PAPER No. 86.

ECONOMIC RAILWAY CONSTRUCTION.

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Introductory.

The preparation of this paper arose from the consideration together of two separate recent and authoritative statements on Indian Railway policy, which it appears can only be reconciled by wide departures from hitherto accepted standards of construction. It aims at suggesting how this can be safely achieved and is written principally with the object of stimulating discussion on a subject which is of immediate importance in many parts of India and nowhere more than in the Punjab.

Economic principles.

It was laid down by the Inchcape Committee in their report that fresh capital expenditure should only be undertaken on remunerative projects for new railways which could earn an average rate of interest of 5½ per cent. per annum. More recently the highest authority in this country on railway policy has publicly stated that the object of such policy should be the provision of cheap and efficient transportation throughout India. The second of these objects can only be achieved by building more railways, as a glance at any railway map will show. If therefore this policy is to materialise, such new lines as are required must comply with the "5½ per cent. test." New railways built now to the standards hitherto accepted will almost inevitably fail to pass this test, and the engineer is therefore faced once more with the perennial problem of "cutting his coat according to the cloth."

The practical limits of expenditure.

The wise engineer, faced with this problem, will begin by finding out exactly the size of the piece of cloth available and seeing if he can possibly grab a bit more. In the case of a railway the latter operation can only be achieved by raising rates for the carriage of passengers and goods. But all or nearly all the lines immediately necessary for the development of the country are through agricultural areas; the intrinsic value of the commodities carried is low, and even with present rates there is danger of strangling the traffic by charging so much that the ekka, the bullock cart, or the camel can compete successfully. For this reason we cannot hope to improve the present gross earnings by an increase of rates in such areas, though there may conceivably be possibilities of doing so

in rich mineral areas where the commodities carried are of higher intrinsic value. The latter are exceptional and will not be further considered here, this paper being intended to cover the commoner case of lines through the agricultural districts of the plains. If we assume, for example, that on such a line the weekly gross earnings per mile are about Rs. 300 and that the weekly working expenses per mile are about Rs. 175, the maximum capital expenditure on which a return of $5\frac{1}{2}$ per cent. per annum can be obtained from the net earnings of Rs. 125 per mile per week will be $52 \times 125 \times \frac{100}{5{\cdot}5}$ =Rs. 1,18,000 per mile of line, and this sum is the limit of the cost which can be incurred on construction to satisfy this test. Actually, construction costs would have to be kept well below this figure, because the working expenses assumed above would be insufficient to cover the annual contribution to the special renewal fund for short-lived structures, the need for which is explained below. *Figure 1 gives in the form of a diagram the maximum expenditure per mile of line, calculated as above, which is justifiable for various rates of weekly earnings and working expenses. Each of these must, of course, be the subject of careful separate estimates, as the common method of estimating working expenses as a percentage of gross earnings is liable in certain cases to prove fallacious ; dotted lines indicating calculations on this basis are also plotted on the diagram but this method is not recommended. A study of the diagram indicates that in the case of lines such as those under consideration where weekly gross earnings are probably about Rs. 250 to 300 per mile, and weekly working expenses about Rs. 150 to 175 per mile, the justifiable capital expenditure does not exceed Rs. 80,000 to 1,00,000 per mile, and the engineer is thus in practice faced with the problem of constructing a serviceable line under present-day conditions for a cost approximately the same as that at which a first class line was built 15 years ago.

Commence from first principles.

This problem is more or less *insoluble if all hitherto accepted standards of construction and equipment are accepted*. But it *can* be done if *a less expensive though equally serviceable standard* is worked to. To obtain this result we must go right back to first principles in the case of every detail of construction, and only build what is absolutely necessary to handle the traffic actually offering when the line opens. Everything else, however useful or desirable, must be left till later when the expansion of the earning power of the line justifiesf urther capital expenditure.

* Based like all the other calculations in this paper on slide rule figures only.

Gauge.

Before going further it is advisable to remark that this paper is not intended to deal with the Indian Railway Gauge problem, though that question is certainly germane to the present discussion. But it has already been recently fully and authoritatively dealt with elsewhere,* and the arguments which follow apply with equal force *mutatis mutandis* to railways of any gauge. The examples given are for the 5′ 6″ gauge, of which the writer has practical knowledge and on which the majority of the railway mileage not merely of the Punjab but of all India has hitherto been constructed.

Fundamental requirements—track.

Proceeding, then, from first principles we will consider what is absolutely needed for a 5′ 6″ gauge line in agricultural and mainly irrigated country such as the Punjab plains. As indicated above we are limited to a capital expenditure of say Rs. 1 lakh per mile at the outside.

The first requirement is naturally a track on which to run trains. Traffic will be light, say one or two trains daily in each direction at first. Speeds will be low, say 25 miles per hour maximum. The wagons will be those which run on the existing main lines, so as to avoid transhipment. They have usually axle loads of 16 tons, widely spaced, and are considered as bringing on a bridge no greater stress than an engine with 3 coupled axles each of about 12 tons load and spaced about 5 feet apart. It is essential that heavier engines should not be used, nor are they necessary, as on gradients of about 1/500 which should be easily obtainable in such country the train load will be some 750 to 850 tons or, say, 40 to 45 four-wheeled vehicles with average loads. For this work 60 lbs. rails should suffice, provided a fairly liberal number of sleepers is allowed. 14 or 15 sleepers per 36 feet rail is suggested for a 60 lbs. rail. But if old 75 lb. rails can be obtained from main line renewals the number can be cut down to 13 sleepers per 36 feet rail, and some economy in first cost will result. Ballast in either case will be allowed at 10 cubic feet per foot run ; as this is enough to make a satisfactory road for low speeds, if it is of good quality.

Bridges.

In considering bridges on such a line, the first question to ask at each site is whether a bridge is required at all. Unless there

*Institution of Civil Engineers, Proceedings, Vol. 213 ; Railway Board Technical Paper No. 212.

is clear evidence that water flows pretty regularly in any nulla or depression, it will quite probably be better to cross it on a well-made bank and accept the possibility of holding up a certain amount of water for short periods or even of a washout once in ten or fifteen years. There are many railway bridges, built at great expense in the past, through which water passes even less frequently. But such places must be constantly watched during the rains and remembered by the engineers so that timely provision may be made for adequate bridging before traffic gets heavy or the line becomes a main traffic artery.

Where bridges are required, the use of cheap methods of construction is necessary, even at the expense of durability. If a structure good for 15 years will do, it is waste of money to begin by putting in one which will last 30, 50, or 100 years because, if for no other reason, the latter is almost bound to have to be reconstructed to meet the requirements of doubling the line or increased loads long before its useful life is ended. But the use of such structures involves the absolute necessity of ensuring that funds for their replacement are at the disposal of the railway administration when needed. For this purpose it is suggested that, after meeting ordinary working expenses and before paying a dividend, there should be set aside annually a fixed sum sufficient, if invested at compound interest, to produce the amount required at the end of the estimated life of each structure. Figure 2 shows diagrammatically the amount invested annually at the "Inchcape rate" of 5½ per cent. at simple and compound interest required to produce Rs. 1,000 after various periods. The financial resources and organisation of any big railway should make the latter method of investment possible, and the enormous advantage of compound over simple interest needs no comment.

In constructing bridges we must therefore abandon the methods hitherto used in this country and turn for examples to the less-developed parts of Canada, the United States and parts of Africa. During the war the writer had the privilege of working with many engineers from those countries, and actually constructed such lines with their help. They carried with success and safety a much heavier traffic than is contemplated in this paper and the introduction of such methods of construction seems desirable on lines that could not otherwise be built at all in the more expensive and conventional way. Admittedly, good maintenance will be needed, but the task of educating the present Indian staff up to it should prove no less possible than that of our predecessors who first taught Indians to drive engines or work machine tools.

Buildings.

In the case of buildings the remarks as to durability made above apply equally. We must abandon our present expensive methods of permanent construction and try rather to adapt to our needs the cheap methods of building in use in this country since time immemorial, improving them where necessary in the light of modern scientific knowledge. The maintenance engineer will doubtless shiver at the thought of maintaining such buildings; but it must be remembered that one of the largest items in the cost of all such maintenance work is labour and that a cooly-day costs the same whether used for whitewashing, leeping a mud wall, or pointing a pucca one. Once one begins thinking on these lines many more suggestions for economy in details will present themselves.

Example of details—A typical line.

Having thus indicated the broad principles involved we will now consider in further detail an example of an imaginary branch line, and show roughly for what cost it should be possible to build it. The example given is not an actual case, but an imaginary one intended to develop the various details proposed.

Let us assume that it is intended to build a light "feeder" branch 5' 6" gauge line 50 miles long in easy agricultural country, mostly irrigated. There will be no large rivers to cross and only a few large canals. Unavoidable bridging on such a line may be expected to average 100 feet of waterway per mile at most. The alignment will be selected so as to be as direct as possible between the various centres of traffic but without any heavy work in banks or cuttings. The gradients, designed to follow the surface levels as closely as possible, will be 1/500 or easier, and the sharpest curve probably 3 degree (1,910 feet radius). Excluding the junction with the main line there will be five stations at average distances of 10 miles apart. Of these, two will at first be crossing stations, one the terminus, and two will be flag stations with small goods sidings. One of the crossing stations and the terminus will be watering stations. The traffic expected on opening will be a maximum of two mixed trains each way daily, and possibly only one in the slack season.

I. *Preliminary expenses* should be light as the survey will be quick and easy work. Rs. 300 per mile seems a fair figure, as the reconnaissance and possibly some preliminary work are almost sure to have been done previously, and little more than staking out will be needed.

II. *Land.*—If land can be acquired cheaply, and the portions not immediately required let on lease for cultivation at a good rent, the cost of more land than is required at once will prove a profitable investment, and its acquisition may save much money when the time comes to improve the line. But if such letting cannot be arranged only the minimum area needed must be acquired. This area will probably be about 11 acres per mile for the main line only. For each of the five stations we must allow an average extra 30 acres or 150 acres in all. The total area of land required will thus be—

50 miles at 11 acres per mile	..	550 acres
5 stations at 30 acres each	..	150 ,,
Total	..	700 acres

or an average for all purposes of 14 acres per mile. Taking the average value of all classes of land as Rs. 500 per acre the cost of land per mile will be Rs. 7,000.

III. *Formation.*—This will consist of low banks and shallow cuttings, the locating engineer having shown no hesitation about "chopping grades" where easier work will result. A formation width of 15 feet should be ample in banks, increased to 20 feet in cuttings to include drains. There will be no tunnels or retaining walls, and an allowance of Rs. 9,750 per mile should suffice for the cost under this head.

IV. *Bridge-work.*—The only possible way of keeping the cost of the bridges within the limits laid down is to adopt timber trestles for all the openings larger than say 3 feet or 4 feet. The latter can best be dealt with by corrugated iron pipes if their price is not prohibitive, or failing that by timber boxes made up of sleepers spiked together. A typical design for a trestle bridge is shown in Figure 4. The use of old girders removed from the older lines in the course of strengthening is suggested as both economical and more satisfactory than built up or trussed timber stringers, which would probably be required in this country owing to the difficulty of getting timber of very large cross section. The use of girders continuous over two or three spans is suggested as a means of reducing the weight and cost of steel work. It is common on permanent main lines in France, though rarely met with in English practice. The bridge over the Lys on the line from Hazebrouck to Armentières is a notable example.

Those who doubt the durability of timber structures in this country are referred to the timber bridges on the Grand Trunk Road between Rawalpindi and Attock. The timber must of course be selected, well-seasoned, and either naturally or artifi-

cially resistant to white ants. Deodar, teak, and sal, the latter of which will soon be available in increasing quantities from the forests of Nepal, are of the former class. Sound sal logs quite suitable both in length and dimensions of cross sections have recently been obtained by the writer for tunnel work and would make admirable trestle legs, for which a minimum cross sectional area of about 150 square inches is required.

The most useful timber of the artificially resistant class is oregon pine, treated by one of the chemical preservatives. It is believed that it can be imported and treated for about Rs. 4-12-0 per cubic foot. This price however compares unfavourably with the present market rates for teak which could be delivered on the work for Rs. 3-8-0 to 4-8-0 per cubic foot and is therefore recommended both as cheaper and more durable. Round sal logs suitable for trestle legs cost about Rs. 2-14-0 per cubic foot delivered at site, but the squares required for the caps and sills of trestles will cost about the same whether of teak or sal.

Construction of such a bridge is quick and easy, once the men engaged on it have learnt the essential points, particularly the art of correctly fitting the joints with one saw-cut. Foundations can be shallow on cheap concrete if the site is dry ; otherwise recourse may be had to piling, which is also cheap and easy with a trained staff and suitable plant.

It is estimated that bridges such as have been described above can be built for Rs. 100 per linear foot of waterway. For 100 linear feet of waterway the provision under this head will therefore be Rs. 10,000 per mile. As these structures are all short-lived, it will be necessary to invest in the special renewal fund a sum sufficient to provide for their renewal. Assuming an average life of 15 years, and referring to the dotted lines on Figure 2, it will be seen that this investment will be Rs. 435 per annum.

V. *Fencing* will not be required. Level crossings will not be manned. The line will be planned to avoid expensive road alteration ; and no provision is therefore needed under this head.

VI. *Electric Telegraph*—No capital expenditure chargeable to railway funds is at present incurred on State Railways for ordinary wires and telegraph instruments, which are all leased from the Government Telegraph Department. But it is perhaps advisable to remark that a maximum of two wires is required, and that it should not be very difficult for an experienced telegraph engineer to superimpose a telephone circuit on the same wires as are used for the telegraph instruments provided selector apparatus is not used. Control can thus be cheaply obtained when required.

VII. *Ballast and Permanent-way.*—This has already been discussed. An approximate estimate for the 60lb. F. F. track suggested is as follows :—

Cost of 1 mile of track with new 60lb. F. F. rails. on deodar sleepers.

	Rs.
Rails—94·29 tons at Rs. 130 per ton	12,258
Freight from Tatanagar to Depot at 13 per cent.	1,594
Sleepers—New deodar 14 per 36 feet rail 2,060 No. at Rs. 9 each including freight	18,500
Fishplates—69 Cwt. at Rs. 9 per Cwt. including freight	630
Fishbolts.—13·4 Cwt. at Rs. 26·7 per Cwt. including freight	360
Spikes—98·5 Cwt. at Rs. 15 per Cwt. including freight	480
Bearing Plates—24·83 tons at Rs. 125 per ton including freight	3,103
Laying—1,760 yards at Re. 1 per yard	1,760
Carriage of material from Depot to site lump sum ..	2,000
Maintenance for six months at Rs. 100 per month ..	600
Ballast—52,800 c.ft at Rs. 15 per 100 cubic feet, including carriage	7,900
Contingencies at 5 per cent.	2,459
Total ..	51,644

say Rs. 52,000 per mile.

If 75lb. second-hand F.F. rails from main line renewals with new sleepers are used, the cost per mile will be reduced to about Rs. 51,000, while if new 75lb. rails are used, the cost per mile will be raised to about Rs. 56,500.

The layout of station yards will be a matter for close attention. The writer has often been struck by the smallness of the siding

accommodation at English roadside stations on lines with light traffic. Can we not emulate them ? It is suggested that it will be sufficient to provide the following at first :—

	Feet of track for the whole line.
(*i*) At each of the two crossing stations a crossing loop 1,500 feet long	3,000
2 dead ends each holding 5 wagons for loaded and empty vehicles	500
(*ii*) At each of the two flag stations one dead end for 5 wagons	250
(*iii*) At the terminal station 2 loops each 1,500 feet long	3,000
2 dead ends for traffic (as above)	500
1 sick vehicle line	100
Sidings for locomotive purposes in the form of a triangle, which will probably be cheaper than a turntable for turning engines	1,500
Total ..	8,850
Add for leads of points and crossings ..	1,850
Total ..	10,700

or say 215 linear feet per mile of line, excluding the sidings at the junction station.

The average cost per mile of line under this head will thus be for the new 60lb. rails—

	Rs. per mile of line.
5,280+215=5,495 feet at Rs. 52,000 per mile ..	54,000
or for second-hand 75 lb. rails—	
5,495 feet at Rs. 51,000 per mile	53,000

or say Rs. 54,500 and Rs. 53,500 respectively to include the allowance necessary for extras such as points and crossings.

Miantenance of this track can be regarded as normally covered by the usual allowance for working expenses, so no provision for the special renewal fund will be needed under this head.

Incidentally it is interesting to note that this rough calculation of the length of sidings required seems to indicate that approximately.

(Number of feet of sidings per mile of line)=3/4 (Number of rupees of gross earnings per mile per week).

An examination of this relationship in the case of existing lines might prove a valuable rough method of checking demands for additional sidings if the correct value of the factor taken as 3/4 above could be established.

VIII.—*Station buildings, quarters, and station machinery.* The expenditure on this head must be on a far more modest scale than in the past. It is principally affected by a matter which concerns working expenses as much as construction, *viz.*, the number and class of the staff to be employed, and this will be discussed first. Economy in expenditure on staff quarters and other buildings is attainable in three ways : (*a*) by reducing the number of men to be accommodated, (*b*) by adopting cheap types of construction, (*c*) by reducing the scale of accommodation per man below the present standards.

Of these the last is undesirable in view of the importance of having a healthy and contented staff to work the line, and will not be further considered.

The reduction of the number of men to be accommodated is primarily a matter of employing fewer men. For example, on a line with only two trains daily in each direction one "shift" of staff is all that is required at a crossing station ; one man at most is needed at a flag station with goods siding, as he can combine the duties of goods and booking clerk, and so on. In this connection it is also useful to consider the propriety of introducing labour saving appliances to reduce the number of men required. Figure 3 shows the maximum capital expenditure which would be justified to save the labour of one man on a 5½ per cent. simple interest basis. In preparing it an assumption has been made that each man employed really costs the railway 10 per cent. more than the actual wages paid ; this is necessary to cover charges for clothing, free quarters, conservancy of railway colonies, etc., which vary to a certain extent with the number of men employed. As an example of its application, which is very wide, the possibility of introducing the "one man crossing station" may be cited. This layout was actually adopted in certain cases in France in the early summer of 1918 when the man-power situation was critical, and is said to have worked successfully. It is shown in Figure 5 from which it will be seen that it is possible to cheaply group all the points and the block instruments under the hand of one man without causing any delay to traffic as long as not more than two trains at

a time have to be dealt with. The dotted lines on Figure 3 show that this design can be economically adopted if its cost does not exceed that of the normal arrangement by more than Rs. 7,200 for each pointsman on Rs. 30 per month with whom it is thereby possible to dispense.

Where villages or towns exist close to stations, as should normally be the case under conditions such as those now being considered, further economy both in the numbers of men employed and in the matter of quarters is possible. Such men as sweepers and bhisties whose duties are not of a " whole-time " nature could be hired locally, and all those members of the staff, whose duties are performed at fixed hours irrespective of the movement of trains, could arrange for their own accommodation in the village and need not be provided with railway quarters. Railway police could be housed with the district police, which would probably result in better co-operation between them. Gang huts need only be provided for one man per gang who acts as a watchman and calls the others if required.

On this basis the accommodation to be provided on our typical line will thus be roughly as follows in s. feet of plinth area :—

	S. feet of plinth area.		
	Quarters.	Offices.	Total.
Junction station, where existing main line offices should suffice ..	3,000	..	3,000
Two crossing stations	2,000	400	2,400
Three flag stations	..	450	450
Terminal station	2,000	250	2,250
Gang huts	2,500	..	2,500
Totals ..	9,500	1,100	10,600

or say 11,000 s. feet making an average of 220 s. feet per mile of line.

Goods sheds will not be required for a long time after opening. If a raised plinth is made near each siding on which consignments can be so stacked under tarpaulins that water will not run under them, and a reasonably prompt wagon supply ensured in working, the losses due to damaged consignments should be negligible. The construction of waiting sheds for passengers will have to be deferred till the earnings justify their cost.

The adoption of cheaper forms of construction instead of those hitherto used should enable us to keep the plinth area cost of all these buildings down to or below pre-war level. The use of mud concrete or sun-dried bricks treated with silicate of soda, and thatched

roofs are obvious methods which suggest themselves. The possibilities of timber building construction in this country do not appear to have been very fully explored ; timber buildings considered suitable for almost as great a range of temperature as ours are common in Canada, and the production of some sort of cheap and durable felt or paper pulp roofing material is a matter to which the attention of mill-owners in India might well be directed. The fundamental requirement of preserving that good and cheap non-conductor of heat, an air space, must not be lost sight of in designing such buildings. Natural or artificial protection against white ants, and pucca foundations are essential. As a result of rough estimates on the above lines, it is considered that an average rate of Re. 1-8as. per s. foot of plinth area can be worked to by one or other of these methods and this has been adopted in our approximate estimate under this head, which is thus 220 s. feet at Re. 1-8 per s. foot or Rs. 330 per mile of line. Provision of Rs. 10 per annum for renewal in 20 years will be needed under this head.

Under the heading of station machinery comes a miscellaneous list of requirements for the operation of the line. Expensive luxuries such as platforms and signals must be sternly omitted ; they are quite unnecessary for a line with such light traffic, as was proved again and again by actual trial under heavy traffic in the Great War. Station equipment such as weighing machines and furniture must be of the simplest. In arranging water supplies, what has hitherto been regarded as a "construction" standard will be sufficient, provided the outlet from the tank is large enough to fill the tenders quickly. The tank should be of such capacity as to hold two days' supply only (*i. e.* long enough to repair or replace a broken pump) and should be situated alongside the line to eliminate the need for water-columns or expensive pipes of large diameter. To fill it a hand "lift and force" pump will probably suffice. Otherwise a small internal combustion engine driving a ram or centrifugal pump will meet the case. Crude oil is a satisfactory fuel. The use of automatic hydraulic rams on canal falls might be worth consideration. The whole installation can thus be planned far more cheaply than with the expensive steam plants hitherto used, and run with half the staff required by them.

For these reasons the cost per mile under this head will be taken at Rs. 1,270 per mile of line.

IX. *Plant* is a difficult item to forecast at present. The use of mechanical appliances to save labour is undoubtedly proving more and more economical in this country. It seems unwise therefore to allow less than Rs. 1,000 per mile under this head, as the net amount chargeable to the project for depreciation of plant.

X and XI. No provision is required on such a line as this for ferries, or rolling stock of which the parent line has plenty.

XII. *General charges* for the construction of such a line should be very low, provided too elaborate a system is not used in such matters as accounts and office procedure. The period of construction should be short, and the cost under this head may be taken as Rs. 4,100 per mile or 5 per cent. of the total.

The following is thus the summary of the probable cost of a line such as we are considering, together with the amount of the annual investment required for the special renewal fund :—

	Cost per mile.	Annual investment for renewal fund rupees per annum.
	Rs.	
I.—Preliminary expenses ..	300	..
II.—Land ..	7,000	..
III.—Formation ..	9,750	..
IV.—Bridge work ..	10,000	435
V.—Fencing ..	..	..
VI.—Telegraph ..	..	..
VII.—Permanent way and ballast.	54,500 (*53,500)	..
VIII.—Stations { buildings including quarters ..	330	10
VIII.—Stations { other equipment ..	1,270	..
IX.—Plant ..	1,000	..
X.—Ferries ..	..	..
XI.—Rolling-stock ..	..	..
XII.—General charges ..	4,100	..
Total ..	88,250 (87,250)	445

*For old rails.

The general financial result of building this line will be roughly as follows :—

	Rupees per annum.
Interest charge at 5½ per cent. on Rs. 88,250 ..	4,850
Annual investment for special renewal fund ..	435
Total annual charges ..	5,285

If the weekly working expenses are Rs. 175 per mile, the minimum gross earnings per mile per annum which will meet all these charges will be Rs. 5,285+52×175=Rs. 14,385, or Rs. 288 per mile per week.

If old 75 lb. rails are used, this amount will only be reduced to Rs. 286 per mile per week, which shows that the advantage of using second-hand 75 lb. rails for such lines is practically negligible. Unless one or other of these minima are reached, the line will fail under the "5½ per cent. test."

Safety.

In conclusion, one more aspect of the subject may be mentioned—that of safety and comfort of passengers. Such a line as this will not be fit for the high speeds and heavy traffic of a main line, but it will carry passengers and goods at slower speeds with just as much safety as they do, provided it is properly maintained. This should be no more difficult to attain than it will be to get the line built in the manner suggested, and it would therefore seem bad policy to reject any such project merely on account of its departure from hitherto accepted standards of construction. Complaints as to discomfort at stations are also possible from passengers accustomed to the conveniences of a main line; to these the correct reply is surely that under present conditions it is only by beginning new lines on a modest scale such as that described that we can provide at all the cheap and efficient transportation so much wanted in India.

The author's thanks are due to Messrs. R. O. C. Thomson and F. W. Rose for assistance with the calculations and diagrams.

ECONOMIC RAILWAY CONSTRUTION

FIG 1.

MAXIMUM CAPITAL EXPENDITURE PER MILE, ON WHICH 5½% CAN BE EARNED.

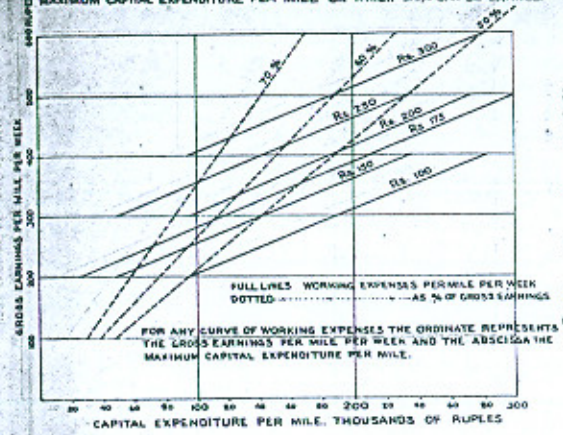


FIG 2.

ANNUAL INVESTMENT REQUIRED TO PRODUCE RUPEES 1000 IN VARIOUS PERIODS.

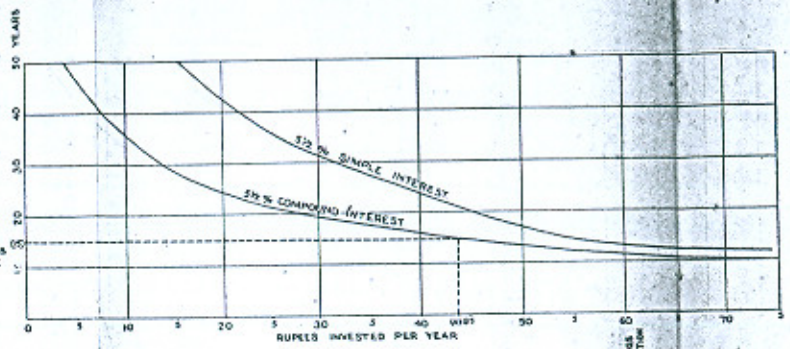


FIG 3.

CAPITAL EXPENDITURE JUSTIFIABLE AT 5½% SIMPLE INTEREST TO SAVE THE LABOUR OF ONE MAN.

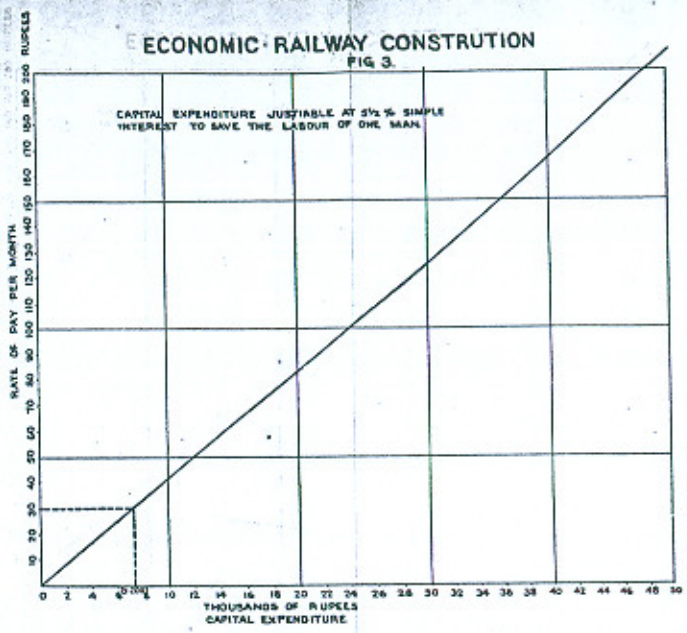
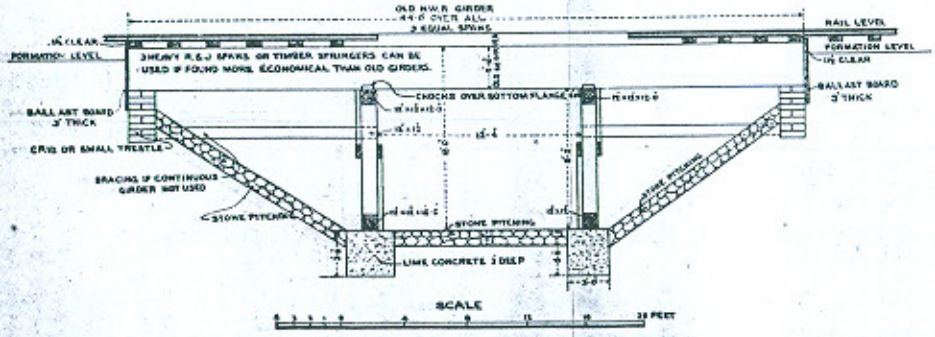


FIG 4.

LONGITUDINAL SECTION



CROSS SECTION

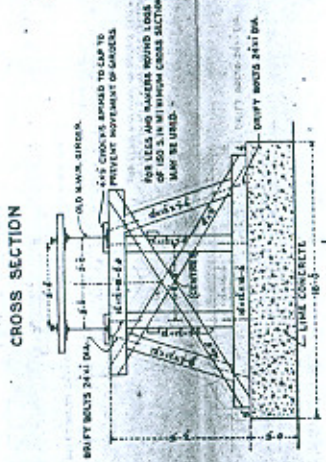


FIG 5.



"ONE MAN" CROSSING STATION

WHEN CROSSING TWO TRAINS, THE FIRST TRAIN TO ARRIVE RUNS OVER THE FACING CROSS OVER INTO ITS DEAD END. WHILE THE SECOND TRAIN IS PASSING ON THE MAIN LINE THE FIRST SETS BACK THROUGH A INTO THE OTHER DEAD END, FROM WHICH IT GETS A DIRECT START THROUGH THE OTHER CROSS OVER AS SOON AS THE SECTION IS CLEAR.

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16.12.21

DISCUSSION.

THE AUTHOR in introducing his paper related that it arose as a result of two recent statements on Indian Railway Policy, *viz.*, the Report of the Inchcape Committee which laid down that fresh capital expenditure should be undertaken only on railway projects which could earn at least $5\frac{1}{2}$ per cent. interest, and the speech of the Chief Commissioner for Railways at the Indian Railway Conference a short time afterwards when he declared that the railway policy should consist in the provision of cheap and efficient transportation throughout India.

It was impossible to give effect to the latter policy unless new lines were built and such lines, if built, had to conform to the conditions laid down by the Inchcape Committee.

Railway rates at present were high enough and could not be increased, and therefore the only way to meet the conditions laid down was by cheapening the cost of construction. Diagram No. 1 gave in a rough and ready way what the cost of construction of profitable lines should be, and its perusal made clear that it could not be hoped to build a line to pass the Inchcape Committee's conditions if its cost exceeded Rs. 80,000 to Rs. 1,00,000 per mile. It was not possible to do this except by lowering the standard of work, *i. e.*, by reducing cost of railway bridges, stations, etc.

Of course "gauge" had a lot to do with the question but it was a very controversial matter, and two or three meetings of the Congress might easily be spent on its consideration without definitely arriving at any decision and therefore he had purposely excluded the "gauge" question from the range of his paper.

To begin with, it was necessary to build a reasonably good track. It was proposed to use the existing North-Western Railway "L class" locomotives which had a 12 ton axle load which brought about the same stresses on the rails as the present heavy goods wagons, and for this work 60 lbs. rails with a fairly liberal number of sleepers would suffice.

Bridges, at present, ran away with a good deal of money and it would be necessary to provide much cheaper bridges for the "economic" line. This could be done by using timber wherever practicable and so following the examples of the Western States of America and the Colonies.

Similarly with buildings—it was necessary to build cheaper buildings of sundried bricks perhaps or similar to those described in the author's paper on Temporary Buildings for the Khyber Railway which was before the Congress that morning.

At the end of the paper he had worked out an imaginary example of a typical railway line. The main points which he emphasised were —

(*a*) To cut land very tight because land was getting very expensive and the more irrigation was developed the more expensive it would become. The Canadian Pacific Railway succeeded in financing itself in its early days by getting control of large belts of land each side of its line at nominal cost, and selling it after construction of the line had caused its value to become inflated. Unfortunately in India, this method of promoting railway construction was not possible.

It was necessary to keep down the height of banks or depth of cuttings to an absolute minimum, and grades wherever necessary should be chopped into short lengths to do so. Timber bridges were proposed and in order to allow for their replacement when their lives were finished, a sinking fund was suggested.

He had gone into the permanent-way question in some detail. The cost worked out at about five eighths of the total cost of the line, and his estimate was on the liberal side. It was essential however to provide really good track to run on.

Sidings were another interesting question. In India, the practice on English Railways of cutting down siding accommodation at small way-side stations to an absolute minimum had not been followed generally, and an effort had been made to deduce a relation between the gross earnings and the number of feet of sidings required per mile of line.

Economy in buildings could be obtained in 3 different ways or by combinations of two or more, *viz*:—

(*a*) by reduction of number of employees;

(*b*) by cheap construction;

(*c*) by reduction the amount of accommodation per person.

For obvious reasons it was undesirable to adopt method (*c*) so it resolved itself into (*a*) and (*b*).

Mr. R. H. Irani remarked that in these days when economy was a leading question, Major Anderson's paper was exceptionally valuable. On page 37 the author suggested 14 or 15 sleepers per rail length of 36 feet for traffic, with maximum axle loads of 12 tons. The speaker knew of one line with 14 sleepers per rail length of 60 lbs. per yard on which speeds were as high as 35 miles per hour without disturbing the track; and he thought that the number of sleepers on the " economic " line could be cut down to 13 per rail length (36 feet).

At present the ballast on branch lines was $10\frac{3}{4}$ cubic feet per lineal foot of track, and he thought this could be reduced to 8 cubic

feet which gave 5" of ballast under the sleepers plus that required for boxing.

Another point was that it seemed inadvisable to use rails which were too light in the first place. If 75 lbs. rails were put down in the first place, the cost would only be about Rs. 5,000 per mile more, while the number of sleepers per rail length as well as the quantity of ballast per lineal foot of track could be cut down further. The cost of operation would also be less and if after 5 or 10 years, when as a result of traffic development, it might be found necessary to use bigger engines to draw bigger loads, this could be done without having to change the lighter rails with 75 lbs. rails. For these reasons the speaker thought it was well worth while to consider using 75 lbs. rails instead of the 60 lbs. rails suggested, especially if old 75 lbs. were available.

As regards bridges, instead of temporary bridges of timber or light section masonry bridges, he suggested Irish bridges, for the railway passing through plain country; there was less maintenance and no risk of collapse. For small culverts and even for say 20 feet span bridges, it was better to put in full section masonry abutments in the first instance, instead of light section walls which might afterwards have to be replaced by heavier structures under traffic at high cost, especially as the interest and sinking fund on the extra cost of heavier section masonry was inappreciable.

It did not seem advisable to economise on bridge construction; perhaps a weaker girder might be put in but certainly abutments should be of full strength.

As to buildings, he did not like the idea of katcha buildings; they might be cheaper in first cost but their annual maintenance and repair was more than double that of pakka buildings. Besides this, the depreciation of katcha buildings was a heavy item. They would require complete rebuilding after 15 years at most, whereas the life of a pakka building could be taken at 100 years. In practice it was found that the annual percentage charge on cost of kutcha buildings on account of interest, maintenance and sinking fund was greater than that on pucca buildings.

The Author suggested that the formation width should be 15 feet in flat country. If 18 feet width was adopted it would be much safer; besides this, it was a very small item, the extra cost being only Rs. 300 per mile.

Reverting to the question of bridge work, the speaker considered "Armco" culverts were very good provided there was 3 feet cushion over them, otherwise it was preferable to build masonry or brickwork culverts.

With regard to figure 5 at the end of the paper, shewing a "one man crossing station" consisting of two dead ends and a

scissors crossing, he was of opinion that this arrangement might have served alright in time of rush, such as during the War, but it was questionable if it would work satisfactorily on commercial lines.

A very small additional expenditure which only amounted to eight annas per week per track mile would have allowed for a loop line with an additional pointsman, which was a far more satisfactory arrangement.

On page 45 it was suggested that gang huts need only be provided for one man per gang who would act as a watchman and would call the others if required. Villages were not always suitably situated to correspond with a gang's beat and he thought that it would be better to provide quarters in order that the gang might live together as in that case their efficiency would be higher, and they would be able to attend promptly to emergent calls during accidents or breaches.

MR. H. W. NICHOLSON apologised for trespassing outside the range of his usual job in venturing to speak on a paper dealing with railways and drew attention to the allowances for sidings in the paper and thought these were rather meagre. He had to pay Rs. 1,50,000 for siding connections at Suleimanki, out of which Rs. 42,000 odd was for signals alone!

With regard to the proposal on page 37 reading "speeds will be low say 25 miles per hour maximum," he thought 25 miles per hour a bit too fast. The speed restriction on an important branch line that he knew was 15 miles per hour.

There was no provision in the cost for the junction between the branch line and its main line.

With regard to the land required, it was well known that the zemindar did not like parting with land but if he was reasoned with he became perfectly amenable to common sense. Why not only take the land actually required for embankments from shallow borrow pits dug outside the railway limits after coming to an understanding with the zemindars? This procedure had been adopted by the Irrigation Department when constructing their works and there appeared to be no reason why the railways could not do likewise.

The figures for land, Rs. 500 per acre, seemed extraordinarily high in view of the fact that the canal authorities only paid about Rs. 10 per acre in undeveloped country. The figure of Rs. 10,000 per mile adopted in the paper for bridges was a very pessimistic one.

With regard to permanent-way, on page 42 the price of sleepers mentioned was Rs. 9 each. He held charge of a canal railway over which over 1,000,000 tons of materials had already passed

without a single traffic accident and the sleepers were second hand kail sleepers costing about a rupee each. A railway officer of repute had once told him if every alternate sleeper was a sound one, that was ample to carry the track and the others in between would hold the ballast together.

He had to admit he cast envious eyes on the old sleepers sold by the North-Western Railway for fuel.

Referring to the question of station buildings, he considered katcha buildings a curse.

He advocated the provision of sound pakka rat proof buildings for health reasons. Apart from that the maintenance and repair of temporary buildings were a very heavy charge.

Coming to the question of working expenses, he had a number of suggestions to make which he hoped the railway authorities would consider.

Why have guards on branch lines? Why not hire the guard's van to a bania as a travelling shop? In this way it might be possible to dispense with both guards and stationmasters.

The speaker knew one engine driver on a branch line who was a regular Napoleon of finance. One day, a train by which the speaker was travelling stopped for 40 minutes at Jalalabad Station and he was surprised to see all the passengers were collected round the engine. On walking down the platform he discovered the engine driver was giving a gramaphone concert and of course making a small charge on the audience. The speaker suggested that men like that were far too clever to be kept in subordinate jobs and thought their brains could very well be better utilized by the railway administrations in more responsible positions.

He ventured to make one more suggestion and that was why not advertise on railway carriages? He felt sure that if this proposal was carried into effect it would be the means of bringing appreciable increased revenue to the railways.

In conclusion, he congratulated Major Anderson in breaking away from present practice and hoped that the paper would result in means being found to further develop transportation in India.

MAJOR H. WOODHOUSE, R. E., said that in the course of his service, he had been connected with three railways, which had been built on the lines of Major Anderson's suggestions.

One was the Northern Railway of German East Africa which paid excellently when first built but afterwards, on reconstruction on more elaborate lines, made a loss.

The second railway was the East African Railway. Col. Wilkinson, R. E., on this line put in 50 per cent. of the siding accommodation which the traffic officers demanded and yet the line worked alright.

The other railway was the German East Africa Central Railway in what is now Tanganyika Territory, 530 miles long. There was not one signal on the line and yet accidents very seldom occurred.

With regard to Major Anderson's figures of cost per mile of track on page 42, he considered the cost of sleepers and rails could be reduced ; new treated soft wood sleepers were now obtainable at Rs. 6-6-0 each and in a few years the cost would be down to Rs. 6 each. The cost of fish-bolts was about Rs. 16 per cwt. as against Rs. 26·7 per cwt. quoted in the paper. He presumed the bearing plates were to be cast iron. It was possible that wrought iron would be better, as cast iron was not satisfactory.

With regard to station buildings, in no case on the East African Railways were passengers given accommodation. On the German East African Railways, the stationmaster was provided with a flat to live in and there was a nice office and baggage room but nothing in the way of accommodation was provided for passengers.

MR. F. A. HADOW remarked that in figure 1 at the end of the paper, the graph started with a railway, the gross earnings of which was Rs. 200 per mile per week but the trouble was to find lines in the Punjab which could hold out a prospect of earning so much ; in fact, in many cases there was no possibility of earning that amount. All sorts of people had suggested methods for estimating the earning capacity of a new line ; there was one formula based on population, others arrived at conclusions after making enquiries in the villages served by the new lines. The latest method adopted on the North-Western Railway was for an experienced officer to take a general purview of the area to be served by the line, and to estimate probable earning by a general "appreciation of the situation." In two or three recent investigations regarding proposed lines, the gross earnings were estimated at about Rs. 90 per mile per week. With steel now costing Rs. 130 per ton and with prospects of an increase, if the demands of the Indian steel industry for protection were met, the speaker could see no hope of railway lines being built which would only have a gross earning capacity of Rs. 90 or Rs. 100 per mile per week. The case was different with proposed lines which might be shewn to be capable of Rs. 200 per mile per week gross earnings.

He was not in favour of wooden bridges. He knew of a certain frontier line in Beluchistan on which such temporary bridges had been provided with piers built of sleeper cogging. They had proved unsatisfactory. In one case a pier caught fire

and a train fell through the bridge. Such accidents caused a great loss of money.

He agreed with the criticism made by other speakers regarding temporary structures. He did not consider the "scissors" type of crossing as the best to provide at small stations and thought this type



was more suitable ; the section shewn in dotted lines could be provided later on if necessity arose. The advantage of this type was that all points were under the eye of the station-master, and station staff could be reduced to a minimum.

In England and America at small stations, the man in charge was a "general factotum" who did all the work without assistance, whereas in India, even at the smallest wayside stations, it became necessary to employ a number of men, each with his own specific job, such as pointsman, *paniwala*, etc.

He thought the remedy was to attempt to breed the class of "general factotum" in India. It was easier and better, within limits, to get a return on capital by reducing working expenses and so improve net earnings than to cut down the capital cost too much.

He agreed that on the type of railway proposed in the paper, day running was an essential condition and he also considered that at least two trains a day should be run. In his experience, passenger traffic was the thing that paid on branch lines in the Punjab provided too many passengers were not allowed to travel without tickets.

He did not think that agricultural tramways were going to solve the present rural transport difficulties in India for the reason that the present system of "mandis" was directly opposed to the tramway idea. Zemindars would much prefer to take their produce to market in their own carts.

The Author had allowed in his estimate for 91 feet width of land to be acquired. This was not too much for broad gauge railways. On the Jullundhur-Mukerian Branch Railway, Mr. Bagley had reduced cost by providing slightly raised Irish bridges. These however had not been entirely successful.

In Kathiawar, Irish bridges had been provided and it had been found that it was essential that the heads of the rails should be kept below the bed of the river and trouble was experienced if the rails stuck up.

Referring to the item in the estimate of Rs. 10,000 per mile for timber bridges, the speaker asked how this rate would compare with that of permanent bridges of the same water-way.

MR. A. LINES said that in reply to the last speaker's question as to cost of permanent bridges, this amounted to about Rs. 80 per lineal foot of bridge extra to cover the price of permanent piers and abutments.

He pointed out that the cost of permanent-way was the principal consideration as it equalled $\frac{5}{8}$th of the cost of the whole of the works.

MAJOR R. N. BURN, R. E., prefaced his remarks by stating that he did not wish to decry the importance of careful enquiry into the capital cost of a project to ensure keeping the capital expenditure to the minimum consistent with the economics of the case, and pointed out that estimates for branch lines recently got out by the construction department of the North-Western Railway of which he was in charge, amounted to an even lower figure per mile than Major Anderson's estimate—but he wished to protest against the point of view that the difficult problem of constructing economically justifiable feeder lines could be solved by going into the matter of capital cost alone : other and more important factors involved being gross receipts and working expenses.

As an illustration of the danger of the capital cost view point, he instanced the construction of the Sialkote-Narowal Railway which was built in a direction that the traffic did not want to follow, owing to its capital cost per mile being less than if it had been built to Amritsar which was the way the traffic did want to go : the consequence being that its goods traffic was almost negligible.

He added that he had recently investigated some dozen or more projects for branch or feeder lines, and he had yet to find the project of which it could be said that it was economically justifiable if built for Rs. 80,000 a mile, but economically unjustifiable if the cost should amount to Rs. 90,000 a mile.

Variations in gross receipts and working expenses, which incidentally it was impossible to forecast with any accuracy, would entirely swamp the small difference in interest charges due to ten thousand rupees a mile difference in capital cost.

He concluded by stating that therefore, although as a business man one should see that money was not wasted on capital cost the problem could not be solved by that aspect of the case.

MR. W. C. CHOPRA said that he would like to point out the importance of constructing railway lines in such manner as not to interfere with natural drainage lines and thought this had been lost sight of in the past. It was far better to provide bridges or culvert crossings, than to hold up water as recommended at the top of page 38. Water thus held up was absorbed into the soil and raised spring level, which under unfavourable circumstances led to water-logging.

MR. K. G. MITCHELL asked the author what was the meaning attached to the word " intrinsic " on page 35 of the paper. Weight for weight and volume for volume, the monetary value of the commodities carried by a railway in an agricultural country, *i. e.*, wheat and cotton, far exceeded that of coals and minerals.

It was generally accepted that the range of the bullock cart was 12 miles and when it came to haulages of 20 or 30 miles the bullock cart was unsuitable. He instanced the road traffic from the area between Narowal and Shadara as an example. This traffic was now being carried by camel and pack transport, and the most practicable improvement appeared to be an agricultural tramway.

He deplored the attitude of some railway enthusiasts that if the traffic in an area appeared to be insufficient to justify a broad gauge railway, it was not worth worrying about, and could be left to find its way as best it could to the nearest railway.

It was perfectly true that agricultural produce would always struggle to reach a market, and would to this end frequently make for the nearest railway, however far ; but he could not see that this was any reason for holding that facilities for reaching the railway were already sufficient.

THE AUTHOR replying to the discussion, said that he was doubtful if the cost of maintenance would not increase too much if further reductions were made in the number of sleepers per rail. 8 c.ft. per foot run was quite sufficient ballast to keep the sleepers out of the mud, but it must be of good quality. He would prefer to see more trains run so as to improve the passenger earnings, which were by far the largest portion of the whole, rather than run longer trains with heavier engines. The economy of " dips " from the maintenance point of view was certainly doubtful, but heavy abutments, making the waterway cost Rs. 250 odd and more per foot run for pucca bridges were out of the question. Armco culverts were too expensive to use for the purpose suggested.

As regards buildings, he would like to know the relative hot weather temperatures inside a kutcha bungalow and one with 9" pucca brick walls. He doubted if kutcha bungalows really did need so much more maintenance, and in any case the true

criterion of economy was that original cost plus capitalised value of annual repairs should be a minimum. He had often observed gang-huts standing empty, and therefore proposed building fewer. As regards formation widths, 18 feet banks soon reduce themselves to 16 feet and there seemed no reason to exceed the latter dimension in building a new line. His figures for working costs included the sinking fund for track, but the fact that treated fir sleepers were available was not known to him when the paper was written. In advocating a maximum speed of 25 miles per hour, he expected the working speed to be about 15 miles per hour. Signals were not needed on branch lines with slow light traffic, nor was there any danger in receiving a train in a dead end at such low speeds.

The type of crossing station proposed by Mr. Hadow would certainly be cheaper, but not quite so quick to work as the one sketched in his paper. As regards land, the suggestion of only temporarily occupying that required for borrow pits was not altogether new to him, but he advocated taking up enough in the first instance to meet the need for reasonable future developments, though not perhaps for such big schemes as new junction yards. The information given regarding land prices would be most useful to him. If day running only was insisted on over such a line, it would lead to a difficulty if the line was of any length, because trains must run in the morning and evening to attract passengers, and if more than 3 or 4 hours were taken over the journey some night running would be inevitable at the ends of the line. The holding up of water by railway banks would need special consideration in each locality. There were many places where it would be a boon, though in others water-logging might result. When speaking of traffic of high intrinsic value he had in mind the conditions on a line such as the Central India Coalfields Railway, where the traffic would probably consist largely of coal, iron and manganese ore.