THE ECONOMIC JUSTIFICATION OF DOUBLE TRACKING

by

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fulfillment of the requirement for the
degree of Master of Science.

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Preface.

In recent years the attention of the public has been turned towards the subject of the more economic operation of railroads of this country for two reasons. First, because of many receiverships and financial troubles of various railroads in spite of fairly good years, and second, because of the ruling of the Interstate Commerce Commission and state legislation concerning rates. Only a comparatively small mileage of new line has been built within the last five years, the energy of the railroads being expended in double tracking and improving the existing line. The problem of, when is it good economy to construct the second track, is very complex. It is the purpose of this paper to make a study of the various phases of railroading which are involved in the construction and operation of the second track.

Many writers and authorities have set forth their opinions in a general way, and in this paper the author attempts to collect some of these opinions in a usable and connected form. Several articles are quoted verbatum, in order to secure the force and elegance of the language of such men as the late Mr. A. M. Wellington, W. M. Camp, Prof. W. L. Webb or J. J. Hill, who are recognized as authorities on the economics of railroading.

The hypothetical problem and solution set forth in Part IV of this paper is believed to be based on fair and reasonable assumption, and it is suggested that perhaps an actual problem might be solved in a similar manner.

The writer wishes to express his appreciation and thanks to Prof. C. C. Williams of the department of Railway Engineering of the University of Kansas, for help and suggestions in the present undertaking and also to Mr. J. A. Brouk, for assistance in the preparation of the manuscript.

Respectfully submitted,

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Approved,

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May 15, 1915.

The Economic Justification of Double Tracking.

CONTENTS.

The Economic Justification of Double Tracking.

Introduction.

It is very difficult to ascertain with any degree of certainty, just at what point in the development of the traffic of a railroad, it becomes more economical to double track than to continue the single track operation of the road. The problem is at once recognized to be a comprehensive one, involving questions of construction, maintenance, and efficient and economical operation.

In a purely construction problem, as for example the crossing of a certain divide, the engineer can say with a close degree of accuracy, at just what depth it becomes more economical to tunnel, rather than to use a deeper open cut. Also the maintenance department cam, from long experience and carefully kept records, decide what kinds of track materials give the best results. Likewise the department of motive power is able to justify itself in the purchase of a new locomotive of improved type, and to combine two sections of a certain train, thus reducing the number of train miles run. On the other hand, the double track problem becomes complex, because of the large number of variables affecting it, and all of the above mentioned items must be duly weighed in any attempt to reach a solution.

The probability of the road's ever needing a second track should be considered in the first location of the line, but as nearly everyone knows, whether particularly interested in railroads or not, the railroads of the United States were built with but little thought of the future. The object was to connect as cheaply as possible and as quickly as possible, the Atlantic seaboard with the Ohio Valley and the Great Lakes, next the Ohio and the lakes with the Mississippi and Missouri Rivers, and lastly to join the Missouri with the Pacific Coast.

The new territory thus opened was unsettled and undeveloped, in fact it was the building of the railroads that facilitated the settlement of all the lands west of the Missouri River. Little thought was givento the growth of traffic and population in the country opened up for settlement, If the location engineers had ventured to say that the thought of a second track should be considered, they would in all probability have been laughed at, and perhaps with good reason, as there were no funds for any need of such a facility.

Railroad building west of the Ohio country was a speculation. There were no figures to show how much traffic would be needed to cover operating expenses, or what proportion operating expenses bear to operating revenues.

Men believed that transcontinental railroads would pay, but the matter was much like the motor bus problem of today, there were no figures to go by. Therefore, pioneer railroad builders could not be blamed for not locating with an idea of a second track being needed forty years in the future.

For certain specific conditions the question almost solves itself. As an example take the case where a long and expensive tunnel is to constructed, even if the volume of traffic does not warrant the item of safety of operation almost demands the second track. Again where the grade over a certain summit necessitates the use of helper engines and the cutting up of the trains, a second track may be justifiable in order to accommodate the engines returning to the foot of the summit.

The more general problem, of a certain division or number of divisions having a heavy traffic, where the length and tonnage of trains is not limited by the ruling grades is of more difficult solution. It is very difficult to say just when the management of a road is justified in abandoning the policy of adding passing tracks, with their burden of extra operators and signal men and the accompanying expensive delays to waiting trains, and to connect up the passing tracks into a continuous second track.

Thus it may be that the general problem is more difficult to solve than the specific, or more local situation. The question may be stated thus; when do we pass the point of economy, all sides of the question being considered, in the process of adding passing tracks.

Part I.

ECONOMIC OPERATION OF RAILROADS.

In purpose and essential features of organization a railroad has been compared to a factory, or industrial plant, which takes certain raw materials and turns out a finished product. The railroad uses the raw matierials of distance and power, and produces train miles and then by transporting goods or commodities the marketable product of ton miles is produced and in the care of passenger service, the product is the passenger mile. In the factory the aim is to furnish the finished product with the least outlay possible for materials and labor. So the aim in railway operation is to furnish the ton mile at the least expense possible. The tracks and terminals of a railroad might be compared to the buildings of an industrial plant and the locomotives and cars to the machinery within the plant. If the business is a growing one, the demand for the product will increase to the point where the plant will be unable to supply the demand. It will then be necessary to add more buildings and machines, if the owners wish to keep pace with their competitors.

So in the railway business the traffic demands may become too great for the capacity of the line and more track, line and terminal facilities, and larger and more powerful rolling stock must be added. With the above analogy in mind, it is obvious that in considering the matter of successful operation of the modern railway system, the problem at once divides itself into two factors or elements: viz., first, the construction, and maintenance of proper track, or line, and terminal facilities, and second, the handling and maintenance of the rolling stock, that is, the cars and locomotives.

Since the purpose of this paper as stated in the introduction, is to discuss the problem of proper line facilities, it will be assumed that the road has an equipment of rolling stock, which is in every way sufficient for the growing needs of the road. However, the item of rolling stock can not be passed over in this problem and some time will be devoted to it later in the discussion.

Looking into the question it is evident that the line and terminal facilities are very closely linked with one another and if in the phraseology of the time worm adage, "a chain is no stronger than its weakest link", of what purpose would elaborate terminal facilities be, if the single track connecting them could not handle the trains with dispatch, or conversely, what would be gained with a well maintained double track line, if the terminals are small and inadequate. A terminal yard choked with unclassified cars is as expensive as train delays at passing sidings.

The Essentials of Good Location.

If it has been decided that the main line facilities of a road need attention, and further if the expense of the second is justifiable, then a careful study of the location of the line should be made. Perhaps the location of the old line can be improved without prohibitive cost. Many existing lines were built in haste and without sufficient study of the conditions of the greatest economy, or perhaps the conditions which controlled the original location of the line do not apply now. That this condition exists is a recognized fact, and many lines are being improved, or have been improved as a result.

The horizontal and vertical alignment are the important features to be considered. The first is in reality the item of distance, while the second makes or abolishes the grades and limits the length of trains operated over the division. A radical change in the location of the line may be justifiable, and the new line placed several miles from the old. Thus the company may be enabled to compete for the business of a city formerly off the line and at same time eliminate a certain heavy grade or a bad crossing of a stream. The item of nearness of a road as a shipping point, becomes very important, even when pertaining only to a small city. The new location may still be used in conjunction with the old as a part of the double track system. Also cases are on record of the selling of the original right of way and track to an interurban or electric road, with profit to both parties concerned.

In relocating a line the engineer has the advantage of having at hand data on the traffic of the existing road, as well as the actual cost per train mile, and the performances of the different locomotives under these particular conditions. Opposed to these advantages it is often difficult to convince the financiers of a road of the advisability of abandoning the old location and building a new, and further there is a question concerning the legal status of abandoning a certain line, as the value of the adjoining property is likely to be reduced.

Before leaving the subject of a good location, a summary of a few of the principle items to be considered in the relocation would be something as follows. The more important points are, the passing by or the entering of cities somewhat off the line, excessive curvature and the improvement of the gradient, the relocation of water tanks, passing tracks, stations and the like with reference to the ease of starting trains. Also a radical change in the length of divisions or engine districts may be advisable, and it may be advisable to use pusher engines over certain summits.

All of these different phases of the question should be carefully considered before the line is double tracked or permanently improved for any mistake in location then becomes doubly serious.

Safety and Dispatch.

The rapid development and improvement of railroads is largely due to the demand for safety to passengers and employes, and the demand for dispatch in the handling of freight. In the passenger business the road which intends to compete for its share of the thru business between large terminal cities must have modern, all steel coaches. These trains must be equipped with the latest improvements for convenience and safety. The heavy steel coaches require larger and more powerful engines, which in turn necessitate heavier rails and a better roadbed. Fast operation requires the clearing of the line for the limited trains, the freight train being necessarily side tracked and consequently is delayed. These delays can be greatly reduced by increasing the number of passing tracks. Here the freight business has been pushed aside for the passenger service, but the freight business is the chief revenue earner of the road, and should not be hindered to the extent of affecting the business of the road.

The retail merchants in some localities in the smaller cities are in the habit of ordering goods from the large cities in the afternoon and having these goods on their selves the next morning. This necessitates the moving of freight trains from one hundred to two hundred and fifty miles in a single night. And in order to do this the trains must be kept moving continuously at almost passenger train schedules. Therefore, this dispatch freight business, which is a very profitable one, can not be neglected by a road nor in any way made secondary, and the line which does not furnish the proper means to promote safety and dispatch can not prosper.

The Operating Ratio.

The operating ratio is the result obtained by dividing the total operating expense by the total operating revenue, this ratio being expressed in percent. Under the very best of conditions the margin between total income and total expenditure is a narrow one. (See the table of operating statistics on page 84). The operating ratio, however, can not be taken as a sure index of the earning power of the road. For example a road may make a large outlay for the item of maintenance of way and structures thereby increasing the operating ratio may be temporarily. Or on the other hand, a road may be scanting its yearly renewals and thus operating at a low ratio. Further, it is the writer's opinion that one is not justified in taking the operating ratios of two roads, which serve practically the same territory, the one being double tracked to a considerable extent, the other scarcely not at all, and saying that the lower ratio is the result of the greater economy of the double tracked line.

Nevertheless, this study of the operating ratios is a very interesting one, and will if carefully made give a fair index as to the policy of the men who are at the head of the road. If for example one compares the Chicago & North Western Line with the Chicago, Milwaukee & St. Paul, which is a parallel road operating in the same territory, he will note some differences in the operating ratios. And some of the items show considerable variance, of these two roads the North Western has the greater percentage of second track. According to the statistics of the Interstate Commerce Commission for June 30, 1912, the North Western operated 17,960.45 miles of road of which 867.84 miles was second track. This is 10.9 percent of the total number of miles of road operated. The Chicago, Milwaukee, & St. Paul the same year reported 9,592.23 miles operated (this includes the mileage of the Chicago , Milwaukee & Puget Sound Ry.) of this 675.94 miles was double tracked, which is a percentage of 7.05 percent of the mileage operated. The Chicago,Milwaukee & St.Paul reports 19.59 miles of third and fourth track. while the Chicago & North Western shows 195.85 miles of third and fourth track. These two roads are competitors for the business of Chicago, Omaha, Sioux City, Minneapolis, St. Paul, Madison and Milwaukee. The Chicago & North Western seems to have laid particular stress on its line to Omaha, as that line is double tracked the entire distance. The Chicago, Milwaukee & St. Paul is a younger road and has turned its attention to the development of the Dakotas, which do not as yet require second track lines. The items in the accounts of the two roads compare very much the same, and although the Chicago & North Western has a slightly lower operating ratio. Yet it is not safe to say that this economy is due entirely to the fact of its being equipped with more second track. The Chicago, Milwaukee & St. Paul is in a position to show a good record in the future and probably will be able to operate at a lower ratio than it does at the present time. If we examine the accounts of two other roads in a similar manner we will be able to find a wider variance. For example the accounts of the Chicago & Alton as compared with the Chicago & Great Western, their territory is not quite the same, yet both are in the corn belt and the Illinois coal fields. The Alton is a high class passenger carrier, while the Chicago & Great Western is almost entirely a freight road. The total mileage of the two roads is almost equal and they have almost the same amount of equipment, but there is considerable difference in many of the other factors. The operating ratio of the Chicago & Alton is considerably lower than that of the Great Western, the Chicago & Alton has 10.7 per cent of second track, while the percentage of the Chicago & Great Western is practically nothing. These differences indicate entirely different policies of operation. The figures in favor of the Chicago& Alton are a result of its general policy of efficient and high class service, and the second tracking was only an item in the building up of this service, and this efficient service is not a result of the second track alone.

If we compare the Chicago & Eastern Illinois with the Chicago & Alton we again find the figures much the same in mileage, and equipment, and the two lines serve the same territory. The Chicago & Eastern Illinois has 16.65

per cent of second track and its ratio of 71.63 per cent as compared with 74.89 per cent of the Chicago & Alton and 78.20 per cent of the Chicago & Great Western, 72.81 per cent of the Chicago, Milwaukee & St. Paul, 71.51 per cent of the Chicago & North Western.

If the natural resources of the territory to the road have been fully developed, the income of the road is practically fixed. It then becomes necessary to decrease the expense side of the account in order to keep up the dividends. The items of maintenance of way and structures and of operating expenses are the largest. If the road is double tracked the item of maintenance of way and structures will be increased, but the item of operating expenses may indirectly be decreased by the second track, thereby doing away with many signal and tower man, and the expensive delays to freight trains which accompany single track operation.

The Ratio of Passenger Revenues to Freight Revenues.

It is a well known fact that the revenues from the passenger service compose the smaller portion of the total revenue than does the revenue from freight traffic. Yet on the single track road it is necessary to side track the freight train for the passenger train, regardless of their relative earning capacities. Often the modern limited trains are not more than half loaded, and as to whether the high class passenger trains are actually a paying proposition is sometimes doubtful. The passenger service is often spoken of as an advertising medium for the freight business of the road, but if this is true, is it good business policy to allow the advertising medium to interfere with the operation of the big revenue earner of the company. It would be better that a way be provided to keep the freight trains moving without interference by the passenger trains of the road.

The Item of Future Returns.

In considering the improvement of a road, the question of how the improvement should be financed, is one of the most important to be considered. Should the additional sidings, or second track, be added slowly over a period of say five years and the charge be made against maintenance, and additions and betterments, or should the work be done in as short a time as possible and the funds raised by selling additional bonds or short time emergency notes.

Under the first plan the management chooses to sacrifice present returns or dividends, and to use the funds for the betterment of the property. This is done because of the belief that the earning power of the road will be increased by reason of its increased capacity and more efficient methods of operation.

When funds for improvements are raised by selling bonds with a relatively long time to run and a low rate of interest, it is necessary to provide for the interest, and also to set aside a sum each year for a sinking fund with which to retire the bonds. In this plan the fixed charges of the road are increased, because of the extra charges for interest. The plan of issuing emergency notes is only an emergency measure, and is used only to raise funds until bonds can be floated at a more favorable rate of interest. Thus we see that no matter how the improvements are financed, the capacity of the company to pay dividends is going to be affected temporarily at least, and the question of how any Public Utility or Service Corporation should finance a needed improvement, is an open one among economists and financiers. Probably all authorities are agreed that the improvements should if possible, be considered before the need is too great, and a provision be made for the expansion several years in advance.

Probable Growth of Traffic.

If a road has reached its economic carrying capacity, a study of the probable growth of traffic in the territory, should be made before extensive improvements are undertaken. Is the territory which the road serves increasing in population? If so, why? Is this new population concentrating in the larger cities, or is it settling upon the small farms and thus increasing that part of the traffic which is known as (the products of agriculture). Or on the other hand is it probable that within a few years a certain iron ore, coal, or timber district will be exhausted, and its population decrease as a result? In the latter case it will become necessary for the traffic department to develop some new industry in order to keep up the volume of business. Perhaps the completion of a certain river improvement will have its affect on the rate between terminals. For example the late renewal of the navigation of the Missouri River between Kansas City and St. Louis will no doubt have some bearing on the rates for slow freight between these two cities. There is much being written concerning the opening of the Panama Canal and the growth of traffic between the east and west by way of the canal. The canal will in no way injure the traffic such as the fast fruit business of the thru roads, but the shipments of implements and heavy hardware which can be ordered a month before needed will have a tendency to seek the lower water rate.

The time for freight between New York and San Francisco by the all water route, is now but thirty days. When the United States government started to finish the Panama Canal, Mr. E. H. Harriman stated that in order to meet this new competition the Union Pacific would double track the entire line from Omaha to Ogden, and this improvement has been completed to Granger, Wyoming.

The late Mr. Wellington in his discussion of the probable growth of traffic, in "The Economic Theory of Railway Location", pages 707 to 718, reaches the conclusion, that the productive traffic varies as the square of the number of tributary sources of traffic. It might be well to include at this point an abstract of his method of analysis.

Mr. Wellington first assumes the simple case of two traffic points, A and B, at a distance of 100 miles apart. These points are considered equal in traffic-contributing capacity, there is supposed to be no intermediate traffic, and this capacity with reference to the line in question is known as AB (See figure 1 below). Next assuming a route with but a small detour a third point C of equal capacity is placed upon the line. (See Fig. 2 below). How does C affect the revenue earning capacity of the line?

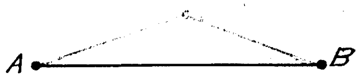


Fig. 1

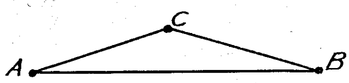


Fig. 2.

The natural answer is that the traffic is increased 50 per cent with the same increase in earnings, etc. But it may be shown that the probable traffic has been doubled and even more than tripled it. Instead of having only the traffic AB, Fig. 1, we have that of AB, AC and CB, Fig. 2. This total is seen to be more than three times AB.

To triple the traffic we must assume the value of AB, Bc and AC to be of equal financial value which they are, as nearly as may be. The natural objection to this statement is, that in Fig. 2, although the points are of equal magnitude, yet the haul on AB is twice that on AC or CB. Therefore, if the volume of each is the same and the rates the same, we have traffic AB equal to AC plus CB, we have only doubled instead of tripling our traffic, that is, from a revenue producing point of view. But these assumptions are not correct, either as respects the volume of, or the rates on traffic, As regards distance it may be said, that if only great and decided differences are considered, the volume of traffic will be at least inversely as the distance, for both passenger and freight. To illustrate, if two given traffic points 100 miles apart are moved up to within 50 miles of each other, and remain otherwise unchanged, the volume of traffic between them will be at least doubled. New York and Philadelphia are 90 miles apart and New York and Boston 231 miles apart. If these cities were to be moved up within 45 and 115 miles of each other, the traffic might be quadrupled and the loss of haul would be more than made up by the increase of volume, even as respects gross revenue, leaving a saving of expenses by reason of the shorter haul and the probable higher rates per mile almost clear gain. In regard to rates it is a safe general rule, that freight hauled only one-half as far will pay a materially larger rate per mile for the haulage proper, excluding the terminal charge which is in effect a part of the rate. The passenger rate might well be the same or lower, but this would only be for the reason that it was profitable to make them lower, to secure the far greater net gain from the increase of volume. The traffic would in all such cases bear a higher rate per mile without decreasing its volume below what would exist with twice the haul.

Taking all considerations together, it is certain that whether great or small distances are considered. The nearness of traffic points are not disadvantages to the financial productiveness per unit of the traffic between them. There are no doubt exceptions to the general rule. For a certain amount of such commodities as coal or salt must be had by a community, yet were the haul less, perhaps industry would be stimulated, and thus the traffic increased.

Therefore, we are justified in assuming the short hauls AC, and CB, to be of more, rather than less value than the long haul AB. And the total of the three traffics will be more than three times as much as the traffic AB alone. This analysis may be extended to five or six points, as in Figs. 3 - 6, each point being assumed to be of equal traffic producing capacity.

	Traffic units.	Comparative traffic.
Fig.1, 2 traffic points,	AB only	1
" 2, 3 " "	AB, AC, CB	3
" 3, 4 " "	AB, AC, CB	
	AD, BD, CD	6
" 4, 5 " "	AB, AC, CB	
	AD, BD, CD	
	AE, BE, CE, DE	10
" 5, 6 " "	AB, AC, CD	
	AD, BD, CD	
	AE, BE, CE	
	DE, AF, BF	
	CF, DF, EF	15.

Fig2.

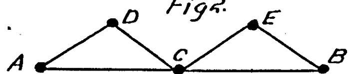


Fig.4.

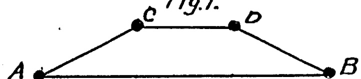


Fig.3.

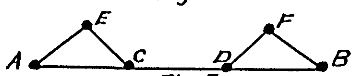


Fig5.

Therefore, in comparing Fig. 1 with Fig. 5, we find that in multiplying the number of points three we have multiplied the traffic by fifteen, or have increased the productiveness of each traffic point five times.

This is illustrated by certain tables and corollaries taken from the text of Mr. Wellington's discussion pages 712-713.

It will be seen from Fig. 7 that when on any given line with any given number of traffic points of equal weight on it we have,

No. of traffic points, 2, 3 , 4, ---------n,

We have for the comparative traffic,

1, 1 + 2, 1 + 2 + 3, 1 + 2 + 3 + -------- ----+(n-1).

In other words, the comparative aggregate traffic for any number of traffic points n is given by the sum of the natural members to n-1 inclusive. The sum of such a series to n inclusive is given by the formula,

$$S = \frac{n(n\ \ 1)}{2} = \frac{n^2\ \ n}{2} \text{ ---------(1),}$$

So that for the aggregate traffic T, due to n traffic points, we have

$$T = \frac{f(n-1)^2 + (n-1)}{2} = \frac{fn(n-1)}{2} \text{ --------(2),}$$

f being any coefficient.

Fig. 6 .

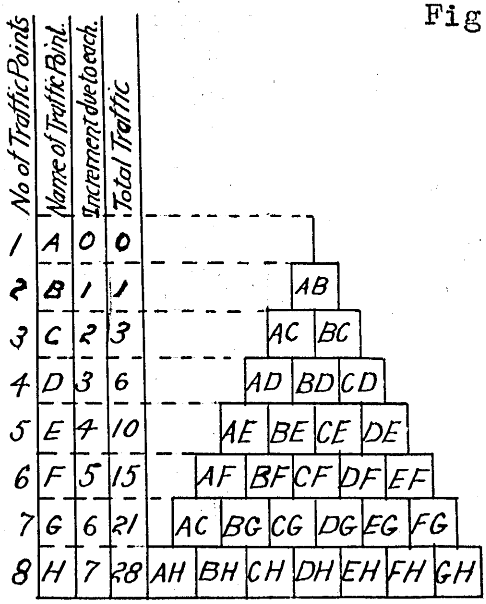


Fig. 6, showing the Law of Increment in Traffic Resulting From the Additional Points, C, D, E, F, etc., Figs. 1 to 6.

For any larger number of points N we have similarly

$T' = \dfrac{fn(n-1)}{2}$ ----- (3), whence the ratio of increase is

$\dfrac{T'}{T} = \dfrac{n(n-1)}{n(n-1)}$. As n becomes a larger number, the ratio of n to n-1 becomes more and more nearly unity, until finally the ratio of T' to T becomes sensibly T'/T equals N^2/n^2 ---(5), which is the equation giving the general law of increase in earnings due to an increase in tributary traffic points on the same length of line: i. e., the productive traffics as the square of the number of tributary sources of traffic.

Table 1.

Showing the effect upon the Aggregate Traffic of Interpolating Additional Traffic Points in the Line.

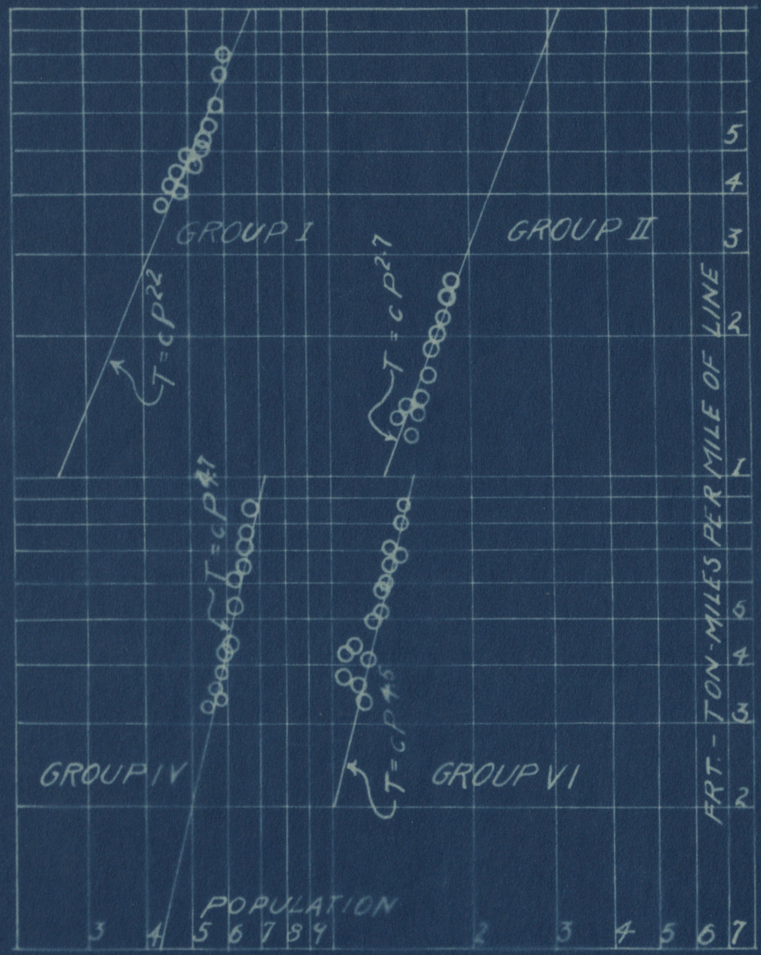
No. of traffic points.	Relative traffic,	Traffic per unit of population.	Per cent of increase of traffic by adding one point.	Absolute increase of traffic by adding one point.
2	1	0.5	---	---
3	3	1.0	200.0	2
4	6	1.5	100.0	3
5	10	2.0	66.7	4
6	15	2.5	50.0	5
7	21	3.0	40.0	6
8	28	3.5	33.3	7
9	36	4.0	28.6	8
10	45	4.5	25.0	9
11	55	5.0	22.2	10
12	66	5.5	20.0	11
13	78	6.0	18.2	12
14	91	6.5	16.7	13
15	105	7.0	15.4	14
etc.	etc.	etc.	etc.	etc.

It will be seen from the last column of this table that the ABSOLUTE gain from a given addition of tributary population is greater in proportion to the amount of other tributary population, but that the additional per cent is very much greater upon light traffic roads. (Table from Wellington Economics of Location ,page 273).

If the points A, B, C, etc. are considered units of population or individuals instead of towns, and consider their number to be indefinitely multiplied, then by the same process of reasoning the same conclusions may be reached with respect to individuals. And probably the results obtained in the case of the individuals will be more nearly correct than where the larger units of from 20,000 to 100,000 are used as in the case of the cities. The percentages of increase gained will be somewhat smaller, but not enough to make any particular difference. In the comparative figures obtained see table I , page 30 .

Prof. C. C. Williams of the University of Kansas has attacked the same problem in a somewhat different manner. He has taken the actual figures for the increases in population and traffic in the different districts of the United States, and has plotted these figures on logarithmic scale and has reached the conslusion that the growth of traffic with the increase of population is at a somewhat faster rate than merely the square of the population. A copy of his results and conclusions are included below, and on the following blue print pages. Prof. Williams arrives at the conclusion that taking the United States as a whole the resulting increase of traffic due to an increase of population is given by the expression ($T = cP^{2.9}$) and for the different groups as shown on the blue prints. In this expression of ($T = cP^{x}$), T equals the ton miles carried for that district, c equals some coefficient, P equals population, and x the unknown power of increase. Whatever may be true relation between an increase in population and the increase of traffic, there is no question of its importance in a proposed expansion of the system.

CURVES SHOWING RELATION OF GROWTH OF TRAFFIC TO GROWTH OF POPULATION IN VARIOUS GROUPS.



CURVES SHOWING THE RELATION OF THE GROWTH OF TRAFFIC TO THE GROWTH OF POPULATION IN UNITED STATES.

TABLE SHOWING THE VARIOUS VALUES OF x
AS OBTAINED FROM THE PLOTTED CURVES

$$T = cP^x$$

T = Ton-miles P = Population C = Coef.

Territory	Commodity		Value of x	
			App	Actual
United States	Total	carried 1 mile	3	2.9
Group I	"	" " "	2.5	2.2
" II	"	" " "	3	2.7
" III	"	" " "	6	5.5
" IV	"	" " "	5	4.1
" V	"	" " "	4	4.3
" VI	"	" " "	4	4.5
" VII	"	" " "	8	8.3
" VIII	"	" " "	3	3.4
" IX	"	" " "	2	2.3
" X	"	" " "	3	3.4
United St'ts	"	Originating on line	5	4.8
Division I	"	" " "	6	6.1
" II	"	" " "	6	5.5
" III	"	" " "	5	4.7
United St'ts	Animal Products	" " "	2	2.0
" "	Agric "	" " "	2	2.0
" "	Mine "	" " "	5	5.0
" "	Forest "	" " "	4	4.3
" "	Manuf. "	" " "	7	7.1
" "	Merdsc. "	" " "	5	5.0

Part I B (The Rolling Stock).

It is not intended to enter into a lengthy discussion on the problem of rolling stock in this paper, yet proper rolling stock is of such vital importance to the economic operating of a road that it can not be passed without some comment. The present tendency is toward larger and heavier freight cars. When Mr. Wellington wrote his treatise on Railway Location, a box car of 30 tons capacity was the exception, rather than the rule. At the present time cars of from 40 to 50 capacity and built entirely of steel are very common. These heavy cars increase the wear and destruction of track and structures, and have been the cause of the demand for better roadbed. The question has been raised as to whether or not it would be more economical to operate smaller cars in the (less than carload) freight traffic as is done in England. This is an open question and much might be written upon it. It is certain that in the heavy thru traffic, as in fruit, grain, livestock and coal and lumber there would be no economy in the use of smaller cars. Though perhaps in the package freight business, which originates in the large wholesale centers and is on the road but a single night, there might be economy in the operating of a smaller car, and in the use of trains more on the order of express service.

The probability that the size of the locomotives will be increased is small. It is generally considered that the present locomotives are the limit in size for econòmic operation, yet the next ten years may see larger locomotives on the road, and there is no doubt that there is room for improvements in the efficiency of the present types.

A certain eastern road is said to be contemplating the use of 135-pound rails, in order to handle heavier engines. The specifications have been adopted by the American Railway Engineering Association for a 140-pound rail. Several roads have tried the oil burning locomotive, and some have abandoned it, while others continue to use oil as fuel. There is little probability of oil ever entirely replacing coal as a locomotive fuel. However, in certain districts as the Southern Pacific in Arizona and California the advantage lies with oil because of its proximity and because of its high heat value. But in the coal districts coal is, and probably will remain the most economical fuel for a long time.

The Use of the Electric Locomotive.

There is an increasing interest being shown in the use of electricity as the motive power for the trunk line roads. The power is furnished from a central plant, and is developed by either water or steam plants. The electric locomotive is ideal in terminal work,,where the item of smoke must be eliminated. The Chicago, Milwaukee & St. Paul Railway is at present electrifying a certain division in Montana, and intends to in time equip the line to the coast in this manner. Water power is very abundant in this district, and the grades of the road are heavy and expensive to operate by coal burning locomotives. This country will be an excellent one to try out the electrified main line, but the electric operation across a prairie country, in competition with the coal burning road is a question of the future. The cost of maintenance due to the third rail, expensive insulation, and transmission lines will be much larger than now, and makes the adoption of this plan doubtful, at least until more data are available. A broken transmission line would in all probability tie up an entire division. The same might be true if a power unit were to be disabled. On the other hand a mishap to one locomotive usually does not affect but the one train.

There are many arguments both for and against the electrification of trunk line railroads, but space will not permit an extended discussion of the topic. We will next take up the consideration of the General System of Operation, now in use on the railroads of the United States.

Part II.

The Organization and the Methods of Operation Of a Railway System.

There are two principal systems for the organization of a railroad, the Divisional and the Departmental.

As to which of these plans a road is operated under, has but little direct bearing on the problem in hand. Nevertheless it might be well to state wherein the two schemes of organization differ, in order to indicate the advantages of the first in the operation of single track lines.

On a small road it is possible for the heads of the principal departments, namely the Legal, Traffic, Treasury, Accounting, and Auditing, Operating, Maintenance and Betterments, to keep in close touch with practically all of the departments by personal inspection. With a larger road this becomes impossible, and the question of subdivision is important, and the two above mentioned organizations are radically different in their methods of subdivisiom.

The Divisional system is arranged on the basis of territorial subdivision of the property as a whole, giving to each territory a more or less complete organization under one person or officer. On the other hand the Departmental system, operates on the basis of territorially subdividing each department, placing an officer in charge of each subdivision, and making him directly responsible to the head of that department. In reality the divisional system is never used in a theoretically complete form, partly from motives of economy, and partly because the work of the different departments requires a high degree of familiarity with local conditions, and because it is not always possible to sharply divide the work of the different departments. Also many other minor things may interfere.

The question of double tracking concerns four departments directly. The Traffic department, the Operating department, the Maintenance department, and the Addition's and Betterment's department. All these are so much a part of the problem that it is impossible to say which is the more closely concerned.

It has been said that if a division has a good chief dispatcher, and a good terminal yardmaster, all will move smoothly on that division. As to how true this is, is difficult to say, yet there is no doubt that much depends on the personality and the ability of these two men. And even more so on a line that is operating right at the limit of its capacity. It is the judgment of the chief dispatcher that says how many trains can be put over the division. And it is the yardmaster who must receive, classify and forward these trains, and furnish fresh engines and crews in order to keep traffic moving.

With this as a preliminary we will take up a more detailed study of the different methods of dispatching trains and the making up of schedules and time tables. Also make a study of the common forms of train orders and rules, and their essential differences when applied to single or double track.

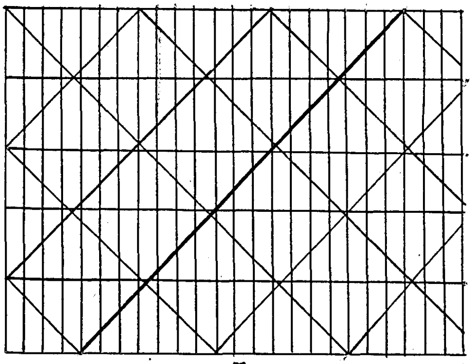
Methods of Dispatching Trains.

It is here that we come into the real problem of economic operation of the road. On a line having a heavy passenger and freight traffic it is absolutely necessary to have both passenger and freight trains on the road at the same time. This situation can be avoided only in very rare instances. It is essential that freight be kept moving both day and night, also the thru passenger trains must be kept moving continuously, although local freights and local passengers are usually so scheduled as to make their run between terminals in the daytime. Because of the fact that passenger trains are operated at a greater speed than freight trains, it becomes necessary for a slow moving train to sidetrack for not only trains in the opposite direction but also for trains of a faster schedule in the same direction. This complicates the sdhedule and makes trouble for the dispatcher. A graphical representation of the course of a train over the division and of the troubles caused by improperly spaced passing tracks, and improperly scheduled trains is given in Byers Economics of Railway Operation, and which may well be included at this point.

(1) Diagram A shows the effect of (a) Sidings at uniform time intervals apart. (b) Trains leaving the terminals at intervals equal to twice the time interval between sidings. (c) All trains in one direction proceeding at the same average speed. It will be noted that there are no delays, and that the entire movement proceeds with perfect regularity. (2) Diagram B shows the effect of starting the southbound trains at intervals somewhat greater than this double interval between sidings. The southbound trains having the right of track, the northbound trains are delayed, at each passing point, by an amount equal to the difference between the double siding interval and the southbound train interval, and arrive at the northern terminal at the same intervals as the departure intervals of the southbound trains, thus reducing the road capacity in both directions, in addition to causing heavy delay expense.

(3) Diagram C shows the effect of increasing one

PLATE 2.



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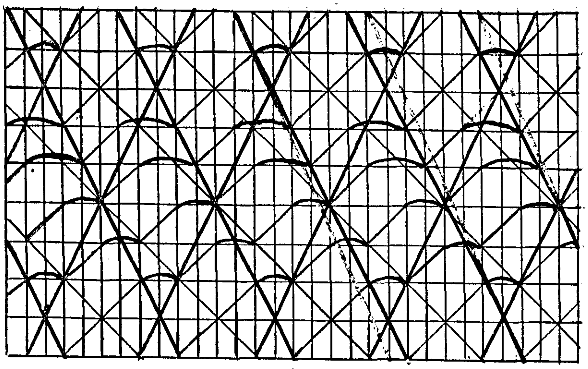

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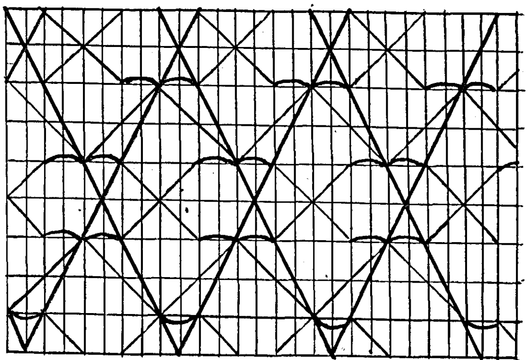

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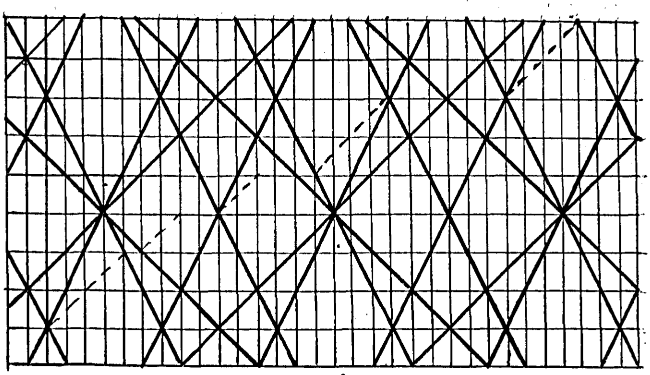
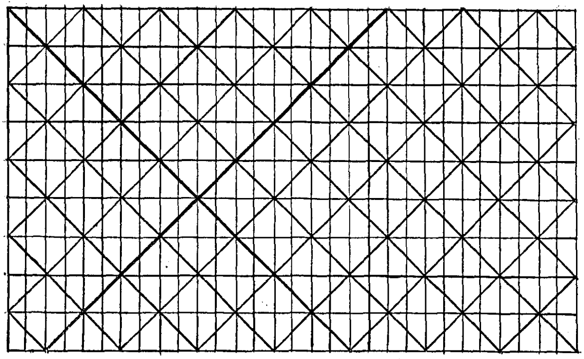
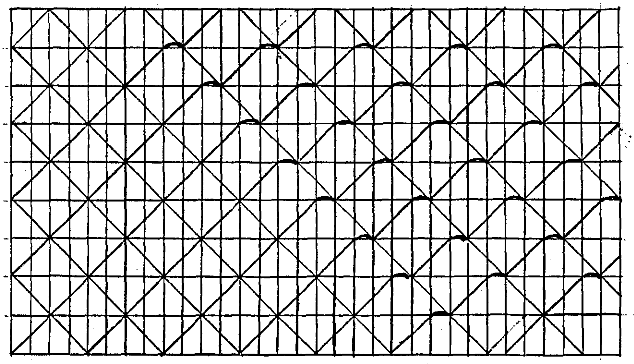


H.

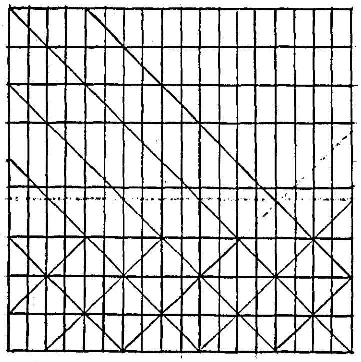
Diagram Showing Spacing for Passing Sidings. (Byers Economics).



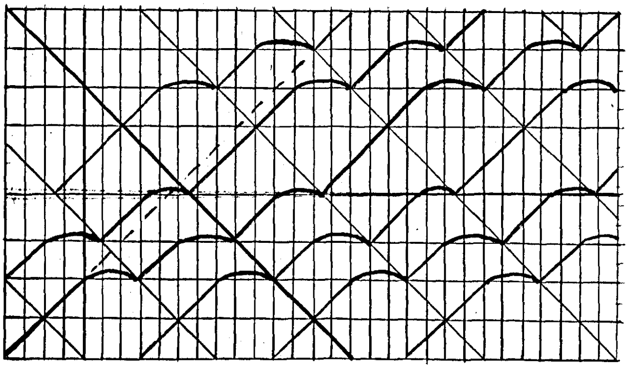
A.



B.



C.



D.

Diagrams Showing Spacing for Passing Sidings.(Byers Economics).

of the siding intervals by replacing two sidings by a single siding between them. Unless the intervals between the southbound trains are increased, the northbound trains can not cross the longer interval. Diagram D shows the result of the intervals between trains, north and south bound are made to equal the longest double interval between sidings. The capacity of the road, southbound is reduced: the capacity northbound is reduced and many delays are caused. Diagram E shows that the capacity of the road remains unchanged, and the delays are eliminated by making all the siding distances apart equal to the maximum.

(4) Diagrams F, G and H show the destructive effect on the total capacity of the road of having two classes of trains, as to speed in the same direction. While it is true, in practice, that due to delays of many kinds, local conditions and other reasons, no perfect system of train movement, such as indicated by these charts is possible, yet certain general rules may be gathered for guidance.

(a) The equal spacing of sidings is desirable.

(b) The time of departure of trains from terminals has a great influence on delays.

(c) The greater the number of classes of trains as to speed, the more complicated and expensive the operation.

(d) The simpler the relation between speeds of the different classes the better.

Betterments are concerned chiefly with rule (a). A passing siding may be extended in length, and thus used as a running track for trains of inferior class. It would seem that a spacing of between three and five miles is the most desirable.

1. A method or system of train dispatching known as Fleet Dispatching is sometimes used on roads, which have an entirely freight traffic of one class, as coal or lumber. In this method all trains are moved in one direction for a period of several hours, or perhaps the entire length of the division. These trains are then sidetracked or held in the terminal and all trains headed in the opposite direction are moved over the division or part of the division as the case may be. This method obviates the necessity for side-tracking for trains headed in the opposite direction, and incidentally does away with the danger of head on collisions. But few passing tracks are needed. It is said that under certain conditions this method can be used with economy. There are many disadvantages to fleet dispatching. A large capacity at each terminal is required, as practically all of the rolling stock of the division is gathered at first one terminal and then the other. While in a method

where the trains alternate in direction the main line in reality becomes part of the terminal and acts as a storage yard for trains in transit.

2. Before the question of increasing the number of sidings is finally settled the length of engine district, or the spacing of the terminals must be decided upon. The principal items to be considered are

(1) A minimum mileage allowance per trip determining the wages of engine and train crews (as a minimum of 100 miles is usually allowed without reference to how much shorter than this was the actual trip made).

(2) The length of run must be too great, as to tax the endurance of train and engine crews, the fireman being the chief sufferer, or to permit the fire and ash pan to become clogged with cinders on account of the distance between ash pits.

(3) Terminal delays to engines.

From five to eight hours are required for the overhauling of an engine at the terminal, at the completion of its run, of this time probably from three to five hours is a constant delay not varying with the length of the run; the shorter the distance between terminals the greater the percentage of the time of the engine so lost.

(4) The cost of engine repairs at terminals.

Much of this expense does not very with the length of the run, and therefore, becomes less per mile the farther the terminals are apart.

(5) The delays to cars etc. at the terminals.

It usually requires about ten hours to reclassify a car at the terminal and therefore, the greater the distance between terminals the less the percentage of delays.

(6) The terminal expense of handling cars.

This item is entirely independent of the length of the division and therefore, the greater the distance between terminals the less the percentage of lost time.

(7) The terminals should be located at points where the ruling grade changes, in order that the fullest advantage may be gained from the low grade line. Thus reducing the distance which the light tonnage train must be hauled. Also branch lines should radiate from the principal terminals if possible, as this makes possible the centralization of shop facilities.

The recent legislation in regard to the length of time which a train crew can be kept on the road, has limited this time to 16 hours; this makes the distance allowable between 100 and 125 miles. On a broken high grade line terminals can be at a greater distance apart than on a low grade line, as the engine is loaded to capacity a less per cent of the time, and can maintain a higher average speed on a broken than on a uniform grade line. The item of proper road facilities should be considered also at this point. The time taken by a train to cover the distance between its terminals can be divided into two items:

First, the time actually in motion and second, the time not in motion. It is the item of time not in motion which must of necessity be reduced to a minimum in order to economically operate the train. The purpose of the side track is to provide facilities for ----

(1) The passing of slow trains by trains of higher speed, moving in the same direction.

(2) The passing of trains in one direction by trains moving in the other direction.

(3) The supplying of water and coal to the engines as often as may be required.

(4) The conveying of information to train and enginemen as to the future movements of the train.

A single main-track with passing sidings at intervals depending on the density of traffic, of course, facilitates all of the above operations. The principal features to be considered in the design of passing tracks can best be explained by the following sketches of properly constructed passing sidings for single track. The siding should be arranged to reduce to a minimum the time consumed in the above mentioned operations. In figure 7 suppose two freight trains are headed in oppposite directions and both must sidetrack in order to allow the passing of a passenger or freight of faster schedule. The westbound freight enters the siding at D, the eastbound entering the other siding at A. Both engines are convenient to the telegraphers office "at lap" and can easily receive orders. After the passing of the superior train both freights can proceed at once. And by elaborating on this layout as in figures 8 and 9, both coal and water can be taken from either of the passing tracks or the main line at the same time. All passing tracks should be located on the summits of the line, in order to economize fuel in starting and air in stopping the train.

By the installation of automatic block signals the operating capacity of the single track line can be greatly increased. A very interesting discussion of the capacity of a single track line, is given in the Railway Age Gazette, April 17, 1914. Operating Capacity of Single Divisions by R. M. Baxter of the Canadian Pacific. I believe an abstract of this article to be of value at this point of the discussion.

"Since the rating of a railroad is based on the tonnage hauled, this article will present by a simple method, the important factors in train operation, which influence

Diagrams of Properly Laid Out Passing Sidings.

(Byers Economics of Raiway Operation).

(Page 637).

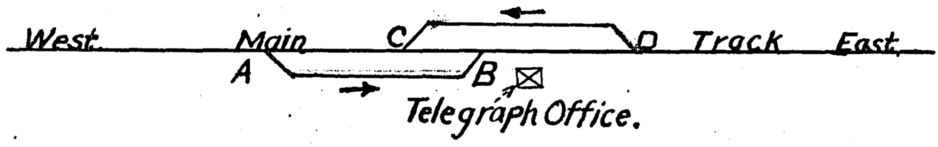


Fig. 37.

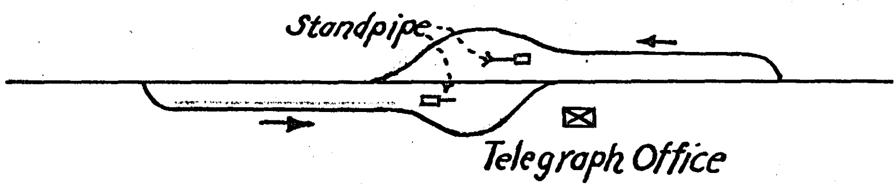


Fig. 38.

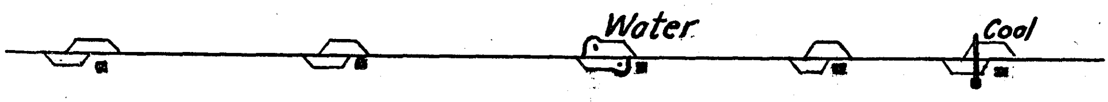


Fig. 39.

the tonnage handling capacity of a single track railroad. It wil also show the reduction in tonnage due to each minutes delay to freight trains, and by this process make it possible to predetermine the maximum capacity, the effect of passenger train movements, and the value of automatic block signals system as a means for increasing the tonnage capacity, or delaying the necessity for building the second track.

In train operation the factors which will bear more directly on the tonnage capacity of single track are:

The number of passing points.

The distance between passing points.

The length of operating district or spacing distance between terminals.

The tonnage rating of locomotives.

The distribution of power.

Facilities for conveying train movement information to train men and enginemen (either by train orders or by automatic block system).

It is assumed that the yards at either end of the district are capable of receiving and forwarding the maximum car handling capacity of the district. In this analysis passenger trains are considered as freight traffic delayers, because of their superiority in class, speed and direction freight trains are delayed in both directions by passenger trains. Track resistance controls the tonnage rating per train, with engines of a given tractive effort, and the number of trains depends upon the speed and distance between the passing points. Therefore, no engine should be loaded beyond its rated capacity, as that would prevent it making the speed necessitated by the varying distances between passing points. The principal factors required in constructing a formula, which will represent the important fixed conditions and the varying operating detentions met with in single track operation are tabulated as follows:

C=Capacity of the section of the track between any two passing points in both directions in tons per minute.

D=Distance between the passing points in miles.

S=Average speed in either direction between any two passing points. This is ascertained by taking the total operating time required by the trains to enter and leave the passing tracks at both ends of the section, plus the time required to run between them, and then dividing this total time by the distance between the passing tracks. This data can be secured from the train dispatcher's office sheets.

W=The tonnage rating of a certain locomotive over the district, or the average tons per train mile of all power.

M= 1,440 or the number of minutes in 24 hours.

From this tabulation we arrive at the following formula:

$C = \frac{SW24}{D} \div M$, which represents the number of tons per minute capacity between any two passing points under ideal conditions for moving freight trains with no interfering passenger trains and none of the operating detentions considered. This formula can also be used to ascertain the capacity in tons per 24 hours between each two passing tracks by eliminating the division by the number of minutes. in 24 hours. When the capacity in tons has been obtained between each two passing points on the district the maximum tonnage handling capacity for the entire district will be equal to the lowest maximum tonnage handled between any two passing points thru out the district; or in other words, that section of track over which the least number of tons can be handled per minute becomes the restricting throat or funnel which limits the maximum capacity of the other sections of track throughout district. The information necessary for substitution in this formula can easily be secured from a dispatchers sheet, and the train performance and the tonnage reports. If, however, a profile is available, a velocity curve (showing the speed of trains in miles per hour) may be projected on it, using the grade line as the base or datum line; then by ascertaining the area between the speed curve and the grade line, for the distance between the passing points the average speed in miles per hour of trains running over the section will be obtained.

A concrete example will best illustrate this principle. Assuming 30 miles per hour as the average speed of trains between passing points which are 7 1/2 miles apart, then 30/7.5 four trains, or two trains each way will be the capacity per hour between the passing points, without interference. Again assuming 7 1/2 miles as the distance between passing points, and the average speed obtained only 15 miles per hour, then 15/7.5 two trains, or one each way between these passing points per hour. These examples show that the distance between passing points and the average speed of trains bears such a fundamental relation to each other, as will determine the number of trains per hour capacity between two given points. The application of this formula to a large number of single track operations demonstrates that the greatest capacity is reached when the distance between passing tracks averages approximately 4.33 miles. If the distance is greater than this, the capacity must be compensated for by increasing the speed, at the expense of train tonnage, while if the distance is less than this the number of passing points becomes excessive by reason of the increased number of delays.

If 2,000 is the average tons per train mile being hauled over the district, or if the district has assigned to it only one class of freight power, the rating of which is 2,000 tons and the restricting section is one having passing points 8 miles apart, and the grades are such that ten miles per hour will be the maximum average speed of freight trains, the capacity will be $C = \frac{S\ W\ 24}{D} \div M =$

$$= \frac{10 \times 2000 \times 24}{8 \times 1440} = \frac{60{,}000}{1440} = 41.60 \text{ tons per minute}$$

tonnage capacity of the section without considering detentions of any character. From this tonnage handling capacity may be found the possible number of cars which can be moved, or the number of trains it is estimated can be run in a given unit of time by dividing the capacity by the average gross car weight to ascertain the former, and by dividing the capacity by the average tons per train mile to obtain the latter.

Thus far no consideration has been taken of the delays caused by trains of superior class and direction, both opposing and following. In actual practice passing points are never equally spaced, their distances apart being affected by natural conditions, as mountains, rivers, plains, etc. And for the purpose of facilitating the demonstration a section of track 100 miles in length will be chosen.

If freights run at the average speed of 20 miles per hour, with no detentions they will traverse the district in five hours. In order to make this time and pass trains at proper passing points without delay, it will be necessary to increase or reduce the speed in proportion to the distance between the passing points (this should be equal to the number of trains per hour both ways multiplied by the distance in miles between these points) or to respace them. However, if this is found impracticable then such a readjustment must be had thru grade revision or realignment.

In the example of the 100 mile district we will assume that there are 20 passing tracks, spaced as shown in the accompanying table.

Operating Capacity of Single Track.

D = Distance between passing tracks in miles.	S = Speed in miles per hour.	C = Capacity in 1000 tons per 24 hours	C = Capacity in tons per minute.	Section Reference numbers
2	8	192	133	1
5	20	192	133	2
3	12	192	133	3
5	20	192	133	4
6	20	160	101	5
6	20	160	101	6
5	20	192	133	7
3	12	192	133	8
4	20	240	166	9
5	16	153	106	10
7	25	171	118	11
2	24	576	400	12
5	20	192	133	13
8	16	96	66	14
3	12	192	133	15
7	25	171	118	16
4	16	192	133	17
6	21	192	133	18
5	18	192	133	19
9	20	106	74	20

By arriving at the maximum tonnage capacity between each two of these passing tracks by means of the formula previously described, it is found that section 14 is capable of handling less tonnage in a given time than any other interval between passing tracks in the district. It, therefore, becomes the limiting capacity section, and the entire district will be limited in the movement of its thru trains to the capacity of this section. This can be remedied by shortening the distance between passing points of the restricting section, or by realignment or by reducing the grade so as to permit an increase of velocity, and thus shortening the time interval between the two passing points. Thus if the length of the restricting district is decreased to six miles instead of eight, with the same gradient the capacity will be increased from 66 to 87 tons per minute. Or the capacity of the entire district will be increased to this amount providing that here are no remaining sections of less capacity. If the gradient is reduced so that 10 miles per hour is obtained as the average train velocity, the capacity of this section will be 87 tons per minute. But in this problem this section will no longer be the restricting section as section 20 has a maximum capacity of but 74 tons per minute.

Greater efficiency in the operation of the district will be secured when the distance between the passing points and the elevations of the gradients are such as will permit of a more nearly constant interval of time for trains between the passing points. As there is not only a safe but a econom-ical limit of speed, the volume of traffic in the final analysis is necessarily limited by the distance between passing points. It is apparent from this, that the nearer an undulating railroad is made to approach a level gradient, the fewer the passing points required, and the more regular becomes the train velocity. To ascertain the average dis-tance between the passing points which will result in the greatest efficiency for the rest of the district which is primarily limited by the previously mentioned restricting section, by transposing our formula, we have

$$D = \frac{S\ W\ 24}{C} = \frac{9.2 \times 2000 \times 24}{96{,}000} = 4.6 \text{ miles apart for an}$$

ideal railroad having no detentions from opposing trains passing each other. It is evident that there must be delays in at least one direction when trains are operated in both directions on a single track. Having arrived at the ulti-mate capacity of the track, and found the value of one minute of time expressed in tons, one will be able to apply for the purposes of illustration, the usual detentions occurring to train movements. The following conditions will be assumed: The delay to trains taking the siding will be ten minutes, five for heading in and five for pulling out. One-half of this time should be charged to each of the trains meeting because in order to balance the power one-half of the trains move in the opposite direction.[3] Each train will then be charged with five minutes. By the standard code second and inferior class trains are not allowed to occupy the main line within 10 minutes of the time following first class trains or within five minutes of the time of meeting such trains. This is time lost to the freight train and means that the tonnage handling capacity of the district is reduced in proportion to the resulting detentions. It is assumed that each freight train will be passed by and will meet at least one passenger train during its trip over the district, thus delaying it the amount of these clearance times. To these detentions should be added the minor delays such as taking water and orders. This will probably amount to 40 minutes per train in the 100 miles and can be apportioned as two minutes per passing track. As the running time thru the restricting district is 30 minutes, the total average estimated operating time required by freight trains to traverse this section equals the sum of these delays, which are tabulated as etc.

	Min.
Observance of clearance rule for following movements	10

	Min.
Observance of clearance rule for meeting trains	5
Time required taking siding	5
Miscellaneous delays orders etc.	2
Running time over restricting section	30
Total operating time, freight, trains	52

As previously ascertained, 66 tons per minute or 96,000 tons each 24 hours is the ultimate capacity of the limiting section, without delays. We now find that in actual operation there will be 22 minutes for normal standing time. This added to the running time of 30 minutes totals 52 minutes which is the total operating time required by freight trains to pass over this territory. The normal operating capacity of the district then becomes $C = \frac{9.2 \times 2000 \times 24}{8} = 55,000$ tons per 24 hours, when the movements of trains are controlled by the train order system which requires the observance of the 10 minute rule. If the absolute or permissive block system is substituted for the train order system and this 10 minutes is regained, then the capacity of the district will be increased to $C = \frac{11.4 \times 2000 \times 24}{8} = 68,400$ tons per 24 hours. Then tabulating the various elements of time as above stated on a percentage basis we find that thru the restricting district the relative values are as follows:

	Per cent
Observance of clearance rule following movements	19.2
Observance of clearance rule following meeting traims	9.6

	Per cent
Time required taking sidings	9.6
Miscellaneous delays, train orders etc.	3.8
Running time over restricting section	57.8
Total	100.0

From this it is seen that 19.2 per cent of the time required to traverse the limiting section is consumed in observance of the clearance rule for following movements: 58 per cent of the time used is for actual running time which means that this speed is 16 miles per hour as the passing tracks are eight miles apart. If this could be increased by a grade revision to 20 miles per hour, the running time would be reduced from 30 minutes to 24 minutes or a saving of 6 minutes obtained. Thus by these two changes the total time could be reduced from 52 to 36 minutes, or the final operating capacity of this section increased from 68,400 to 79,200 toms per 24 hours, or assuming that the average gross weight of cars is 40 tons, then the capacity expressed in cars will be 1,980 per 24 hours for the thru movement over the entire district. Under the improved conditions the standing time detentions for freight trains at each of the passing tracks will approximate 12 minutes, and as there are 20 passing points, the approximate total standing time will be 20 times 12 minutes or four hours, which must be added to the total average running time between all of the passing points. In this case the average running time is 20 miles per hour, and as the length of district is 100 miles it requires five hours to traverse the district, without detentions. Adding to this the detentions of four hours the total operating time required to pass over the district will be nine hours, or an average speed of 11.1 miles per hour. As the capacity has been found to be 79,200 tons per 24 hours, the capacity per minute will be 55 tons, and any condition that will retard the movement of trains one minute thru the restricting section will reduce the capacity of the entire district 55 tons. Therefore, the introduction of one passenger train, which we will assume running at an average speed of 30 miles per hour, will reduce the capacity of the district 2,090 tons, for the passenger train occuping the main line of the restricting section of the main line 16 minutes. (this being the time required to run 8 miles at 30 miles per hour). will delay freight trains at one of the passing points of the restricting districts 22 minutes when movements are controlled by the train order system. This makes a total detention to freight traffic moving thru this section of 38 minutes, which at 55 tons a minute is 2,090 tons. If, however, the territory is operated under the permissive block system, it will reduce the capacity only 1,540 tons, for under this system the passenger train will delay the traffic only 28 minutes instead of the 38 minutes because practically all of the 10 minutes clearance for following movement is obtained.

When there are ten passenger trains operated each day, five each way, under the block system the maximum handling capacity of the railroad will be 68,800 tons per 24 hours, or 1,595 cars of 40 tons gross weight each, whereas under the train order system the capacity will be 58,300 tons or 1,457 cars per 24 hours. This may never be reached in actual practice, it shows the ultimate tonnage which can be handled. Mr. Baxter makes the following comments upon the practice of running trains in fleets, "The running of trains in fleets does not increase the capacity of a single track line operated under the train order system, however, much the plan may be advisable for other reasons, for it is necessary to maintain a safe operating distance between trains, and the time lost to rear sections by waiting for the forward sections to proceed, will equal if not exceed the entire time required to run one train over the entire district. The yard capacity of the district terminal should in no case be less tha one-half of th total capacity of the single track railroad both ways, in addition to the space necessary for the handling of industries. This means that the district terminal should have a capacity equal to the inbound tonnage multiplied by the average time required to break up inbound trains and to reassemble into outbound trains. Generally speaking many of the restricting sections of single track line exist between the district terminal and the first station out from the terminal. By the above method a revision of the district may be made that will obviate the need for building of the second track for several years to come. The building of the second track, however, should not according to Mr. Baker be delayed beyond the time when the detentions due to the passing of trains by means of passing tracks equals the time required to run between the pas sing points."

The above analyses and solution certainly seems reasOnable and no doubt is a useful one. Another interesting example of what can be done by the use of permissive absolute block signal system, is an article in the Railway Age Gazette, Nov. 23, 1906, entitled Single Track Train Operation on the Wheeling and Lake Erie, and an abstract of this paper follows:

"The accompanying photograph shows graphically the extra and regular trains run on Sept. 2, 1906, on the main line of the Wheeling and Lake Erie, between Toledo and Stubenville, over an especially busy stretch of single track line. The following tables sum up the information contained in the chart:

	Eastbound	Westbound	Total
Total number of trains, (helpers and short runs)	85	75	160
Total number thru freight trains	34	30	64
Total mileage of thru freight trains	2,250.1	2,101.1	4,351.2
Total hours of thru freight trains on road	257.08	261.28	518.36
Total hours delay to thru freight trains	105.27	115.41	221.08
Average speed of thru freight between terminals	8.7	8.0	8.4
Average speed of thru freight while moving	14.8	14.4	14.6

Total number of cars handled on thru freight trains 2,612

Average number of cars handled on thru freight trains per train ----- ------------------------------------- 42.3

Total number of meeting and passing points (Huron-Junction to Pittsburg Junction) ---------- 296.

Least number of meeting or passing points any one hour 6.

Greatest number of meeting or passing points any one hr.21.

It will be observed that the time spent in delays on thru freight runs averaged a little over three minutes per mile run. Detail records for a period of two years on different divisions of the Southern Pacific lines, showed that the time actually consumed in stops on freight runs having physical characteristics similar to the Wabash lines east of Toledo varied from 30 seconds to one minute per mile run on single track line, according to density of traffic. The higher figure of the Wheeling and Lake Erie, is due to the congested condition of the line.

While there is no information available showing the time actually consumed by freight trains on a double track line, which of course would be affected by the number of fast passenger trains which freight trains running in the same direction would be required to clear, it is reasonable to assume that the delay on a double track line under average conditions, namely one minute per mile run.

Assuming that the line between Pittsburg Junction and Huron Junction were doubled tracked, the time allowance for stops on the 124 miles would be two hours and four minutes, which would seem to be ample. On this basis the delay of 221 hours and eight minutes would become 72 hours and 30 minutes, a saving of 137 hours and 37 minutes, and as this saving in time would readily convert from "delayed to moving time" the average speed of thru freight trains between terminals would become 11.8 miles per hour instead of 8.4 miles per hour as at present. The actual running speed of trains need be no faster than at present. Overtime payments now average $12,000 per month in train service, and probably would also be delayed in the same proportion as delayed time, or a saving of $8,000 per month on this item.

The increase in speed of thru freight trains between terminals would mean a gain of 1,753.48 train miles on the particular day shown on the chart. The average earnings per freight train mile for September were #3.21. Applying this to the increased train mileage (1,753.48 train miles) the earnings on this particular day would be increased $5,629, and as this is only an average day's business, the annual gross earnings would be increased approximately $1,590,000. Allowing 60 per cent for operating expenses the net earnings would be $600,000, and this amount capitalized at five per cent would be equivalent to earning interest on $12,000,000. At the same time the road would be getting the benefit of a double track line, which would enable it to increase the volume of its traffic three times. It will be seen that if with a double track line there were an average movement of 11.8 miles per hour between the terminals, instead of 8.4 miles per hour, this result alone would increase the capacity alone over 40 per cent. The chart shows considerable delay at Bolivar and Navarre and to eastbound trains at Sherwood, due to inadequate yard facilities at Columbia, necessitating the holding out of freight trains until this yard can be relieved. When the new 2,000 car yard at Brewster, now in process of construction and the 22-mile cutoff from Bolivar Orriville, is completed, the delay at Columbia will be done away with. The estimate of the cost of double track between Huron and Pittsburg Junctions, including quite a number of line and grade changes, to improve alinement and to attain a 0.4 per cent maximum grade eastbound and a 0.6 per cent maximum westbound, is $3,404,550 to which should be added about $124,000 to cover electric block signals, to bring the line up to modern practice.

These articles scarcely need any discussion, Mr. Baxter's articles and development of the capacity of a single track line is very logical and worth the study of any traffic man. The example of the Wheeling and Lake Erie is a good one to show how a line may become clogged and worked beyond its capacity. This line is plainly past the point of economical operation as a single track line. Further reference will be made to these articles in Part III and IV of this paper.

Part III.

If we make a brief study of the actual trackage and mileage data of the principal systems of the United States I believe it will give us a better understanding of the actual conditions, with reference to the second track, of the different roads.

From the reports of the United States Interstate Commerce Commission, the data on the number of miles of road and number of miles of second and third and fourth tracks may be obtained. The following tables are taken from the same.

Section A--1, Abstract of Reports Rendered by Operating Steam Railway Companies of Class 1-Eastern District (Class 1 roads are those having annual operating revenues above $1,000,000).

Description of road. Mileage operated on June 30, 1912	Delaware Lackawana & Western.	Lehigh Valley R. R. Co.	Delaware & Hudson Co.
43. Miles of road	958.60	1453.99	851.71
44. " " second track	540.10	605.89	326.16
45. " " third track	------	73.58	19.12
46. " " fourth etc.	-------	37.58	20.52
47. " " yard	1,029.30	1,173.67	610.12
48. Total all tracks	2,528.00	3,344.35	1,827.63

Mileage owned on June 30, 1912			
49. Miles of road.	239.73	311.00	328.00
50. " " second track	138.84	193.99	42.90
51. " " third track	------	44.79	13.59
52. " " fourth track	------	29.76	13.29
53. " " yard etc	407.45	3,317.59	172.13
Total all tracks.	786.01	896.43	569.91
Per cent of second track operated to total miles of road operated.	56.3	41.6	38.2

Eastern District Continued

Description of road. Mileage operated on June 30,1912.	Grand Trunk Western R. R. Co.	Pere Madq. R. R. Co.
43. Miles of road	347.05	2,330.17
44. " " second track	327.91	276.18
45. " " third "	------	-------
46. " " fourth "	------	-------
47. " " yard etc.	201.55	836.99
48. Total all tracks	876.51	3,443.34

Mileage owned on June 30, 1912		
49. Miles of road	330.91	1,803.22
50. " " second track	323.07	58.45
51. " " third "	--------	--------
52. " " fourth "	-------	--------
53. " " yard etc.	193.80	719.19
Total all tracks	847.78	2,580.86

Per cent of second track operated to total miles of road operated.	94.2	11.85

Eastern District Continued.

Description of road. Mileage operated on June 30, 1912.	Chicago & Eastern Ill. R. R. Co.	Buffalo Rochester & Pittsburg R. R. Co.	Bessemer & Lake Erie R. R. Co.	Erie R. R. Co.
43.	1,275.38	569.82	212.54	1,988.11
44.	291.16	192.42	129.96.	940.09
45.	20.20	------	------	18.46
46.	-------	------	------	18.41
47.	669.84	319.86	180.20	1,561.68
48. Total all tracks	2,256.58	1,082.10	522.70	4,526.75

Mileage owned on June 30, 1912				
49.	1,005.97	356.22	328.87	789.31
50.	157.11	111.13	------	444.50
51.	20.20	------	------	.10
52.	-------	------	------	.05
53.	652.07	263.62	------	581.51
54. Total all tracks	1,835.35	730.97	8.87	1,815.47

Per cent of second track operated to total miles of road operated.	22.8	33.6	61.2	47.0

Eastern District Continued.

Description of road operated on June 30, 1912	Michigan Central R. R. Co.	New York New Haven & Hartford	Boston & Maine R. R. Co.
43. Miles of road	1,816.76	2,090.25	2,291.02
44. " " second track	598.78	856.09	589.11
45. " " third track	5.71	132.38	8.39
46. " " fourth etc.	5.71	146.41	2.02
47. " " yard etc.	1,359.67	1,446.75	1,312.14
48. Total all tracks	3,786.63	4,671.88	4,202.68

Mileage owned on June 30. 1912.			
49. Miles of road	270.07	1,238.52	725.43
50. " " second track	270.07	463.43	235.43
51. " " third track	5.71	62.37	2.56
52. " " fourth etc.	5.71	61.75	------
53. " " yard etc.	391.65	815.03	399.60
54. Total all tracks	923.21	2,641.10	1,363.02

Per cent of second track operated to miles of road operated.	33.0	41.0	24.8

Eastern District Continued.

Description of road. Mileage operated on June 30, 1912.	Baltimore & Ohio R. R. Co.	Central R. R. Co. of New Jersey.
43. Miles of road	4,455.06	669.43
44. " " second track	1,242.40	262.28
45. " " third track	167.36	41.06
46. " " fourth etc.	39.24	30.34
47. " " yard etc.	2,846.80	698.83
48. Total all tracks	8,750.86	1,701.94

Mileage owned on June 30, 1912.		
49. Miles of road	544.85	156.15
50. " " second track	410.98	96.16
51. " " third track	117.49	30.16
52. " " fourth etc.	22.71	30.39
53. " " yards etc.	558.12	348.74
54. Total all tracks	1,654.15	661.80

Per cent of second track operated to miles of road operated.	27.2	39.2

Eastern District Continued.

Description of road mileage operated June 30, 1912.	Philadelphia & Reading R. R. Co.	Cleveland, Cinncinatti, Chicago & St. Louis
43. Miles of road	1,015.16	2,011.64
44. " " second track	519.33	425.61
45. " " third track	100.75	-------
46. "" " fourth track	------	-------
47. " " yards, sidings	1,175.61	1,100.42
48. Total all tracks	2,810.88	3,547.67

Mileage owned on June 30, 1912.		
49. Miles of road	346.17	684.86
50. " " second track	181.59	268.83
51. " " third track	67.42	------
52. " " fourth track	------	------
53. " " yards, sidings	617.15	512.22
54. Total all tracks	1,212.33	1,415.91

Per cent of second track operated to miles of road operated.	51.5	21.2

Eastern Lines Continued.

Class I.

Description of road, mileage operated on June 30, 1912.	Pennsylvania R. R. Co.	Pennsylvania Co.	Pittsburg, Cinncinatti & St. Louis Ry. Co.
43. Miles of road	4,021.20	1,750.93	1,467.00
44. " " second track	1,452.00	764.36	640.69
45. " " third track	480.14	126.95	100.21
46. " " 4th., 5th., & 6th.	437.14	95.76	42.03
47. Miles of yard track and sidings.	3,876.60	1,533.88	986.25
48. Total all tracks	10,267.08	4,271.88	3,236.18

Description of road, mileage operated on June 30, 1912	Philadelphia, Baltimore & Washington	Lake Shore & Michigan South.
43. Miles of road	713.49	1,775.43
44. " " second track	248.09	614.01
45. " " third track	62.29	347.78
46. " " 4 th., 5th., & 6th.	45.36	234.29
47. Miles of yard track and sidings	355.09	1,193.55
48. Total all tracks	1,424.32	4,165.06

Eastern Lines Continued.

Mileage owned on June 30, 1912	Pennsylvania R. R. Co.	Pittsburg, Cinncinatti & St. Louis Ry. Co.
49. Miles of road	2,157.31	1,113.91
50. " " second track	1,000.35	539.36
51. " " third track	362.34	90.42
52. " " 4th., 5th., & 6th. track	332.37	39.33
53. Miles of yard and sidings	2,308.24	2,568.30
Total all tracks	6,308.24	2,568.30
Per cent of miles of second track operated to miles of road operated.	34.0	43.5

Mileage owned on June 30, 1912.	Philadelphia, Baltimore & Washington.	Lake Shore & Michigan South.
49. Miles of road	227.23	878.84
50. " " second track	151.72	549.85
51. " " third track	61.65	338.96
52. " " 4th., 5th., & 6 th. track	44.72	234.29
53. Miles of yard and sidings	213.64	956.73
Total all tracks	698.96	2,958.67
Per cent of miles of second track operated to miles of road operated	34.8	34.6

Western Group.

Class I.

Description of road. Mileage operated on June 30, 1912.	Union Pacific	Chicago & North Western Ry. Co.	Chicago, Rock Island & Pacific.	Chicago, Milwaukee & St. Paul
43. Miles of road	3,575,06	7,960.45	7,566.05	9,592.23
44. " " second track	723.02	867.84	283.24	673.94
45. " " third track	2.07	104.49	8.01	14.91
46. " " 4th., 5th., & 6th. track	2.07	95.36	------	4.48
47. Miles of yard track	1,267.77	3,307.13	2,022.20	3,010.22
48. Total all tracks	5,569.99	12,335.27	9,878.50	13,297.68
Mileage owned on June 30, 1912.				
49. Miles of road	3,547.18	7,744.85	5,369.08	9,258.88
50. " " second track	723.02	799.55	282.24	597.48
51. " " third track	2.07	104.49	8.01	12.83
52. " " 4th., 5th., & 6th. track	2.07	95.36	------	3.55
53. Miles of yard track & sidings	1,264.97	3,196.15	1,536.65	2,920.25
Total all tracks	5,539.31	11,940.40	7,195.38	12,793.39
Per cent of second track operated to miles of road operated.	20.2	10.9	3.74	7.05

Western Group Continued

Class I.

Description of road.	Great Northern Ry. Co.	Chicago & Alton R. R. Co.	Duluth Missabe & Northern R. R. Co.
43. Miles of road	7,432.36	1,025.72	351.04
44. " " second track	178.84	193.00	118.00
45. " " third track	9.28	-------	------
46. " " 4th., 5th., & 6th. track	13.05	-------	-------
47. Miles of yard track and sidings	1,871.42	393.27	176.18
48. Total all tracks	9,554.95	1,611.99	645.32

Mileage owned June 30, 1912.

49. Miles of road	6,553.38	679.93	349.14
50. " " second track	178.84	155.79	118.10
51. " " third track	9.28	-------	------
52. " " 4th., 5th., & 6th. track	13.05	-------	-------
53. Miles of yard track and sidings	1,774.96	242.04	176.18
54. Total all tracks	8,529.51	1,077.75	643.42

Per cent of second track operated to miles of road operated.	2.4	18.9	29.6

Western Group Continued

Class I.

Description of road. Mileage operated on June 30, 1912.	Northern Pacific	Chicago, Burlington, & Quincy R. R. Co.
43. Miles of road	6,420.02	9,074.10
44. " " second track	619.84	761.10
45. " " third track	4.02	23.55
46. " " 4th., 5th., & 6th.	-----	------
47 " " yard track and sidings	2,053.51	2,779.49
48. Total all tracks	9,037.39	12,638.24

Mileage owned on June 30, 1912.		
49. Miles of road	6,071.30	8,737.14
50. Miles of second track	539.92	703.66
51. " " third "	4.02	23.55
52. " " 4th., 5th.& 6th.	-------	------
53. " " yard track and sidings.	1,840.55	2,766.18
54. Total all tracks	8,455.55	12.230.53

Per cent of second track to miles of operated road.	9.65	8.42

Western Group Continued

Class I.

Description of road. Mileage operated on June 30, 1912.	Southern Pacific R. R. Co.	Atchison Topeka & Santa Fe Ry. Co.
43. Miles of road	6,379.76	8,200.86
44. " " second track	332.81	801.90
45. " " third "	-------	--18.82
46. " " 4th., 5th., & 6th.	-------	5.94
47. " " yard track and sidings	2,405.96	2,887.98
48. Total all tracks	9,048.53	11,915.50

Mileage owned on June 30, 1912.

49. Miles of road	35.12	7,176.91
50. " " second track	24.51	721.78
51. " " third "	-----	6.23
52. " " 4th., 5th., & 6th.	-----	5.94
53. " " yard track and sidings	70.41	2,588.89
54. Total all tracks	130.51	10,499.75

Per cent of second track to miles of operated road.	5.2	9.75

Southern Group.

Description of road. Mileage operated on June 30, 1912.	Illinois Central R. R. Co.	Norfolk & Western Ry. Co.
43. Miles of road	4,762.70	2,018.36
44. Miles of second track	750.95	417.31
45. " " third "	27.77	3.20
46. " " 4th., 5th., & 6th. track	147.20	-----
47. " " yard track and sidings	1,966.33	1,100.13
48. Total all tracks	7,654.93	3,539.00

Mileage owned on June 30, 1912		
49. Miles of road	2,273.00	1,199.73
50. " " second track	396.55	417.31
51. " " third "	27.77	3.20
52. " " 4th., 5th. & 6th. track	112.60	------
53. " " yard track and sidings	1,096.94	1,100.13
54. Total all tracks	3,906.86	3,520.37

Per cent of second track operated to miles of operated road.	15.7	20.62

Southern Group Continued.

Description of road. Mileage operated on June 30, 1912.	Chesapeake & Ohio Ry. Co.	Chicago & Great Western Ry. Co.
43. Miles of road	2,305.50	1,496.22
44. " " second track	574.80	105.37
45. " " third "	--------	-------
46. " " 4th., 5th., & 6th., track	---------	-------
47. " " yard track and sidings	930.10	537.49
48. Total all tracks	3,810.40	3,139.08

Mileage owned on June 30. 1912.		
49. Miles of road	2,030.90	756.01
50. " " second track	475.50	57.43
51. " " third "	--------	------
52. " " 4th., 5th., & 6th. track	--------	------
53. " " yard track and sidings	913.30	652.07
54 Total all tracks	3,419.70	1,465.51

Per cent of second track operated to miles of operated road.	24.9	7.0

Data and Discussion of the Railroads of the United States as a Whole.

a. Mileage and Per Cent of Second Track.

We have examined the mileage data of the principal systems of the United States as individual systems. For the sake of general rather than specific information, the condensed figures for the entire United States are interesting.

We find that in 1913 the railroad mileage of the entire United States was 242,177 miles of line (or 367,658 miles all tracks) of this 26,320 was second tracked (approximately 10.85 per cent). Of this only about 1500 miles of double tracked line is west of the Missouri River. While on that which lies east of the Mississippi River the percentage is much higher; therefore, we see that it is the lines between Chicago and the Missouri River that are really just on the point of needing the second track. It will throw some interesting light on the subject of railroad railway incomes as a whole if we examine Table II . This table shows in a condensed manner the progress of the railroads since 1899, one of the interesting points is the steady increase of the operating ratio (the ratio of total income to total expense)., A close study of this table will show that about 1905 the railroads enjoyed an area of prosperity which period of prosperity lasted

Railway Income Account 1889 -- 1913.

Showing Mileage, Net Capital, Revenues, Expenses, Taxes, Maintenance, and Transpoetation Charges and Net Revenues from Operation, with Ratios Based on Reports to the Interstate Commerce Commission, 1889 to 1913.

Table II

Year	Miles of Line	Miles of Track	Net Capital (thousands)	Freight Revenue (thousands)
1889	157,759	200,950	$ 7,422,074	$ 642,433
1890	163,597	208,612	7,577,328	714,464
1891	168,402	215,999	8,007,990	736,794
1892	171,563	222,351	8,294,690	799,316
1893	176,461	230,137	8,331,603	829,054
1894	178,708	233,533	8,646,600	699,491
1895	180,657	236,894	8,899,573	729,993
1896	182,428	240,129	9,065,519	786,616
1897	183,284	242,013	9,168,072	772,849
1898	184,648	245,333	9,297,168	876,728
1899	187,543	250,142	9,432,042	913,737
1900	192,556	258,784	9,547,985	1,049,256
1901	195,561	265,352	9,482,649	1,118,543
1902	200,154	274,195	9,925,664	1,207,229
1903	205,313	283,821	10,281,598	1,338,020
1904	212,243	297,073	10,711,794	1,379,003
1905	216,973	306,796	11,167,106	1,450,773
1906	222,340	317,083	11,671,941	1,640,387
1907	227,455	327,975	12,920,353	1,823,652
1908	*230,494	333,646	12,833,592	1,655,419
1909	*235,402	342,351	13,711,868	1,677,615
1910	*240,831	351,767	14,338,576	1,925,553
1911	*246,238	362,710	15,008,707	1,925,951
1912	/ *240,238	360,714	15,333,522	1,956,802
1913	& 242,177	367,657	15,294,625	2,184,533

* Figures since 1908 exclude switching and terminal companies.

/ Includes only Class I and II roads.

& Bureau figures 98 per cent of traffic represented.

Railway Income Account

Table II Continued.

Year	Passenger Revenue (thousands)	Total Revenue inc. Mail, Express etc. (thousands)	Operating Expenses (thousands)	Taxes (thousands)
1889	$254,040	$ 964,816	$ 644,706	$ 27,590
1890	260,786	1,051,877	692,093	31,207
1891	281,179	1,096,761	731,887	33,280
1892	286,806	1,117,407	780,997	34,053
1893	301,492	1,220,751	827,921	36,514
1894	285,350	1,073,361	731,414	38,125
1895	252,246	1,075,371	725,720	39,823
1896	266,563	1,150,169	772,989	39,970
1897	251,136	1,122,089	752,524	43,137
1898	266,970	1,247,325	817,973	43,828
1899	291,113	1,313,610	856,968	46,337
1900	323,716	1,487,044	961,428	48,332
1901	351,356	1,588,526	1,030,397	50,944
1902	392,963	1,726,380	1,116,248	54,465
1903	421,705	1,900,846	1,257,538	57,849
1904	444,327	1,975,174	1,338,896	61,696
1905	472,695	2,082,482	1,390,602	63,474
1906	510,033	2,325,765	1,536,877	74,785
1907	564,606	2,589,105	1,749,515	80,312
1908	566,833	2,393,805	1,669,547	84,555
1909	563,609	2,418,677	1,599,443	90,529
1910	628,992	2,750,667	1,822,630	103,795
1911	657,638	2,789,761	1,915,054	108,309
1912	657,422	2,826,917	1,958,963	119,900
1913	691,802	3,118,929	2,164,851	129,052

Railway Income Account

Table II Continued.

Year	Ratio Exp. and Taxes to Earnings	Net Operating income (thousands)	Percentage on Capital	Maintenance of Way and Structures (thousands)
1889	69.66	$292,520	3.94	$144,822
1890	68.74	328,577	4.33	152,719
1891	69.51	333,159	4.16	153,672
1892	69.56	356,457	4.30	164,189
1893	70.79	356,316	4.27	169,258
1894	71.68	303,822	3.51	143,669
1895	71.18	309,819	3.48	143,976
1896	70.68	337,310	3.72	160,345
1897	69.09	326,428	3.56	159,434
1898	70.90	386,215	4.15	173,315
1899	68.77	410,305	4.35	180,411
1900	67.89	477,284	5.00	211,221
1901	68.06	507,185	5.35	231,057
1902	67.81	555,667	5.59	258,382
1903	69.20	585,459	5.70	266,422
1904	70.91	574,582	5.37	261,280
1905	69.82	628,406	5.63	275,046
1906	69.29	714,103	6.12	311,721
1907	70.63	760,278	5.88	343,545
1908	73.20	639,703	4.98	329,373
1909	69.86	728,705	5.31	308,450
1910	70.06	824,242	5.74	368,509
1911	72.54	766,398	5.31	366,025
1912	73.54	748,054	4.88	363,495
1913	73.55	825,026	5.39	418,023

Railway Income Account

Table II Continued.

Year	Ratio to Earnings	Mintenance of Equipment (thousands)	Ratio to Earnings	Transportation Expenses (thousands)	Ratio to Earnings
1889	15.01	$106,709	11.06	$330,915	34.29
1890	14.52	114,039	10.14	354,189	33.67
1891	14.01	117,048	10.67	384,385	35.05
1892	14.01	128,712	10.99	406,729	34.72
1893	13.86	136,876	11.21	435,466	35.67
1894	13.39	112,894	10.52	394,513	36.75
1895	11.92	113,788	9.42	431,149	35.69
1896	13.94	133,982	11.65	442,218	38.45
1897	14.20	122,762	10.94	432,526	38.55
1898	13.89	142,625	11.43	464,674	37.25
1899	13.73	150,919	11.49	486,160	37.01
1900	14.20	181,174	12.18	529,116	35.58
1901	14.54	190,300	11.98	565,266	35.58
1902	14.39	213,381	12.36	609,962	35.33
1903	14.01	240,430	12.65	702,510	36.95
1904	13,23	267,185	13.53	758,239	38.39
1905	13.21	288,441	13.85	771,229	37.03
1906	13.40	328,555	14.13	636,203	35.95
1907	13.23	368,062	14.22	970,953	37.49
1908	13.76	368,354	15.39	≠868,252	≠36.27
1909	12.75	363,913	15.05	814,088	33.66
1910	13.39	413,110	15.02	916,615	33.32
1911	13.12	428,367	15.35	987,382	35.29
1912	12.86	448,303	15.86	1,013,340	35.85
1913	13.40	511,143	16.39	1,096,553	35.15

≠ Traffic expenses excluded since 1908, amounting to about two per cent of gross earnings.

until 1908, it being in 1906 that Mr. Hill of the Great Northern wrote his appeal for more capital for railroad extensions. The prosperity of the country since 1907 has not been sufficient to have justified any such outlay of capital as he deemed necessary. (A discussion of Mr. Hill's letter and criticism of the same is given on pages 98-105 of this paper). This table II reveals to us the fact that if the cost of operation increases as steadily for the next fifty years as it has for the last ten years the operating margin will be so narrow that many roads will be unable to show a profit. (Perhaps state ownership will be the solution if not perhaps higher rates will be necessitated). The Railway Library for 1913 summarizes the Capitalization of the entire railroad systems of the United States for June 30, 1913 as per Capitalization of Railways in 1913. This Bureau's summary (Railway Library) of capitalization for the year 1913, as reported by 433 operating roads covering 242.177 miles of line, of which 10,900 were used under trackage rights, is as follows:

Summary Showing Capitalization of 433 Companies

Operating 242,177 miles of Line for 1913.

Capital Stock	$7,316,115,837	
Funded Debt	10,121,583,089	
Receivers Certificates	35,742,519	
Total 202,336 miles owned		$17,493,441,445
Rental 39,841 miles, $129,300,750 capitalized at 5 per cent		2,586,015,000
Total 242,177 miles		$20,059,456,455
Deductions:		
For Railway Stock owned	$3,055,092,238	
For Funded Debt owned	1,729,739,061	$4,774,831,299
Net Capitalization 1913 (242,177 miles)		$15,294,625,146
Net Capitalization 1913 per mile operated		63,154

That this approximation is over rather than under the actual net capitalization is indicated by the fact that no deduction is made on account of

Other than railway stock owned	$654,580,554
Other than funded debt owned	212,149,104
Total	$866,629,655

In 1911, by a somewhat different process, the commission, with only 234,717 miles represented, arrived at $63,944 as the net capitalization per mile of line.

Net Capitalization of all Roads in 1913.

Accepting $15,294,625.146 as approximately the net capitalization of the 242,177 miles of reporting roads to this Bureau, it is only necessary to put an arbitrary valuation on the 10,000 miles from which no returns were received to arrive at a close estimate of the net capitalization of all the railways of the United States. In its last complete report, of 1911, the commission gave $25,008,390 as the gross capitalization of the class 111 roads, which operated 10,139 miles of line yielding an average of $22,000 per mile. The Bureaus report contains figures from quite a number of these roads, while it has failed to get reports from a few of the class II roads. It is, therefore, fair to assume that $25,000 a mile would be about the correct capitalization for the missing roads. Using this as a basis, the following statement shows the net capitalization of all the railways in the United States in 1913.

Summary Showing the Net Capitalization of all the Railways in the United States, June 30, 1913.

Net Capitalization 242,177 miles shown supra.	$15,294,625,146.
10,000 miles not represented at $25,000 per mile.	250,000,000
Total for 252,177 miles of operated lines.	$15,508,849,822

Net Capitalization per mile of line.	$61,064
" " " " " track (370,000 miles).	41,915

There are only two items on the foregoing computations to which any doubters can raise a question, the deductions on account of securities owned. Any objection to these items is answered by the fact that in 1913 the operating companies received no less than $279,868,243 income from investments, in other railway stocks and bonds and other securities. This is equivalent to nearly six per cent in the railway securities or nearly five per cent on all securities owned. It contains more or less duplication, or the demonstration of value would be more or less complete.

If we accept these figures as authentic, as the writer believes, they are generally considered to be, we shall have some valuable average data to use in our hypothetical case in the next part of this paper, it can be applied to specific cases, only as a basis for a preliminary estimate. At this point a comparison of the capitalization, income and mileage of two typical first class roads, operating in the same territory, etc. will be of interest. For this comparison let us take the Chicago & North Western and the Chicago, Milwaukee & St. Paul, in point of per cent of double track they differ somewhat, the North Western having 10,9 per cent as opposed to 7.05 per cent of the St. Paul. The following tables will make this comparison for us.

Summary of track mileage of Chicago, Milwaukee & St. Paul (includes Chicago, Milwaukee & Puget Sound) June 30, 1913. (Poor's Manual 1914).

	Main track	2nd. track	3rd. track	4th. track
Lines owned	9,321.99	666.05	22.27	13.11
Lines owned jointly	102.92	5.20	1.94	1.93
Trackage rights	285.11	78.36	1.14	----
Totals	9,711.02	749.61	25.35	15.04

	Com. track	sidings	Total
Lines owned	44.42	2,948.63	13,066.47
Lines owned jointly	4.98	139.68	256.65
Trackage rights	------	--------	364.61
Totals	49.40	3,138,31	13,687.73

General Income Account, Year Ended June 30, 1913.

Earnings	1912	1913
Passenger	$16,568,863.86	$18,457,135.51
Freight	55,796,064.81	67,964,161.10
Other transportation	6,196,480.92	6,919,685.75
Totals	$79,255,355.36	$94,084,054.69
Average per mile	8,281.51	9,787.35

Expenses		
Maintenance of Way and Structure	$10,007,206.66	$10,648,785.06
Maintenance of Equipment	11,475,528.92	13,871,985.71
Traffic expenses	1,818,641.87	1,894,399.14
Transportation expenses	32,564,967.75	35,065,842.01
General expenses	1,398,839.01	1,403,011.92
Totals	$57,255,184.15	$62,883,967.60
Average per mile	5,982.68	6,541.00

Capitalization figures for the Chicago, Milwaukee & St. Paul. (from Moody's Analyses, 1914).

Assets	1913
Property investment	$553,236,532
Working assets	192,395,917
Deferred debit items	5,780,887
Accrued income not due	84,391
Total	$751,499,727

Liabilities	1914
Capital stock	$232,623,100
Funded debt	455,849,766
Working liabilities	10,298,981
Accrued liabilities not due	5,810,589
Deferred credit items	3,178,764
Appropriated surplus	319,234
Profits and loss	43,417,093
Total	$751,497,727

Chicago & North Western Railway Co., Mileage for 1913.

(Poor's Manual)

	Main track	2nd. track	3rd. track	4th. track	Sidings
Total length of lines operated	7,975.94	905.21	104.49	95.36	3,279.47
Miles owned	7,744.85	799.55	104.49	95.36	3,196.35

Total operated 12,335,27

Total owned 11,940.40

Chicago & North Western, General Income Account,

Year Ended, June 30,1913.

Earnings	1912	1913
Passenger	$19,555,567.15	$20,557,623.25
Freight	46,691,540.41	54,661,588.23
Mail	1,494,403.31	1,475,435.66
Express	2,430,309.31	2,903,872.25
Miscellaneous	3,526,771.07	3,637,401.64
Total	$75,698,591.58	$83,035,921.08
Average per mile	9,377.76	10,413.02

Expenses	1912	1913
Maintenance of Way and Structure	$9,368,721.19	$11,501,186.43
Maintenance of equipment	9,869,853.15	11,568,446.04
Traffic expenses	1,340,086.16	1,348,983.37
Transportation expenses	30,924,938.30	32,241,257.68
General expenses	1,498,244.50	1,592,857.65
Totals	$52,701,843.03	$58,252,780.22

Capitalization Figures for the Chicago & North Western.

Assets	1913
Property investment	$356,912,809.
Working assets	46,189,253
Deferred debit items	10,481,781
Accrued income not due	-----------
Total	$431,588,847

Liabilities	1913
Capital stock	$154,884,143
Funded debt	200,778,000
Working liabilities	10,419,743
Profit and loss surplus	36,438,744
Appropriated surplus	3,976,049
Accrued liabilities not due	1,990,284
Deferred credit items	5,101,384
Total	$431,588,847

We see that the earnings per mile of the North Western are more than those of the Chicago, Milwaukee & St. Paul, however, the earnings of the Chicagom Milwaukee & St. Paul have increased materially since the opening of its Pacific extension. The Chicago & North Western has held the advantage of not only having a double track line from Chicago to the Missouri River but also by reason of its connection with the Union Pacific. And the handling of thru traffic. Of the two roads the Chicago & North Western is rated the stronger financially, but the future of the Chicago, Milwaukee & St. Paul certainly looks favorable, especially with the improvement and double tracking of its main line west of the Twin Cities. Even granting that a single track line up to a certain point can be operated as economically as a double track line, the psychological effect on the travelling public from an advertising standpoint of the second track is a bvaluable one. (Perhaps this has had something with the fact that the Chacago & North Western has outstripped the Chicago, Milwaukee & St. Paul in point of passenger earnings).

Having collected these data on capitalization, etc., we are ready to study Mr. Hill's article on the need of more extensions and the reply of the Engineering News, stating that the need id for more second track and less extensions of branch lines.

This article is, therefore, given as it appeared in the News for Jan. 24, 1907.

Concerning Railway Extensions.

(Articles from Eng. News, Jan. 24, 1907).

" Public attention has been attracted during the last week, by a letter written to Governor Johnson of Minnesota by Mr. James J. Hill, president of the Great Northern R. R. Co. The gist of this letter is that the railway systems of the country are congested with more traffic than they can handle, that the only remedy for this condition is an enormous increase in railway facilities, necessitating a large investment of capital and national governments must let the railroads alone lest the investor be frightened away. The letter is of course drawn out by the action of the Minnesota officials in delaying approval of the Great Northern's proposed stock increase.

The stupendous size of Mr. Hill's estimate for needed railway expansion is what has challenged attention. He figures that $5,500,000,000 ought to be spent in the United States in railway improvements in order to properly handle business. As the present capitalization of the railways of the United States, water and all, is less than 16 billions, it means that an increase of nearly one third in facilities is needed. (1914 figures-total capitalization of all roads of United States in 1913, $15,508,489, note small increase in seven years as compared with Mr. Hill's estimate).

Admitting the need of an increase in facilities, we see no need for such rapid extensions, let us examine Mr. Hill's argument a little more closely. At the outset he submits this, as proof that the railways have been standing still when they should have been growing, the following figures: (A striking tale is told by the statistics of railroad building in the United States. In the ten years ending with the year 1906 there has been an increase of but 21 per cent in mileage, but the most impressive fact is that the building has fallen off just as the demand for trackage has increased. At this time when the demand is the greatest the rate of construction is the least).

Year	Total Mileage	Inc. per cent	Inc. per cent per An.
1870	52,898	--------	--------
1880	93,671	77.00	7.00
1890	163,597	74.60	7.46
1904	213,904	30.75	2.19
1906 *	220,000	2.90	1.45

* Estimated

Before forming any conclusions from the above figures we should ask, what do they really represent? From extended experience we can say that they largely pepresent extensions into new countries in the form of branches and spurs. Only a small portion of the mileage built is thru lines, designed to divide the business with existing lines and to lessen the congestion thereon. Now whether the country builds 5,000 or 12,000 miles of these branches in a year has little bearing on the question of whether the main line roads are doing all they should to increase their facilities.

If it were true that all of the 220,000 miles of road were congested with traffic, then the country would be having conditions even worse than Mr. Hill pictures. The bulk of this 220,000 miles is made up of branches and local roads. The average railway in the United States carries 100,000 passenger miles and about 1,000,000 ton miles per mile of line. That means about 300 passengers and 3,000 tons of freight to be moved per day. Of course, the main lines greatly exceed this and the branches fall below this figure. Probably there are not more than 50,000 miles on which the traffic has outgrown the facilities. The problem is, therefore, to apply the remedy only where needed. Again quoting Mr. Hill, 'The limit of a common carrier has been reached when it is at all times moving over its system as many cars as can be run over its tracks with safety and transferred and dispatched from its terminals and junction points without unreasonable delay. Beyond that point increase of business can not be handled by increasing cars and engines.

The best judgment of many conservative railroad men in this country is that an immdeiate addition of not less than five per cent per annum to the railroad trackage of the country, for the next five years should be made in order to relieve the situation, and to put an end to unreasonable delays in the transaction of business. Investigations made by public officials disclose the fact that the railroads have been endeavoring to meet the demands made upon them. They have utilized as never before the carrying capacity of each mile. Not only were there 35 per cent more locomotives and 45 per cent more cars in use in 1905 than in 1890 but each engine and car was doing more work. The passenger miles travelled per locomotive in 1895 were 1,218, 967 and 2,048,558 in 1905 an increase of 68 per cent, and the ton miles per freight train locomotive increased from 4,258,221 to 6,690,700 or an increase of 57 per cent. Trains run faster, cars are larger, locomotives have improved so as to increase the general efficiency of the business.

In the great centers the inadequacy of terminal facilities prevent the free flow of traffic. The Great Northern has 36 switch engines in use in the twin cities while only 28 are used in hauling freight into and out of the same. Suppose that only 25 per cent additional track, with necessary terminals and equipment making 33 per cent, is to be built in the next five years, or, say in round numbers 75,000 miles of track as the requirement for the country to meet immediate needs. No practical man would furnish the facilities required, including additional equipment and terminal facilities, for less than $75,000 a mile. The question of terminals alone is almost prohibitive. Terminals now in use were acquired when land was cheap, and can be enlarged only by heavy outlays. In many cities it is not only a question of cost since the area needed can not be had at any cost. The new work would amount to $5,500,000,000 or a yearly average of $1,000,000,000. That is the sum which should be spent before the commerce of the country can be moved properly".

The basis of Mr. Hill's computation from the above quotation and our preceding analysis shows its essential error. He is correct in stating that there is need for additional trackage, and particularly for additional terminal facilities: but his attempt to measure the total requirement as a per cent of the existing mileage is manifestly too inaccurate to have any standing.

The actual situation as we see it is this: A considerable portion of the main lines west of Chicago need to be double tracked, some work on this problem has been done but the problem needs to be attacked on a much larger acale. The Chicago & Great Northern for example has only 90 miles of double track for a system of over 6,000 miles and the Northern Pacific, has 120 miles of double track. Both of these companies have been active in building braches, which has added to the congestion of the main lines, they must now turn their attention to the double tracking of their main lines. In this conncetion it may be pointed out that for the best service to the public at the least capital outlay, our railroad ought to be made up of double track main lines with a net work of feeders, rather than of a large number of single track lines. The railway development of the 79's and 80's grid-ironed the country with a larger number of single track lines than could be supported, the growth of traffic since then has made profitable many lines which were once bank-rupt. Additions to railroad capital can in may cases be better spent in second track, yards and terminals than in building new competing thru lines. Turning now to the problems of congested terminals we wish to express our hearty approval of the latter part of Mr. Hill's article. (The prohibitory expense of enlargement of terminals and the lack of available space may be met by decentralization of traffic. Terminal troubles admit of a more general dif-fusion of business, permitting transfers to be made and forwarding to be done where land can be secured at reasonable prices. The heavy transfers must be made away from the larger cities.

No student of transportation problems, who has watched the rapid growth of terminal expenses, can fail to reach conclusions similar to those of Mr. Hill. It is to the public's advantage that the number of exporting points be increased; that the development of rival grain markets to Chicago, Minneapolis, and Duluth be encouraged that new jobbing centers be given a chance to grow. We are all well aware that this is opposed to the ideas commonly held, nevertheless, it is sound doctrine. New York must learn that it is not to her advantage to be over congested with freight, and it is best that a portion of the grain export business go th Galveston, Newport News, and Boston. Were this not the case the prosperity of Chicago would be hindered rather than helped by excess business. In this connection it is well to call attention to the diversion of thru freight around the larger citire. In the same letter Mr. Hill says, " The average speed of a freight train is from 12 to 15 miles per hour. The average distance travelled by each freight car is about 25 miles per day. That is, the entire freight equipment of the country is employed to the fair limit of its capacity only two hours out of every 24. On single track lines freight must stand on sidings for the passing of passenger trains and cars are delayed for days in the sorting at terminals".

" Here is the real root in the difficulty of the railroads in dealing with the congestion of traffic. It is all very well to reduce the delays of shippers in the consigning and unloading of cars, but these delays amount to only a small portion of the cars' time. It is not the road delays that account for a large portion of the cars' lost time, it is the time lost in terminals.

The problem of how to design yards in order to lessen these delays and keep cars moving is the problem which the railroads are up against today".

The above article reveals some interesting things: It has been eight years since Mr. Hill wrote his letter and the entire single track miles of line of the United States have been increased to 242,177 miles in 1913. The total number of miles of track is equal to 367,658. Of this 26,320 miles are second track, against 17,056 miles of second track in 1905, and also the capitalization of railroads has been increased to $15,508,849,822 or $61, 064 per mile of line, or $41.915 per mile of track. The mistaken reasoning of Mr. Hill in regard to extensions has been proven by time, and the soundness of his logic in regard to increased terminals etc. has been proven true, The prediction of the future of Galveston as an export port has not reached what the railroad builders of certain lines had hoped. This we see in the financial troubles of the Chicago, Rock Island & Pacific R. R. Co., the Kansas City Southern R. R. Co., and the St. Louis & San Francisco R. R. Co.

The question of the government interfering with the credit of the railroads is with us today and even in a more acute form than at the time mentioned above. In spite of enforced policies of economy we have receiverships, and financial troubles due largely to the over building of the 80's, or more properly the overbuilding of branches. The roads that are naturally located to serve a good territory can easily earn dividends, while others less favorably located can not raise the capital for needed improvements.

From this mass of preliminary materials, it would seem to the writer that the point at which the construction of the second track should be undertaken is somewhere between 40 and 60 trains per day, that is, assuming that the terminal facilities are adequate for the proper handling of such traffic. We will now pass on to Part IV of this paper and attempt to analyze the cost of second track as compared with passing tracks. In both the question of first cost and costs of maintenance and operation are considered.

Part IV.

The Cost of Second Track vs. Passing Track.

(a). Initial costs.

In comparing the first costs of single and double track, we should assume that the first track is in actual use and of proper standard construction. Mr. Camp in his 'Notes on Track' makes this comment on the construction cost of double track: "The first cost of rails, ties, fastenings and ballast for double track is twice that for single track, but the same ratio does not hold true in other particulars -- it always favors the double track. In instance in earthwork with slopes 1 and 1/2, to 1, a roadway 18 feet wide, in cuts or fills of 10 feet deep, may be widened to 31 feet (the width required for double tracks with 13-foot center) with the handling of but 40 per cent more materials, the proportion of materials growing less as the depth of cut or fill increases. The same ratio will hold in relation to the cost of bridge abutments, etc. In most regions cuts and fills of the above dimensions are only ordinary with roads handling a traffic so large that they can afford to double track. The cost for filling or excavating per yard of material should be less on the second track since the facilities for the handling of machinery etc. are much better. Taken all around, the cost for earthwork should usually not exceed 50 per cent of that for a single track on the same location. As regards cost of construction of a second track, it ought to be considerably less than the cost of the first one, as the materials can be distributed more cheaply; also the company has opportunity to build its own track and thus save the contractors profit.

(b). Next considering the item of repairs and maintenance, Mr. Camp writes as follows: " Approximately twice as much will be required for tie renewals for two tracks as for one. Where trains run frequently the rails lose but little from rust, so that the cost of renewing rails for double track will not much exceed the cost of rail renewals for the same length of single track carrying the same traffic. There is also much work, such as ditching, mowing grass and weeds, cutting brush, policing, repairing and renewing fences, track walking, bank-edging, maintenance of snow fences and protecting banks, and other work which requires the same time for single as for double track;

in fact the cost of mowing and cutting brush on double track is often less than on single track, due to the narrower width outside the slopes at cuts and fills. Regarding lining and surfacing the cost of two tracks will not be twice that for one, because each track undergoes only half the service which one track would in carrying all the traffic. Unlike the matter of rail-wear, however, the work of maintaining two tracks in line and surface is more than the work required on one track bearing all the traffic, because of the disturbing action of rain and frost, also double track is as a rule not so well drained at subgrade as single track. Data on this item seems to indicate that the cost of raising and tamping double track to hold it in surface is from 40 to 70 per cent greater than like service on single track of the same length to carry the same tonnage. In another respect, double track is favorable to lower cost of surfacing than it might otherwise be, as there is less interruption of the work, for the same number of train movements, and the trains are more likely to run regular schedule, so that track work can be laid out to better advantage. For example a freight train of several sections becomes delayed, so that of necessity the meeting point must be changed, the different sections might become so strung out that the work of a section crew would be delayed the greater part of a half day. It is not entirely the time lost while workmen stand aside for trains to pass, but the uncertainty regarding the time when trains will be along, which often catch the work when it is partly done, requiring it to be done the second time, or in many instances causing delay as a matter of precaution in the starting out of the work. Taking all matters into consideration, it is, therefore, a reasonable estimate that the cost of keeping up of two tracks on the same roadbed to carry a stated amount of traffic does not exceed that necessary to maintain one track to carry the same amount of traffic, by more than 45 to 55 per cent". As a result of his studies of this question Mr. Camp draws the conclusion, that using average cost data covering the various items of labor and material accounts of track maintenance, that the ratio of the expense of maintaining single track to that of maintaining double track carrying an equivalent tonnage, to be 1 to 1.52. In this calculation interest charges are not taken into account.

In considering the item of fixed charges, the fixed charges on the double track will usually be greater than on the single track because of the increased capitalization. That is the interest on bonds, if bonds are issued to cover the expense of the construction, will be greater than before the extra expense was incurred. But if the additions are made gradually and a sum taken from what normally would go to surplus, is used for the building of the second track, then the fixed charges will be increased only the amount of the extra taxes.

(c). In considering the difference of the costs of operation on the single and double track line, the principal item to consider is the expense due to delays to trains at the passing sidings. Also the expense of starting and stopping the train. The latter is dependent on the grades at the passing siding, the weight on the train and the condition of the tracks etc. Many attempts have been made to analyze the costs of stopping and starting trains. Again we find that the Mr. Wellington has made an estimate on the costs of starting and stopping of trains. He states on page 810, paragraph 1102 of his work on location, that from 30 to 60 cents per stop may be taken as a fair cost of stop apart from the effect on the length of trains. This estimate assumes no item of delay which is, of course, dependent on the length of time which the train is held while waiting for clearance orders after the passing of the other train, or for the arrival of the train which is to pass. In the Bulletin of the American Railway Engineering Association, Vol. 19, March 1915, is an article on the Cost of Starting and Stopping Trains by Mr. F. W. Green, General Manager of Louisiana and Arkansas Railway.

Mr. Green first abstracts an article by J. A. Peabody, Signal Engineer of the Chicago & North Western, published in Engineering & Contracting, Feb. 1906. The essential features of Mr. Peabody's article are as follows:

Item	Passenger	Freight
Coal to stop train (air pump)	30 lbs.	50 lbs.
Coal to accelerate train(estim'd)	275 "	500 "
Total coal	305 "	550 "
Value of coal at $2.15 per ton	$o.33	$0.56
Brakeshoe wear (from laboratory tests) including tires.	0.03	.15
Wear of draft and brake rigging, etc. (estimated)	0.06	.29
Total	$0.42	$1.00

Note: The passenger train was considered as stopping from, and accelerating to , a speed of fifty miles per hour on level tangent, weight of train 530 tons, including locomotive and tender half loaded. Net loss of time 2.5 minutes. The freight train was considered as of 80 cars, 2,000 tons; stopping from and accelerating to a speed of 35 miles per hour. Mr. Green by means of several formulae reaches this final conclusion:

Coal stopping and starting (formula II), 81 lbs. at $3. per ton (coal for brake system.	$0.01
Coal starting (formula 8, for acceleration)	.28

Water used (formula 7, 155 gals. at 15 cents per 1,000 gals.	$0.02
Crew wages stopping (formula 9), 90 x $2.15/3,600	.05
Crew wages starting (formula 10)	.05
Wear and tear on brakeshoes and tires.	.00
Wear and tear on draft rigging, estimated	.20
Lubricants supplies and other items estimated	.01
Consequential delays to all trains, (disregarded)	.00
Total	$0.61

The formula referred to is as follows:

Nomenclature for Formula.

A = Force producing acceleration in pounds per ton of 2,000 lbs.

C = Number of cars to train,

c = curvature in degrees,

D = Diameter in feet in which required acceleration is attained, and thru which A acts.

d = Diameter of cylinder in inches,

f = Pounds of coal required for acceleration (air brake system),

F = Pounds of coal required for acceleration,

g = Per cent of grade,

G = Acceleration of gravity,

h = Velocity head in feet,

q = Cost of coal per pound,

Q = Total cost of fuel,

R = Sum of locomotive, tractive, grade, curvature, and acceleration resistances in pounds per ton,

S = Frictional resistance in pounds at drawbar of locomotive, due to losses between cylinder and drawbar. (See Goss Locomotive Performance page 418).

T = Total tons in train including locomotive,

t = Time in seconds during which force A acts,

V = Speed in miles per hour,

w = Rate per second for wages of train and engine crew.

W = Amount of train crew wages,

Y = Gallons of water corresponding to fuel consumed in stopping and starting.

Development of Formulae by Mr. Green, American Railway Engineering Association, Vol. 16, March 15.

Assuming a resistance for the entire train on level tangent of six pounds per ton (plus a proper allowance for frictional losses in the locomotive to be referred to later), grade resistance at 20g, curvature resistance at 0.8 cents, acceleration, resistance at $\frac{70\,V^2}{D}$, frictional resistance of locomotive corresponding to losses between cylinder and drawbar at $\frac{3.8\,d^2 L}{J\,T}$, we may write

$$R = 6 + 20g + 0.8c + \frac{70\,V^2}{D} \quad \frac{3.8\,d^2 L}{J\,T} \qquad (1)$$

The fourth term is taken from Henderson's "Locomotive Operation", the fifth from Goss "Locomotive Performance" page 418, modified to the extent of adding the factor T in order to reduce to a value per ton of train. We may now write, $H = \frac{R\ T\ D}{495,000}$ and assuming four lbs. of coal per horsepower hour,

$$F = 4\ H, \text{ or } \frac{R\ T\ D}{495,000} \qquad (2)$$

From Henderson's "Locomotive Operation" 2nd. edition, page 5, we obtain,

$$A = 70\ V^2/D \qquad (3)$$

and also,

$$A = 95.6\ V/t \qquad (4)$$

Equating (3) and (4) and solving for t, we have,

$$t = 1.3657\ Dw/V \qquad (5)$$

Obviously, $W = wt$, and hence, $W = 1.3657\ Dw/V$ (6)

If we assume an evaporation of seven pounds of water per pound of coal, the pounds of water will be 7F, and the gallons of water will be,

$$Y = 7\ F/\ 8.34, \text{ or } 0.84\ F \qquad (7).$$

Since we are to determine the cost of coal consumed by the stop, over and above the amount that would be consumed for the acceleration distance, if no stops were made, we must deduct the fuel that would be consumed in this distance if the train made no stop. We may then write,

$$Q -- RTDq/495{,}000 \quad - \quad \frac{(R-70V^2/D)\ TDq}{495{,}000} = 70V^2\ Tq/495{,}000, \quad (8)$$

assuming one minute net loss of time in bringing train to a stop, and 30 seconds average time tbetween stop and start, the value of crew wages will be,

$$90w \qquad (9)$$

The value of crew wages accelerating will be the accelerating time less the time that would be used for the same distance if no stop were made; in other words the net loss will be one-half of the accelerating time, hence from (5) we may write,

$$\text{Crew wages lost accelerating} = 1.3657Dw/2V \qquad (10)$$

The air brake system, when a $9\frac{1}{2}$-inch compressor is used, will require 3.14 pounds of coal per car in train per hour, or 0.000871 pounds per second, according to data furnished by an air brake company; multiplying this by the number of seconds lost during the period of stopping and starting and adding 0.00673 pounds per car for an assumed brake - cylinder pressure of 30 pounds per square inch and a piston travel of 8 inches, we may write,

$$f = 0.000871C(90 + 1.3657D/2V) + 0.0073C = (0.00784 + \frac{0.0006D}{V} + 0.00067)C - (0.0851 + \frac{0.0006D}{V})\ C \qquad (11)$$

The result of $0.61 was obtained by assuming a freight train of 2,000 tons, from a speed of 25 miles per hour, and accelerating the same to the same speed in a distance of 3,000 feet with fuel at $3.00 per ton, on level tangent; 50 cars in train. The author does not consider the item of brake shoe wear, and justifies himself by stating that certain tests as conducted by the chief engineer of the Griffin Wheel Company, of Chicago, in which the item of brakeshoe and tire wear is so small that at ordinary speeds it may be disregarded entirely. Probably these results would be more fair if $0.05 were allowed for the item of brakeshoe wear. This would bring the total up to $0.66 per stop, for ordinary stops. This is not an unreasonable result. This formula is applicable to local conditions by the substitution of the proper factors. A graphical solution of equation (8) is included in the article.

The question of the saving of time and expense in time of wrecks, by being able to maintain traffic on the second track is an important one, and one which should be considered, but the writer has been unable to procure any information which would give him an idea as to what percent of the tie ups on a single track road might be avoided were there a second track.

No matter what the correct cost of the stopping and starting of trains, there is this certainty that on the the second tracked line all stops due to trains in the opposite direction will be eliminated.

Operation Costs due to Maintenance of Signal Service.

The actual cost of installation of an automatic block signal system is probably greater for a single track line than for the double track line, and in probably the cost of maintenance is greater on the single track installation than on the double. If a manual block system were used on the single track, and the automatic block system substituted on the double track line, the cost of blockmen will be eliminated. However, the maintenance item on the block system will be considerable, although not as much as the cost for blockmen's wages in the manual system.

Part V.

An Assumed Problem and the Solution of the Same.

If we make the following assumptions in regard to length of the division to be considered, and the number of trains and passing tracks on the division or district, an illustrative example may be solved which will show the principles involved. Assume 100 miles between terminals. This district to be equipped with 24 passing tracks of proper length, and spaced approximately four miles apart. This spacing of a passing track every four miles seems to be what the weight of opinion indicates as the maximum closeness for passing tracks. The result of the writer's study leads to the belief that a line having between 40 and 60 trains per day should double track. We will, therefore, assume 48 trains per 24 hours, over this line, four of these to be limited passenger trains, two to be fast mail trains, and six local passenger and dairy trains. Of the freights 28 to be thru freights and four local freights. This is about the density of traffic on the important single track lines, Illinois, Iowa, and Indiana.

It now becomes necessary to attempt to estimate as to whether or not the losses due to stops and delays to trains operating on this single track, would equal or excel the interest on construction cost, plus the other extra fixed charges, plus the losses in earning power due to delays of trains if the same traffic were handled over a double tracked line. If this first item of single track operation losses exceeds the second item of double track operation losses we are justified in saying that the line should be second tracked. The following figures from (Webb Railroad Construction) were used in the estimating the cost of the second track.

Cost of construction of a mile of Single Track based on data from Webb's Hand Book of Railroad Construction. (Corrected for heavier steel).

	First Track	Estimated Second track.
1. Right of Way, 12.2 acres @ 100	$1212.00	00.00
2. Cleaning & Grubbing 1 @ $50	50.00	00.00
3. Excavation 22 cts. per yard	2840.00	1140.00
4. Rock excavation (32.44 yds. @.80	26.00	14.00
5. Culverts	417.00	167.00
6. Trestling	107.50	97.00
7. Bridges	792.00	712.00
8. Cattle guards	56.00	50.50
9. Ties, 3000 per mile @ 75 cts.	2250.00	2250.00
10. Rails 90-lb. per yard @ $30 per ton	4245.00	4245.00
11. Rail sidings	547.00	273.00

Table from Webb continued.

	First Track	Estimated Second Track
12. Switch timbers and ties	$ 21.00	21.00
13. Spikes	139.00	139.00
14. Splice bars	227.00	227.00
15. Track bolts	28.00	28.80
16. Track laying	500.00	500.00
17. Ballasting	1540.00	1540.00
18. Turnouts and switches	75.00	50.00
19. Road crossings	13.00	13.00
20. Section and tool house	82.00	41.00
21. Water stations	15.50	00.00
22. Turn tables	31.00	00.00
23. Depots etc.	500.00	00.00
24. Terminal grounds etc.	1000.00	00.00
25. Fencing	150.00	00.00
26. Engineering and office	640.00	00.00
27. Interest on construction	60.00	30.00
28. Rolling stock	5000.00	00.00
29. Telegraph	500.00	00.00
30. Block signals	2500.00	2500.00
Totals	$26,564.80	$14,039.00

We will assume a cost of $15,000 per mile to second track a class B road and $20,000 per mile to second track a class A road under conditions of heavy, and with very light cuts and fills.

Estimate from Gillette's Cost on the Cost of Passing Sidings.

In Gillette's Cost Data we find the cost of passing tracks of 3,000 feet in length given as from $4,000 to $8,000, each including the cost of turnouts etc. If we assume $7,500 as the cost of a track of 3,000 feet in length, and since we know that for a satisfactory passing it must be of the double turnout type. (See drawing of passing tracks page 48). Therefore, an assumption of $15,000 is not far wrong for the first cost of the double track.

If we assume interest at .05 per cent, gives	$ 750	per yr.
" " " taxes " .01 " " , "	150	" "
" " " maintenance " .02 " " , "	300	" "
Cost of two extra operators as	2,000	" "
Total yearly charge against one extra passing track.	$3,200	" "

This estimate is intended to be large enough to include cost of small operators tower, telegraph instruments etc.

We will now attempt to find the items which may be charged against the second track.

First, 100 miles of second track at $20,000 per mile equals $2,000,000. Assuming the interest on this amount at five per cent gives a yearly charge of $100,000.

If we estimate the cost of maintenance chargeable to the second track as being two per cent of the first cost gives a charge of .02 x $2,000,000 = $40,000 per year.

The cost of operation due to trains having to take sidings to allow trains of superior speed and class and headed in the same direction to pass is not so simple to estimate. This item is at once seen to be a function of the number of trains operated, and the relative speeds of the trains of different classes. We have in this case 16 freights and eight passenger trains in each direction. The total time for the first class freights to cross the 100 miles will be assumed as seven hours. Estimating that each of the first class freights must stop four times to take water, and no times to permit the passing of passenger trains headed in the same direction, as water could usually be taken while waiting for superior trains to pass. (Note, it would at first seem that the stops for the taking of water should not be considered in the charges against the second track, since this must be done whether the line is double or single tracked. This is true, nevertheless, if we take into account the same number of stops for coal and water in figuring the delay losses on the single track operation as we do in the double track operation, no error will enter the estimate. The losses due to the stops for water and coal merely cancel each other). Since there are 28 of these first class freight trains per day, we have a total of 28 x 4 = 112 stops per day on the first class freights under double track operation.

The two local freights would be held up at least eight times besides four times for fuel and water, making a total of 12 x 4 = 48 stops chargeable to the locals. The six local passenger trains probably would not need to be delayed more than twice each to allow the overtaking and passing of them by superior trains, thus giving a total of 6 x 2 = 12 stops chargeable to the local passenger trains. (Note local passenger trains would usually take water during the regular stop at the stations.)

Therefore, the total number of stops absolutely necessary under the double track operation, as assumed is 112 + 48 + 12 = 172. If we assume these stops or delays to be of an average duration of 7½ minutes, which is five minutes more than the duration of the ordinary stop allowed by Mr. Green in his formula (9) page 116. This 1½ minutes stop Mr. Green figures as costing $0.66 for a 2,000 ton train. We must add to this the cost of crew wages for five minutes more, and also add the lost earning power of the train for $7\frac{1}{2}$ minutes. The additional crew wages will be \$2.15 x 300/3600 = \$0.18 per stop. If we take the average net revenue per freight train mile as given in Moody's Analyses as \$2.42 in 1913). And assuming the average freight train speed as 15 miles an hour, and further assuming that to return this revenue the freight trains of the country are actually in operation not more than eight hours per day including stops, the earning capacity of a train per minute will be \$2.48 x 15/60 x 3 = \$0.201 per minute. The total time lost per stop we assumed as $7\frac{1}{2}$ minutes, therefore, $7\frac{1}{2}$ x \$0.201 = \$1.5075 minus the lost earning power of the train. The total cost of the $7\frac{1}{2}$-minute stop will be \$1.507 + .66 + .18 = \$2.347. Then \$2.347 x 172 - 365 = \$147,344.66 per year. (Lost in stops in 100 miles). The item of additional taxes directly chargeable to the second track is a little difficult to estimate, because of the varying rates of different states. In 1913 the average rate per mile for the whole of the United States was \$535 per mile, it would seem that \$250 would be a fair proportion chargeable to the second track. The total yearly charge against the 100 miles of second track would then be \$147,344.66 + \$25,000 taxes plus \$100,000 interest on first cost plus \$40,000 per year maintenance. Total \$312,344.66 chargeable to the second track operation.

We will next attempt the losses due to stops and earning power lost on the single track lines handling the same number of trains. It is believed that it is a fair assumption to say that each first class freight would be compelled to side track four times for the taking of coal and water and two times for the passing of passenger trains in the opposite direction, and two times due to being overtaken by passenger mail trains headed in the same direction. This gives a total of 28 x 10 = 280 stops for first class freights. The two local freights will have an average of 16 stops each, 16 x 4 = 64, giving a total of 344 stops to freights, The six local passengers will probably have to side track at least six times in crossing the 100 miles, 36 for local passenger, making a total to all trains of 380. Adding to this three stops for west bound thru passenger and mail trains gives a total of 383 stops. Then 383 x 365 x $2.347 = $328,518.25 as the yearly charge or loss due to delays. But under the double track operation we estimated this charge plus the increase of interest and taxes and maintenance to be $312,344.66. If our assumptions are correct this line can be second tracked and a net saving of $16,173.59 be affected per year. Or $161.17 per mile will be added to the net income of the road. The average net operating income for the whole of the United States in 1913 was $3.141 per mile. Or under our assumptions the net income of this 100 miles, using average values, is increased but 5.13 per cent.

Recapitulation of Results.

Losses due to Delays under Single Track Operation.

$2.347 x 383 x 365 = $328,518.00

Losses due to Delays under Double Track Operation.

$2.347 x 172 x 365 = $147,344.66

Saving or reduction of Losses $181,173.59

Fixed Charges on Proposed Second Track (Annually).

Interest on $2,000,000 @ 5 per cent	$100,000.
Maintenance on 100 miles @ 400 per mi.	40,000
Taxes 100 x $250	25,000
Total fixed charges	$165,000
Net saving on 100 miles	$16,173.59
Net saving per mile	$161.17

Average net income per mile of road in United States in 1913 according to the Railway Library Statistics was $3.141. Then by this assumption the net income of the division is increased 5.13 per cent.

This shows that a slight variation of these assumptions either way can change the result to a large extent, and tends to show that to say just what the result of the second track will be is very difficult.

In other words this traffic justifies an expenditure of $20,000 per mile for a second track, provided this money can be obtained at five per cent, and that the assumptions made here are reasonable.

There the question will be raised at once as to the right of taking into account the lost earning power of the idle train as well as the purely mechanical loss and the loss of wages during the stop or delay of the train. If the equipment of the road is working to its capacity then there is a certain value on every minute of time lost, but if nothing is to be gained by saving say 30 minutes on the time of a train in crossing the division then we are not justified in considering the lost earning power of the train.

If we do not consider this element of lost earning power, we would then have a cost of stops as follow, that is considering the crew wages for the full $7\frac{1}{2}$ minutes and disregarding fuel consumption for idle engine.

Single Track Operation,

383 stops x 0.84 x 365 = $117,727.80

Double Track Operation,

172 x 0.84 x 365 = $52,735.20.

Net saving in cost of stops $64,992.60

Fixed Charges on Second Track (Annually).

Interest on $2,000,000 at 5 per cent	$100,000
Taxes $250 per mile	25,000
Maintenance $400 per mile	40,000
Total	$165,000

Here we see that the saving effected by the second track would lack $100,000 of meeting the fixed charges on the second track. And it is this very analysis that makes the question of installing the second track a difficult one, if the road is not hard pressed for rolling stock and its traffic is not increasing very rapidly. According to this analysis the road is not justified in second tracking. In our first analysis in which we capitalized the lost time of the trains, we found a small margin in favor of the installation of the second track. Yet even in that case it probably is a question of the probable future growth of the traffic rather than increased net income. Also we have in no way considered the item of increased safety because of the second track, nor the increased drawing power of a double tracked line because of increased dispatch in operation of freight trains. Further the item of clearing the line in time of derailment, can not be estimated in dollars and cents.

Conclusion.

In conclusion it may be said that the results obtained are merely conservative estimates since the data used is entirely estimated. Yet if it were required to solve a similar problem in actual practice, the proper way to attack the problem would be to take the district in question and keep a careful record from the time sheets and dispatchers sheets of all time lost in delays caused by waiting for trains at passing points. Then on a basis of the actual earning power of the district in question, capitalize this time loss and thus find the loss due to delays. If this equalled or exceeded the fixed charges on the proposed second track, one would be justified in saying that the district needed a second track. This would seem proper if one were certain of the future increase of traffic or at least its remaining near where it is at the present time. Also before the second track is installed the passing sidings should be installed up to one every four or five miles or as near that limit as the topography of the line would require. And before the second track is installed the dispatchers sheets should be carefully studied to make sure that the installation of one passing track would not greatly increase the capacity of the line. We saw that the fixed charges on a passing track 6,000 feet in length based on a cost of $15,000, are but $2,200 a year, which item can be considered with a higher degree of certainty than can a section of second track. If after carefully weighing all of these items it seems that the increased efficiency of the line, more than balances the increased expense. We can say that the company is justified in double tracking its line.

The Economic Justification of Double Tracking.

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