE 21, 1956 CONSISTING OF ROAD FREIGHT TRAINS AND INDUSTRIAL SWITCH RUNS

T.R.R.A. ENGR DEPT MAR 15, 1957

T M C CHART NO. 1-D

FREIGHT CAR ARRIVALS IN THE SAINT LOUIS GATEWAY DAILY BY HOUR OF ARRIVAL



THIS CHART REPRESENTS CARS OF ALL RAILROADS IN SAINT LOUIS GATEWAY FOR THE STUDY PERIOD, JUNE 11, 1956 THROUGH JUNE 21, 1956 ARRIVING IN ROAD FREIGHT TRAINS AND INDUSTRIAL SWITCH RUNS

T.R.R.A. ENGR DEPT MAR 15, 1957

FIGURE 20

T M C CHART NO. 2-D

FREIGHT CARS DEPARTING THE SAINT LOUIS GATEWAY DAILY BY HOUR OF DEPARTURE

THIS CHART REPRESENTS CARS OF ALL RAILROADS IN SAINT LOUIS GATEWAY FOR THE STUDY PERIOD, JUNE 11, 1956 THROUGH JUNE 21, 1956
DEPARTING IN ROAD FREIGHT TRAINS AND INDUSTRIAL SWITCH RUNS

T R R A ENGR DEPT MAR 15 1957

The TRRA experienced total railway operating expenses per revenue freight car handled of $15.86 in 1958.[9] This is similar to the crew payroll costs of a switch engine hour ($15.64) experienced by the New York Central Railroad in that year.[10] This is an unusually high level of cost per car. A terminal district of more conventional size such as Syracuse, New York produced 5.93 revenue cars per switch engine hour at a cost of $3.72 per loaded car handled.[11] High volumes of classification are done at this latter point. The St. Louis operations are performed within a maze of small flat yards rather than a single humping facility more suited to high volumes.

The transit time for loaded cars passing through the St. Louis terminal was not abnormal when measured by the standards of the performance of smaller terminals. The costs of the operation were unmercifully high however. It should be noted that to the high cost of TRRA services must be added the terminal costs of the participating railroads. Each such railroad performs its own classification and train make up work.

B: THE TERMINAL MODERNIZATION COMMITTEE SOLUTION

The Terminal Modernization Committee (TMC) chose to attack the costs of handling this fantastic volume of traffic through a yard consolidation program. The existing pattern of yards, thirty-nine in all, was deemed unquestionably obsolete. The TMC knew that economic advantages accrued through the extended use of the hump yard technique and the elimination of many yards and transfer activities. Having started from the premise of the desireability of yard consolidation the committee had next to decide upon the functions that the new yard would perform. The yard was titled Walsh Yard. Two basic options of use were considered.

The first of these would have all road trains to and from St. Louis handled in the yard of the respective carriers as at present. All transfer runs between these yards would be concentrated into transfer uns between the former and Walsh Yard. Transfer operations would still be necessitated. Existing non-TRRA yards would be retained at their present poor levels of utilization. As the committee noted "this represents a change of an important detail but no in the fundamental principle of the present operation".[12] The number of transfer runs would be considerable reduced. Several yard facilities could be retired. The classification and assemblage of road trains would <u>not</u> be performed at Walsh Yard.

Plan number two had four variants. Each incorporated the operation of in-bound road trains directly into Walsh Yard. For the first time road trains would be classified directly by the TRRA. Outbound trains could be handled in one of the four following ways.

In plan 2A, all outbound trains would be classified and blocked in accordance with the requirements of individual road haul carriers. The yards of the road carriers are replaced by a single new facility.

In plan 2B, classification of cars for each outward route is made into a "through" group and a "local" group. Cars blocked into a "through" group would depart from Walsh Yard in solid blocks to some other terminal for further classification. It is presumed that such terminals would be low-cost classification points in relation to the congested conditions at St. Louis. Such terminals would be Kansas City for the Missouri Pacific lines west, Little Rock for the Missouri Pacific south, Parsons for the Missouri-Kansas-Texas, Springfield or Memphis for the Frisco, Frankfort for the Nickel Plate, Cincinnati for the Baltimore and Ohio, and Indianapolis for the New York Central.

Cars classified at Walsh as local outbound would be destined for points short of these outlying terminals. They would be moved from Walsh Yard in solid blocks by transfer runs to the yard of their respective roads. Here they would be made up for outbound trains to be dispatched from these various points. The departures from Walsh Yard would all therefore be in solid blocks upon which no train order work had been performed, thus simplifying the design requirements.

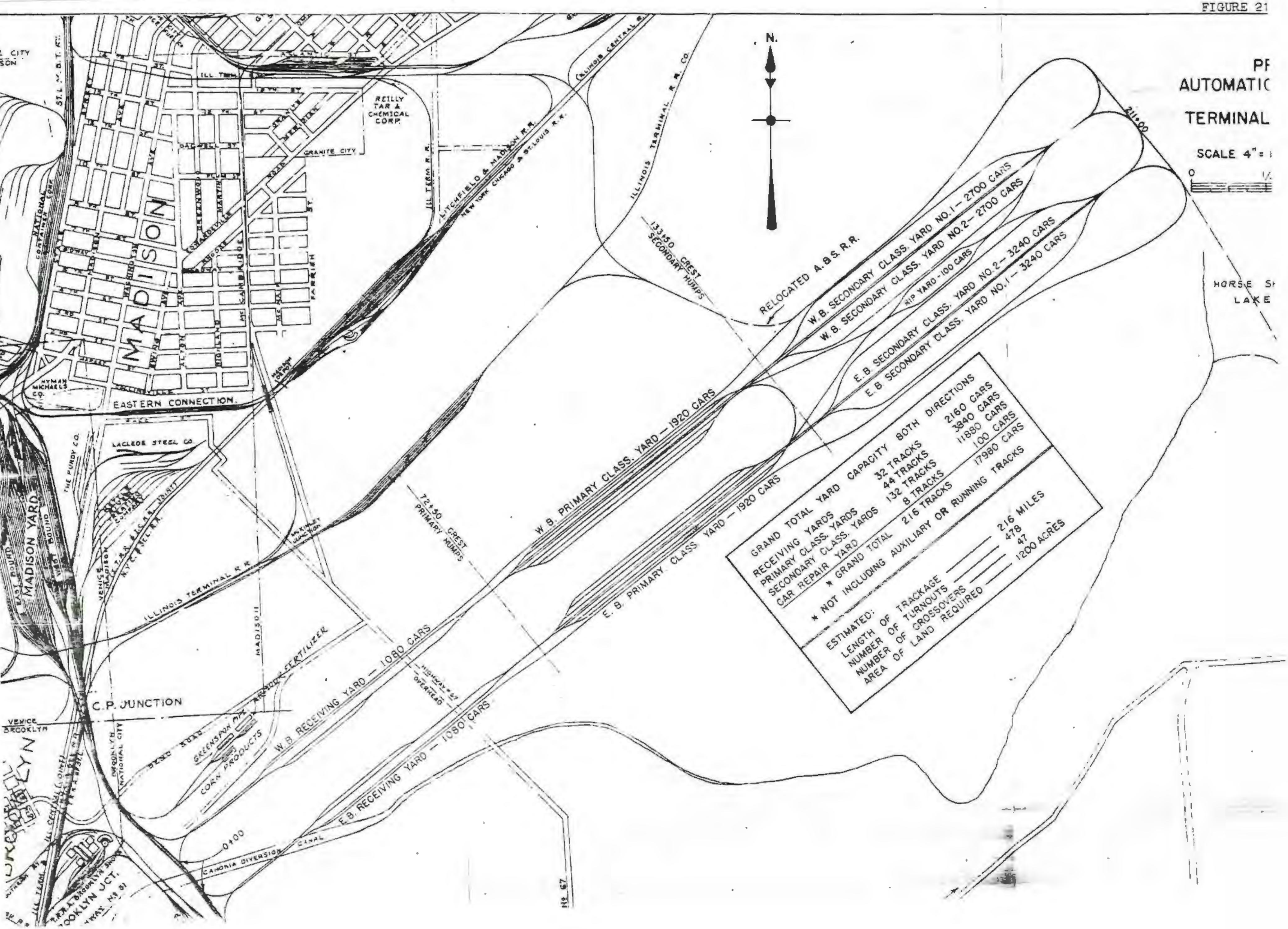
In order to reduce the classification work and trackage requirements of plan 2B, in plan 2C all cars for a particular road would be sent to the yard of that road in a block rather than differentiated into two groups as in 2B. When received by the road, further classification and train make up would be performed as necessary. This plan differs from plan one only in the respect that road trains shall operate into Walsh Yard. This diminished the number of transfer runs required.

Plan 2D would limit the arrival of road trains into Walsh Yard to those which are not required to cross the river from the west. Like plan 2C this plan is designed to reduce the pressures of volume upon Walsh Yard.[13]

The above plans presumed the necessity of building a large hump yard. The avoidance of yard construction was also considered. The use of the TRRA as an intermediary in transfer activity could be diminished, if, in its place, direct transfer runs would be inaugurated between member lines for the principal volumes of traffic. The direct transfer technique would make St. Louis analogous to Chicago in its operating pattern. It was expected, however, that the total number of transfer runs would actually increase, together with average detention time and total expense. This plan was therefore rejected at the outset.

The varieties of plan two represent an attempt to consolidate all classification work into a single efficient yard. Plan 2A was rejected as it would require too large an installation. A yard of at least four hundred classification tracks would be needed. The class tracks, the committee concluded, would have to be grouped into three parts each filled by a hump technique. Cars would go over each hump in succession. Each humping operation would further refine the classification assignments. Such a yard would require forty thousand

FIGURE 21



PR
AUTOMATIC
TERMINAL
SCALE 4" =

cars standing capacity and cost in excess of sixty million dollars.[14] Plans 2B, 2C and 2D are seccessive reductions in the function of Walsh Yard to match the physical capacity of a single major freight yard, using conventional humping techniques. Plan 2D was considered physically feasible. It was regarded as an optional addition to plan one to be considered further at some latter date. The return on the marginal investment would have been greater than that on plan one alone.[15] The TRRA decided however that a consolidated transfer yard (plan one) presented a sufficiency of problems at that immediate time.

C: DESCRIPTION AND LIMITATIONS OF WALSH YARD

The Terminal Modernization Committee selected plan one as the only method of operation suitable to the St. Louis terminal problem. Any other plan, it was felt, would require a yard beyond a practical size and of prohibitive construction costs. Madison, Illinois was chosen as the site for this yard. Two square miles of area were to be occupied by 216 miles of yard running track. The standing capacity of this yard was 17,980 cars.[16] It should be noted that this yard design would make Walsh Yard the largest in the world. No other facility even approaches this yard in its overall dimensions. A map of this proposed yard is given on page 104.

It should be noted that this facility, like so many other hump yards, is divided into specialized sub-sections. There is, however, no departure yard per se in this design. Departing blocks of cars are pulled directly from the classification bowl to the yards of receiving railroads. The sequence of yardings received by a car is: first, receiving yard; second, classification yard no.1; and third, classification yard no.2. From the receiving yard of sixteen tracks width, cars are humped into a primary classification yard of twenty-two tracks. A single hump lead feeds this class yard. In order to perform the desired number of classifications, however, additional classification work is to be performed upon the cars waiting in the primary class yard. From each primary class yard are extended two hump leads. Each lead feeds a different segment of the secondary class yard. The first classification yard therefore acts as the receiving yard to the second. In addition there are two such sequences of yards placed parallel to one another. Thus there are two receiving yards, two primary class yards and four secondary class yards in all. Each class yard is fed by a hump lead.

It was noted that the limitations of yard design restricted the function of Walsh Yard to that of a central transfer station (plan one). The volume conditions of this terminal necessitated a hump feed technique. Although this technique is regarded as superior, the characteristics of this technique are responsible for the limited function of Walsh Yard. To perform the required classifications for this limited function, six active humps were necessitated. These were needed to handle the requisite volume in peak periods and avoid undue congestion.

The ability of the hump lead to absorb traffic is a function of the car flow rate across that hump. The basic premise of the paln of the TMC was that the humping rate could not exceed four miles an hour. This performance was regarded as exceptionally high and attainable only under the most controlled conditions. This required that the most limited amount of classification would be performed, i.e., the length of cuts would be long. Walsh Yard was to be operated at this four mile an hour humping speed into the primary classification yard. The function of this yard was to establish the preliminary conditions essential to further classification work. The speed required at this hump was felt to be incompatible with the desired number of classifications. The secondary class yards were to total 132 class tracks. The secondary class yard feed, using four hump leads, would require more conventional humping speeds of two miles an hour. As the speed is halved in relation to the primary hump, the number of hump leads is necessarily doubled, for the same capacity. The primary yard sorts cars into groups associated with one of the secondary yard hump leads. Unless such assignment is made in the primary yard it will be necessary to set up conflicting routes from he hump leads of the secondary yard. By feeding a group of secondary class tracks exclusively from one hump lead, this problem of conflicts can be avoided and the highest practical humping speed maintained.

This yard, therefore, consists of two receiving yards and six class yards. The critical element in forming this giant yard pattern is the presupposed incompatibility of humping speeds with the capacity to classify onto many tracks. It is the same limitation that we examined in Chapter Four.

common to all hump yard designs today. An attempt to prepare preclassified groupings for the receiving railroads is seen in the size of the secondary class yard. One hundred thirty-two tracks are provided from which to route cars to thirty-nine principle yards. This allows an average of 3.38 blocks to be assembled for each receiving yard. This number is sufficient for the most skeleton preclassification. It is scarcely enough to meet the overall needs of the receiving railroads. Further classification work will have to be performed by the receiving railroad prior to economic road haulage.

Individual railroads would receive cars from Walsh Yard in transfer runs. These runs would represent a major cost of operation but would still be far below the cost of the transfer pattern now existent.

D: AN ALTERNATE YARD PROPOSAL

The capital cost of the physical plant proposed by the TMC was forty-five million dollars. This cost is a function of the sheer bulk of its design. This bulk, in turn, is a function of the need to have the capacity to absorb cars at peak rates of 1000 per hour and succeed in performing a modicum of classification.

Capacity has two dimensions - size and velocity. By breaking the limitations on velocity we are in a position to trim the bulky dimensions and capital cost of the yard. For these conditions hump speeds will have to be doubled, from the planned four to eight miles per hour. The result, as will be seen, almost halves the trackage requirements of Walsh Yard.

It is also possible to expand the function of the yard to those described in plan 2A. This plan, it will be remembered, is for the yard to perform the total classification work of the St. Louis terminal district.

The design suited to plan 2A output, using high speed feed techniques, is a hump yard of three leads on two hump crests. Each crest is associated with one stage of the two stages of activity, classification and train creation. These stages, escribed in Chapter Four, pages 84 to 85, are in sequence as follows:

1. Receiving yard.

2. Primary hump yard, classifying by train membership criteria. This yard is the receiving yard of stage two.

3. The second stage hump and class tracks of short length. This ICS section-grid is specifically designed to create the train order desired in train output. Two such grids and hump leads are needed to make this stage of sufficient capacity to handle the peak output desired.

4. Departure tracks, fed by remote controlled motive power from the second stage class tracks. Here final train assemblage, coupling and testing of air brakes is performed prior to haulage by the road locomotive.

In order to more closely examine the characteristics of a high velocity yard, let us outline each yard segment in greater detail.

The receiving yard must be of sufficient capacity to absorb trains as eliviered to it without congestion. The peak arrivals to this yard are shown below in Table 12 by length of peak.

TABLE 12

Peak Train and Car Arrivals - St. Louis

Duration of peak in hours	Number of train arrivals	Average trains per hour	Average number of cars arriving per hour @ 30 per train
1	35	35	1050
2	70	35	1050
3	90	30	900
4	107	27	800
6	138	23	690

Source: Compiled and derived from New Yard Facilities Proposed to Expedite Freight Movement, Report of Terminal Modernization Committee, Terminal Railroad Association of St. Louis, St. Louis, April 3,1957.

Receiving yard work includes the removal of brake air pressure and the inspection of all cars. The standard time allownace for this work is one minute per car. A work force of sixteen men could perform inspection on 960 cars in one hour. As this is the anticipated peak load such a work force will be adequate. Track space will have to be provided for trains of from 150 to 10 car length. Average train length is thirty cars. Sixteen tracks of 6,600 foot length will provide capacity for 2,400 cars. This is 2.3 times the hourly peak, a safe load factor. Three additional tracks are to be provided as running tracks through the receiving yard, making nineteen in all. Short trains may pull into the receiving tracks behind the preceding train. An escape route for the locomotive is provided by these running tracks, located between pairs of receiving tracks and coupled to them every sixteen car lengths by crossovers. Sixteen car lengths was the average train length of switching and transfer runs.

The primary classification yard must handle ten thousand cars a day. By designing this yard for a standing capacity of six thousand cars we committ ourselves to a limit upon detention of the average car of 14.4 hours in the St. Louis gateway. The primary Walsh Yard held only 3,840 cars, but no accumulation period was required for these cars. They could be shoved to the hump as soon as they were ready, without waiting for the arrival of any complete train. The primary hump must be used to classify cars by train membership criteria. The number of trains to be assembled in this yard at any one time determines the number of class tracks required. Outbound trains must be assembled for nineteen railroads and twenty-eight routes. If one local and one through train were assigned each route, fifty-six class tracks would be necessitated. It will be preferable however to use a maximum width yard of approximately seventy-two tracks. Track length will vary from thirty to 150 cars. The specific shape of the yard is not relevant to this analysis.

From the farther end of the primary class yard, ladder tracks must focus down toward two hump leads. Each lead must feed to a secondary class yard. Trains sorted over these humps are fed into an ICS grid by block membership using a fifteen track grid of twenty car lengths. By so doing, we can create the high internal train order conditions so desireable in yard output. Volume conditions in the St. Louis Terminal necessitate rapid emptying of the ICS grid. Humping to this grid would ordinarily cease during the period in which the grid is being emptied. In order to minimize idle hump time and permit higher utilization, the grid must be emptied in one uniform move by automatic power units. This move must begin upon completion of humping. Each class track of the grid must have its cars propelled forward simultaneously with the others. Emptying time will then equal the time to clear a single track and not the sum of times for all tracks.

The end of the grid pattern is marked by the presence of inert retarders which stop cars rolling from the secondary hump. The simultaneous clearing move is to a similar set of tracks beyond the inert retarders. This move can be completed within one minute thereby permitting humping of a following train almost immediately. During the period of humping to the ICS grid,motive power units will shove blocks of cars from the advance grid (beyond the inert retarders) to the departure yard in proper sequence to an assigned track. The job of train creation will then have been completed.

The technique of simultaneously shoving cars from the ICS grid to an advance grid is necessitated by the extreme volume conditions which call for the assemblage of thirty trains per hour during peak periods. To handle this volume two secondary humps and grids are needed.

Departure yard capacity is dictated by peak output and the time needed to prepare a train priot to departure. One hour is sufficient to pump brake air into an average length train, test and depart. The one hour duration peak load will, therefore, determine track capacity needs. A 3000 car capacity will provide a 3:1 ratio of capacity to peak load, an adequate safety factor for emergencies.

E: THE ECONOMICS OF THE ST. LOUIS YARD PROPOSALS

The significance of the yard proposals reviewed here lies in their ability to give an economic return upon the investment required. These costs are forty-five million dollars for Walsh Yard and 40.4 million dollars for the ICS design. In the strictest sense, the two designs are non-comparable. The functions undertaken by the ICS design were far more extensive than those of Walsh Yard. Whereas Walsh was a central transfer point, the ICS design would repace the outlying yards of member railroads in their entirety. It would perfrom the operations of plan 2A of the TMC study, which the TMC found beyond the capacity of present design.

The salvage values developed by these designs are quite different, also. The Walsh Yard was given only a one million dollar credit from this account. Few facilities could be retired with its creation. The ICS design would permit retirement of many yards in whole or part. No more than one-half of the total yard trackage could be retired, however, as these yards would be partially utilized as industry yards and storage pointsfor empty equipment. The amount of salvage from the abandoned system under this plan is unknown. The capital costs given above therefore exclude this amount.

The investment required by Walsh Yard is listed in Table 13. The investment estimates for the ICS design are based upon the plans and costs of Walsh Yard. Modification

TABLE 13
PART VI

ESTIMATED COST OF WALSH YARD

Engineering		$ 800,000
Property (1200 acres of land & improvements @ $2500 per acre)		3,000,000
Grading (2,625,000 cu. yds. @ $1.50 per yd.)		3,938,000
Drainage		400,000
Trackage		
New 115# rail, 130,000 L. F. @ $13.50	$ 1,755,000	
SH 100# rail, 1,008,000 L. F. @ 9.00	9,072,000	
Crossovers - 48 @ $6600 - New)		
Turnouts - 478 @ $3300 - New)	1,895,000	
		12,722,000
Automatic car retarder system		8,500,000
Interlocking & double track CTC from Merchants Bridge to Valley Jct., via "Illinois Transfer R. R.", and from "Q" Tower, E. St. Louis to "CP" Jct. and Walsh Yard		2,750,000
Air compressors, including building		150,000
Air, water and sewer lines and fire protection		500,000
Flood lighting		500,000
Communications, including paging and talk back, radio equipped yard locomotives and T. V. for checking inbound cars		285,000
Pneumatic tubes		160,000
Ice plant & icing machines		1,825,000
Buildings:		
Main Yard Office		500,000
Yardmasters tower		50,000
Retarder towers (6)		120,000
Locker & washroom facilities (2)		175,000
Outside yard clerks (4 locations)		40,000
Cafeteria		250,000
Car inspectors buildings & section houses		75,000
Track scales (2 @ $100,000)		200,000
Total carried forward		$36,940,000

TABLE 13
continued

Total brought forward	$36,940,000
Car repair facilities:	
Car shed	100,000
Paving & jacking pads & platforms	200,000
Machine tools, etc.	60,000
Buildings - office & locker room	50,000
Power transmission lines	200,000
Diesel enginehouse facilities	2,500,000
Storeroom	350,000
Highway grade separations	3,000,000
Access and relocation of roadways	350,000
Relocate Alton & Southern Railway	250,000
Parking areas for employees	75,000
Incidentals & contingencies	1,000,000
	$45,075,000
Less salvage value and income tax saving on write-off to Operating Expenses for abandoned trackage *	1,000,000
Estimated net cost of project	$44,075,000

* Does not include value of 10 or more TRRA 1,000 h.p. switch engines which can be released upon completion of this improvement or similar recovery of property values by other carriers benefited by Walsh Yard.

Saint Louis, Missouri
April 2, 1957

Source: Report of the Terminal Modernization Committee, Terminal Railroad Association of St. Louis, New Yard Facilities Proposed to Expedite Freight Movement. St. Louis, April, 1957.

of those costs is made only where relevant to the issues under analysis. The revised investment for the ICS design yard is listed in Table 14. No attempt has been made to update these costs from 1956 levels as their significance lies in a comparison with the Walsh design and not in their absolute dollar values.

The economic issue under consideration is a proposition that an increase of velocity of movement through a yard is accompanied by a decrease in capital requirements for the facility. The capacity of the yard is established at the hump, as well as the standing capacity of the class tracks. The comparison given in this chapter demonstrates a reduction in capital costs in spite of the expansion of the functions that the yard was to perform. Had the incremental cost of the new functions been excluded the demonstration would have been more conclusive. However, we would not then have demonstrated, through the St. Louis problem, the value of the ICS grid under volume conditions. It is to this issue that we now turn.

The value of the ICS grid in stage two of the yard is revealed only indirectly. A railway system is highly interrelated in its parts. It would be desireable to demonstrate this interrelation by showing a reduction of terminal costs at one location in a system consequent to an increase of work and costs at another location. The linkage between yards in the system lies in the cost-reducing inputs given one yard by another. This input is the internal train order of its car sequence.

The St. Louis terminal is only part of a railway

TABLE 14

ESTIMATED COST OF ICS DESIGN FOR WALSH YARD (Plan 2A)

Costs Adjusted from Walsh Yard Estimates

Engineering (note 1)	$ 2,400,000
Property (note 2)	2,227,500
Grading (note 2)	2,923,600
Trackage (note 3)	
New 115# rail, 130,000 feet, @$13.50	1,755,000
SH 100# rail, 587,400 feet, @ $9.00	5,286,600
Crossovers - 48 @ $6600 - new	316,800
Turnouts - 478 @ $3300 - new	1,577,400
Automatic car retarder system (note 4)	4,250,000
Interlocking controls and junctions, CTC on connecting lines (note 5)	5,500,000
Track Scales (1 @ $100,000; note 6)	100,000
Car repair facilities (note 7)	
Car shed	300,000
Paving & jacking pads & platforms	600,000
Machine tools etc.	180,000
Buildings, office and locker rooms	150,000
	$27,666,900
Other items, not included above, same as Walsh estimate.	12,755,000
Estimated cost of yard	$40,421,900

Notes for Table 14 on next page.

Notes to Table 14

1. Walsh estimate tripled due to additional engineering work required.

2. Based upon relative standing capacity of the two yards.
   13,350 ÷ 17,980 = 74.25%
   Property - 1,200 acres x 74.25% = 891 acres @ \$2500
   Grading - 2,625,000 cu. yards x 74.25% @ \$1.50

3. SH trackage requirements:

Yard	No. of Tracks	Track length	Car Capacity	Feet of Track
Receiving	16	150 cars	2,400	105,600
Running tracks	3	150	450	19,800
Class Yard #1	72	30-150	6,000	264,000
" " #2	15 (2)	20 (2)	1,200	52,800
Departure	30	20-150	3,000	132,000
Car Repair	10	30	300	13,200
Totals			13,350	587,400

4. The use of three humps and associated control equipment rather than six requires only 50% of Walsh estimates.

5. Item doubled to allow for extended CTC and interlocking controls on several routes from departure end of yard.

6. One hump rather than two to be fitted with scale.

7. Car repair facilities expanded, costs tripled.

system. Output to the other yards will reduce costs at other locations. The theory of yard interrelations coherently demonstrates this. Empirical evidence is given in the practice of maintracking which the railways accept as essential to economic operation.

As these two yards perform vastly different functions, their estimated operating costs are even less comparable than data of investment. The Walsh Yard could perform no classification upon outbound road trains. It merely prepared trains for transfer runs to other yards where this work might be done. The operating savings anticipated from Walsh Yard are given in Table 15. These savings are estimated to accrue within the St. Louis area alone. Comparable savings data from the ICS design yard would have to include savings from three sources. The first would be the elimination of classification at many yards in St. Louis. These savings would accrue from the consolidation of geographically dispersed yards into a single yard operation of specialized design. Second, is the elimination of yard work at locations other than St. Louis due to the increased train order inputs to those yards. Third, there are those costs reduced by more efficient train operation of trains created in the ICS design yard. A local switch run, for example, whose cars are in perfect sequence, can perform more work per switch engine hour since it is not delayed by the necessity of properly sequencing its cars.

The expanded function of Walsh Yard in the ICS design proposal will enhance the savings possible under the TMC's original plan. There is little doubt of that. Additional

TABLE 15
PART VII

ESTIMATED EFFECT OF WALSH YARD IN REDUCING ANNUAL OPERATING EXPENSES OF ALL LINES WITHIN SAINT LOUIS GATEWAY

Decreased Operating Expenses	Per Annum	
Switch Engines	$7,610,000	
Yard Masters, Yard Clerks, Car Inspectors, Operators and Miscellaneous Yard Personnel	1,088,000	
Per diem and equivalent daily value of mileage cars	3,026,000	
Reduced injuries to persons and freight loss and damage	300,000	
Total Estimated Savings		$12,024,000
Increased Operating Expenses		
Retarder Operators	$ 155,000	
Fieldmen in Classification Yard	88,000	
Power Requirements for Retarders, Flood Lighting, etc.	72,000	
Maintenance of Retarders and Associated Equipment	120,000	
Maintenance of Additional Trackage	150,000	
Estimated Depreciation on New Facilities	500,000	
Increased Property Taxes	132,000	
Total Increased Expenses Per Annum		1,217,000
Net Reduction in Annual Operating Expenses		$10,807,000

Annual Return on Net Cost of New Facilities

$$\frac{\$10,807,000}{\$44,075,000} \text{ equals } 24.5\%$$

The foregoing savings are not distributed among component lines but approximately 40% would accrue to TRRA, 10% to other switching lines and 50% to the road haul carriers.

offsetting costs are incurred, however, in creating the high internal train order conditions we regard as desirable. The extent to which these increased costs would be offset by the lowered unit costs of classification within a high volume yard is unknown. In addition, these savings from lowered unit costs, even if negative, have significance for us only in their relation to the cost of other railway operations. As this relation cannot be known at this time there is little value in pursuing a comparison of savings, Walsh vs. ICS. Such an analysis, it is anticipated, would provide additional empirical data to demonstrate that yards are interrelated in their work.

The concept of yard interrelationships is well established in railway thinking. A corollary to the principle of these relationships is that trains of high internal order may have economic value. Such trains can be created only on a grid track pattern. The grid varies from the conventional only in regard to ladder to class track length ratios and the techniques of feeding and emptying which have been suggested. The short grid pattern provides the access to individual cuts necessary to build trains of highly sequenced cars.

By applying the ICS grid to the St. Louis situation we have illustrated the fallacy behind the view that states: to create X classifications in a yard one must have X class tracks. By feeding trains of randomly sequenced cars to a grid, the number of possible classifications becomes the product of grid track width times the number of trains passing through the grid. The one to one correspondence of trackage and classifications is thereby broken. The capital requirements for a yard designed to produce a high number of classifications no longer prevent construction of such facilities, as was the case in St. Louis. Plan 2A, rejected by the Terminal as beyond manageable scope,finanacially and physically, is accomplished,using the ICS grid, while reducing capital requirements established for Walsh Yard. The economic power of this technique is thereby suggested.

F: THE PRESENT ST. LOUIS SITUATION

The Walsh Yard would have returned 24.5% on the investment annually. This is based upon the annual operating savings of all the roads affected by the plan. Some roads would receive a greater return upon their share of investment than others. The response of the roads to the proposal to build Walsh Yard was negative. The project was vast and expensive. It was the validity of the theory of yard interrelations, however that killed the plan. The railroads are pressedfor capital and must invest what they have at the greatest return to themselves. By investing X dollars into new yards at the geographic center of their own systems they could gain a higher return than with Walsh Yard. Walsh is on the outskirts of the member railroad systems. An efficient yard at this point could not effect savings in the member railway systems as much as an equal investment deeper within those systems.

For example, the New York Central chose to build a new yard at Indianapolis in 1957. Construction was delayed until 1959. This location provided the Central with a low cost classification facility for the entire Southern District. Many yards are to be reduced in importance and functioning with the opening of the new Avon Yard. Savings from yard force reductions could not have been as great from the same investment if the new yard had been on the outskirts of the system at St. Louis.

Because the cost and delays of interchange through St. Louis were so onerous, the TRAA undertook to alleviate the situation in early 1960. Its method was not to build a new yard, as this had already been rejected, nor did it explore variations in yard design which would increase the return from a new facility. It chose to shift much of the classification work in St. Louis to outlying yards of the member railroads. It published a new tariff for its interchange services. Whereas formerly it charbed a set fee per car for interchange haulage between two member roads it established a variable rate per car if certain conditions were met. To obtain a decreasing rate per car, a railroad must present the Terminal with a block of preclassified cars of fifteen car lenth or more. Such a block could move to the receiving railroad without switching.[17]

An economic incentive, therefore, has been provided to encourage member railroads to preclassify their trains prior to arrival in St. Louis for delivery to other railroads.

If it chooses, the member road may do this work at its St. Louis yard prior to its request to the terminal railroad to handle these cars in interchange. The Terminal Railroad Association has reduced its costs by avoiding switching and instead performing only direct transfer hauls between the yards of member roads. It has reflected these savings in its new tariff. The terminal costs of member roads has undoubtedly increased as they are performing more work than they did previously. As railway costing is inefficient in producing accurate data for a specific variation in terminal costs per car it is problematic whether or not the railroads have decreased their total cost by the use of the new TRRA tariff. The railroads have made extensive use of this plan and must therefore either believe that these total costs have been reduced or that the increased speed of movement through the St. Louis Gateway justifies any possible increase of cost. The probable result of the plan is that costs are largely unchanged, whereas the time required to traverse the St. Louis terminal has been reduced.[18]

The St. Louis terminal problem has been solved for the present, therefore. Yard construction was rejected, paradoxically perhaps, because of the value of a single yard to a system of yards. Corporate dimensions defined that which is a railway system, and in so doing prevented new yard construction at that location which is most truly a turbulent center of our national railway system.

Footnotes

Chapter Five

1 New Yard Facilities Proposed to Expedite Freight Movement, unpublished report of the Terminal Modernization Committee, Terminal Railroad Association of St. Louis (St. Louis, April 3, 1957), p.3.

2 Ibid., p.10.

3 Federal Coordinator of Transportation, *Report on Economy Possibilities of Regional Coordination Projects,* prepared by Section of Regional Coordination, pp.5-18.

4 T.M.C. op.cit., p.17.

5 Ibid., p.18.

6 Ibid., p.19.

7 Ibid., p.20.

8 Ibid., p21.

9 Sixty-ninth Annual Report of the Terminal Railroad Association of St. Louis, Fiscal year ended December 31, 1958, p. 5.

10 Annual Report Form A to the Interstate Commerce Commission of the New York Central Railroad Company, 1958, Schedule 320, Accounts 378-80.

11 New York Central Railroad Form T-13A, September 1958, Syracuse Division.

12 T.M.C. op.cit., p.6.

13 Ibid., p.9.

14 Ibid., p.10.

15 Ibid., p.37.

16 Ibid., p.11.

17 *Railway Age*, May 9, 1960, p.24.

18 Ibid., p.25.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

The classification process is based upon the belief that train operation is more economic in aggregate cost than operation of cars singly. The trucking companies have penetrated the former rail monopoly by a technique of haulage which does not accept the basic railway premise.

The long term success of the railway industry depends upon its ability to generate net revenues. Reduction in the cost of yard operations is a key factor in the necessary attempt to control total costs. Only if yard costs are minimized can the industry reflect in its total costs the economic advantages of multiple-unit (train) operation. The service defects imposed by yard operation must also be surmounted if the trucking industry is to be surpassed.

A: CONCLUSIONS

1. Control of yard costs must begin with an analysis of yard operation. This analysis finds that the apparent input and output of the classification yard are identical. Only the relationship of the cars to one another is changed. This introduces us to the first conclusion: that the function of the yard is to create order.

2. Randomized car sequences must be ordered. Car relationships are broken up by classification of cars. The separation of cars constitutes the first stage of a two stage process. The second stage is the assemblage of cars into groups or sequences deemed to be economically advantageous. Stages one and two correspond to the work of train dissolution and assemblage. The second stage is performed today in the same manner as it was 100 years ago. Given the changes in technology, it is more than suspect as being less economical than possible.

3. The assemblage of cars into blocks prior to train creation occurs because: further work would, in some cases, be unnecessary and therefore uneconomic; andgiven the existing level of technology further order creation cannot be done economically. The latter cuase of blocking is a most serious limitation. It prevents the fullest realization of low cost train and terminal operation. Blocking of cars is, therefore, only justified in a moderate degree.

4. The yards of a system are interrelated. Their internal train order outputs constitute an input to the receiving yards. Work and cost minimization must consider this structural interraction.

5. There exists a need within the national railway system for yards of extremely high capacity in two dimensions. These dimensions are: a) the capacity to absorb high volumes of cars per day into a classification process, and b) the ability to create, economically, car sequence output which is

highly ordered.

B: RECOMMENDATIONS

In recognition of the above conclusions, the following recommendations to the industry are in order.

1. Hump Capacity

The car absorbtion capacity of hump yards must be increased by the use of higher humping speeds. This may be accomplished by studying and utilizing the three following closure prevention techniques, individually or in combination.

a) Use flange counters rather than track circuitry between the hump crest and the class tracks to actuate switching controls. This will diminish switch lock-up time and allow greater closure to occur harmlessly.

b) Remove the master retarder and withdraw some or all group retarders to the individual class track. By so doing, we can reduce closure inducing forces to a negligible amount.

c) Use a device to detect the distance beyond the hump at which two successive cuts will separate to their individual routes. The random route alternations of successive cuts can thereby be used to advantage. The presence of a closure problem can be measured by the distance to route separation. As the cuts travel a common route of increasingly great length they will be in increasing danger of closure effects. Cuts which find a free route quite early in their free motion down the hump slope are not in danger of closure impacts. It is probable that this danger will not exist, given the random input. Therefore we can hump at higher speeds than now allowed.

2. Train Creation

In order to break the limits on train order output the following should be investigated.

a) The traditional ratio of class track length to ladder track length must be reexamined. Short block, high internal train order output necessitates more class tracks of short length.

b) Use an ICS grid in the track pattern of the classification yard. It should be located between the class yard and the departure yard. In cases of quite small hump yards, it may be the class yard itself. In larger yards the ICS grid may be held for occupancy be one train at a time, thereby gaining flexibility and reducing capital requirements.

c) Employ remotely controlled locomotives throughout classification yards and in emptying the ICS grid in particular.

The use of these techniques will enable the carriers to economically eliminate random car sequence in trains and thus advance in their drive to create a better transportation service.

APPENDIX ONE

Track circuitry in hump yard classification switches is accepted as necessary for two reasons. First, the circuits insure the clearance of a route before occupancy by a second cut. Collisions are thereby avoided. Secondly, the clearance of a circuit at some switch is used as an indication that the points are ready for movement.

The first of these reasons for conventional circuitry is doubtful. All cars are moving in the same direction down the hump. Only closure rates, if existent, present any possibility of collision. Hump rates are limited to the extent necessary to avoid this problem. Therefore the conventional full length track circuit is unneeded for classification switches.

Track circuits require the flow of electrical current through rails, wheels and axles. The reliability of the circuit depends upon good contact between rails and wheels. This contact varies in quality with weather and track conditions. Also, an extremely short track circuit would indicate non-occupancy when it is straddled by a long car. Switch movements would occur at embarrassing times and derailments could result. This is especially true as freight cars have recently been designed with lengths up to eighty-eight feet. If counting circuits are used in conjunction with a short track circuit the counters will fail to count the essential unit.

The unit to be counted for switch control purposes is the number of wheels or axles that have passed the switch point. This needs to be known in order to find the moment at which the last wheel of a cut has cleared the switch point. It is at this time that the point is ready for movement to lie up a new route. A counter, applied to a track circuit, could only count occupancy and non-occupancy periods. The number of axles per se would not be counted.

In order to provide the requisite signal to the switching circuits that the switch points are free to move the following design is recommended.

Axle counters should take the form of flange counters. The flange counter should be placed on the inside head of the rails immediately behind the switch point, one on each rail leading from one of the two switch points. The counter mechanism may take two forms. The first would use a sealed microswitch, opening a circuit as a flange detector pin is pushed downward by the passage of a flange. The second is an inductor similar to that of hot box detector control circuitry.

Cut length is detected by a photoelectric cell device beyond the crest of the hump. At the time that the light beam is broken by a cut, a flange counter at the same location is reset to zero and begins to count. The axle (flange) count is completed for that cut when the light beam is again detected by the electronic eye. This count is then stored and sent to the comparator unit for each switch over which the cut is to move. As the cut moves over the switch another count is made by a flange counter at that location. A comparison between the two counts is made. When the counts are identical, the switch is free to move. If the automatic switching circuits require that the points be moved, the command to do so can then be executed. The identity comparison does not of itself issue the command that the points be moved. A diagram of these information flows is given.

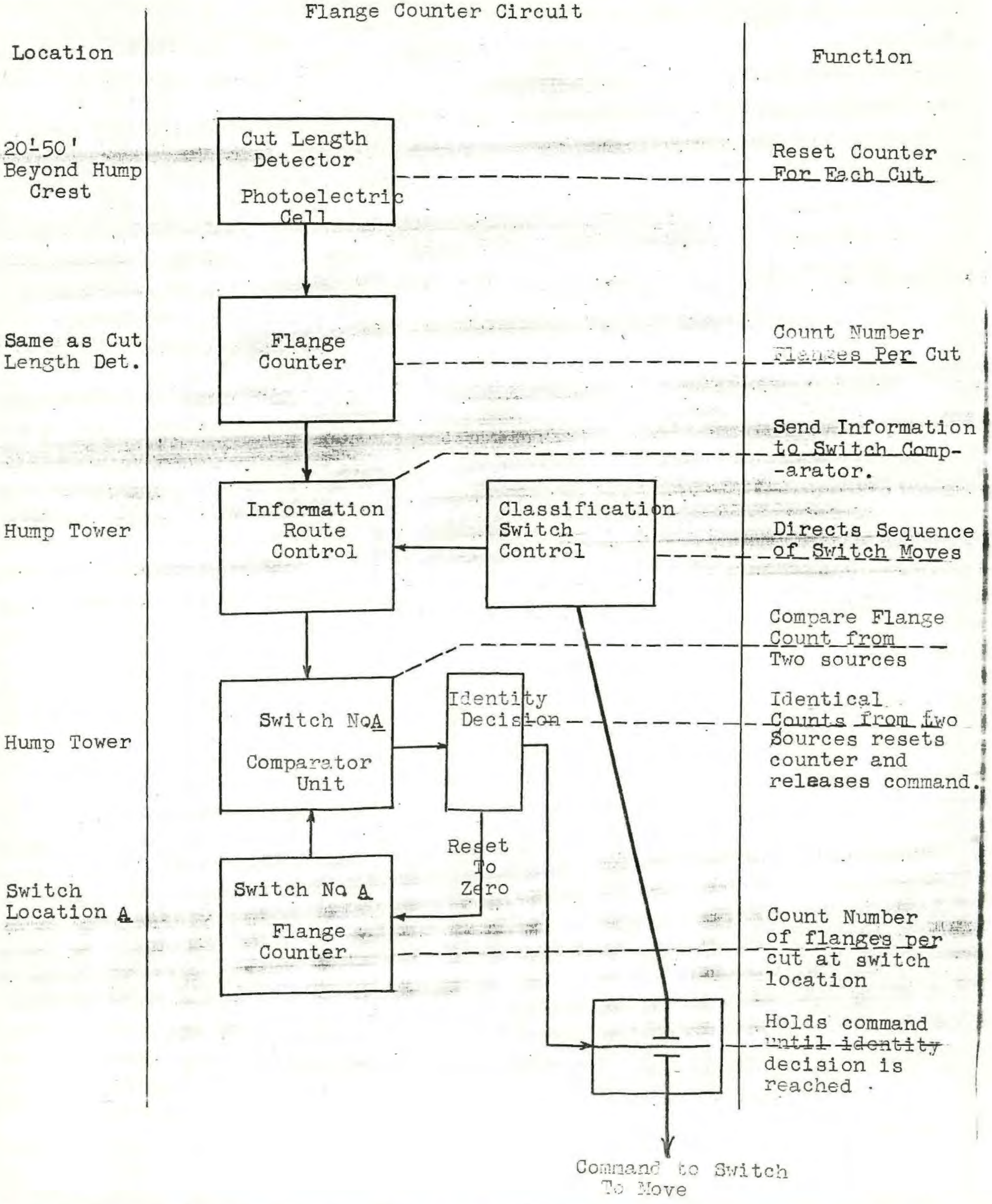
It is doubtful that such circuitry would be a great deal more expensive than existing track circuit designs. The greater obstacle to implementing such design is the probable relauctance of existing suppliers to undertake such a major change.

If applied to classification switches it will considerably reduce the separation requirements for successive cars and permit higher humping rates.

FIGURE 22

Information Flow Chart For

Flange Counter Circuit

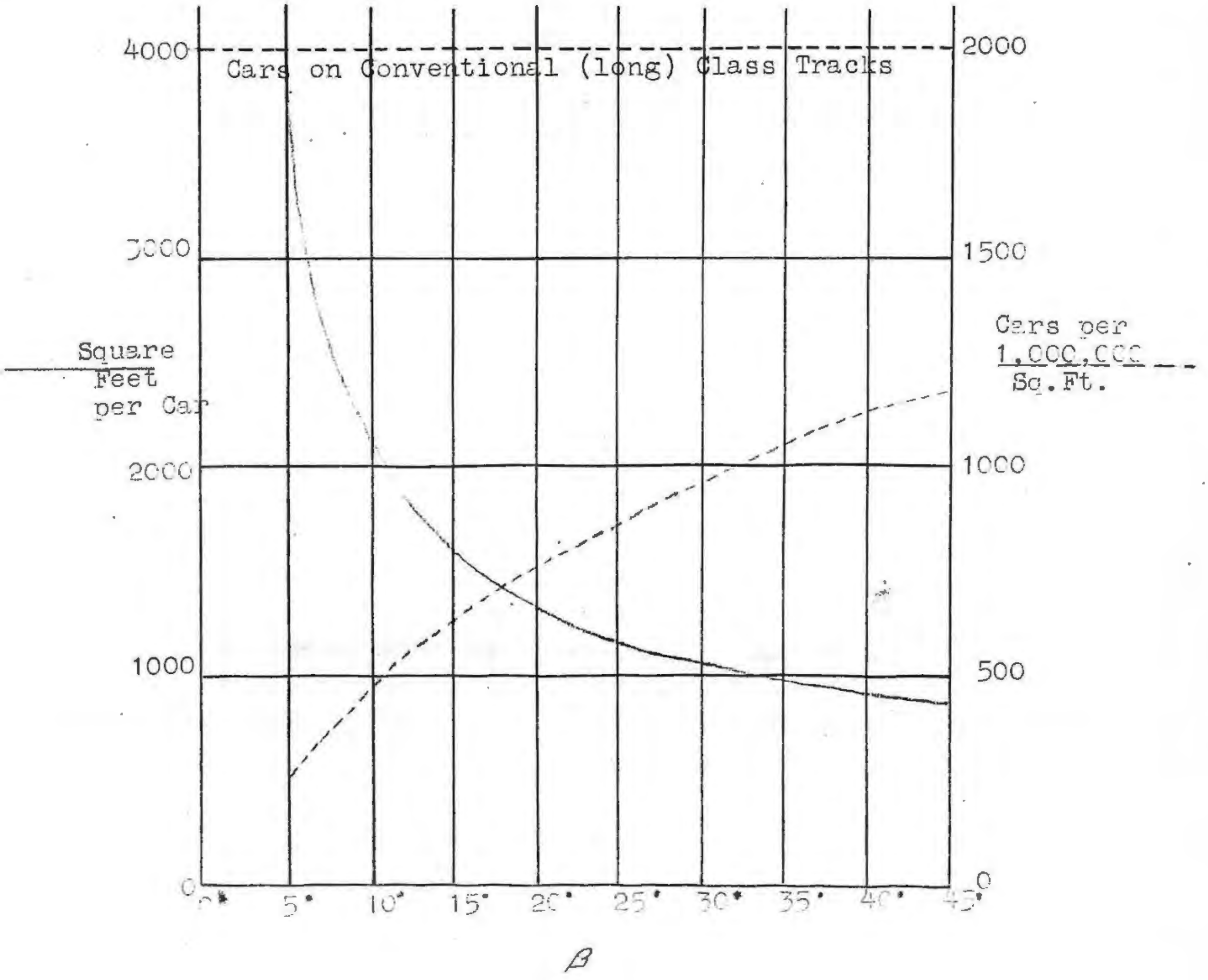


APPENDIX TWO

The ICS track pattern, in its most extreme form, would allow one car per class track. As would be anticipated, the land space required by such a design is considerably in excess of that for conventional design. A critical factor in this regard is the angle of separation (β) between the ladder and class tracks. This relation is shown below in Figure 23.

FIGURE 23

Relation of Area/Car and Cars/Million Sq.Ft. To Angle of Separation



The data presented in Figure 23 assumed a car length of 41 feet, clearance between cars of 2 feet, car width of 10 feet over eaves and 7 feet from the center line of the ladder track to the clearance point of a car on the class track.

The area required per car is (X)(Z) where:

$$X = (W + CL)/(\mathrm{Sin}\,\beta)$$

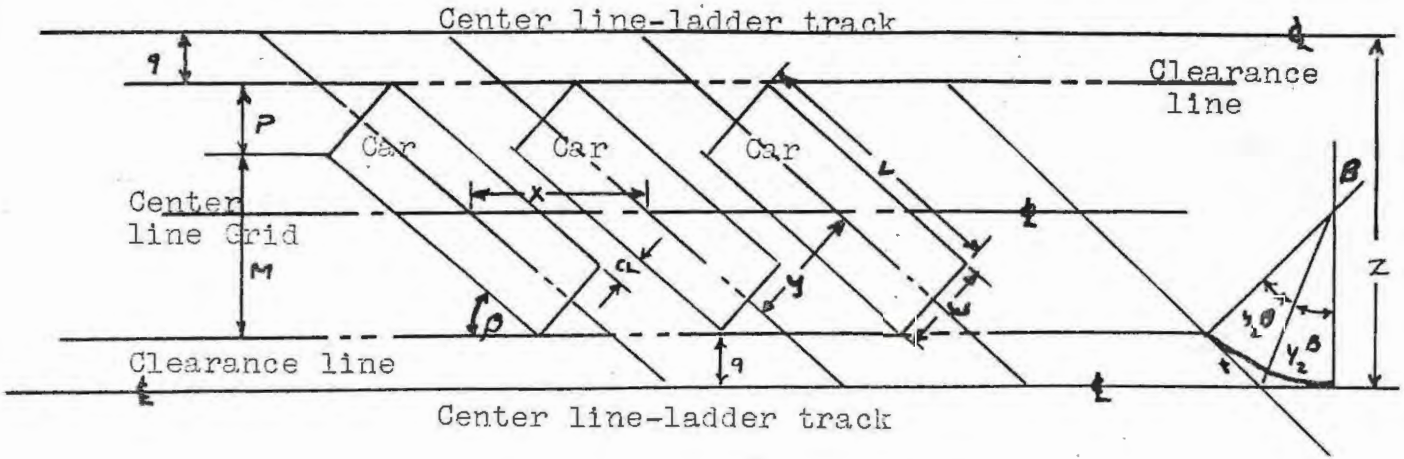
and

$$Z = L \cdot \mathrm{Sin}\,\beta + W \cdot \mathrm{Sin}(90-\beta) + 2(\mathrm{Sin}\,\beta\left[r \cdot \mathrm{Tan}\,\beta/2\right]).$$

Notation is presented in Figure 24 below.

FIGURE 24

Notation Used in Land Requirements Analysis



Cl = Clearance between cars
L = Length of car
W = Width of car
Y = W + Cl
X = Y/Sinβ
Z = M + P + 2Q

M = L Sinβ
P = W Cosβ
Q = Sinβ(r·Tan$\frac{\beta}{2}$)

This method is acceptable for values of β less than 30 degrees. Above this value some distortions are present in the data in Figure 23. Also a troublesome assumption is the value of car length near 40 feet. New designs are commonly 65 feet in length.

BIBLIOGRAPHY

ARTICLES

"The Theory of the Design of Railway Freight Terminals", International Railway Congress Bulletin, XXI (1907), pp. 595-618.

"Report from Europe", Modern Railroads, June,1958.

"Squeeze Push-Button Yard into Busy City Area", Modern Railroads, June 1958,p.82.

Modern Railroads, XIV (July,1960), p.50.

The Official Railway Equipment Register, LXXV, no.2 (October, 1959).

"The Motionless Freight Train", Railway Age, March 31,1923, p.851.

"Hump vs. Flat Yards", Railway Age, May 7,1927,p.1378.

"Maintracking", Railway Age, April 7, 1928,p.792.

Railway Age, Operating Economy Series, No.4, XCI, No.5 (August 1,1931).

"Lackawanna Improves Yard Operation", Railway Age, March 19, 1938,p.502 ff.

"Possibilities for Maintracking", Railway Age, CVII, September 9,1939, p.378.

"Getting Trains Out of Yards", Railway Age, CXIV, April 10, 1943, p.704-5.

"Smaller, More Frequent Trains", Railway Age, CXVII, November 4, 1944, p.693.

"How Can Carriers Secure Better Car Handling in Yards and Terminals?", Railway Age. CXXXII, May,1952, p.44-47.

Railway Age, October 5, 1953, p.20.

Railway Age, May 24, 1954, p.16.

Railway Age, Centennial Issue, CXLI (September,1956), p.265.

"How About Shorter Trains-Oftener?", Railway Age, October 21, 1957, p.9.

"Newest Yard Is Built To Grow With Traffic", Railway Age, October 21, 1957, p.27.

Railway Age, February 24, 1958, p.14.

"How Long Should a Freight Train Be", Railway Age, February 24,1958, p.29.

"New Yards Score As Men Back Up", Railway Age, March 3, 1958, p.30.

"Soviet Automatic Train Engineer", Railway Age, CXLIV (June 23,1958), p.25.

"Yard Automation Pays Off", Railway Age, July 14,1958, p.21.

"Trains Enter This Yard Fast", Railway Age, August 4, 2958, p.13.

"L&N's New Yard Aids Shippers", Railway Age, January 26, 1959, p.31.

"Communications Guide For a Modern Classification Yard", Railway Age, March 11, 1959, p.14.

"Get Those Terminal Costs Down", Railway Age, June 1, 1959, p.38.

Railway Age, June 15, 1959, p.9.

Railway Age, October 19,1959, p.42.

Railway Age, November 30,1959, p.80 .

Railway Age, December 21, 1959, p.46.

Wright, Walter E. "How Cars in Multiple Cut Costs", Railway Age, January 4, 1960, p.14.

Railway Age, January 25, 1960, p.22.

Railway Age, CCXLVIII, No.13 (March 28, 1960), p.22.

Railway Age, May 9, 1960, p.24-25.

Trains, December, 1947, p.50-53.

Trains, June, 1957, p.17.

Trains, March, 1957, p.12.

Trains, April, 1959, p.10.

BOOKS

American Railway Signalling Principles and Practices, Chapter XXI, Hump Yard Systems, New York, Association of American Railroads, Singal Section, 1948.

Barriger, John W. *Super Railroads for a Dynamic American Economy*. New York, Simmons-Boardman, 1951.

Beckmann, Martin, McGuire, C.B. and Winston, C.B. *Studies in in the Economics of Transportation*. New Haven, Yale University Press, 1956.

Byers, M.L. *Economics of Railway Operation*, New York, Engineering News Publishing Co., 1908.

Delaware, Lackawanna & Western Railroad Company. *Rules of the Operating Department*, effective April 27, 1952, np,np, nd.

Droege, John A. *Freight Terminals & Trains*, New York, McGraw Hill Book Co., 1925.

Drennan, C. M., *ABC's of Air Brakes*, New York, Simmons-Boardman, 1954.

Eastern Railroads President's Conference, *Yearbook of Railroad Information*. New York, Eastern Railroad Presidents Conference, 1959.

General Railway Signal Company, *The Design of Retarder Yards and Retarders*. Bulletin 155, March,1929. Rochester, New York. General Railway Signal Company.

Loree, L. F. *Railroad Freight Transportation*. New York, Appleton, 1922.

Miller, Sidney L. and Cover, Virgil D.,et.al. *Rates of Return: Class 1 Line Haul Railways of the United States, 1921-1948* n.p., University of Pittsburg Press, 1950.

Railway Track And Structures Cyclopedia, Dick, Merwin H. (ed.) New York, Simmons-Boardman, 1955.

Rose, J. R. *American Wartime Transportation*. New York, Crowell, 1953.

Union Switch and Signal Company, *Freight Classification Yards, Design and Operation*, Bulletin No. 1955. Union Switch and Signal Company, January, 1939.

Union Switch And Signal Company, Modern Yard Operation, Bulletin No 108. Union Switch And Signal Company, September, 1926.

PUBLIC DOCUMENTS

U.S., Federal Coordinator of Transportation, Freight Traffic Report. Vol.1, Vol.2, Washington, D.C., 1935.

U.S., Federal Coordinator of Transportation, Report on Economy Possibilities of Regional Coordination Projects. Washington, 1935.

U.S., Interstate Commerce Commission, 72nd Annual Report on Transportation Statistics in the United States for the Year Ending December 31, 1958. Washington, 1959.

REPORTS AND PROCEEDINGS

American Railway Engineering Association, Proceedings, 1917, Vol.8. American Railway Engineering Association, Chicago, 1917.

Crane, Roger. "Some Examples of Operations Research Work", Proceedings of the Railway Systems and Proceduress Association, December, 1953. p.97.

New York Central Railroad Company. Annual Report to the Inter-State Commerce Commission, for the years ending December 31, 1958 and 1959.

Sixty-ninth Annual Report of the Terminal Railroad Association of St.Louis, fiscal year ended December 31, 1958.

UNPUBLISHED MATERIALS

Agreement between the New York Central Railraod Company, Western District, and the Brotherhood of Railway Trainmen, Cleveland, Ohio, December1, 1955.

Exhibit Accompanying testimony of James M. Symes, President, The Pennsylvania Railroad Company, before the Subcommittee on Transportation, House Committee on Armed Services, at the Hearings on Adequacy of Transportation in the Event of Mobilization, July, 1959.

Humphreys, Russell W. "U.S. Army Control of Port-Bound Traffic during World War II". unpublished Master's thesis, Wharton School, University of Pennsylvania, 1948.

New Yard Facilities Proposed to Expedite Freight Movement, report of the Terminal Modernization Committee, Terminal Railroad Association of St. Louis. St. Louis, April 3, 1957.

New York Central Railroad, Form T-13 A, Comparative Summary of Operation of Yards, January, 1960.

New York Central Railroad, Form T-13 A, Comparative Summary of Operation of Yards, September, 1958.