Please read and send in as full a discussion as possible at earliest date.

Canadian Society of Civil Engineers.

INCORPORATED 1887.

ADVANCE PROOF—*(Subject to revision.)*

SOME THEORIES UPON RAILROAD LOCATION,

By J. G. G. Kerry, A.M. Can. Soc. C.E.

March, 1903.

Railway location is again becoming one of the most important branches of civil engineering, partly because Canada is entering an era of railroad construction unequalled in magnitude by any that she has passed through since the completion of the C.P.R. main line in 1885, and partly because the critical study of railroad transportation, commenced, in engineering departments at least, after the publication of the revised edition of Wellington's "Economic Theory of Railroad Location" in 1891, has established principles which call for the almost complete reconstruction of the more important of the older lines.

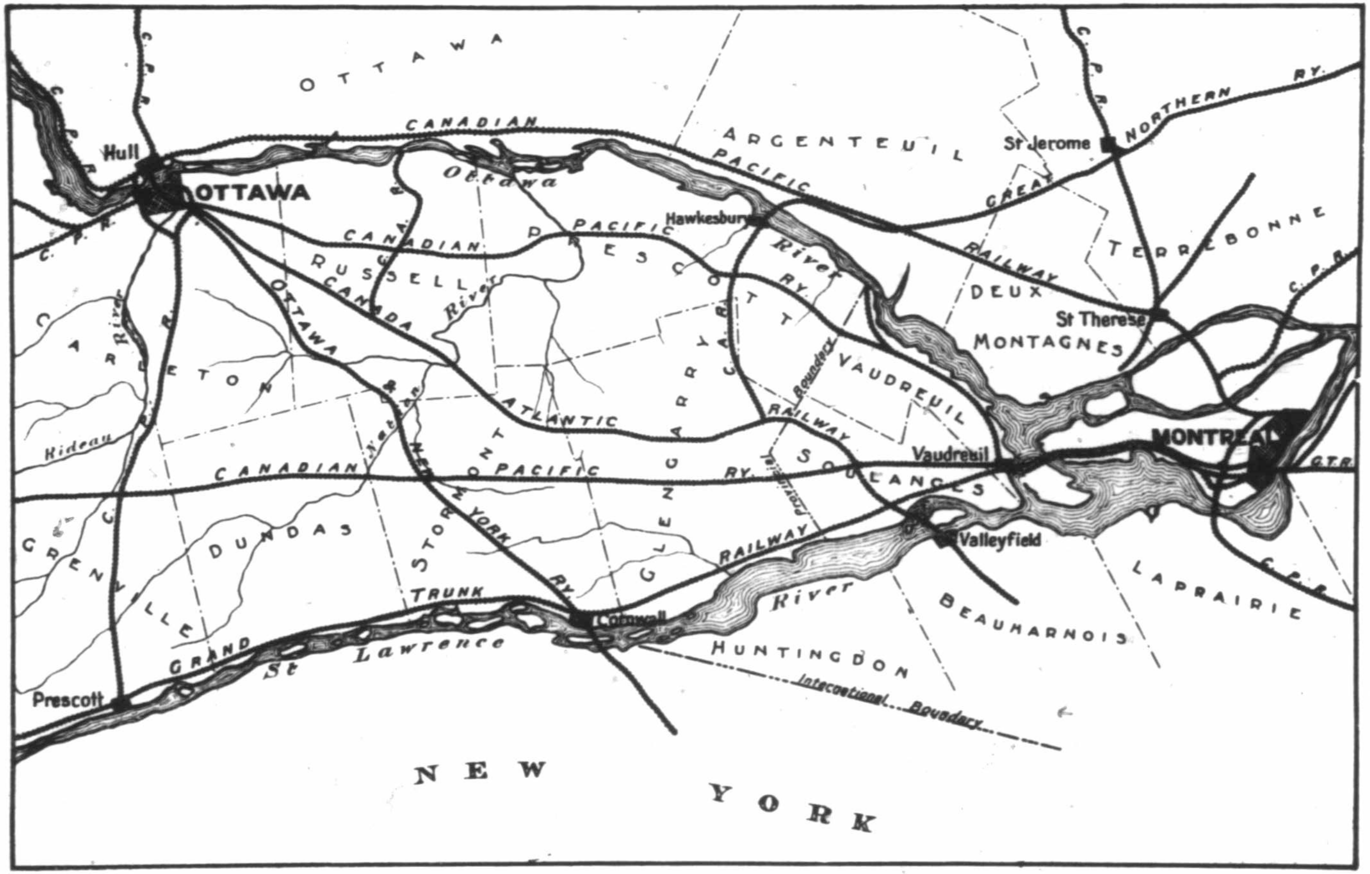

OTTAWA
Hull
OTTAWA
CANADIAN PACIFIC
ARGENTEUIL
St Jerome
NORTHERN RY.
GREAT
TERREBONNE
DEUX MONTAGNES
St Therese
MONTREAL
G.T.R.
C.P.R.
Hawkesbury
River
Ottawa
RUSSELL
PRESCOTT
CANADA ATLANTIC
CARLETON
Rideau
CANADIAN PACIFIC RY.
VAUDREUIL
Vaudreuil
SOULANGES
Valleyfield
LAPRAIRIE
BEAUMARNOIS
HUNTINGDON
International Boundary
Provincial Boundary
GLENGARRY
STORMONT
DUNDAS
GRENVILLE
GRAND TRUNK RAILWAY
NEW YORK RY.
Cornwall
Prescott
St Lawrence
NEW YORK

FIGURE 1.

The great factors in any railroad location, in order of importance, are—

(1) The aims and ideas of the promoters

(2) The position of present and future traffic centres.

(3) The topography of the country.

(4) The economic advantage of adjusting roadbed and rolling stock to one another.

(5) The requirements of modern operating practice.

(6) Difficulties of construction.

The general route of a railroad is rarely determined by engineering considerations. The promoters of the line—be they politicians, railroad men, or speculators—have some political or financial end to attain, and to that end all other considerations will be subordinated. In Canada the completion of our great railways has marked successive stages in the political and commercial growth of the country—the Grand Trunk united the old Canadas, the Intercolonial linked them to the Maritime Provinces, and the Canadian Pacific connected the whole Dominion.

The struggles that took place over the location of these roads are matters of history, and show how clearly the public realized that the problem was of economies rather than of engineering. The history of all the minor lines that have grown up around the great lines is more or less similar, and it is hardly necessary to add that they all have been built where they were thought to be of most immediate advantage to their promoters. It has frequently happened that the route has been determined before an engineer has even been called in for consultation, and in easy country such a practice cannot be considered altogether objectionable. An engineer's training does not fit him in particular, as distinguished from other classes of railroad officials, to foresee the great economic and commercial changes that will be sure to follow the opening up of railroad communication, and at times he would be almost at a loss to choose between competitive routes, had they to be judged from an engineering standpoint only. The four lines that now connect Montreal and Ottawa furnish a good example of this point (see Figure 1); they connect termini that are about one hundred miles apart and yet are as much as fifty miles distant from each other, and their lengths vary from 112 to 125 miles; it can, however, hardly be said that the proportions of the traffic they carry

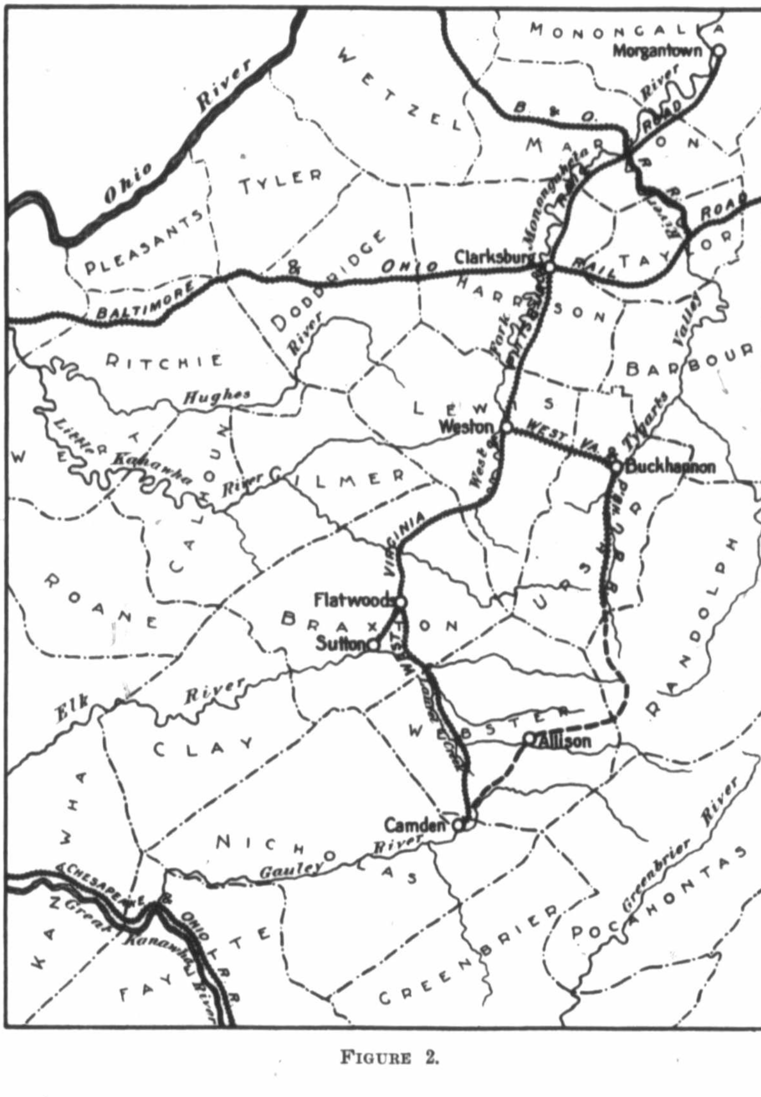
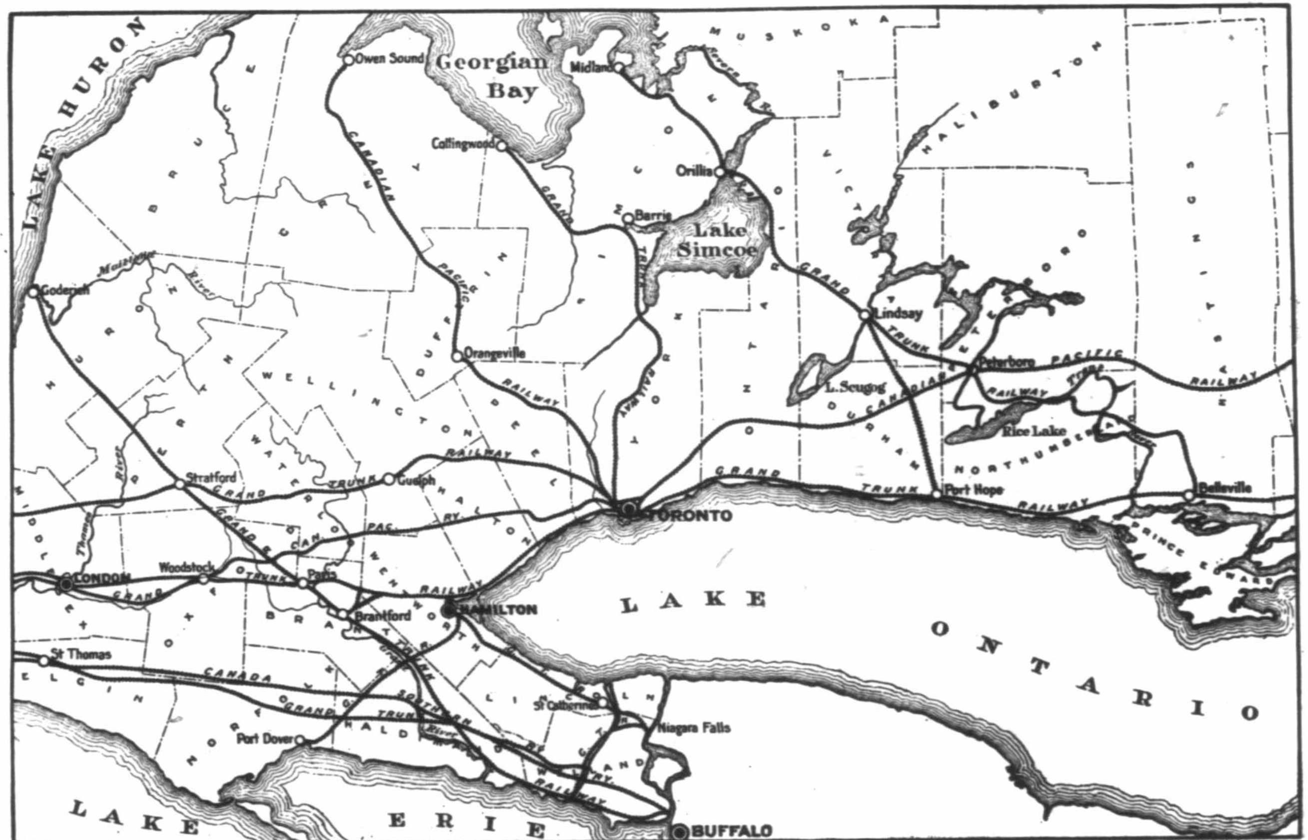

MONONGALIA
Morgantown
WETZEL
Ohio River
TYLER
PLEASANTS
MARION
Monongahela River
B. & O.
ROAD
Clarksburg
BALTIMORE & OHIO RAILROAD
DODDRIDGE
HARRISON
TAYLOR
BARBOUR
RITCHIE
Hughes
LEWIS
Weston
WEST VA. & PITTSBURG
Buckhannon
Tygarts Valley
Little Kanawha River
WIRT
CALHOUN
GILMER
West Fork
VIRGINIA
UPSHUR
RANDOLPH
ROANE
Flatwoods
BRAXTON
Sutton
WEST
Elk River
CLAY
WEBSTER
Allison
Camden
KANAWHA
NICHOLAS
Gauley River
Greenbrier River
POCAHONTAS
GREENBRIER
CHESAPEAKE & OHIO R.R.
Great Kanawha River
FAYETTE

FIGURE 2.

are materially affected by this variation or by any other difference in the engineering detail of the lines; that proportion is determined by terminal facilities and by the support of connections. Instances, on the other hand, are not unknown where the promoters have undertaken to locate a line through what is by no means easy country, and the history of such attempts is the most forcible argument that an engineer can bring forward when opposing any repetition of the same policy. The writer conceives it to be the duty of a chief engineer to form and express an independent opinion upon the merits of any route that he is instructed to examine, the adoption of the route being a question for his employers to decide. A remarkable instance of location without engineering advice occurred in the planning of the Pittsburg and West Va. Railroad, now part of the Baltimore and Ohio system (see Figure 2), but originally built, like the Algoma Central and the Ottawa, Arnprior and Parry Sound, to serve the great business interests of its promoter. It was projected to reach the headquarters of the Gauley River, and the route adopted for the main line was to follow the Buckhannon River; the location parties succeeded in reaching the Elk River crossing, where they found themselves confronted by a range of hills perhaps 800 feet high, forming the side of a high plateau upon which the Gauley River ran, and it became necessary to abandon the original scheme. At the time, the company was building a narrow gauge line with 2 per 100 grades and 18° curves nearly parallel to the main line, and this had to be reconstructed and extended up a favourable valley to the Gauley plateau; the length of line reconstructed being 38 miles.

The growth of the great railroad systems will, in part, save the lines of the future from those curious deviations, due to the influence of local subsidies or to the personal feelings of promoters, that are a feature of many of the older locations.. The fact that a railroad line that has been located and built can never be rebuilt on a better line without serious difficulty and expense, and in many cases cannot be rebuilt at all, is not always realized. There are many places in Canada where the forgotten quarrels or friendships of long years ago have left a permanent record of their occurrence in the shape of an inferior line. Such a place will be found on the old Midland Railway in the township of Mara, where the Railroad Company, decided, as the result of a subsidy quarrel, to avoid every village in the township and to open no stations within it. The policy was carried out, but in time an agreement as



LAKE HURON
Georgian Bay
Lake Simcoe
LAKE ONTARIO
LAKE ERIE
Owen Sound
Midland
Collingwood
Orillia
Barrie
Goderich
Orangeville
Lindsay
L. Scugog
Peterboro
Rice Lake
Port Hope
Belleville
Stratford
Guelph
TORONTO
LONDON
Woodstock
Paris
Brantford
HAMILTON
St Thomas
St Catharines
Niagara Falls
Port Dover
BUFFALO
MUSKOKA
HALIBURTON
VICTORIA
PETERBORO
HASTINGS
NORTHUMBERLAND
DURHAM
ONTARIO
YORK
SIMCOE
GREY
BRUCE
HURON
PERTH
WELLINGTON
WATERLOO
DUFFERIN
PEEL
HALTON
WENTWORTH
BRANT
OXFORD
MIDDLESEX
ELGIN
NORFOLK
HALDIMAND
LINCOLN
WELLAND
PRINCE EDWARD
CANADIAN PACIFIC RAILWAY
GRAND TRUNK RAILWAY
CANADA SOUTHERN

FIGURE 3.

to subsidies and stations was reached, and the quarrel forgotten. Its record remains in lonely stations and a ruined grade line.

Making an exception of those numerous lines which have been built in Canada for the set purpose of opening up new regions for settlement, and whose very existence is due to public liberality, it may be said that all railroads are built as business concerns to transport passengers and freight, and that the share of the business offering that they secure is a fair measure of their success. It has been pointed out in the most recent economic discussion, that the possibility of any producing district shipping into a given market is largely controlled by its transportation facilities, and that therefore every improvement made by the railroad will increase the business opportunities in the district, and consequently the traffic of the line. There have been many bankrupt lines in Canada on account of lack of traffic; there can be none that will succeed without it, and every effort should be made to secure it where it exists and to create it where it is lacking.

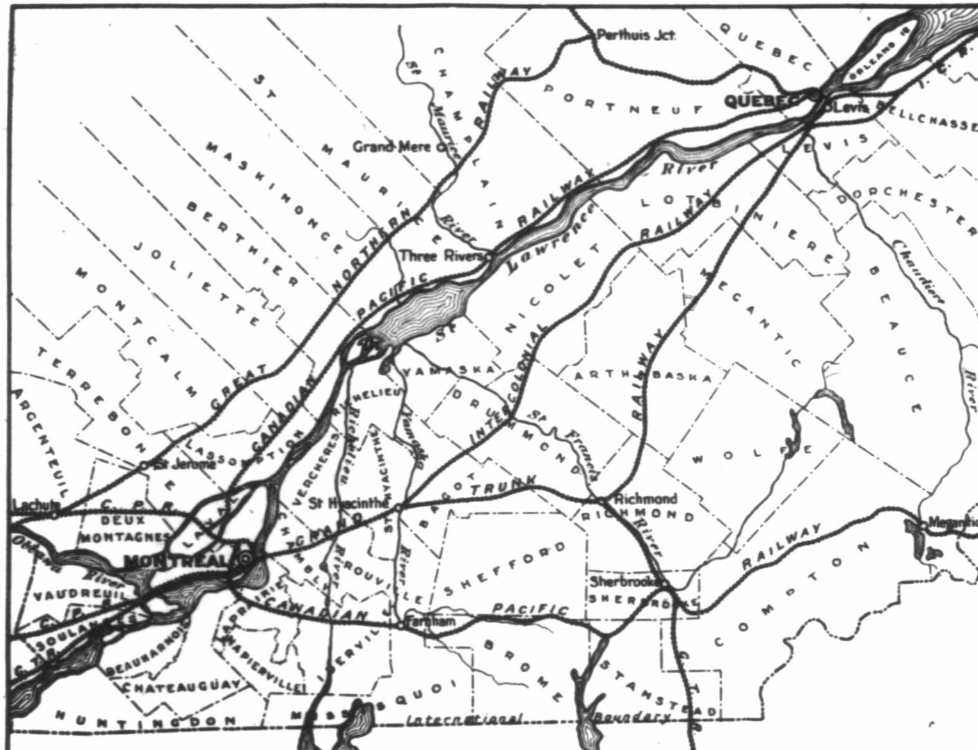
The control of through traffic is hardly affected by the details of location. It is a question of terminals and alliances, and lies within the special province of the general manager or president. It may be advisable to modify the general route to secure such traffic, it certainly will be worth while to reduce the grade line in order to handle it, but it is wise to recognize that it may be entirely cut off from even a powerful system. For example, the extension of the Intercolonial Railway to St. Hyacinthe transferred all its traffic from the Quebec branch of the Grand Trunk to its own new lines.

A notable example of a series of lines that have failed to secure the through traffic which they were planned to handle is found in the Wellington, the Buffalo and Goderich, the Toronto Grey and Bruce, the Northern and the Midland, and other of the "Portage Roads" between Lake Huron and Lake Ontario (see Figure 3). They all hoped to carry a heavy share of the east-bound grain business, and no skill of the locating engineer could have affected the final result. Their failure is to be ascribed to their own financial weakness and consequent inefficiency, and to their inability to recognize the control that established interests have over any trade. They might have had some success had they been a part of a thoroughly organized through system and backed by powerful grain shipping interests; being but one link in an unorganized system they failed. The desirability of adding yet another to their number by building the "National Transportation Route" between Collingwood and Toronto is often urged at the present time. It seems to the writer that this line, no matter how skilfully built, will prove an utter failure unless it is but part of a vast lake, rail and river transportation system under one management, and in any case he is frankly doubtful of the ability of the present St. Lawrence Canal system to hold its own against railroad competition.

Through traffic may therefore be considered as a very important factor in the future of a railroad, but one to which it is not wise to give great weight, except under instructions from the general officials. It is far otherwise with local traffic, the development of which depends upon the facilities provided by the railroad company for handling it, and which, being largely a monopoly, should be most carefully fostered.

Much of the railroad line now projected will run through practically unsettled districts, and it may be safely predicted that the situation of the future centres of population that will control local trade will be determined by the presence of natural resources, and by the location of the railroad. It follows that the more nearly these two causes can be brought together the better it will be for the future of both country and railroad. It is not easy in preliminary survey to recognize the existence of the natural resources, nor to realize how great their future development may be. The location engineer, indeed, gets but few opportunities to observe the growth of traffic on the lines that he has planned; but he should certainly know what staples constitute the bulk of the traffic in adjoining districts, and why they are produced there. Statistics are published annually by the Department of Railways and Canals giving the tonnages of different articles of freight handled upon various railroad lines. The location of the Great Northern Railway (see Plate XX.) is a recent example of a line avowedly laid out to approach as nearly as possible to the great Laurentian water powers, which were considered to have the greatest traffic producing possibilities of all the resources in the district.

In Eastern Canada the commercial centres are well established and practically all traffic originates near them. Any effort to ignore these existing centres will result in the material disadvantage of both town and railroad; the town will be handicapped in its commercial growth and the railroad will lose the business that would have been created. The locations of fifty years ago are full of efforts of this kind, made, it is said, largely in the hope of inducing the town to move on to land in the immediate vicinity



Perthuis Jct.
QUEBEC
QUEBEC
Levis
LEVIS
PORTNEUF
CHAMPLAIN
ST MAURICE
MASKINONGE
BERTHIER
JOLIETTE
MONTCALM
TERREBONNE
ARGENTEUIL
Grand Mere
Three Rivers
St Maurice
NORTHERN
GREAT
CANADIAN
PACIFIC
RAILWAY
St Lawrence
River
NICOLET
LOTBINIERE
MEGANTIC
BEAUCE
DORCHESTER
Chaudiere
River
ARTHABASKA
WOLFE
DRUMMOND
St Francis
INTERCOLONIAL
YAMASKA
RICHELIEU
VERCHERES
Richelieu
St Jerome
L'ASSOMPTION
Lachute
C.P.R.
DEUX
MONTAGNES
MONTREAL
Ottawa River
VAUDREUIL
SOULANGES
BEAUHARNOIS
CHATEAUGUAY
HUNTINGDON
NAPIERVILLE
LAPRAIRIE
St Hyacinthe
ST HYACINTHE
GRAND
TRUNK
BAGOT
SHEFFORD
ROUVILLE
Farnham
MISSISQUOI
BROME
STANSTEAD
International
Boundary
Sherbrooke
SHERBROOKE
Richmond
RICHMOND
COMPTON
Megantic

Figure 4.

of the railroad station, and owned by the railroad promoters. The series of towns along the north shore of Lake Ontario, between Toronto and Kingston, are proof of the inability of a railroad company to compel an eastern town to move; they still stand where they stood 50 years ago when the railroad was built past them.

Brantford (see Figure 3) has furnished the most remarkable example of the power of an established town to hold its own against a railway company. The Great Western passed it by about 1850, when it had a population of 3,877, and located through its rival, Paris, which had a population of 1,890, the final choice having been influenced, it is said, by a subsidy. To-day, after over fifty years of struggle, Brantford has at last succeeded in getting the main line traffic of the old Great Western diverted into it, and in spite of transportation difficulties, has grown into a city of over 16,000 inhabitants, one of the most active manufacturing centres in Canada.

It may therefore be taken as good practice in Eastern Canada to carry the location directly into the existing towns, no matter how great may be the cost of right of way or the sacrifice of engineering niceties, for the return will in nearly every case give ample profit on the expenditure. In exceptional cases it may be necessary to construct a freight loop around the town if too serious a sacrifice of grade would otherwise be required, but by the use of momentum freight can be carried directly through a town situated in a hollow. The C.P.R. line into the town of Lachute has 1.00 per 100 falling grades on each side of the town, and runs its traffic straight through without stopping, unless there is local business to be attended to.

The preponderating share that the C.P.R. secures of Montreal-Quebec traffic, although its line is nine miles longer than the I.C.R. and about equal to the G.T.R. (see Figure 4), is an extreme example of the value of a properly located station site.

That any man who can handle surveying instruments is popularly regarded as entirely competent to make a railroad location is but a most general proof of the important influence exercised upon the details of location by topography. The engineer must know his country thoroughly, and it may be said that any man who is sent out on location without having opportunity to study all the information that has been accumulated in the past about his district is improperly equipped. The various Canadian governments have for years been sending out exploring and surveying parties to gather information about unsettled areas, and when it is remembered that these parties are generally in charge of trained observers and surveyors, the value of their reports and of their maps cannot be overestimated. The very fact that these reports are not made by railroad engineers increases their value, for the observations deal largely with the general and mineral resources of the country, which should be controlling factors in the location, but which are often not noted by an engineer absorbed in the study of those details which appear on plan and profile.

Maps and local knowledge are the two first things to be secured in the equipment of a survey party. Where accurate maps cannot be obtained, there is no source of information of more general value than the men who have worked for long periods in the district, and have had years in which to learn what the engineer is usually expected to acquire in a few weeks. The knowledge that they possess may not be such as to be immediately applicable to the problem of selecting a line; but the first duty of an engineer is to get thoroughly acquainted with the general topography of the district, and by availing himself of the services of the local men and by exploring with the assistance of such minor instruments as the hand level, the aneroid barometer, and the pocket compass he can accomplish this speedily.

It is to be remembered that the great engineering errors in railroad location are made in most cases before the instrumental surveys are even started, and that the more widely the preliminary explorations are extended, and the more completely all local sources of information are utilized, the better will the engineer be fitted to deal with the problem that he has been given to solve. The policy now adopted by some Canadian lines of keeping small reconnaisance parties in the field to work up information requisite for future locations is admirable practice, the value of the result being, however, in direct proportion to the character of the men employed, for there is no task that calls for more steady, thoroughgoing, conscientious hard work than the complete exploration of any piece of country. Exploration should never be regarded as complete until the engineer is able to select the route along which his detail surveys will be made.

The work of exploration is almost unnecessary in districts of which complete topographical maps have been published. A sheet showing all roads, towns, rivers, streams and contour lines with 20 feet intervals, leaves little for the engineer to desire for his preliminary studies, and such sheets are obtainable for parts of the Eastern states. The writer has noted, however, that many published topographical maps are inaccurate in detail, and would always go over a paper route before commencing to make a survey of it. It is a consequence of the large area and sparse population of Canada that no such maps are as yet published here, but their value to the public at large and to the engineers in particular cannot be doubted. It seems therefore full time for a body such as the Can. Soc. C.E., the majority of whose members have need of satisfactory local maps, to commence to agitate for the establishment of a topographical survey. Much valuable work has already been done by the Geological Survey and by the Crown Lands Departments; but these are bureaus organized for special purposes, to the work of which accurate maps are merely an essential detail, and the task of making a general survey of the whole of Canada is one of such vast dimensions that it can appropriately be entrusted to an independent office only. The American policy of co-operation between the central government surveys and the several states might advantageously be copied.

When the exploration has been completed, railroad location becomes a problem of detail surveying, in which the necessity of reducing first cost to a minimum has to be constantly balanced against the demands of the operating departments for a straight and level track. Surveys with instruments of precision are necessary to adjust the alignment so nicely to the local contour that no stretches of track will be built over which rolling stock cannot be advantageously operated; and the area that can be covered by a precision survey is so limited that nothing but this local adjustment should be expected from it.

In making such an adjustment the fact that a railroad is simply a great machine for moving traffic must always be kept in mind. It is a machine which has the unique distinction of having two great and often apparently independent parts, the track and the rolling stock; and these are designed by two distinct bodies of men, who have been trained along entirely different lines, and whose views as to the best schemes for future improvement are often antagonistic. The work of the locating engineer will, in most cases, remain unaltered in service for a much longer time than that of his mechanical confrere, and should therefore be designed so that the operating department will always be able to take full advantage of the improvements in rolling stock that are constantly being made.

DIAGRAM SHOWING OPERATING RESULTS GRAND TRUNK RAILWAY.

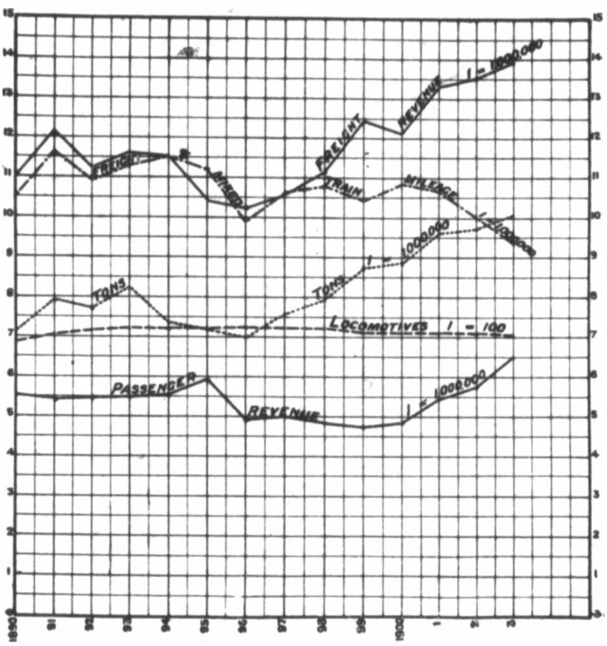


FIGURE 5.

The engineer certainly cannot make this provision without some knowledge of the mechanical principles which control locomotive design and of the developments that may be expected in the immediate future. These developments are usually foreshadowed by the practice of the lines carrying the heaviest traffic, and are thoroughly discussed in the current technical press.

Engineers generally do not recognize how available the publications of that press are when systematically bound and arranged in libraries, such as that of the Can. Soc. C.E., nor how quickly any important article can be found in it with the aid of the engineering indexes now regularly issued.

In the "Economic Theory of Railroad Location," the variation of operating costs with train mileage was made the base of all calculations; and although the systematic studies now made by the audit and statistical departments show that train mile cost is not the same for trains in dissimilar service, the heavy freight traffic is of such preponderating importance to Canadian railroads that increase of train-load can be accepted as proof of improvement in operating. The following table, compiled from the statistics published by the Department of Railways and Canals, shows the results attained in the operation of the Grand Trunk Railway during the past fourteen years. The facts most worthy of note that it brings out are the recent rapid increase of tonnage handled, the decreasing freight train mileage, the unvarying number of locomotives in service, and the relative importance of the freight business; and these are shown graphically in the accompanying cut (Figure 5). Were the figures for the present year as yet compiled, they would show with much greater distinctness the features referred to, for the traffic of this spring is beyond all precedent in its magnitude.

TABLE OF OPERATING STATISTICS, GRAND TRUNK RAILWAY.

Date of Report.	Miles Operated.	Number of Passengers Carried 1=1.000,000.	No. Tons Freight Carried 1=1,000,000.	Passenger Train Mileage 1=1,000,000.	Freight Train Mileage 1=1,000,000.	Mixed Train Mileage 1=1,000,000.	Passenger Revenue 1=1,000.000.	Freight Revenue 1=1,000,000.	Number of Locomotives.	Number of Box, Cattle and Refrigerator Cars
1890	3114	5.92	7.13	5.08	8.17	2.36	5.53	11.06	687	13744
1891	3122	5.87	7.91	5.40	9.33	2.25	5.42	12.15	701	14864
1892	3143	5.91	7.74	5.50	8.79	2.20	5 46	11.22	717	15529
1893	3158	5.90	8.25	5.42	8.99	2.33	5.46	11.62	722	16014
1894	3168	5.70	7.35	5.79	9.29	2.21	5.54	11.55	722	16014
1895	3158	6.20	7.18	6.33	8.95	2.30	5.94	10 47	722	16014
1896	3162	5.05	7.00	5.44	7.85	2.09	4.95	10.23	722	16014
1897	3162	5 08	7.59	5.64	8.52	2.08	5.00	10.58	722	16517
1898	3162	5.56	7.95	5.52	9.00	1.80	4.86	11.17	722	15536
1899	3162	6.04	8.77	5.57	9.34	1.08	4.75	12.34	710	16418
1900	3147	6.18	8.88	6.12	9 88	1.00	4.83	12.11	710	17513
1901	3153	6.21	9.62	5.82	9.65	1.01	5.48	13.33	710	17138
1902	3138	6.55	9.75	..	..	..	5.65	13.58	709	18068
1903	3142	7.33	10.08	6.16	8.30	1.01	6.51	13.99	705	18412

In considering these figures, it is fair to take the freight and mixed train mileage together. The railroad man will see in the results evidence of increased efficiency in operating, but to the engineer they are particularly interesting, as showing, by the decreased train mileage, that the freight tonnage is being moved with a decreasing cost and mechanical effort per ton.

A regret may here be expressed that the Canadian Government does not see fit to call for ton and passenger mileage in its statistical requirements, and that it does not furnish such statistics in connection with the operation of the Intercolonial Railway. In the mechanical act of transportation the work done is but half measured when quantities only are recorded.

That the most efficient railroad is the one whose track and motive power are best adjusted to each other is the lesson of modern operating, but before considering how this adjustment should be made, it will be well to notice the great development in rolling stock that has taken place since the days of the C.P.R. surveys. The specifications of about 1885 called for the use of rolling loads, consisting of engines weighing 110,000 lbs., followed by 3,000 lbs. per lineal foot; those of to-day require engines of 225,000 lbs. followed by 5,000 lbs. per lineal foot.

The modern car for heavy ore and coal traffic has a nominal capacity of 100,000 lbs. and a weight of about 36,000 lbs. Remembering that it is not unusual to overload these cars, and that some of them are not above 30 feet in length, it will be seen that the extra heavy specification of to-day is not in advance of the extremes of present practice, and that weights as high as 40,000 lbs. are sometimes concentrated on a single car axle. These ore cars are, however, somewhat exceptional, and for regular freight traffic cars of 60,000 lbs. capacity, with weights slightly over 30,000 lbs., are most common.

During an extensive discussion before the New York Railroad Clubs in November, 1901, Mr. Vauclain stated that a load of 45,000 lbs. per axle might be considered the limit of good locomotive practice at that date, and although in special cases it has been exceeded, there are but few engines in service on the continent to-day with axle loads exceeding 50,000 lbs. In Canadian practice the maximum axle loads vary from 45,000 to 50,000 lbs. on the various roads, the heaviest loadings being found on engines of the 10-wheel and mogul types. In the discussion referred to, the increase of grate area and boiler heating surface were pointed out as being the latest achievements of locomotive engineering.

The following table gives a few details of some recent heavy engines:—

TABLE OF LOCOMOTIVE DETAILS.

Road.	Type.	Driving wheel base.		Total wheel base, engine and tender.		Weight on driving wheels.	Maximum load on one driving axle.	Heating surface.
		Ft.	In.	Ft.	In.	Lbs.	Lbs.	Sq. Ft
Atchison, Topeka & Santa Fe	2100	20	0	62	0	232,000	....	4682
St. Paul, Minneapolis and Sault Ste. Marie	2100	19	4	57	4	184,360	....	3015
Pittsburgh, Bessemer & Lake Erie	280	15	7	58	0	225,200	59,400	3805
Union	280	15	7	54	9½	208,000	45,600	3322
Chicago, Burlington & Quincy	262	12	1	54	5½	130,000	...	3343
Southern Pacific	460	13	8	52	2	130,000	....	2222
Cleveland, Cincinnati, Chicago & St. Louis	442	7	6	55	4	100,000	....	3340
Canada Atlantic	442	7	6	....		86,030	....	2290
Canadian Pacific	460	14	6	52	5½	126,750	45,750	2421
Grand Trunk	460	25	8	53	9	132,610	42,260	2460
Grand Trunk	260	15	8	50	11	140,740	49,530	1991
Intercolonial	280	15	11	50	11	154,750	45,100	....
Canada Atlantic	280	15	0	....		156,000	....	....

NOTE.—The weight on a single axle is sometimes increased beyond the figures given above by the use of traction increasers.

It has often been stated that the increase of rolling stock weights must very soon cease, and as often the prediction has proved to be entirely wrong. There are some facts that to-day point to at least a temporary suspension in this increase. These are the establishment of a standard box-car, the proven difficulty in economically handling trains more than 70 cars in length, and the difficulty of obtaining satisfactory rail to use under existing rolling stock.

Almost any piece of Canadian track is likely, owing to the free movement of cars, to be subjected at any time to the maximum carloads mentioned, unless special action is taken by the operating department to protect lines that are unsafe under such loadings. The heavy grade lines to the east of Montreal will cause the very heaviest classes of locomotives to be introduced on our roads as the traffic increases, and the location engineer must therefore recognize that his line may be subjected to the heaviest loadings that the practice of the future will sanction.

In order to adjust his line so as to permit the easiest train movement, the engineer must thoroughly understand the action of the forces that affect that movement. These forces are locomotive power, momentum, gravity, curve friction and that miscellaneous group known as running resistance, and all of them are variable in amount according to circumstances.

Locomotive power is produced in the boiler and firebox, and is determined at any speed by the amount of steam that can be obtained. The maximum tractive force is rarely made more than one-fourth of the weight on the drivers in order to avoid slipping, and the minimum can be calculated when the size of cylinders, length of stroke, diameter of drivers and mean effective steam pressure are known. Formulae for such calculations will be found in modern pocket books, and are contained in a paper on the "Economics of Railway Improvements," read before the Can. Soc. C.E. in 1901 by W. W. Colpitts.

The kinetic energy or "momentum" of a moving train is measured by the height to which the train would be lifted by it against the action of gravity alone. The formula for this height is given by Wellington as

$$H = 0.0355\ V^2 \qquad (1)$$

where H is in feet and V in miles per hour. The expression includes a term which varies with the design and loading of the cars, and should be slightly greater for empties.

The resistance of gravity in lbs. per ton is given by the well-known formula—

$$Rg. = 2000 \times \frac{F}{100} \qquad (2)$$

where F is the rise of the grade in feet per 100. It is the one absolutely determinable train resistance, and varies only with the grade.

Curve friction is given in lbs. per ton by the formula—

$$Rc = 1 + \frac{D}{2} \qquad (3)$$

where D is the degree of curve. This resistance is known to be a variable quantity, depending upon the condition of wheel and rail, and upon the design and loading of the rolling stock. It can be greatly increased by loading to such an extent that side bearings come into play. In an instance mentioned in the Proceedings of the Western Railway Club (May, 1901), an engine which pulled 405 tons of empties through sharp curvature and up a 1.00 per 100 grade could not handle more than 355 tons of overloaded cars up the same track; empties are ordinarily assumed to pull 30 per cent. more heavily than loads. Extra resistance due to overloading will be felt mainly on entering and on leaving curves.

Running resistance varies with temperature, wind, snow, lubrication, speed, condition of track, strength of track and condition of rolling stock, and may briefly be said to be so variable that only a fair average value can be ascertained. Many formulae have been proposed for it, but are not generally accepted. The Baldwin Locomotive Works have proposed the formula—

$$Rt = 3 + \frac{V}{6} \qquad (4)$$

where R is in lbs. per ton and V. in miles per hour. This may for the present be accepted for speeds exceeding 12 miles per hour, nearly all experimenters agreeing that the resistance increases with the speed. No equation has yet been suggested for the resistance at low speeds, values at 20 at starting, 10 when V=2, and about 5 when V=5 having been suggested. An average value of 6 to 7 lbs. may be taken up to speeds of 5 miles per hour.

It is noteworthy that the M.C.B. Committee, in their celebrated brake report in 1887, state that this resistance may be taken as constant between speeds of 12 and 25 miles per hour, and may be given a value of 6 lbs. for cars in service and 8 lbs. for new cars. The resistance was increased by about 2½ lbs. by a 3° curve; the figures were obtained from trains with locomotives attached.

In a paper recently read before the Am. Soc. C.E. (Dec., 1902), Mr. J. S. Dennis states that, as the result of 3,000 miles of dynamometer car observations, he concludes that the resistance practically does not vary between speeds of 7 and 35 miles per hour, and may be taken at 9 lbs. for the locomotive and for empty cars, and at 2.6 lbs. for the load, giving an average of 4.7 lbs. The tests show an increase of from 5 to 6 lbs. at starting speeds, and include only the car resistances, the locomotive value being obtained by a separate test. Owing to the unexpected conclusions, and the lack of detail description as to the methods followed in making the deductions from the observations, these results will be accepted with some hesitation. Taken in conjunction with the M.C.B. tests, they may, however, be accepted as proof that the assumption of an average resistance of 5 lbs. would never be seriously in error for freight cars in good condition, and working at ordinary speeds in good weather, but the writer would prefer to use the Baldwin formula until further evidence is forthcoming. It is at least on the safe side.

It is probable that improvements in car design will further reduce running resistance, and it is therefore justifiable to use a low value for it. The effect of so doing would be to magnify the importance of grade reduction. The great increase of running resistance due to climate and weather must be left to the operating department to provide for.

The movement of a train subjected to these varying forces and resistances can best be shown by acceleration and retardation curves similar to those published by Mr. Dennis and by Mr. Colpitts. In preparing such diagrams for use in location and grade reduction studies, it appears to be customary to assume the use of some standard engine and standard train weight. The writer would express the opinion that the use of the details of any particular class of locomotive is not justifiable in such calculations. The purpose of the engineer is to adjust his track to the performances of all classes of freight locomotives, and accordingly only those details which are true for all classes ought to be taken into account.

The use that is to be made of the facts concerning locomotive performance in location and grade reduction is entirely different to the application of the same facts to daily operation. Train loading is now so closely watched and so systematically recorded that the operating officials know that they must get the utmost service out of every machine under their orders; and in this they can be greatly assisted by rating tables, based either on the theoretical calculations of the performance of each separate class of locomotive in service, or upon the results of actual service tests made with or without the assistance of a dynamometer car. No matter how minutely such tables have been prepared, weather conditions require a large margin to be left for the exercise of judgment by the responsible officials.

Briefly, it is the practice of the day to load every locomotive fully up to its capacity, and the engineer may therefore safely assume that the tractive power of every locomotive per unit of train weight will be equal, provided that the locomotives are being operated in the same service.

As all locomotive power comes from the combustion in the firebox, and as it is known that this is most satisfactory when taking place at a uniform rate, it seems safe to assume that the horsepower a locomotive can produce is a constant at ordinary operating speeds of from 10 to 35 miles an hour, and does not vary with the speed. An inspection of a set of horse-power curves will show that this is approximately true, some classes increasing their horse-power with speed and others decreasing it. In view of the present demands for increasing speed in freight service, the latter classes will probably disappear in due time.

The tractive power of any locomotive may therefore be given in lbs. per ton of train weight, as

$$Ts = 2000 \times \frac{Fs}{100} + R \qquad (5)$$

where Fs is the rise of the ruling grade in feet per 100 and R is the running resistance at the proposed standard speed, Vs.

The horse-power being assumed to be constant, the tractive power at any speed is given by

$$T = \frac{Ts \times Vs}{V} \qquad (6)$$

and the average tractive power between any two speeds, V_1 and V_2, by

$$Ta = \frac{Ts \times Vs}{} + \left\{ \frac{2.3025 (\log V_1 - V_2)}{V_1 - V_2} \right\} \qquad (7)$$

this formula being obtained by integration from the relation—

$$T \times V = Ts \times Vs = \text{Horsepower} = \text{Constant.}$$

In any run of length d feet, the surplus or deficiency of tractive power exerted will be measured by the gain or loss of train velocity, the extra work being absorbed in changing the kinetic energy of the train. Therefore the formula

$$(Ta - R)\, d = 2000 \times .0355 (V_1^2 - V_2^2) = 71 (V_1^2 - V_2^2) \qquad (8)$$

will give the distance to be run to acquire an increase of speed from V_2 to V_1 Ta being the average tractive force exerted between the given velocities, and R the average resistance from all causes.

If the ruling grade be chosen, it is easy to calculate by the above formulae the relation between distance and velocity, when the train is moving on any given grade, and to represent this relation by a diagram similar to those previously mentioned. It would differ from them, indeed, only in not being dependent upon the performance of any particular locomotive.

Such diagrams are used in practice to obtain the speed that the train will have at any point on the line, and are essential on roads in which the use of "momentum grades" in location is permitted. It should be noted that in the discussion the train is considered as a single body, all parts of which are subject to the same forces, an assumption which is frequently far from true. A new diagram will be required if the ruling grade be altered, and in use the profile grades must be increased by the equivalent of the curve resistance. The curves, as plotted, show clearly that the effect of momentum is a temporary one, and that the train will gradually slow down to that speed at which the tractive power alone is able to keep it moving up the grade.

The safety of using "momentum grades" in location is one of the disputed points of present practice. Comparing "momentum" with locomotive tractive power, it may be said that tractive power is directly dependent upon the condition of the engine and the skill of its crew, and will often be much below its calculated value, and that momentum is equally uncertain if the velocity which is essential to its existence is obtained from surplus engine power. Momentum which is obtained by the action of gravity is the most dependable of mechanical forces. The use of momentum grades is universal in operating practice. As a case in point, the Lachute example, already referred to, may be quoted, or the action of the Grand Trunk Railway in moving Gananoque Junction about 1½ miles eastward in order to place it at the top of a long up-grade, which included a stretch of 50 feet to the mile gradient.

The possibilities of using momentum to advantage are greatly limited by topographical conditions. As already remarked, it gives no assistance at the upper end of long grades, and the use of short, sharp grades is limited by the necessity of changing the rate of grade slowly at summit and hollow, which will sometimes altogether prevent their introduction. Its assistance can be gained only at the price of reduced speed, which may be undesirable where fast service is necessary, and there is always an uncertainty as to the continued existence of the conditions which make the required velocity of approach a possibility. The necessary control of speed due to features of the existing track, the demands for new stations and sidings by future industrial development, and the establishment of level road on railroad crossings may at any time render momentum operation impossible. During the past year the Railway Committee, in one instance, sanctioned the putting in of a level railroad crossing across a line carrying one of the fastest and most important passenger traffics in Canada, and in the very centre of a long grade averaging 35 feet to the mile. This example—the crossing of the Grand Trunk line by the Aurora and Schomberg Railway—indicates very clearly the caution that should be observed in planning momentum grades.

When used, they should be introduced as close as possible to the foot of the hill, and there seems no strong objection to rates of grade as steep as the pusher equivalent of the ruling grade. A stalled train cannot be divided into fewer than two parts, and for certainty of operation a doubling siding should be placed at the head of every serious momentum grade.

The writer is of opinion that railroad practice sanctions the use of momentum wherever thorough surveys have demonstrated the impossibility of securing a direct line without it. He knows no district naturally more adapted for its use than the country lying to the north of Lake Ontario and to the east of Toronto, and there its free application would probably result in shorter and more direct lines. In practice, many cases occur where the raising of a grade line by but a few feet would result in great economy, and in such instances it would seem folly to refuse to make use of momentum to gain those feet.

The value to an engineer of a study of rolling stock development lies in its enabling him to modify his ideas as to a satisfactory road for operation, in accordance with the progress that is made by the mechanical departments. Railroad location is in detail so absolutely a matter of topography that the operating requirements sufficiently important to affect it are usually expressed in a few general rules as to grade and curvature, and these rules are sometimes accepted in practice without full understanding of the reasons for adopting the limits prescribed.

The theory that minimum train mileage will result in maximum economy of operation is, as has been said, generally accepted as the working maxim of present day operating, The importance of the rate of the ruling grade is easily understood when it is realized that grade resistance is about two-thirds of the total train resistance on many Canadian lines, and as the locomotive cannot exert more than a certain maximum pull, the train mileage necessary to move a given tonnage is proportionately increased. Train movement is most economically effected on lines of long uniform grades, with the lowest possible rate of rise, simply because power is produced by a locomotiv e most economically at a uniform rate; and if in the future some power, such as electricity, the effort of which can be immediately increased to meet any increase of resistance, be successfully adapted to freight train movement, the importance of low ruling grade will be greatly reduced. There is no tendency towards the adoption of electric power for heavy freight service at present discernable in practice, the employment of that power being restricted to street car and underground lines.

The selection of the ruling grade to be used is the most important technical problem to be settled by the surveys. It is exceedingly difficult to reduce it below the rate of the general rise of the country except by developments, the economy of which in many cases may be questioned, and the practice of laying down the ruling grade before the topography of the line has been studied is capable of little defence; in the past it has resulted in far too free use of the maximum. Wellington's claim that the ruling grades of many lines could have been reduced by one half without material increase of cost is perfectly correct as regards some of the older Canadian lines. It must be recognized that the economic effect of grade reduction can, and daily is being secured by increase of motive power, and that in general it will be cheaper to attain that effect by the latter method than by attempting to reduce the grade beyond the limit that the ground sets. Abrupt rises, such as the Niagara escarpment, which occur perhaps but once in the length of a line, must be overcome either by developments or by pusher grades. For heavy traffic, where the pusher engines can be kept fully occupied, the latter is preferable, and on light traffic lines its equivalent can be secured by the use of doubling tracks. The writer knows one instance where a ruling grade of 30 feet to the mile was secured by a development involving an increase of 9-10 of a mile in a distance of 2½ miles, as well as an increase of about 140° curvature and two railway grade crossings. This line was intended to be as perfect as engineering skill could make it, and yet all the above difficulties could have been avoided by the use of a grade of 53 feet to the mile, at a point where abundance of motive power was always available. It is not to be concluded that pusher grades are always better than developments, but only that both methods, and the advances they have in connection with the local topography, should be studied. The use of the rolling grade should always be avoided when possible.

In railway economics but little advantage is shown to result from reduction of curvature. There is, however, no doubt, that it is received with general approval by all employees connected with the operating department, and that it will become even more popular as train speeds and weights of rolling stock increase. As already noted, train resistance is materially increased by curvature, and compensation by grade reduction must therefore be made on all ruling grades, and preferably on all heavy grades. On account of the known increase of this resistance with bad condition of track and rolling stock, the compensation should be liberal, and should be carried out to the ends of the transition curves. The effect of curvature in increasing starting resistances is not known, but very strong objection to stalling on a curve exists among train hands. The maximum degree of curve to be used should, like the ruling grade, be determined by the local topography, the demand for easy curvature being mainly from high speed traffic, a variety which occupies far more space in the public and the railroad mind than its financial importance seems to warrant. In Eastern Canada there seems but little need of curvature sharper than 4°.

The increase of running resistance at starting also must be compensated for. Important yards really form a special location study in themselves, but minor yards are much alike in design, and can be treated in a general way. The running resistance is increased by about 2 lbs. by temporary stops, and by from 6 to 10 lbs. by prolonged ones. Assuming the upper limit as the safer in practice, and making an allowance for the extra power a locomotive can exert at low speeds, the formula for yard grade would be

$$\frac{7}{8}\left(5 \times 2000 \frac{Fr.}{100}\right) = 15 \times 2000 \frac{Fy}{100} \qquad (9)$$

Fr and Fy being the rise of ruling and yard grades respectively in feet per 100, and 5 and 15 the track and yard running resistances in lbs. per ton. Where sand is used, and with compound engines working simple, less compensation will be required. The equation given is unsatisfactory, in that it makes no allowance for the powerful assistance that may be obtained from the springs in the draft gear, and it is noteworthy that in the Burlington tests in 1887 the trains always started with this assistance, and stalled after moving a short distance. Practically a level yard is the most desirable, and when it cannot be obtained, a grade reduction of at least 0.50 per 100 should be tried for. The flattened grade should be continued for such a distance that the train can acquire a speed of 5 miles per hour, this being the speed at which most of extra running resistance will be found to have disappeared. The running resistance averages about 7 lbs. up to this speed, and the distance is given by the formula

$$\left(5 \times 2000 \times \frac{Fs.}{100}\right) d = \left(7 + 2000 \frac{Fy.}{100}\right) d + 0.0355 \times 2000 \times 5^2 \qquad (10)$$

It is desirable that the train should acquire speed rapidly, and therefore the grade leaving the yard should be as low as possible, and at least such that it will be about 3 feet below a ruling grade, drawn from a point half a train length back of the point last determined.

At the lower end of the yard it may be desirable to use a short length of sharpened grade, in order that the main yard can more easily be made level. Such a grade will act simply as a permanent brake, and its length and rise should be adjusted to the assured velocity of approach. There are comparatively few stopping points to be provided for on any line, and the adjustment of the grades to and from them to suit theoretical considerations should not prove excessively costly.

With the recent increase of rolling stock weights has come an enormous increase in the proportion of "cripple" cars having defective draft gear. The design of couplings and drawbars is being very carefully studied by the Master Car Builders' Association, but it is also necessary that the possibility of subjecting these connections to sudden shock should be avoided as far as possible. Any condition which permits or compels the cars to crowd together, particularly when the engine is braked or running without steam, makes it certain that the connecting gear will be subject to some shock when the engine is subsequently given steam. By acting with judgment, the driver can make the shock very light, and a break in two can be considered as more directly due to his handling than to any arrangement of the grade line. The possibility of the cars crowding together should, however, be prevented when this can be done, and the grade line must be arranged so that the forces acting on the several cars in the train are nearly equal. Vertical curves are introduced for this purpose, and should be made with as small a rate of change of grade as topography and economy will permit. There is no theoretical reasoning from which a proper rate of change can be calculated, and there will always be a tendency for the cars to crowd whenever the grade falls more quickly at the rear end of the train than at the head if the engine is not under steam.

When the limits of grade and curvature have been fixed, railroad location becomes little more than the solution by survey of a series of problems, in each of which the operating economy of lowered summits, reduced curvature, and shortened distance has to be balanced against the cost, as shown by the surveys and estimates, of making these improvements. The proper figures to use in calculating operating economy are very difficult to determine, and the values given by Wellington are still generally accepted in practice in spite of the great advancement that has been made in operating methods during the last ten years. The train mileage, upon which all economic calculations are based, is itself so uncertain a quantity that there is no special advantage in having very close values determined by the saving resulting from unit improvements in grade and curvature and distance. The statistics published annually by the Department of Railways and Canals give details of the train movement on the various Canadian roads, and furnish valuable figures for the prediction of train mileage on new roads. The character, resources and population can be determined by inspection and by consulting various official publications; and the history of a road through a similar district is a fair indication of the future of the one that is to be built. It is to be regretted that the gradual absorption of the minor lines into the great systems will prevent the publication of the results of their operation, the earning power and train movement of the main line and all its branches being reported as a whole by the great systems. The striking feature of the minor Eastern Canadian lines is the very slight tendency to increase shown by their traffic returns, a feature which calls for decided caution in traffic estimates.

In the future the skill of the engineer will be less hampered by financial necessity than it has been in the past. That minor lines are in themselves unremunerative is generally recognized, and the construction of the class of lines that formerly depended upon the future and upon local assistance for financial resources has become almost an impossibility. The backing of one of the great systems, or very liberal public subsidy is essential to the successful carrying out of these minor enterprises, and the current of public opinion is certainly setting against subsidies, except for the opening up of new districts. In establishing their own branches, the great systems will feel no imperative necessity for an economy that can be measured by units no greater than thousands of dollars, and will be willing that the roadbed, in common with the track and the rolling stock, shall become a subject of more liberal expenditure. Grading does not to-day constitute nearly so large a proportion of railroad cost as it did twenty years ago.

As a general principle, the writer would consider it good practice to assume that a proposed line will eventually carry a heavy traffic and to make the location accordingly. By the use of cheap structures, and by the introduction of temporary grades and curvature, the cost of construction can be greatly reduced, and the line left in excellent shape for improvement when the traffic shall have developed. The old Great Western branch into Brantford is an example of such a location, having an excellent alignment and heavy grades, which can be easily reduced to a maximum of 15 feet to the mile. There is no evidence that the location was made with a view to future improvement, but the profile certainly suggests it. On the other hand, the Buffalo and Goderich line, through the same city, is an example of long tangent location secured by an utter disregard of any grades not exceeding 1.00 per 100, and often in situations where their improvement is impracticable. It should be generally recognized that the executive department of a railroad will sanction a scheme for improving an existing line in preference to one that involves a new location, the legal and land difficulties that are involved in the latter case being almost entirely avoided in the former. The calculations of the economies resulting from detail improvements cannot be made with sufficient accuracy to justify an engineer in accepting their indications except in the most general way; and where the resulting gain shows but a small margin over the cost, the improvement may safely be left to the future.

Operating details, whose importance has not yet been measured by the science of economics, should also be considered during location. Of these the need of ample yard room is the most important. In the present great rush of traffic, it has proved much more difficult to keep the yards clear than to keep the lines open, and there is probably no railroad to-day that is not carrying out great yard extensions. It is difficult to foresee during location where the demand for yard space will be made, and perhaps the most satisfactory provision for the future that the locating engineer can make is the selection of ample areas of level ground in the vicinity of all important centres, and preferably where a level grade and a straight alignment can be obtained. There are few yards to-day on the older lines which are not surrounded by settled districts that have grown up since the establishment of the yard, and the cost of extending these yards is made almost prohibitive by land values. The C.P.R. land purchases in the vicinity of the Viger Station in Montreal and the G.T.R. purchase of the old Parliament Building property in Toronto are good examples of this. The yard expropriation limits of 300 feet by 1,950 feet, set by the Railway Act, are altogether insufficient for modern traffic, and the length should be extended to 4,000 feet, a limit which will only have to be exceeded in important divisional yards. It may be noted that the number of these latter yards is likely to decrease in the future, as there is a decided tendency to extend the lengths of the train runs, divisions of 150 to 160 miles being operated, where formerly 100 to 120 miles would have been considered a maximum length. Mr. Dennis suggests, in the paper previously referred to, that it is desirable to reduce the ruling grade for a few miles out of divisional yards on account of the increased running resistance. The necessity for this, however, should be more than off-set by the better steaming condition of the locomotive when starting out. It is to be noted that the provision for yard building to be made is for yards where trains can be handled by simple direct movements over easy grades and alignment, and not for a mere multiplication of tracks.

The location of signals, stations, and stopping points can be fairly well foreseen, and the line should be arranged to give as clear a view of these points from both sides as possible. A little handcar experience will convince any engineer of the desirability of a straight and open track near stations, no matter how good the signal arrangements may be.

Snow removal will be a perennial source of expense to Canadian roads, and its accumulation should be prevented by location if possible. It is customary to elevate the grade two or more feet above fields and flats, in order that the rail may be always windswept. In cuts ample width should be provided, and the rail raised well above the bottom of the cut wherever the wind directions are such that serious drifts will be formed. In bush location the change of snow movement that will be caused by clearing should not be overlooked.

That satisfactory track is largely a question of thorough drainage has long been acknowledged, but the fact that the necessity for drainage is a matter of natural soil has not been as clearly recognized by the railroad engineer as by the common road builder. Cases occur where an inexpensive shift of the line would throw it upon a dry and open sub-soil, and alter the drainage conditions completely.

Every effort should be made to avoid road and railroad crossings, swing bridges, and lines along public streets, not only because of construction cost, but particularly to secure freedom of traffic movement. The power to locate such crossings of other lines of transportation has to be obtained from the Railway Committee of the Privy Council. This is rather unfortunate, as that body has a decidedly political complexion, and a railroad, no matter how carefully built, may have its line ruined by a level crossing forced upon it by government authority. It is difficult to suggest an improvement upon our present method, unless it be by the creation of a non-political commission; and for the present it would seem that the road which has consistently avoided the building of level crossings itself is in the strongest position to fight any applications for permission to cross its lines.

The necessity of securing a good foundation for the roadbed is a point that should not be overlooked, as that detail affects both construction and operation. Every soft spot should be thoroughly tested before the location is finally laid down, and if any great depth of weak material is discovered, the line should be changed so as to avoid it. The writer knows of at least one serious sinkhole over which the original location and construction was carried without any investigation. Bad foundation is not only a construction danger, but will be found to be the cause of a wave motion, when under traffic, that materially increases the tractive effort required, and renders it extremely difficult to maintain the track in good condition.

It would appear superfluous to remark on the necessity of always considering construction during location, were it not that many locations are made which require material alteration before the line can be built. It may be said that no engineer who has not had previous experience in location, construction and operation is capable of making a first-class location. There is unfortunately no line of work in which the best workmanship is more likely to escape general observation, an appreciation of which fact is perhaps the reason that so many capable railroad engineers have taken up other branches of their profession.

A most vigorous denunciation of a location, apparently without regard to construction difficulties, will be found in "Eighty Years' Progress in Canada," a volume published in 1863. It came from the pen of Mr. T. C. Keefer, and expressed his opinion of the ability displayed in the location of the Great Western Railway between Niagara Falls and the head of the Dundas Valley during the early fifties.

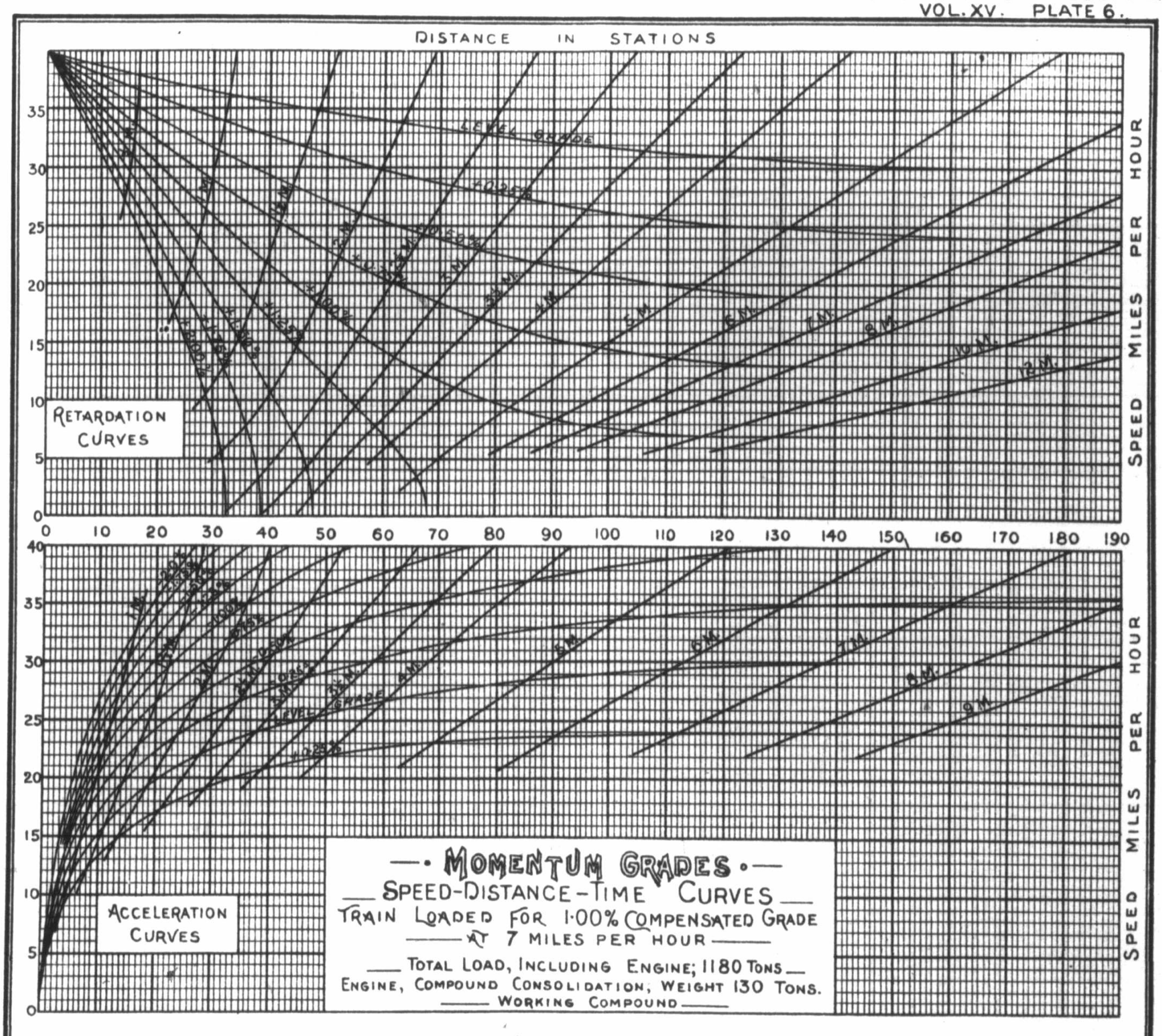
A notable case occurred on the extension of the B. and O. lines northward down the Mononganela Valley from Morgantown, West Va. The river is subject to great floods, and it was considered necessary to keep the grade line well above flood level, the location being made a short distance up on the side hills of the valley. In places the profile showed a succession of short, sharp cuttings through points running out from the main hill. The material in these cuttings was in reality nothing but the debris of forgotten slides, but this was not noticed either by the location or the construction engineers. When the winter came every slide started to move again, as its supports had been cut through, and a heavy yardage of most difficult material had to be removed from the finished roadbed. On another West Virginia road it was found necessary to relocate some miles of the line, because it was fitted so closely to the contours of the side hill that it would have been impracticable to obtain a full width roadbed, although the centre line showed an excellent profile. In a minor degree, it will be found possible to shift many locations, so as to materially reduce the cost of construction, either by obtaining a smaller yardage or by locating through material that can be moie easily handled. Mistakes in not taking advantage of the nature of the ground are particularly likely to occur on lines that are being located by contour plan.

The fall of the Cornwall Bridge is the most striking example that has occurred in Canada, of a failure due to insufficient consideration of the necessities of construction.

It may be said that every district has its own peculiarities, and that if the engineer does not spend some time in studying the characteristics of the local material, he is bound to make some serious errors in his location, the results of which will be generally set down to unavoidable natural causes, whereas they are really due to the failure of the railroad management to recognize the need of thoroughly trained men for the carrying out of its work.

Lastly, it is to be remembered that all Canadian railroads must be built under the provisions of the Railway Act, and of such Provincial Acts as may be in force. The engineer should therefore know the requirements of the Act, for although railway managements may take most vigorous action to influence government opinion upon great questions, they are perfectly prepared to accept all legal requirements as to matters of detail.

In conclusion, the writer may say that he has seen all the examples mentioned, and has made surveys and reports in connection with many of them.


DISTANCE IN STATIONS
RETARDATION CURVES
ACCELERATION CURVES
SPEED MILES PER HOUR
LEVEL GRADE
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190
— MOMENTUM GRADES —
SPEED-DISTANCE-TIME CURVES
TRAIN LOADED FOR 1·00% COMPENSATED GRADE
AT 7 MILES PER HOUR
TOTAL LOAD, INCLUDING ENGINE; 1180 TONS
ENGINE, COMPOUND CONSOLIDATION, WEIGHT 130 TONS.
WORKING COMPOUND