be increased or diminished accordingly.

While this method of ascertaining the number of trains per day is only approximate, it is certainly much more accurate than to attempt to make an independent estimate of the gross tonnage on the new road. The rate of growth of traffic should be similarly ascertained, as a railway should be built not only to take care of the present traffic but also that of the road in the reasonably near future.

Cost per train mile is the basis of all economic comparison, as the effect of the number of trains on the cost of operation is much more direct than is the actual tonnage handled. The cost per train mile should thus be ascertained with reasonable accuracy. The annual reports published by the railway companies usually give these figures; if not, the reports of the Inter-State Commerce Commission give this information for every railway in the United States. From this mass of statistics the train mile cost of the most nearly similar road should be taken and assumed as the train mile cost of the proposed road. It must also be remembered that these costs are increasing rapidly, the average for the whole United States for the year ended June 30, 1896, being 95c., while for the year ended June 30, 1910, it had increased to $1.49.

Equipped with this information as to the sources of traffic, the estimated average number of trains per day, and the probable cost per train mile, the engineer is ready to make a reconnaissance of the country to be traversed. The reconnaissance should always be of an area rather than a line. An area wide enough to take in any possible line should be examined. All combinations of probable lines should be studied. As the reconnaissance proceeds a map of the country should be made showing the details of the topography by contours 10 to 50 ft. apart; the elevations of controlling points should be shown with the greatest attainable accuracy. From such a map carefully prepared all lines and combinations of lines can be studied. Approximate condensed profiles can be drawn, and distances, grades and costs can be approximately ascertained. With such information, the choice of routes can usually be narrowed down to one or two, or in rare instances to three lines over which it is necessary to run surveys.

The value of a proper reconnaissance cannot be too strongly insisted upon. It is owing to the lack of it that the graver errors of location are usually due, such as the selection of an improper route or ruling grade, passing of traffic centres, etc. There is no way in which money can be so profitably spent. Great pains should be taken to secure the most expert engineer for this class of work. In engineering and economic importance, reconnaissance far outranks location or construction. It is not an exaggeration to say that for every dollar which an engineer can save on construction, he can save five on location, and ten on reconnaissance.

The really essential factor in a location made for freight traffic is the ruling grade. The maximum is not always the ruling or limiting grade, as it might be operated by the aid of a helper engine, in which case it may not limit traffic. A very long grade of a lower rate may, by taxing the boiler capacity, become the ruling grade instead of a shorter steeper one. To ascertain the economic value of any change in grade, or to compare two different grades, the number of round trips per day required to handle the given or estimated traffic should be ascertained. The difference will be the saving in trains each way per day. This multiplied by the ascertained cost per train mile, by twice the length of the division in miles and the number of days in the year, will give the annual saving. Capitalizing at the proper interest rate will give the capitalized value of the better grade. If the additional cost is not greater than the capitalized value when properly equated for distance, rise and fall, curvature, etc., then the lighter grade is an economic one, and should be adopted.

As many items of expense will not be affected by changes in the number of trains, the saving per train mile for a train eliminated is not as great as the cost per train mile for the entire traffic. The saving is in reality in the neighborhood of 50%, and this percentage of the ascertained total train mile cost should be used in estimating the economy due to a difference in ruling grade.

In figuring on the economics of a grade reduction on an old road where the traffic and the average number of trains per day are known, it is essential that the actual loads hauled by each locomotive be determined and compared with their rated capacities. This difference is due to the inability of the operating officials to get perfect results. This "personal equation" must be taken into consideration in figuring the number of trains per day with the new grades, as they will no more be able to get the best results under the new conditions than they were with the old. In making a reduction from a high rate to a low, for instance, from 1% to a 0.3% or 0.4%, it must not be forgotten that the proportion of the actual loads to the theoretical rating will be lower on the low grades than on the high. Time is an essential factor. On a 1% grade in good weather, the actual loading may usually be made 90% of the theoretical, while on 0.3% it is unlikely that more than 75% of the rating can be hauled if time is to be made.

The proportionate amount of ruling grade on the divisions has also an important bearing on the loading of trains, the greater the proportion its length bears to the length of the division the lighter the actual train loads must be, and this, too, must be taken into consideration in determining the average number of trains per day required to handle the traffic on the proposed new grade.

Serious error would undoubtedly arise if the theoretical number of trains required to handle the traffic on the proposed new grade were compared with the actual trains on the present one.

While fixed charges—which are largely determined by the cost of construction—are of lesser consideration than operating expenses, they are still of prime importance. No road can pay dividends to stock holders, or afford to reduce freight rates until its fixed charges are met. So it is of the greatest importance that the engineer introduce no features that will increase the cost of construction without reducing the operating expenses by at least as great an amount as the interest on the added cost. The cost of moving a given tonnage being the sum of the operating expenses and the fixed charges, it follows that a reduction in the cost which does not increase the operating expenses is only of less importance than one which reduces the operating expenses without increasing the cost. Such a reduction in cost is a practical improvement to the standard of the road, as it increases the margin between receipts and expenditures, and so permits of an increase in dividends, or has a tendency to permit of a reduction in freight rates, if that be the object aimed at.

In Canada most of the new construction is through districts which at the time of completion furnish but little traffic: much railway has been built on which the traffic did not justify even one daily freight train per day each way. It is a safe statement that 80% of the mileage constructed in Canada would not furnish at the date of completion traffic sufficient for two freight trains each way per day. Under such conditions, the receipts are low and the operating expenses high, and it is of the utmost importance that the construction cost be kept low. On the other hand, the country is growing fast, and traffic is increasing rapidly. It is thus necessary that the engineer keep always in view the almost certain necessity of a good road in the future. He should, therefore, so locate and construct his line that the first cost be low, and that the standard may be raised, when necessary, without unduly increasing the total expenditure. In order to get the very best results, the line giving best grades, alignment, etc., should always be first located. From this, as a standard, the engineer should work to the final or economic location. Working from a poor to a better is apt to lead to grave errors.

Where low construction costs are necessary, and it is probable that a high standard will be required in the future, it is much more effective and advisable to use short sections of temporary line with steep grades, sharp curves, etc., on the heavy or difficult sections, maintaining the higher standard for the light or easy portions of line, than it is to adopt a generally lower standard for the whole route. The first cost of the former will probably be less; it may be operated with helper engines as the traffic increases, and may be improved when advisable, while the cost of improving a generally poor road is frequently prohibitive.

The use of sharp curves with short tangents is often a very effective means of reducing cost without materially increasing the operating expenses.

The effect of moderately sharp curvature is essentially different from steep grades, inasmuch as it is not limiting in its effect. The use of one sharp curve does not justify the use of another just as sharp, whereas the use of one ruling grade on a division does justify another as steep.

The use of curves up to 14° does not increase the maintenance or operating expenses. A mile of road in which there are 100° of 10° curve, the balance being tangent, does not cost any more to maintain and operate than the same length of road with 100° of 2° curve—in fact, if there is any difference, it is in favor of the sharper curvature.

Unless the curvature is so sharp as to be limiting in its effect, there is no serious objection even on the best class of road to a few sharp curves where the amount saved by their use is sufficient to justify their introduction. The conditions which cause curves to be limiting are when they are so sharp as to prevent the use of the higher grades of modern equipment, and when they limit the haulage capacity of the locomotives, or their speed.

Modern equipment is so constructed as to traverse safely 14° curves, and much sharper with guard and hold up rails. The standard compensation for curvature on grades is 0.4 ft. per degree. A 10° curve is thus equivalent, as far as resistance is concerned, to a 0.4% grade; and a 15° curve to a 0.6% grade. On a 0.4% it is only necessary that the grade on a 10° curve be made level in order that the resistance be not increased. The same thing applies to a 15° curve on a 0.6% grade. It is, therefore, evident that on a road whose ruling grades are 0.4% 10° curves are not limiting to the haulage capacity of the locomotives, nor are 15° curves on a 0.6% grade.