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INVESTIGATION OF NEW RAILWAY SCHEMES

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I—General Remarks

The first railway line to be laid in India was the short length from Bombay (Victoria Terminus) to Thana, a distance of 22 miles. This was in the year 1853. Since then the construction and opening of every new length of line has been welcomed as another step forward in the progress of the country. The benefits that railways conferred upon the parts of the country which they served were easily understood and appreciated by the people. It was through the opening of railway lines that distant places in this vast country came to be knit together and it was as a result of this unifying influence of railways that India, with its vast disparity of climates, peoples and languages came to deserve the name of one country geographically. The expansion of railways offered a safe, reliable and cheap means of transport and revolutionised the scope and methods of trade and travel.

Till about 20 years ago, railways held more or less a monopoly of transport. This position, however, has now been challenged and changed. Road and aerial transport have come in as serious rivals. Due perhaps to certain legislative and financial anomalies that favoured road transport and laid restrictions on rail transport, the former had been scoring heavily against the latter. Without entering into the rail-road controversy it will not be irrelevant here to state that motor transport has been able to hold out because it is heavily subsidised by the taxpaper. Whereas the capital cost and the cost of maintenance of roads is paid for by the taxpayer—railways also contributing a portion of this subsidy—the receipts are taken away by the owners of the motor vehicles. They pay only a very small portion of the liabilities resulting from the construction and maintenance of roads. Railways, on the other hand, besides providing their rolling stock, have to buy their own land, construct their own formation, bridges, buildings and the line with all the accessories that are required for the safety and comfort of the travelling public. Motor transport should, in fairness, be similarly required to pay its own way on the same basis as the railways. It should be made to pay the cost of maintenance of roads and interest on their capital cost.

As a result of this competition, railways have been deprived of a great deal of the more paying traffic. There is consequently an atmosphere of pessimism prevailing regarding the future of railway development. During the past 10 years the N. W. Railway has constructed no branch lines, except the Sind Right Bank Feeders Railway—84 miles long—opened to traffic in July, 1940. This line would serve the area irrigated by the Right Bank canals of the Lloyd Barrage and canals system. It passes through an area that has no metalled roads and, therefore, little or no road competition. The Sind Government have further guaranteed not to construct any competitive roads parallel to this railway. The line is estimated to pay about 6 per cent. net on the capital cost.

In spite, however, of the handicap to which railways are subject, there can be no doubt that for mass transport they are the most economical and reliable means of transport both in peace as well as in war. Railways are the foundation of all other kinds of subsidiary means of transport.

Railway Schemes are investigated by Engineers and Traffic Officers.— The survey and further investigation of schemes such as irrigation, drainage, water supply, road communications and other similar engineering projects fall almost entirely within the jurisdiction of the engineer. The same may be said of railway lines of comparatively short length that are constructed for certain specific purposes such as to connect a quarry, a mine or a factory to a main line station, to transport timber from a forest or to carry materials and heavy machinery for the execution of a large engineering project. To a great extent strategic railways fall within the same category. Making allowance for the limitations imposed by military considerations the investigation of such railways also is the work of the engineer. With certain reservations such railway schemes resolve into the simple problem of the cheapest and the most direct means of transport between given obligatory points.

When, however, a railway line has to be constructed as a commercial undertaking by itself, it differs in its implications from other engineering schemes. Such a means of communication has to be considered as a national asset. It is not undertaken merely as a philanthropic scheme but with a view to obtain the maximum of income by carrying the maximum of traffic. The general alignment of such a railway is recommended to the engineer by the traffic expert, as the result of a traffic survey of the area proposed to be served by the Railway. After the exact line is decided on by the engineer, the traffic officer estimates the volume of traffic and earnings that will be obtained, and the standard of the line that would carry the traffic. The engineer on his part estimates the cost of overcoming the engineering difficulties of the alignment and assesses the scope and extent of the works involved. They have jointly to estimate whether the railway would pay a reasonable return on the capital cost and whether the line should be constructed or not.

II—Preliminary Survey

Its Importance.—A preliminary survey is the very first stage of the investigation of a railway line. It is carried out rapidly with the aid of simple survey instruments. In the plains, no high technique may be involved in carrying out a preliminary engineering survey, yet it is the most important stage in the examination of the scheme from various points of view. It is as a result of the preliminary survey that the position of a line in the country is fixed and the very important decision, whether a line should be constructed or not, taken. The subsequent stages, namely, the final location and ultimately the construction, constitute, as it were, the superstructure on the foundation laid by the preliminary survey. It would, therefore, be realised that the importance of a preliminary survey requires that the work be entrusted to an engineer who possesses considerable experience not only in surveying but also in construction and in maintenance. He should also be conversant with the main factors affecting the volume of traffic. While investigating the alignment in the field, the engineer should be capable of visualising the traffic as well as the engineering possibilities, and also be able to assess the relative merits and demerits of various geographical and topographical features and their effect on the first cost of construction and on the cost of maintenance and the working of trains as affected by grades and curvature. If he possesses these qualifications as well as an eye for the country, he should be able to fix on the most suitable alignment serving the sources of traffic.

Standards of Construction.—According to the volume of traffic a line has to carry per annum, and therefore, according to the axle-loads of locomotives, lengths of trains, and their frequency, which in turn affect the strength of track, bridges, length of loops, etc., the Government of India (Railway Board) have laid down five standards of construction :

(*i*) H. M. or Heavey Mineral. Broad or meter gauge. A line that has to carry very heavy mineral traffic.

(*ii*) Standard A. A first-class line of the same gauge as parent line suitable for a main through route.

(*iii*) Standard B. A secondary standard for a reasonably good chord or branch line of same gauge as parent line.

(*iv*) Standard C. A low standard for a light line of same gauge as parent line.

(*v*) Standard D. Lines of lighter standard than C. The standard of railway to be adopted for a particular branch line would depend upon the volume of estimated traffic to be carried.

Unless the country happens to be hilly and difficult from the construction point of view, the cost of a line per mile would depend on the standard that is adopted. Cost per mile of some of the branch lines constructed by the N. W. Railway during the past (about) 20 years in the plains is given below:

COST AND OTHER PARTICULARS OF SOME OF THE BRANCH LINES CONSTRUCTED BY THE N. W. RAILWAY

Name of railway	Standard of construction	Gauge	Waterway of bridges per mile	Cost per mile
			Ft.	Rs.
Shahdara—Narowal ..	C	5′—6″	31.91	58,956
Lyallpur—Jaranwala ..	C	5′—6″	48.1	71,055
Sargodha—Shahpur City ..	C	5′—6″	38.32	1,27,438
Batala—Qadian ..	C	5′—6″	14.98	76,232
Jassar—Shakargarh Chak Amru	C	5′—6″	18.7	60,406
Rohtak—Gohana Panipat ..	C	5′—3″	11.98	54,647
Fort Abbas—Kut ul Imara ..	C	5′—6″	6.38	56,502
Bahawalnagar—Cholistan ..	C	5′—6″	6.20	66,450
Sind Left Bank Feeders ..	C	5′—6″	20.37	50,862
Sind Right Bank Feeders—				
(*i*) Conversion ..	C	5′—6″	21.65	46,000*
(*ii*) New Line ..	C	5′—6″	12.06	46,600*

*Accounts have not been closed so there may be slight variations.

General Principles of an Engineering Survey.—There is considerable difference in the methods adopted in locating a line in a hilly country and in the plains. Some of the general principles that are common to both are enumerated below:

(*i*) A preliminary survey is meant to determine the most suitable alignment through a part of the country both from the engineering and from the commercial points of view. The entire area that has to be served should, therefore, be reconnoitred for all the possible alternative routes. Such a survey, therefore, is the survey of an area and not of a line. In a hilly country, engineering problems may outweigh minor traffic considerations. Alternative routes will be limited and the most economical alignment as regards first cost and operation may avoid subsidiary traffic points.

(*ii*) Reconnaissance should be carried out personally by the most senior officer of the survey party. He should not delegate this responsibility either wholly or partly to his juniors as otherwise the final decision may be affected adversely. Errors made in alignment cannot be rectified later; those of construction perhaps can, although at a disproportionately large cost.

(*iii*) Alternative routes should be examined right through from one end to the other, and not in parts. The merits or demerits of an alignment cannot be appreciated until the entire length has been investigated.

(*iv*) The locating engineer should guard against the temptation of getting prejudiced in favour of an alignment that may happen to be easily accessible by road or which may fall in open country as against alternative alignments falling at a distance from a road or passing through country with temporary physical obstacles such as jungle or tall crops that may be standing at the time of survey.

(*v*) A railway line on the curve costs more to construct, and later on, more to maintain than the line on the straight. Curvature also costs more in operation of trains and should, therefore, be kept down to the minimum possible. Total curvature along alignments is proportionate to the total of angular deflections. Effect on operation is directly proportionate to this. As regards first cost and maintenance this is proportionate to the length of curves and not to the degree of curvature. For the same deflection angle the length of a curve is inversely proportional to the degree of curvature. Having fixed the deflection angle, a sharper curve, which does not affect the safe speed limit of the section should, therefore, be preferred to a flatter and, therefore, longer one.

(*vi*) Stations should be sited as close as possible to the sources of traffic. This should be done even if it involves the purchase of more expensive land.

It may be remembered that the one strong point in favour of motor transport is its door-to-door service. This the railways lack. Stations should be located on comparatively high ground and where they can be conveniently approached from villages and towns they are intended to serve. Goods platforms should be sited at convenient distance from *mandies* and other sources of traffic so as to reduce the secondary lead and handling charges at stations to the minimum. At a time when railways were the only means of transport, traffic did find its way to stations in spite of any inconveniences that resulted from the not very convenient siting of stations or even of the railway line. Towns and markets grew up round stations wherever they happened to be sited. This will not be the case now. Badly located stations will not draw traffic. The convenience of entraining and detraining is an important essential for attracting traffic.

Preliminary Survey in Hilly Country.—Engineering considerations are ordinarily the main deciding factors of an alignment in a hilly country. The position of the line joining obligatory points is determined by the configuration of the country, the ruling gradient and the sharpest curvature that is adopted. If the line has to cross a range of hills it would follow an alignment which would take it to the lowest saddle or to the pass in the range. It would be here that the crossing will be effected either by means of a cutting or through a tunnel whichever is economical. Alternative routes may be practicable and have to be examined and compared.

In such a country it will ordinarily be necessary to deviate from several of the subsidiary sources of traffic. If justified, these points may be connected to the railway stations by means of feeder roads.

A good deal of survey technique has to be employed in locating a railway line correctly in a hilly country. Given the capital to spend, a railway line can, of course, be constructed almost anywhere but an engineer aims at obtaining the most economical line not only in first cost but also from the point of view of maintenance and operation.

Various processes involved in carrying out a survey in the hills are described generally in books dealing with the subject. It is, however, evident that surveying is best learnt in the field by practice and experience. The statement originating from some American engineers that "hill surveyors are born as such" is unfortunate and may be ignored. Given the opportunity, almost everybody possessing the necessary academical training can learn hill surveying in the field. All that is necessary is keenness and the ability to undertake sustained long treks.

Following are some of the practical hints relating to the location of a railway line in hilly country:

(*i*) Obligatory points which a railway line must serve are usually fixed by the administration, *e.g.*, a railway line was to be located from Kalka to Simla passing through Solan and Dharampore. The alignment joining these points was to be determined by engineers with as much consideration of the recommendations of traffic experts as was practicable.

The writer did the location of half the length of Khyber Railway starting from Jamrud. The alignment of this railway from Jamrud to its terminus at Landi Khana is, from an engineering point of view, not the very best. The locating engineer could not get a free hand in determining the route. Because of military considerations he had to follow the Khyber Roads, deviating from it only for the development of the alignment. In places curves were not practicable and reversing stations had to be resorted to.

(*ii*) Ruling gradient would depend on the nature of the country and the requirements of the railway. For very heavy traffic there may be justification for flatter grades even at the expense of heavier works and longer length of the line. Alternatively steeper grades with double-headed trains may be more economical.

(*iii*) Reconnaissance is to be carried out along all the alternative routes. At this stage approximate levels of the saddle and of other key points along the alignment are taken with a barometer and distances either scaled off the topographical sheets or measured roughly with pedometers. This information will ordinarily be sufficient to give an idea of the ruling gradient and comparative values of the alternative routes.

The method of development, or of obtaining the length for laying a gradient on a hillside has to be determined at this stage. It may be possible to go along the side of the hill till the summit is reached. Where this is not possible, development may be by means of loops or it may be by means of zigzags or with hairpin curves. In more difficult cases reversing stations may have to be introduced. There may also be a combination of these methods.

(*iv*) The ranging out of the alignment on the requisite grade is then undertaken. Work is generally started from the highest point in a section and carried downwards.

A theodolite with a vertical arc is dipped to the angle of the ruling gradient—flattening out the slope where necessary to allow for the compensation of average curvature. An Abney Level or a *ghat* tracer are also handy instruments for ranging the line in this manner. The instrument man, keeping on the higher side, moves the staff man about the lower side so that the height of the instrument above ground is intersected on the staff. The point is demarcated by earth or stone *burjis* or by a dab of whitewash on the ground. The instrument man then moves up to the leading point and repeats the operation. The line thus traced out on the ground by joining the consecutive *burjis* is the line on the ruling gradient.

A traverse is then run as close as possible to the grade line already traced out on the ground. Distances are taken either by chaining—

keeping the chain horizontal—or by local triangulation or by stadia and reduced to the horizontal.

Plane-tabling is then done and finally, after running a line of levels, contouring.

In very difficult country the ranging of the grade line at the very outset may not be possible. This may have to be done after traversing and contouring have been completed and the position of the line marked on the plans.

On the Khyber Railway the most difficult part of the alignment was the Ali Masjid Gorge. In this area the points of which the position and levels had to be transferred to the plane-table sheets were first marked at site by dabs of whitewash on rock. The *khallassis* doing this work had to be held in position by means of ropes secured to anchorage higher up on the hill. Distances of vertical angles of these points were taken by means of a tacheometer. Both horizontal and vertical distances were calculated and plotted. Contouring was done at site by interpolation.

When contoured plans are ready, the grade contour or the line joining points on successive contours on the ruling gradient is first drawn. This would be an irregular line (see Fig. 1). The correct centre line of the railway is then laid out on the plans with proper curves. Allowance is made for compensation of curvature accurately. Any appreciable deviation of the centre line from the grade contour is adjusted. To make this adjustment the grade contour is re-laid starting from the intersection of the centre line and of the last contour. Levels along the centre line are then read from the contours and a longitudinal section plotted.

PARTICULARS OF SOME OF THE HILL RAILWAYS IN INDIA

Name of Railway	Length	Gauge	Radius of sharpest curve	Steepest grade	Cost per mile when first opened to traffic
	Miles				Rs.
Kalka—Simla Railway ..	59.93	2′—6″	110′ (48°)	1/33 Un-compensated.	3,32,523
Kangra Valley Railway ..	102.99	2′—6″	191′ (30°)	1/25 Com-pensated.	2,65,130
Khyber Railway	26.35	5′—6″	818′ (7°)	1/25 Com-pensated.	11,70,795
Darjeeling—Him-alaya Railway	51.07	2′—0″	60′ (56½°)	1/20	79,922
Nilgiri Railway	28.96	3′—3⅜″	318′ (18°)	1/12 Rack section. 1/24 Adhesion section.	2,34,186

Preliminary Survey in Plains.—The 1″ = 1 mile scale Survey of India maps give a great deal of useful information regarding topography, position of villages, religious places and structures and even cultivated and uncultivated land. These should be obtained for the area which the proposed railway would serve.

Obligatory traffic points, such as station sites at large villages, and the obligatory engineering points, like the crossings of rivers and other large drainage lines, should be marked on the maps, and a pencil line drawn joining these points. A careful study of the topographical details helps in marking what may be the best alignment.

At this stage the following points may be kept in view:

(*i*) Straights, as long as possible, passing through or close to the obligatory points should be drawn. Stretching a thread over the obligatory points on the map helps in marking the alignment as a sort of the average of the obligatory points.

(*ii*) Changes of direction are introduced where found necessary. It will, however, be remembered that curves are to be avoided in and near station yards, close to large bridges, in deep cuttings, and at places where the view would be obstructed by gardens, villages, etc. In the case of stations that are likely to grow into large yards, the station reach must be straight for a length of about three miles. This would allow the outer signals being visible from a distance of half a mile and the home signals from outers and also from stations (see Fig. 2).

(*iii*) Graveyards, places of worship, villages and houses, etc., should, of course, be avoided. While still following the general alignment, it may be possible to avoid more expensive land. Gardens should be avoided not merely because of the cost of their acquisition, but also for the reason that they supply fruit and may be sources of traffic to the railway. It may take only two hours to fell a tree but perhaps 50 years to grow it.

(*iv*) Square bridges for the same waterway cost less than skew bridges. Large canals and important drainage lines requiring major bridges should, therefore, as far as practicable, be crossed on the square.

(*v*) The crossings of rivers and large drainage lines are to be fixed carefully at places where the channel has a long, straight reach and a well-defined course. It will probably be necessary to introduce curves in the railway alignment on either side of the proposed bridge in order to obtain a square crossing. Large bridges are never put on the skew (see Fig. 3).

(*vi*) While marking the line on the map, strike local mounds, knolls and outcrops of rock, if possible. During construction they supply spoil for the bank and perhaps materials that may be good for ballast or as building materials. Incidentally mounds are useful during survey operations. A theodolite fixed on top of a local mound enables long straights being ranged. They also serve as permanent landmarks in locating and demarcating the line.

(*vii*) The Survey of India maps show the boundaries of agriculture and waste land, etc. Without deviating materially from the direct route, the line, where possible, should be made to pass through cheaper land. By the adoption of this procedure less price of land shall have to be paid by the railway, and the more fertile land—the potential source of traffic—shall not have been taken over for non-agricultural purposes.

(*viii*) In aligning past villages, where stations are never likely to be provided, there is no object in laying the line too close to the population. Taking the line close to villages necessitates the provision of more level crossings and of fencing, and involves the acquisition of more fertile and expensive land. Moreover, the proximity of the railway becomes a permanent source of inconvenience and even of danger to the inhabitants as well as to the railway traffic.

(*ix*) Between the obligatory points a direct route should, as far as possible, be followed. Deviations may, however, be justified to touch important villages. Railway fares and freights are, of course, proportionate to the length of the line but unjustified addition to length has to be avoided.

After marking the line on topographical sheets, the next step for the engineer is to ride or walk along the alignment and its alternatives, following the route with the help of landmarks. Certain modifications in the alignment may be found necessary as a result of this reconnaissance, particularly in the siting of stations.

Next, the line should be ranged from apex to apex by means of a transit theodolite. Great care should be exercised in starting the line accurately from its end. A slight difference in the direction between the first two pegs would get multiplied several times proportionately to the length of the straight. It is never satisfactory to start on bearings or on angles. If important landmarks can be located, the direction at the beginning should be taken by measurement from these. A large flag carried on a tall bamboo pole, fixed on top of a tree, located by reference to, say, a *pacca* well, a road culvert, a village mosque or temple, etc., shown in the map, can be sited from two or three miles. A bonfire lit on high ground at night can be seen from a distance of several miles. After taking the direction in this manner the first instrument peg is fixed accurately by sighting from the starting point and as far from it as possible.

There is no transiting of the instrument in this process; therefore, no likelihood of any instrumental errors. This length is then produced by siting back and transiting.

In order to reduce the accumulation of error at one end it may be desirable to start work from near the middle of the straight and work to each end. It may be remembered that once a line has been ranged, but is found to have gone off the desired alignment, or struck obstacles, another line can be laid quite accurately by altering the direction at the first peg proportionately to the deviation necessary to avoid the obstacle anywhere along the line.

While ranging lines the following general principles may be remembered :

(*i*) It is not possible to remove collimation error completely and obtain perfect results in extending a short length by the backsight and transit method. In ranging long straights, it is preferable to leave a certain amount of collimation error in the instrument and then to use it in a manner that would eliminate the error. To do this—

(*a*) Use the instrument face right to put one peg from one setting, and then face left to put the next peg, and so on, alternately. The alignment, theoretically, would be zigzag but for practical purposes straight. There would be no accumulation of error.

(*b*) From one setting fix two temporary pegs, one from face right and the other from face left (see Fig. 4). These pegs may be fixed side by side or, if they happen to be too close to each other, then one a little in advance of the other along the alignment.

Then fix the mean peg by measurement or, better still, sight on an arrow or a pencil at the measured mean point, and clamp the instrument on that sight. Then remove the temporary pegs and fix permanent peg and nail as the instrument point.

A perfect straight line will thus be ranged. After a little practice both the instrument man and the leading flag-man get accustomed and very little additional time is taken than if only one peg were fixed from one setting.

(*ii*) To avoid the error resulting from the inexact verticality of the hairs, always sight with the intersection of the x-hairs or as close to the intersection as possible.

(*iii*) Pegs should be fixed on relatively high ground, such as bunds of fields, banks of irrigation lines, etc., by a judicious selection of the positions where they are least likely to be disturbed by agricultural operations.

(*iv*) Peg should be driven so that its head is flush with the ground. Pegs sticking up above ground draw the attention of cowboys, etc., and are either removed for burning or hacked away just for the fun of it. During survey operations their position is to be found not by seeing the peg easily, due to its sticking above the ground, but by means of the *burji* made of earth or clods, etc., put uniformly, say five feet to the right or left of the peg.

(*v*) While ranging the line nothing is gained by perfect accuracy in levelling up the theodolite. It is sufficient to have the bubbles floating.

(*vi*) The instrument should, however, be levelled accurately for reading angles. Mean of at least four readings of the angle should be taken. In reading an angle the telescope should not be transited, otherwise instrumental errors would vitiate the reading.

(*vii*) To obtain accurate results, flagmen should be trained to hold the ranging rod vertical ; even then the lowest point of the rod should be sighted.

(*viii*) It is not satisfactory to offset round obstacles such as a large tree, or an isolated hut, etc. If the removal of the obstacle is not practicable, a direct sight through or over it at a higher level may be possible and is to be preferred.

After the line has been ranged, modified where necessary and accepted finally, the information to be collected in the field is :

Levelling

(*i*) Chain along the line with a steel-band chain accurately with the help of properly trained chainmen and put in pegs every 100 feet apart. At changes of direction put in T. P.s and curve pegs.

(*ii*) Take detailed levels at every 100-foot peg and at every other point where the configuration of land changes. Take detailed levels at crossings of canals, drainage lines, etc., so that their correct section can be plotted. Take bed and full supply levels of all irrigation lines and their R.D.s at the railway crossings. These are later verified by reference to irrigation authorities.

(*iii*) The high flood levels of rivers and other drainage lines should be fixed by consulting villagers in the neighbouring fields. They will be able to show on trees, walls of huts, etc., how high the maximum flood has ever risen. This should be done at several places and reduced levels taken and compared. It may be noted that some villagers may give very exaggerated accounts, particularly if they feel that exaggerated accounts of floods in their lands may result in the line being shifted elsewhere.

(*iv*) Bench-marks are left along the line at about two per mile. These are fixed on masonry culverts, boundary stones, stone pillars, etc. Where none such are available, there on nails driven into the trunks of trees. The latter on young trees may not remain reliable after some time as they would be growing.

(*v*) The plane-tabler is to fill in topographical detail along the alignment. Usually about 400 feet either side of the line will be sufficient, except at station sites and crossings of large drainage lines where larger areas have to be surveyed.

(*vi*) Whatever survey work is done it should be demarcated at site so that it can be utilised during the succeeding stages. Instrument points should be made permanent by constructing cement concrete pillars which may preferably have distinctive shapes as shown in Fig. 5. A nail is fixed at the instrument point. The pillars should not stick up above ground level but have their tops either flush with the ground, or if the situation is such that the pillar is likely to be disturbed, it should be buried about two feet below the ground level. The exact chainages of the demarcation pillars should be recorded and shown on plane-table sheets. Tying of the pillars to landmarks, *viz.*, recording their distances from two or three objects such as trees, junctions of field boundaries, etc., is of great help in locating them later, particularly in the case of pillars that are buried below ground surface. The information should be shown on plane-table sheets either diagrammatically or by means of notes.

While in the field all information that will be useful for grading the longitudinal section, designing works and for estimating, should be collected from the local Revenue, P.W.D., Irrigation and Drainage

Departments and from District Boards. Some of the items of information are enumerated below:

(*i*) Rates of different classes of land, including that near larger villages, which, if it falls within municipal limits may be a building site and much more expensive than ordinary agricultural land.

(*ii*) Building materials such as good clay for bricks, stone suitable for masonry and ballast, lime stone, *kankar*, shingle, good sand, coal or wood fuel for burning bricks. Information even regarding materials and local methods of construction of temporary sheds and huts for labour, etc., will be of help in estimating.

(*iii*) Sources of supply of labour—skilled and unskilled.

(*iv*) The local schedules of rates for the more important items of work, materials and labour should be obtained from the P. W. D. and District Engineers.

(*v*) Details of bed and full supply levels of all irrigation channels, their discharges, bed slopes, velocities and waterways that will be accepted for various discharges.

In the case of watercourses, general principles should be settled. From the railway point of view, so far as the running of traffic over it is concerned, a Hume-Pipe culvert is not a bridge. An open top or a girder bridge, on the other hand, affects the smooth running. Since, however, there would be a certain amount of loss of head in the case of Hume Pipes and none in the case of open culverts, the Irrigation Authorities would rather have the latter than the former.

(*vi*) Details required to arrive at the waterways of drainage lines should be collected. These would be catchment areas, rainfall, sections across the channel and high flood levels. An existing bridge for a road or railway upstream or downstream of the proposed railway should give reliable information regarding the waterway required across the railway.

On completion of the fieldwork, the plotting and grading of the longitudinal section is to be done. The latter is a very important step in the designing, as it were, of the railway, and should be done by the senior engineer who did the ranging out of the line and is, therefore, fully conversant with the lie of the country. Before starting, the grading the ground line should be inked.

The sites of all bridges should be marked on the profile. Full supply or high flood levels, depths of girders to be utilised, heights of bearings, free board or clearance to be allowed above the H. F. L. and F. S. L. It may be noted that the freeboard is taken from the lowest point on the under-side of the girder and not from the bottom of the bed-plate or the top of the bed-stone. On broad gauge, the height from formation to rail is taken as 1.5 feet on meter gauge and on narrow gauge 1.25 feet. These would, of course, vary a little with the depth of rail and sleeper. The calculated formation level is plotted over the site of the bridge. The same is done in the case of other bridges and culverts. Levels on Hume-Pipe culverts have to be worked from invert level, diameter of the pipe, thickness of pipe and the minimum earth cushion. It may be noted that to allow for variations in theoretical and working F. S. Levels at watercourses, the formation level should be kept about two feet higher than the F. S. Levels.

High flood levels along the line should be marked and formation level fixed at least two feet higher than this.

Levels of station yards may be fixed, say, at two feet above ground level. They may, however, be affected by heights determined by culverts in the neighbourhood. As far as possible, a station will not be located in low-lying country liable to flooding.

Curves will be shown by the symbolic diagram in the longitudinal section and details of deflection angles, radii or degree of curvature, chainage of T. P.s will be shown. A sample of the longitudinal section and of plan is given in the Rules for the Preparation of Railway Projects issued by the Railway Board.

The longitudinal section should now be ready for grading. Obligatory levels arrived at above will determine the grade lines. The ruling grade is used only sparingly at approaches to high bridges, etc., in order to reduce earthwork. If ruling grade passes through curves, compensation should be made for curve resistance by flattening out the grade by the amount of curve resistance converted into equivalent grade per cent. The rate of compensation is :

For broad gauge (5′-6″)	0.04% per degree of curvature.
For meter gauge	0.03% per degree of curvature.
For narrow or 2′-6″ gauge	0.02% per degree of curvature.

It may be noted that total compensation round a curve depends on total deflection angle and is independent of the degree of curvature.

Example for broad gauge railway :

$A = 30°$

$R = 2{,}865$ feet $\qquad D = 2°$

L. C. $= 1{,}500$ feet

Compensation per chain $= .04 \times 2 = .08$

Total compensation $= 15 \times .08 = 1.20$ feet.

For the same deflection angle if

$R = 1{,}910$ feet or $D = 3°$

L. C. $= 1{,}000$ feet.

Compensation per chain $= 0.04 \times 3 = 0.12$

Total compensation $= 10 \times .12 = 1.2$ feet.

A simple way of checking the total compensation is to multiply by 0.04 the number of degrees, expressed in decimal fraction for minutes and seconds.

Unless full use of the ruling gradient is essential it may be sufficient to adopt a flat grade in round figures which is a little flatter than the exactly compensated curve :

Example—

Ruling grade 1 in 300 or 0.33%

Degree of curvature = 3°

Compensation = .04×3 = 0.12%

Compensated grade = 0.33 − 0.12 = 0.21% or 476.19%

1 in 500 or 0.20% may be adopted.

A thread is stretched between the obligatory grade points to see what heights of bank and depths of cuttings are balanced. Points of the changes of grade are adjusted as considered suitable.

Following points may be noted :

(*i*) Avoid too many changes of grade.

(*ii*) From drainage and maintenance point of view, bank is preferable to cutting.

(*iii*) Changes of grade should be avoided within 100 feet of points and crossings, and in the vicinity of bridge abutments. Hume Pipes or arch culverts, having earth cushion on them, are not affected by the position of the changes of grade.

(*iv*) Down grades starting outside stations and going away from them are useful in so far as they help the trains starting from the stations in picking up speed rapidly. Down grades towards stations are undesirable as in the case of a signal being against, a longer distance is required in which to pull up.

(*v*) Steep grades, up in the direction of stations, should be avoided just outside the outer signal and within 1,000 feet of it. If the signal is not lowered, trains have to stop there and find difficulty in restarting. Wherever grades exist in such a position, heavy wear on rails will be noticed due to engine wheels skidding in restarting.

(*vi*) Grades steeper than 1 in 400 are to be avoided in stations, as loose vehicles will roll off on them. Levels or very flat grades should ordinarily be provided.

(*vii*) In undulating country cuttings and fillings are balanced so that spoil from the former goes to complete the earthwork in adjacent fillings. At the same time it may be remembered that from the point of view of maintenance and drainage, bank is to be preferred to a cutting.

(*viii*) In areas affected by shifting sand a cutting would tend to get filled up in a storm and rails would get covered and if a train came on it may get derailed. In such areas formation level should be kept high so that track runs on a bank instead of in a cutting.

III—Traffic Survey

The earliest railways in this country, and as a matter of fact everywhere else, were constructed on engineering surveys and estimates. They passed through the most fertile parts of the country, touched large towns or connected seaports to the fertile agricultural areas inland. An estimate of the traffic earnings before undertaking the construction of such railways was not considered necessary and probably no attempt was ever made to frame one. Railways were necessary for the opening up of the country, for the eradication of famine, for the distribution of surplus produce to places where it was needed or for export to foreign countries, and from political and strategic considerations. As they were the only means of transport and passed through rich areas, they also proved a great success commercially. It was at later stages, *i.e.*, when extensions, branch lines and feeders came to be constructed, that the commercial aspects of railways came into prominence. Every project had then to be justified financially before it could be sanctioned. It was also then that methods for estimating the traffic likely to be carried and the earnings to be realised came to be studied.

Direct and indirect Advantages of a Railway.—The traffic returns of a railway line are its direct receipts or the sums of money realised from goods and passenger traffic carried by the railway. The availability of a cheap and reliable means of transport for carrying the produce of an area results in the opening up of virgin country, the enhancement of the prices of produce, the appreciation of land and of the value of other property.

Besides this, it affords strategic and political advantages. Excepting the actual receipts to the railway, all the other advantages are indirect. Though their value to the country may be very large, yet they do not constitute direct pecuniary profit to the railway. The income to the railway is only its receipts at the stations. If the net receipts give a return equal to, or greater than the market rate of interest, the line is a paying proposition and a commercial success. Otherwise it is not.

Traffic Carried by Railways in this Country.—In this country, the main industry is agriculture and goods traffic comprises mostly of the export of surplus agricultural produce. Next comes passenger traffic. The standard of living of the masses being low, people travel more as a matter of necessity than for pleasure. Townpeople go to other towns on business, villagers to attend courts and fairs. Both town and village dwellers go to perform pilgrimages.

Railways are built to carry not only the traffic that exists, but also to create and carry more traffic. When a line is opened, it starts by carrying whatever is offered. In course of time, however, more traffic develops. The existence of a cheap and reliable means of transport tends to develop the habit of travel among the people, widens their circle of acquaintance and of social relations. Agricultural produce reaches better markets and fetches higher prices. More extensive and intensive cultivation of exportable articles is thus encouraged. In this manner the volume of traffic goes on increasing particularly if the line passing through towns is connected to large trade centres. For the first five to six years the increase is very marked, being as much as 8 to 10 per cent. per annum. After this period, the increase continues, but at a much lower rate. After full development has taken place, the volume of traffic from agricultural areas remains steady, for the reason that the quantity of the produce is almost steady. This is affected only by, say, a revolutionary change in the system of irrigation or in places by failure of rain.

The increase in traffic along a new railway line is estimated to be proportional to the square of the population and the number of the tributary sources of traffic, *i.e.*, the number of additional villages, etc., that may be touched.

It may be mentioned here that important villages and other sources of traffic must be touched even by deviations from the direct route so as to increase the number of the tributary sources of traffic. One may be led to believe that the object should be to connect large villages situated at long distances from big cities, as due to the longer haul most of the receipts would be from such places, whereas receipts from villages situated nearer would be less due to the lesser haulage distance. This, however, is not correct. When haulage is less, the volume of traffic is ordinarily greater and that makes up for the lesser distance travelled. The volume of traffic between Lahore and Amritsar is proportionately larger than that between Lahore and Delhi.

The population of towns as compared to the population of villages contributes more traffic per head of the population.

Traffic a Function of the Density of Population.—Since the income at railway stations is chiefly from passengers and from the export of agricultural produce, it is evident that the volume of traffic obtained from any area is a function of the density of population of the country passed through and falling within the influenced area. The more dense the population, the more intensive is the agriculture and consequently more the exportable surplus produce. There may be exceptions to this. Along Mandra—Bhaun Railway the area of arable lands as compared to the population is proportionately less. The occupation of a proportion of the people is military service. Agricultural produce of the area is almost all consumed locally. There is, therefore, very little goods traffic but a great deal of passenger traffic along this branch line.

Traffic Estimate.—A traffic estimate is based on certain unknown factors and is, at its best, in the nature of a guess regarding the future course of events. The main guide in this respect is the experience gained from lines already in operation. Figures of traffic obtained by comparison with railway lines passing through similar country give fairly reliable results.

Traffic Zone.—The area on each side of a railway line which is influenced by the line and which supplies traffic to it is called its traffic zone. The residents of this area and the surplus agricultural produce from it are taken as travelling by the new line. The average length of travel on the new line depends on the position of large villages and towns along it, the direction in which traffic would flow in order to reach the seaport. Usually half to two-thirds of the length of the branch line would be the length of the passenger haul over it.

The length of the traffic zone is the length of the new line. Its width depends on the range of the local means of feeder transport—the bullock-cart and the pack animal. By means of the latter, the villager takes out the agricultural produce in the morning to the nearest market place at a railway station and after selling it returns home the same day. A total distance of 12 miles is taken as a fair day's work. Without taking it as a hard-and-fast rule, and so far as the estimate of traffic is concerned, the feeder transport may be taken to originate within a distance of six miles on either side of the railway. The width of the traffic zone would thus be 12 miles.

Local obstacles such as a river situated at less than six miles from the railway line may reduce the width of the traffic zone (see Fig. 6). It should, however, be possible to locate the line so as to obtain the minimum width of not less than six miles on either side free of all obstacles to road transport. Another important factor to be noted is that the traffic zone of the new railway line should not overlap the zone of an existing railway. Branch lines would join the parent line by one of the three methods shown in Fig. 7. Whatever may be the layout the new line starting from the junction station should deviate from the parent line as sharply as topography would permit, so that the traffic zones of the two overlap each other for as short a distance as practicable. Lines that have to run parallel should have a distance of not less than 12 miles between them.

Adopting the width of the traffic zone, the next step is to estimate the volume of traffic obtainable from this area. Various formulæ have been evolved, those well known being by Palmer, Birkenshaw and Lines, and modifications of these known as the B. B. & C. I. and the G. I. P. Railway Formulæ. More detailed reference to these is made elsewhere. None of the formulæ can, however, be accepted as definitely applicable to every case. There are several factors that affect earnings. Local conditions such as the fertility of soil, means of irrigation and standard of living of the inhabitants.

The figures of traffic earnings are calculated as gross receipts. From these are deducted the operating expenses. Net earnings give the dividend on capital cost. Gross receipts comprise of:

(*a*) Direct earnings—

(*i*) Earnings collected at stations on the line for outward passenger traffic.

(*ii*) Earnings collected at stations on the line for outward goods traffic.

(*b*) Indirect earnings—

(*i*) Addition to the income of the parent line for traffic originating on the branch line and terminating on the former.

(*ii*) Income to the parent line originating on it and terminating on the branch line.

Direct Earnings.—Earnings from passengers depend on the density of population in the traffic zone. Figures of population are collected from civil records. The rural and urban populations are considered separately. Average lead on the new line is taken from one-third to half of the total length of the line. Third class fare is calculated at three pies per passenger mile. The number of passengers and earnings, therefore, are estimated by the formulæ described later.

For upper class passengers and for other coaching traffic, 10 per cent. of the earnings from third class passenger traffic is taken. In the Punjab, these earnings for branch lines usually work out to from Rs. 75 to Rs. 125 per mile per week.

For estimating goods earnings the quantity of surplus agricultural produce from the traffic zone is worked out. The average yield is taken at 8 to 12 maunds per acre of the land under cultivation per annum and consumption at 6 maunds per head of the population. The balance is the exportable produce. The average haul over the branch line depends on the position of *mandi* towns on the branch line and the direction in which traffic would follow. Each individual case is to be decided on its own merits. For estimating purposes freight rate is taken at 0.3 pies per maund per mile. Terminal charges for the handling of goods at both ends which are in addition to the charges for carrying them by rail are levied at 6 pies per maund.

Inward goods traffic to agricultural area comprises of hardware, kerosene oil, sugar, machinery, piecegoods and a certain quantity of agricultural implements. Their quantity is arrived at by the proportion to outward goods that exists on similar other lines. This may vary from one-third to half. The average of classified rates for these commodities is 0.42 pies per maund per mile. The total of outward and inward goods earnings for a line passing through a fairly fertile area would give a figure of Rs. 40 to Rs. 75 per mile per week.

Indirect Earnings.—These will depend on the position of the nearest important business centres, district headquarters, etc., situated on the parent line and to which people residing along the branch line would travel. On the opening of the branch line, a certain percentage of the passengers would travel beyond the branch line for business and pleasure to towns where better amenities of life are available. Similarly, traders living in towns along the parent line would go to the branch line stations on business. The percentage of such passengers would depend on local conditions and could, at the most, be guessed. A comparison with traffic on lines with identical conditions would be useful. The percentage may vary from 1 per cent. to 5 per cent.

Goods Earnings.—A certain percentage of the outward goods traffic of the branch line would travel over and enhance the traffic of the parent line. This would depend largely on the direction in which traffic would move in order to reach the seaports or large towns with factories that would consume the produce. Oil seeds would go to seaports, cotton to towns having ginning and pressing mills. It must, however, be remembered that some of the goods traffic originating on the branch line and travelling on the parent line may have been reaching the parent line even prior to the construction of the branch line. The latter in such a case would get no credit in the shape of indirect earnings.

Formulæ for Estimating Traffic Earnings

Palmer's Formula.—This was perhaps the earliest attempt made to establish a relation between the density of population and railway receipts. The formula is confined to rural earnings only. Mr. F. Palmer, District Engineer, E. I. Railway, estimating the figures for the Mughalsarai—Gaya Railway in 1896, assumed that the receipts at wayside stations in Bengal and Behar for goods and passenger traffic were equal to a sum of one rupee per head of the population within the directly affected area. This area was assumed to be eight miles in the beginning, increasing to 12 miles as the country was more fully opened. Income from towns was estimated for separately by obtaining data from local traders. This was a fairly reliable method. For incorporation into the formula, it was assumed that income from urban population per head is twice that of the income from rural population. The fornmula is:

$$E = KLD + 2P.$$

where E = annual earnings in rupees from rural population.
L = length of the line in miles.
D = density of rural population.
K = a coefficient giving the width of the traffic zone varying from 8 to 12 miles.

The results obtained from the formula are not of general application.

Birkenshaw's Formula.—This formula has two parts, one for estimating the third class passenger earnings and the other for estimating the goods earnings. It combines the receipts from rural and urban areas but fixed a length of travel on the new line and fare and freight for that length.

Passenger earnings are, of course, from third class passenger traffic and the average distance travelled on the new line is taken at half its total length. Urban population is taken to contribute three times the earnings per head as compared to rural population.

Formula for Passenger Earnings—

$$X = F\,(CDL + 3P)$$

where X = third class passenger earnings from outward traffic in rupees per annum.
F = average fare per outward passenger in rupees or half the length of line in miles × 3 pies.
C = coefficient giving width of the traffic zone,
i.e., 6 miles for first 10 years.
8 ,, ,, 20 years.
12 ,, ,, 30 years.
D = density of population per square mile.
L = length of the line.
P = urban population.

For upper class passenger and other coaching traffic, a percentage of the third class earnings is added. This percentage is arrived at from figures obtaining on adjacent lines.

Formula for Goods Earnings—In this formula it is presumed that a quarter ton goods are carried per passenger per annum and that average lead over the line is half the length of the line in miles.

$$Y = \frac{G\,(CDL + 3P)}{4}$$

where Y = goods earnings in rupees.
G = average lead in miles × 8 pies per ton.

Line's Formula.—This formula is for estimating the earnings from third class passenger traffic. The formula, like all others, is of an empirical nature. Data required is the density of rural population within the traffic zone and the figures of urban population. Two constants are employed the value of which varies rather widely. These values are fixed by an analysis of receipts from similar other lines. The formula is :-

$$X = F\,(r\,CDL + tP)$$

where X = annual earnings.

F = average fare per passenger. This is arrived at by ascertaining the number of third class tickets sold at stations on a similar branch line and receipts under that item. It is checked by calculating fare from average lead on the branch line.

NOTE.—The value of F worked out for rural and urban population would differ. It will be higher for the latter but considering the fact that tickets for return journeys to villages are purchased by the rural travellers at market towns it will be seen that the average value of F will be suitable for the formula to cover both rural and urban population.

r = a factor for rural population varying from 1 to 2.
t = a similar factor for urban population varying from 6 to 16.
C = total width of the traffic zone—12 miles.
D = density of rural population.

B. B. & C. I. Formula.—This formula is for estimating receipts from third class passengers. Estimate total population in the traffic zone and assume that 1 per cent. of this will travel daily.

In other words, this formula is based on the assumption that each head of rural and urban population would make 3.65 journeys per annum over the average lead distance of the line.

G. I. P. Formula.—This formula is based on the assumption that each member of the total population of the traffic zone makes one local and one through journey per annum. The length of the through journey is taken at two to three times the local journey.

Working Expenses.—These include the cost of maintaining the line and other works, working and maintenance of locomotives, coaching and goods stock, and the cost of maintaining transportation and commercial staff. For the purpose of booking, this expenditure is divided into the following main heads :

A.—Maintenance of structural works such as the railway line, bridges, buildings, etc.

B.—Maintenance and supply of locomotive power.

C.—Maintenance of ferry steamers and harbours.

D.—Maintenance of carriage and wagon stock.

E.—Expenses of traffic department.

F.—Expenses of general departments such as General Manager's and Divisional Superintendent's Offices, Medical Department, etc.

G.—Miscellaneous expenses such as law charges, taxes, compensations, sanitation, etc.

It may be noted that working expenses take away the major portion of the gross earnings of railways.

The ratio between working expenses and gross earnings is called the "operating ratio." This ratio varies from 50 per cent. to 80 per cent.

The difference between the gross earnings and the working expenses, which is a small margin, is the net profit. The engineer and the traffic surveyer have to keep in view the fact that this margin is to be as large as possible.

Effect of the Volume of Traffic on Working Expenses.—Certain charges making up the working expenses are such that they are not affected by the volume of traffic. These are interest on capital cost of the line and general charges, items F. & G. above.

It is only the train operating charges that are affected more or less by the volume of traffic that is carried, but not in proportion to the increase or decrease in the volume of the traffic. Thus, as the volume of traffic and, therefore, the gross earnings increase the operating ratio decreases and the net profit increases.

It may be stated that the low capital cost of a railway line is its very important asset. Traffic officers who have to work the lines should co-operate with engineers in keeping down the first cost and should not demand accommodation and facilities that cannot be fully justified. Provision on new lines should be cautious. Estimates of earnings may turn out to be too optimistic. If, on the other hand, the volume of traffic proves good, additional sidings, high level platforms, sheds and offices, etc., can be added as and when justified by actual experience.

While investigating the project of a new railway line, if traffic figures work out low and the line is not a paying proposition, it may be possible to lower its standard and therefore the capital cost. The line may then become a paying scheme.

Effect of Distance on Working Expenses.—Operating expenses do not vary in direct proportion to the distance over which traffic is carried. More than 50 per cent. of these are not affected by distance. These expenses depend on:

(*i*) Capital cost of the line.

(*ii*) Gradients and curvature over which trains are hauled.

(*iii*) Distance.

The method of charging freight rates and fares which is easily understood by the public is by the distance. Thus receipts vary directly with the distance whereas working expenses do not.

The unit of working expenses is a "train mile."

It will be realised that with flat grades the additional traffic that a branch line contributes to the parent line is carried over the latter with very little additional expense. It is estimated that "smalls" contributed by a branch line are carried over the main line with practically no extra cost.

Wagon-loads are carried with five to 20 per cent. extra cost and train-loads with 60 per cent. extra cost.

IV.—Financial Prospects

Return on the capital outlay on a railway line is estimated in the manner given below.

After opening a new railway line traffic would take from five to six years to develop fully; therefore, the full return on which a project is justified would not come in till after the above period of development had passed.

Expenses—

(*a*) Working expenses of the branch line.

(*b*) Working expenses of the parent line for new traffic interchanged with the branch line.

NOTE.—On Indian railways this latter is calculated from the operating ratio which is taken as half that of the average of operating ratio for ten years on the existing system.

Earnings—

(*a*) Gross earnings of branch line.

(*b*) Gross earnings of parent line for interchanged traffic.

Capital Outlay.—Capital cost including interest during construction.

Net Earnings $= (a' + b') - (a + b)$.

Return Per cent. $= \dfrac{(a' + b') - (a + b)}{\text{Capital Outlay}} \times 100.$

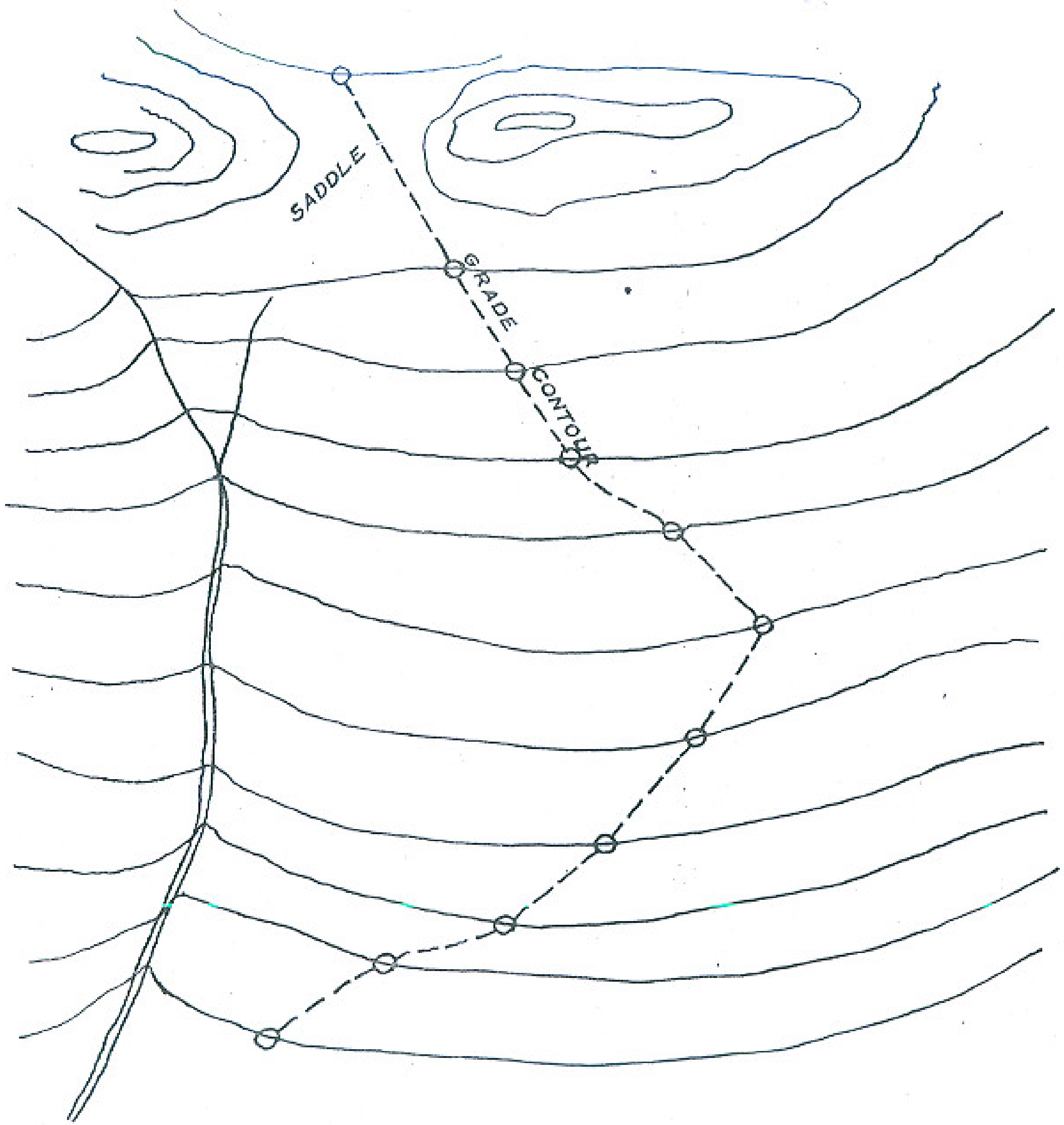
The working expenses and earnings for the year 1939-40 of two of the branch lines of the N. W. Railway are given below :

	Kangra Valley Railway Rs.	Mandara-Bhaun Railway Rs.
Capital Cost including interest during construction	3,15,80,693	32,02,978
Working Expenses of the Branch Line—		
Repairs and maintenance of structural works	1,03,017	44,034
Maintenance and supply of locomotive power	1,11,229	1,21,956
Maintenance of carriage and wagon stock	30,423	15,933
Expenses of traffic department . .	53,463	23,813
Expenses of electric department . .	20,468	8,504
Total . .	3,18,600	2,14,240
Appropriation to depreciation Reserve Fund at 1/60th of the Capital Cost	4,94,157	46,331
Total . .	8,12,757	2,60,571
General administration (20 per cent. of the total of above items)	1,62,551	52,132
Hire of rolling stock (5 per cent. of the gross earnings)	Branch line has its own rolling stock	8,722
Grand Total of Working Expenses	9,75,308	3,21,425
Gross Earnings of the Branch Line—		
Coaching	2,00,764	1,13,622
Goods	1,04,489	60,815
Total . .	3,05,253	1,74,437
Guarantee payable by Punjab Govt.	4,00,000	. .
Grand Total of gross earnings . .	7,05,253	1,74,437
Net earnings for branch line proper	—2,70,055	—1,46,988

	Kangra Valley Railway Rs.	Mandara-Bhaun Railway Rs.
Additional Earnings and Working Expenses for Traffic interchanged with Main Line—		
Additional earnings to main line ..	2,95,249	4,42,907
Working expenses of main line to carry additional traffic @ 50 per cent. of the normal operating ratio of the entire N. W. Rly. system..	1,12,047	1,68,083
Net earnings of main line ..	1,83,202	2,74,824
Total net earnings	86,853	1,27,836
Return per cent.	—0.27	3.99
Return per cent. excluding the guarantee	—1.54	..

During the past 14 years, the return for the entire N. W. Railway system including the strategic sections has varied between 4.8 per cent. in 1925-26 and 1.8 per cent. in 1932-33. For this period they were the best and the worst years respectively. The return for 1939-40 is 3.32 per cent. (excluding worked lines, but including strategic sections). Excluding the strategic and worked lines the return is 4.74 per cent.

FIG. I.



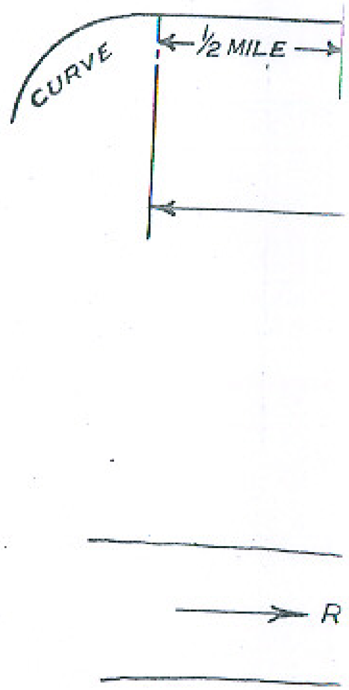


FIG. 2.

DESIREABLE LENGTH OF STRAIGHT FOR A STATION

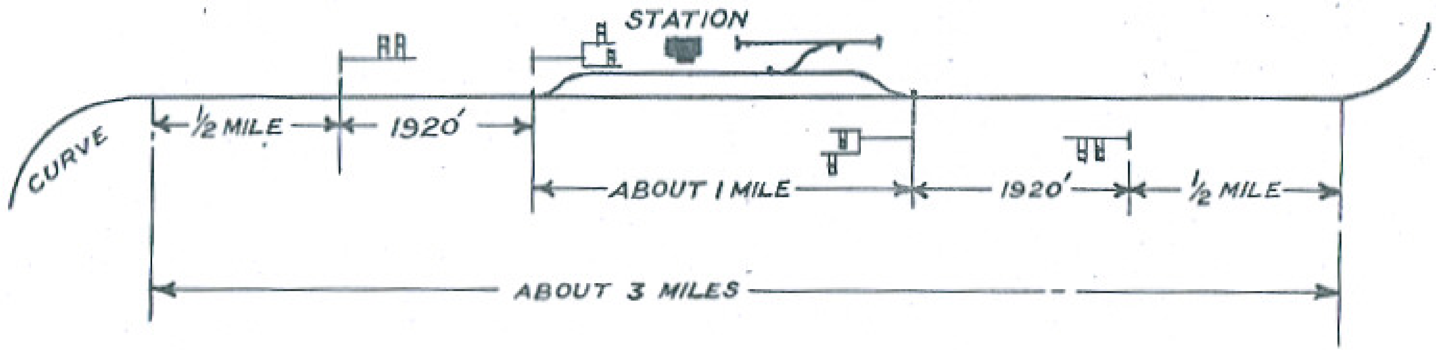


FIG. 3.

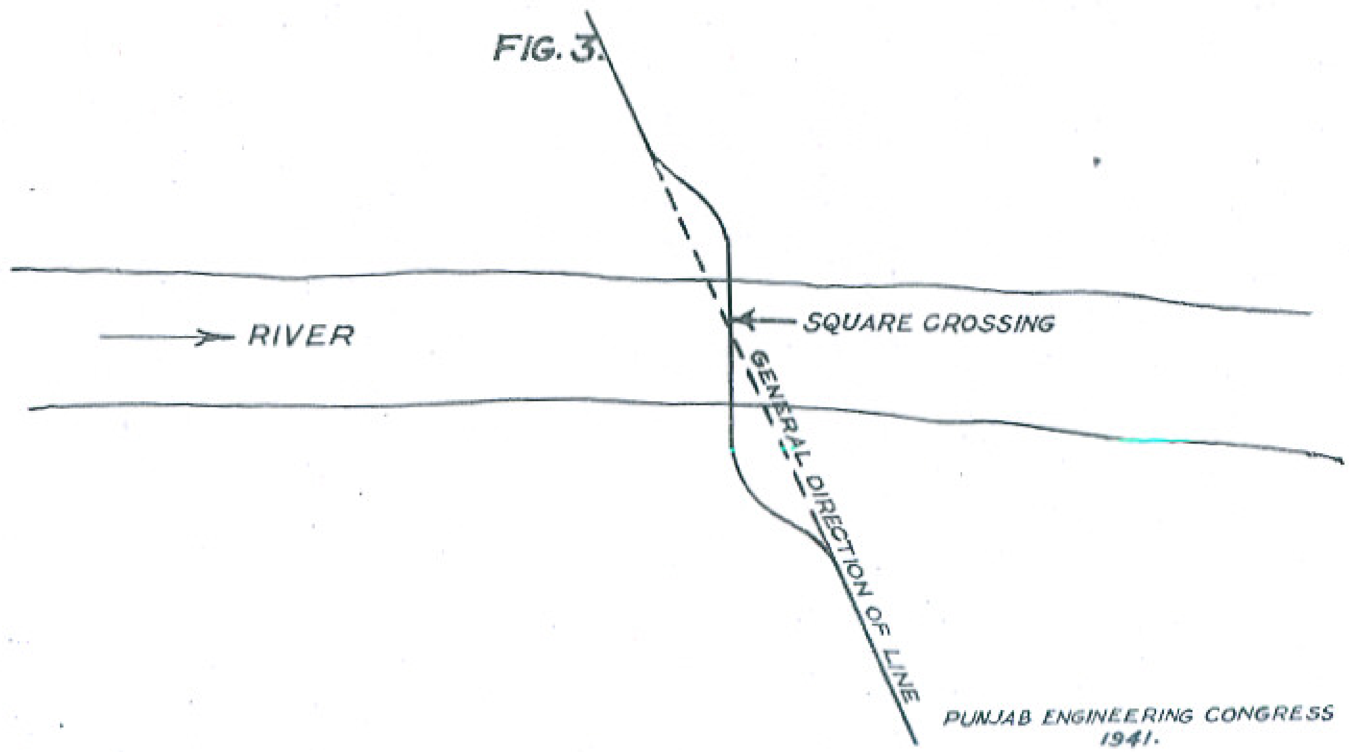
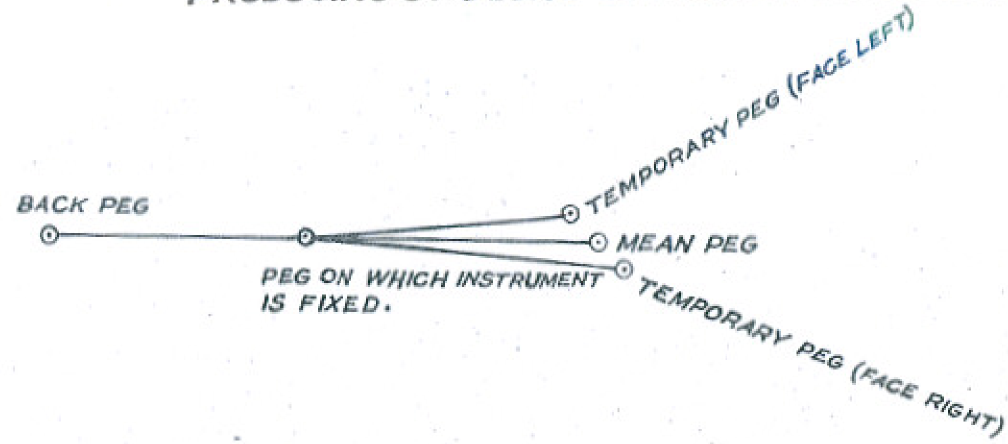


FIG. 4.

PRODUCING STRAIGHT BY MEAN PEG METHOD



TRAFFIC
HATCHED A

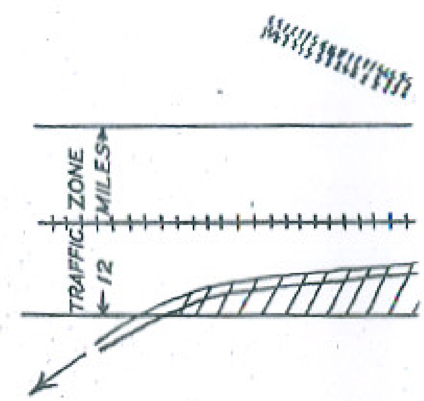
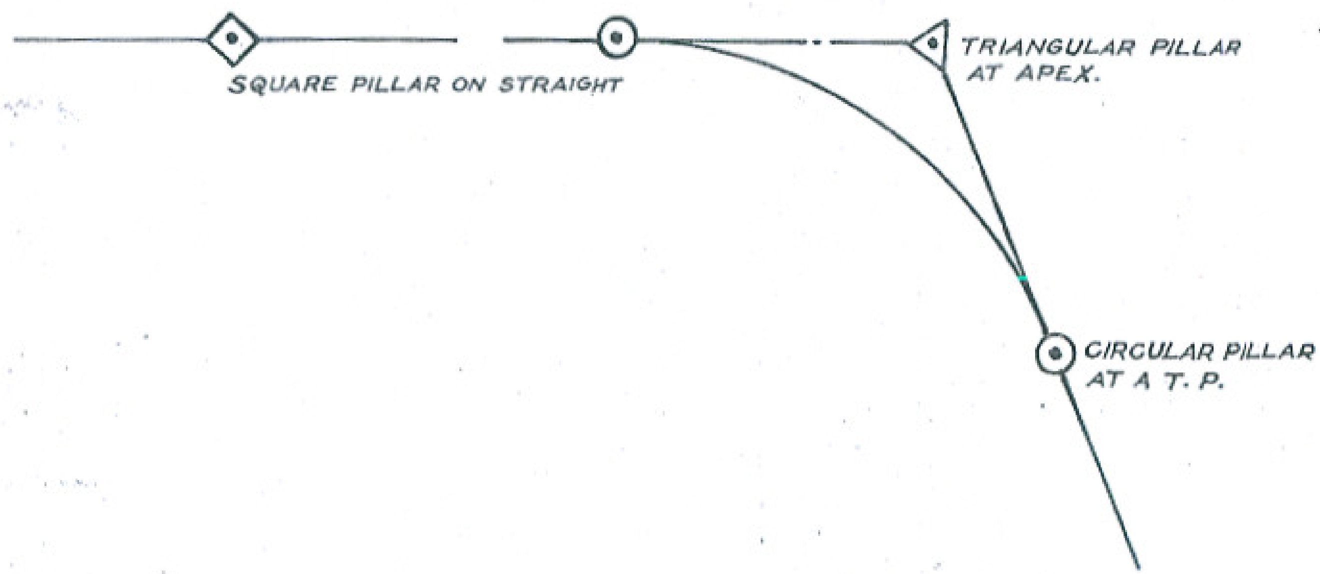
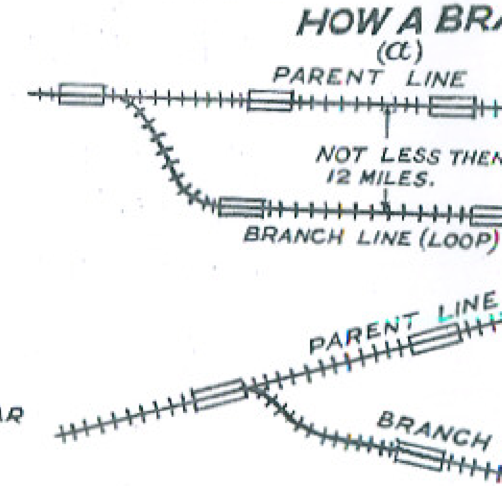


FIG. 5.

DEMARCATION PILLARS



HOW A BRA



AN PEG METHOD

PEG (FACE LEFT)

G

ARY PEG (FACE RIGHT)

R PILLAR

CULAR PILLAR
A T. P.

FIG. 6.

TRAFFIC ZONE REDUCED BY OBSTRUCTIONS
HATCHED AREAS ARE A LOSS TO THE TRAFFIC ZONE.

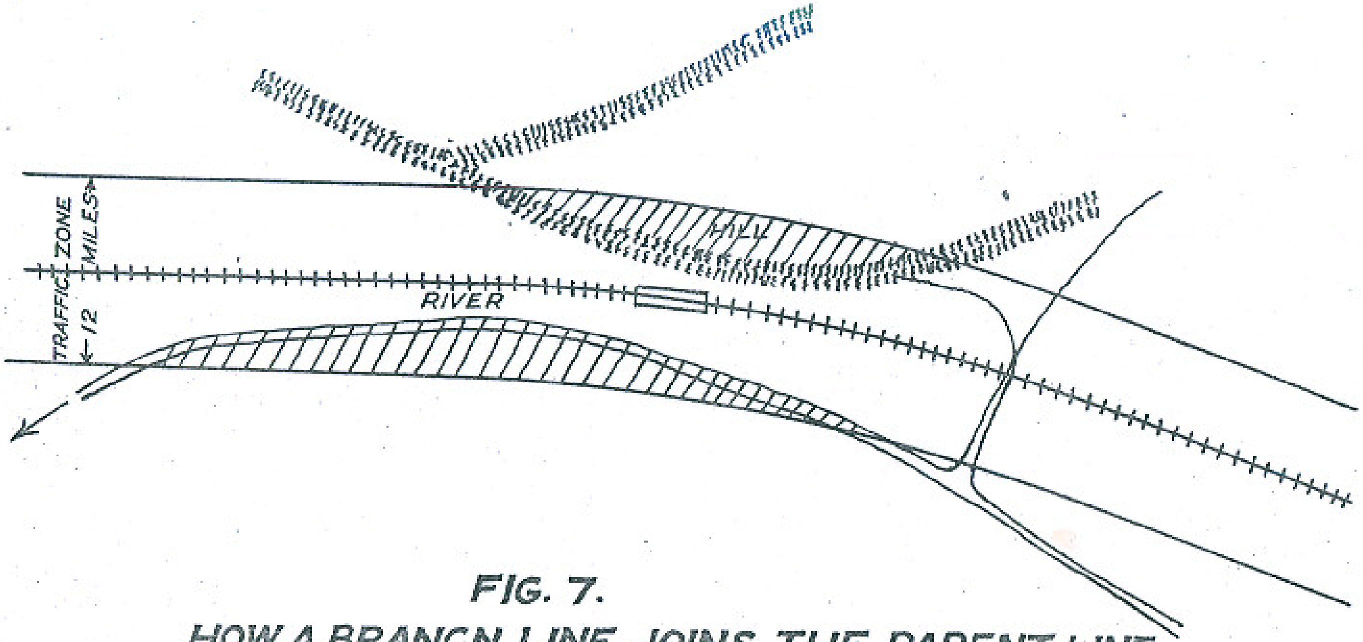
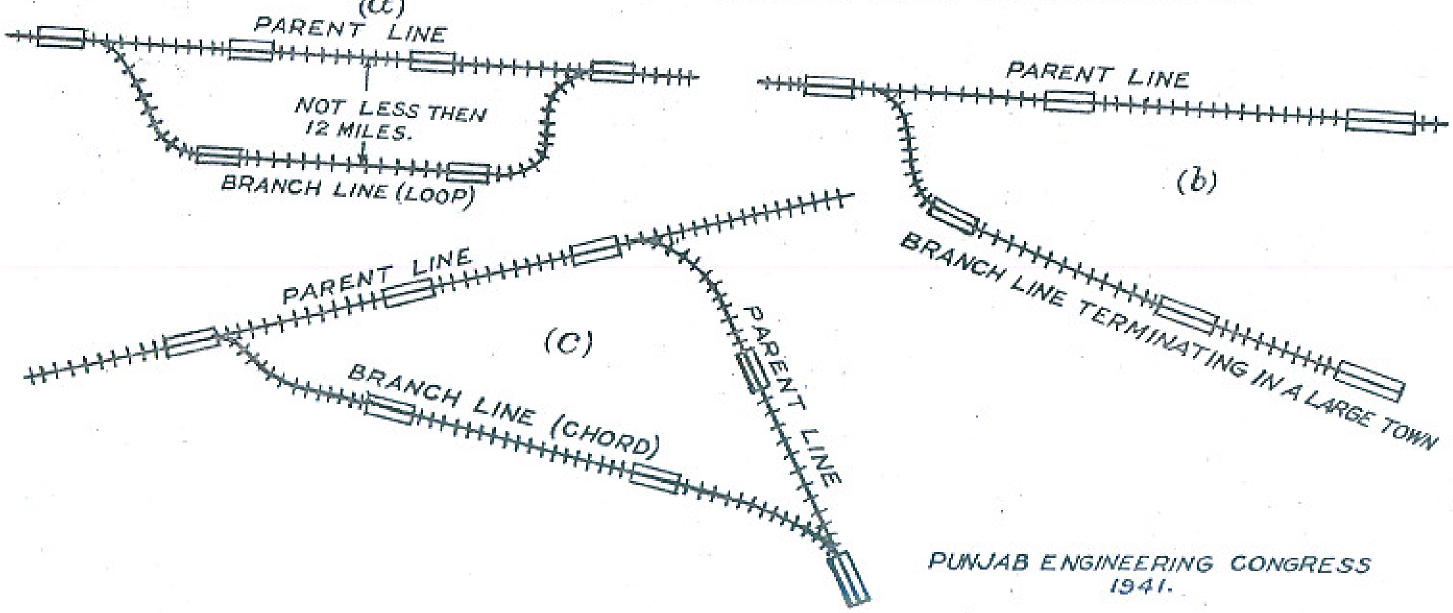


FIG. 7.

HOW A BRANCH LINE JOINS THE PARENT LINE



DISCUSSION

The AUTHOR, while introducing his Paper on the Investigation of New Railway Schemes, said that the Paper was being read at a time when, unfortunately, the outlook for further railway extensions as commercial undertakings did not appear very bright. This was particularly so in the Punjab, which had a network of motorable roads.

As long as railways were the only means of quick and long-distance transport in this country, they enjoyed a sort of monopoly of carriage. The well-known traffic formulæ for estimating the volume of traffic for a proposed railway line were all based on the assumption that the entire surplus produce and all the passengers obtainable from the area intended to be served by a railway would travel by railway only. The phenomenal development of motor transport during recent years, however, had altered the conditions considerably. Those sections of railways that have good-surfaced roads parallel to them have suffered serious loss of traffic. A large proportion of the lighter and more paying goods and passenger traffic was getting diverted to roads.

Traffic estimates in the future would have to allow for this contingency. They would have to make allowance for what percentage of the traffic would go by road and what would, as a matter of necessity, be left over for the railway to carry.

The Author further remarked that it was evident that the advantages of a railway were not all converted into station earnings. There were innumerable indirect benefits. Some of these have been referred to in the Paper. Railways, however, have to be justified on the strength of what moneys are received at railway stations. By this measure and as a result of road competition some of the branch lines were proving unremunerative. Unless they were to be subsidised some of them might have to go. They would, of course, be missed by many, including those responsible for the maintenance bills of parallel roads.

To serve a particular area and to tap its traffic in the future there must be either a railway or a road. Rarely both, except, perhaps, in the case of important arterial lines of communication where, in spite of road competition, the railway might find enough to carry and to justify itself commercially.

The latest branch line constructed by the North Western Railway was the Sind Right Bank Feeder. This was opened to traffic in July last. The cost of construction of this line was estimated to be about Rs. 61,000 per mile. The traffic estimate of this line showed a very good return. In spite of a liberal provision of railway facilities and accommodation works the line had actually been constructed for about Rs. 46,000 per mile. Thus any excessive optimism that might have been shown in arriving at the gross earnings should be more than compensated by the substantial saving effected in the cost of construction.

Incidentally, this happens to be the cheapest broad-gauge line ever constructed by the North Western Railway. It is probably the cheapest in India.

The second cheapest line was the Sind Left Bank Feeder Railway (Rs. 50,862 per mile) and the third was Rohtak—Gohana—Panipat Railway (Rs. 54,647 per mile). The Author said that all of these three lines were constructed under his executive charge.

In the case of the Sind Right Bank Feeder Railway, the possibility of competitive transport had not been overlooked. The Provincial Government have been made to guarantee not to construct roads parallel to the railway. This was the only guarantee and was perhaps the first of its kind.

The engineering portion of this Paper does not describe any revolutionary departure from the usual practice of railway surveys. It was merely an attempt at recording certain practical hints that suggest themselves to those who have experience in this type of work and which it was hoped will be of interest to other engineers as well. Several of the details that apply to railway surveys were equally applicable to surveys for roads.

R. B. A. N. Khosla said that the Author had presented a very valuable Paper in very clear language. The two tables given by him on pages 200 and 204 and the details of working expenses and earnings on the Kangra Valley and Mandhra Bhaun railways were of particular interest. The Paper would, however, have gained greatly in value if the expenditure and returns on the various railway systems had been analysed by subheads and compared with a view to give at a glance a general idea of costs and returns on railway projects on similar terrain. It would, for instance, be helpful to have given figures of cost of formation, sleepers, rails and fastenings, culverts, small bridges, etc., per mile; of the major drainage and river crossings; of tunnels in hilly country and of other special features of work on plains and in the hills. Similarly, figures of financial returns for as many projects as possible should be analysed and compared.

The Speaker hoped it would be possible for the Author to have them prepared and send in his written reply to the discussion.

Mr. S. L. Kumar said that the Congress, more particularly the Members belonging to the Railway Service, were indebted to the Author for presenting this interesting Paper which outlined the fundamental principles involved in the investigation of new railway schemes and also gave useful tips for the survey and construction of new lines based on the very extensive and varied experience of the Author.

Some of the things discussed in this Paper were of a controversial nature or needed considerable revision to suit the modern conditions. For example, most of the formulæ mentioned in this Paper for determining the amount of traffic that will come to a new railway were based on the assumption that the railway held the monopoly of transport. They would, therefore, have to be modified in those cases where a competitive means of transport already existed.

Another important fact which the Speaker would like to emphasise was that some of the older conceptions relating to railway transport no longer held in view of the rapid changes which this industry had undergone all over the world. Of these changes, two needed special mention. In the first place motor transport as a serious rival of the railways had come to stay. No railway administration could afford to ignore this. The second change was the ever-increasing desire of the travelling public for faster and still faster means of transport. It was the lack of full appreciation of these two changes that had been and perhaps still was a serious obstacle in the way of Indian Railways regaining a good part of their lost traffic.

Had these two changes been fully appreciated about 15 years ago, some of the lines opened to traffic between 1920 and 1930 on the North Western Railway would never have been constructed. A good many of these lines were built to a cheaper standard of construction and were therefore not designed to carry trains at speeds exceeding 25 to 30 miles per hour. These lines thus started with a serious initial handicap. Another factor which ruined completely any chance of success of some of these projects was the existence of parallel metalled roads with suitable means of road transport. The competition this transport was going to offer was completely ignored. It was, in fact, believed by some traffic survey officers that as soon as the railway came into operation, the motor and other vehicular transport services would forthwith cease to operate. Even a layman would have laughed at such a presumption.

When the Speaker read for the first time the traffic survey report of that ill-fated line between Lyallpur and Jaranwala in 1926, he had a strong suspicion that the Author of that report had made up his mind, before he started the survey, that he had to prove that this line was going to be a paying proposition. The first mistake (and a serious one too) he made was that he assumed that all passenger traffic which was carried on between Lyallpur and Jaranwala and other villages on the road by lorries and tongas would all be diverted to the new railway. Such optimism was not justified even in those days when the railway earnings were the highest recorded.

He assumed further that the average lead per passenger in local traffic would be half of the total length of the line. This is correct for main lines but not for short feeder lines connecting two existing parallel lines. In such cases people living in villages within a radius of 3 to 4 miles of the terminal stations at either end will never use the feeder railway. The average lead should, therefore, have been assumed as being equal to about one-third of the total length of the line.

Similarly, the statement made by the Author in Paragraph 4 on page 214, *viz.*, " when haulage is less, etc., ... " did not apply to such feeder lines and was only partially true for main lines. It was agreed that the volume of traffic between Lahore and Amritsar was larger than that between Lahore and Delhi, yet the percentage of total available traffic carried by the railway between Delhi and Lahore was much higher than the percentage of available traffic carried by the railway between Lahore and Amritsar. Further, in the case of short feeder lines, the traffic, both goods and passenger, from the villages within a short distance of the terminal station, would come to the town directly by tongas, carts, etc., and will never be offered to the feeder railway. Only the traffic from the more distant villages will be carried by the railway. In fact, a short feeder link such as between Lyallpur and Jaranwala can only pay its way if it provides a faster means of transport between any two large towns, reduces the distance between two very important stations or has no competitive means of transport. None of these conditions were satisfied by this and some other feeder railways in the Punjab.

In the last paragraph on page 220, the Author had said, "while investigating . . . scheme." This statement was only partially true. It was incorrect if the lower standard of construction was going to reduce the maximum speed of trains so that people would much rather go by the competitive means of transport. It was generally accepted that motor transport offered door-to-door service, was usually cheaper and took less time for journeys up to 40 or 50 miles. As it consisted of small units, it provided frequent service between any two stations. On the other hand, it was less reliable and far less safe than railway transport but people would not take to railways unless they are offered better treatment and amenities and a very much faster transport than the motor service could offer. If the railway held the monopoly of transport in any particular area then the standard of construction and of amenities could be safely lowered and not otherwise. One of the best methods therefore, for the railways to meet the road competition, wherever it existed, was to use diesel cars or similar light units running at very high speeds.

Mr. Brij Mohan Lal remarked that the Author's Paper was of great interest to engineers of the Buildings and Roads Branch, in so far as it related to survey of railways in plains and hills. The Speaker was of opinion that the practical hints given by the Author on survey, laying out of railway embankments and cuttings would be of great use to those who were engaged on survey and construction of roads. There was a big programme for the construction of roads by the Buildings and Roads Branch over the next two years. The Speaker hoped that the construction staff would benefit from the experience of the Author.

Mr. G. R. Sawhney congratulated the Author on writing such a useful Paper which would be gratefully received by all young engineers for reference, whenever called upon to construct a railway line.

In the absence of such a booklet or pamphlet, a number of books had to be consulted by young engineers when called upon to design even simple things like points and crossings. The Paper would not only be of help to the railway or the road engineer but would also be very much appreciated even by those irrigation engineers who may be called upon to construct short lengths of railway lines for headworks or querries, etc.

The Author, while replying to the discussion, said that R. B. A. N. Khosla, in his criticism, suggested the addition of certain statistical information regarding the cost of railway lines, so that, while prospecting a new line, costs of formation, bridges, sleepers, rails and fastenings, etc., could be obtained at a glance by referring to such information. It will be realised that an estimate for a railway or for any other large scheme could be of little practical use if it were arrived at merely by reference to the costs of other similar schemes. Details of earthwork, bridging, etc., must be worked out in each individual case. All that could be estimated roughly by reference to completion cost was perhaps the total cost per mile of a line. For this purpose tables at pages 200 and 204 of the Paper supplied the necessary information.

The Author said that he was obliged to Mr. S. L. Kumar for his careful study of his Paper and his exhaustive criticism. He fully agreed with him that the well-known traffic formulæ given in the Paper would not apply if there were a competitive means of transport, parallel to the railway alignment.

This fact had already been brought out in his introductory remarks, where it was stated that traffic estimates in the future would have to allow for what percentage of the traffic would go by road and what would, as a matter of necessity, be left over for the railway to carry.

The sad end, to which some of the branch lines have come, *i.e.*, being found unremunerative, they were dismantled, was mainly due to road competition. A higher standard of construction would have enhanced their capital cost and made matters worse, financially. Any incentive to passenger traffic because of higher speeds would by no means have compensated for the additional amount of interest; as the difference in cost would have been considerable.

The Author further remarked that Mr. Kumar, he was afraid, had missed the point in stating that half average lead would apply to main railway lines only. These latter carry relatively intense traffic along their entire length, so there was no question of average lead being less than the length of the line.

As regards branch lines of length, say, 40 miles or more, the average lead would depend on the situation of main sources of traffic along their alignments. Lyallpur—Jaranwala Section, which Mr. Kumar had in mind, was a particularly bad case, otherwise a lead of half the length of the line was by no means too optimistic.

With reference to Mr. Kumar's remarks regarding the comparison of traffic between Lahore and Amritsar and Lahore and Delhi, the Author agreed that the volume in the former would be greater. That is what affects the earnings. It was immaterial if the percentage of all traffic available was less, even if Mr. Kumar's theory of the lesser percentage were accepted as being correct.