THE C.P.R.'S CAPACITY AND INVESTMENT STRATEGY IN ROGERS PASS, B.C., 1882-1916.

By

(C) Gary G. Backler,

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ABSTRACT

CP Rail is currently confronted by a capacity problem on its main line in Rogers Pass, at the summit of the Selkirk Mountains. The single-track, steeply graded facility is inadequate for the forecasted demand for traffic flows in the westbound direction. The Company must decide whether to continue to operate over the present line, incurring high operating costs and escalating congestion costs, or whether to invest in an 8.9-mile tunnel which, by reducing the gradient against westbound traffic, will stem congestion and reduce the level of operating costs in future years. CP Rail must make a trade-off between construction costs and operating costs.

The Company has made such a trade-off in Rogers Pass on at least two previous occasions. The first occasion was that prior to completion of the initial transcontinental rail link, when the decision was taken to breach the Selkirk Mountains by a surface crossing through Rogers Pass. The second occasion was that prior to the decision, taken in 1913, to abandon the surface alignment through Rogers Pass in favour of a five-mile tunnel beneath the summit of the Selkirks. This thesis identifies the factors which impelled the taking of trade-off decisions in each situation, allocates an appropriate weighting to the factors, and examines the criteria upon which the investment decisions were based.

Previous historians of the C.P.R.'s operations in Rogers Pass emphasise the influence of avalanches upon the investment decisions taken. Many of these historians interpret the C.P.R.'s surface operations as an unremitting campaign to protect its

traffic against snowslides, and they interpret the Company's decision to construct the Connaught Tunnel as an acknowledgement of defeat in the campaign.

This thesis emphasises the economic and commercial aspects of the C.P.R.'s operations in Rogers Pass, and a quantitative approach towards the analysis is adopted. Part One of the thesis is concerned with the initial decision to construct the C.P.R. main line across the surface of the Selkirks through Rogers Pass. Part Two is concerned with the decision to abandon the surface alignment.

Part One begins with an explanation of the engineering and economic problems of locating railway lines through mountainous terrain, and examines how these problems were handled by the C.P.R. in the specific circumstances of Rogers Pass. The expectations of the railway builders for construction and operation through the Pass are compared with the realities which were encountered. Analysis reveals that the gap between expectations and realities was not wide, and that the surface alignment adopted by the C.P.R. provided an adequate, economical solution to the problem of breaching the Selkirk Mountains by rail, at least until the turn of the 20th Century.

Part Two begins with an analysis of the influence of avalanches in Rogers Pass upon the decision to relocate the main line underground. The analysis strongly suggests that neither the 1910 avalanche disaster in particular, nor the cost of protecting traffic from snowslides in general, were sufficient to justify investment in the Connaught Tunnel.

An examination of the operating conditions, traffic growth and traffic forecasts through the Selkirk Mountains in the early years of the 20th Century reveals that the C.P.R. faced high operating costs and escalating congestion costs on the surface route by 1913. The Company had already invested in system improvements elsewhere in the mountains in order to reduce these costs. Confronted by the inadequacy of its existing facility for forecasted demand in Rogers Pass, the C.P.R. decided in 1913 to drive a double-track tunnel beneath the summit of the Selkirks, and to abandon the surface route. Analysis of the C.P.R.'s evaluations of alternative proposed tunnels confirms that the principal economic benefit of the project was the savings in train-haulage costs, and not the savings in the cost of avalanche defence.

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To ANDREA,

"O how I long to travell back
And tread again that ancient track..."

Henry Vaughan, "The Retreate"

CHAPTER 1

INTRODUCTION

Rail access to the west coast of Canada is rendered expensive by the topography of British Columbia, where four major mountain ranges intrude between the western seaboard and the eastern boundary of the province. In constructing railways through B.C., the builders have always had to face the dilemma of either investing large sums of capital per mile of line in order to obtain an easy alignment over which traffic may flow smoothly, or building to inferior standards and subsequently incurring high operating costs in the movement of trains. Clearly, these trade-offs between construction costs and operating costs, and between immediate costs and delayed costs, must be made in all railway construction, and indeed in the provision of any transportation infrastructure. Nevertheless, the trade-offs are particularly crucial, and the dilemma is particularly acute, in regions of rugged terrain, where constructional and operating characteristics, and therefore costs, often differ markedly between alternative routes.

CP Rail is presently confronted by such a dilemma as it seeks a solution to its next major main-line capacity problem. This problem is posed by the 8.16-mile ascent from Rogers to Stoney Creek, on the eastern approach to Rogers Pass, B.C., at the summit of the Selkirk Mountains. The ascent is over single track, and at a maximum gradient of 2.2 per cent. against westbound traffic for most of the distance. The elevation gained in the 8.16 miles is 899.9 feet. The heaviest westbound trains, already powered by eight locomotives from Golden, require the assistance of an additional five pusher locomotives between Rogers and Stoney Creek. Each train must be brought to a complete stand when the pushers are inserted, and again when the pushers are switched out after the ascent. This necessity to stop the trains twice within ten miles, together with the necessity of returning the pusher locomotives light down the single track against the prevailing flow of traffic, restricts the capacity of the main line. Moreover, the single-track configuration of the existing main line between Beavermouth, east of the Selkirk summit, and Glacier, to the west, contributes to delays in the meeting and passing of trains, further restricting main-line capacity.

CP Rail is therefore contemplating the construction of a second main track across the summit of the Selkirks, between Rogers and a point 3.1 miles west of Glacier. The maximum gradient of this track would be one per cent. against westbound traffic, and the maximum angle of curvature would be six degrees. Such an alignment would dispense with the necessity for pusher locomotives, and would resolve the conflict between eastbound and westbound flows, since eastbound traffic would continue to travel over the present line. However, in order to maintain the stipulated gradient and curvature, construction of this alternative route would require the driving of an 8.9-mile tunnel beneath Rogers Pass. The cost of the realignment project is estimated at $300 million in 1980 dollars.[1] Moreover, the financial viability of the project is rendered questionable by the uncertainty of future traffic volumes and by the unremunerative nature of the grain traffic, which constitutes some fifteen per cent. of CP Rail's westbound flow by weight.

CP Rail, then, is confronted by a dilemma at the summit of the Selkirk Mountains. It must decide whether to continue to operate over the present line, incurring high operating costs and escalating congestion costs, or whether to undertake a massive, indivisible capital investment intended in future years to stem congestion and to reduce permanently the level of operating costs. This decision situation has two distinct facets, and these may be framed in interrogative form. First, what is the alignment which is appropriate to the traffic flows through the mountains? Then, second, what is the appropriate level of investment which should be undertaken in order to secure this alignment? Only after these two fundamental questions have been answered can a decision be reached concerning the adoption of the project.

This is not the first occasion upon which Canadian Pacific Railway management have sought answers to these questions. Indeed, they have been forced to address the questions on at least two previous occasions. The first occasion was that prior to completion of the initial transcontinental rail link, when the decision was taken to breach the Selkirk Mountains by a surface crossing over the summit through Rogers Pass. The second occasion, some thirty years later, in 1913, was that prior to the decision to abandon the surface alignment through Rogers Pass in favour of a five-mile tunnel beneath the Pass. This was the Connaught Tunnel, and it is by means of this tunnel that all of CP's main-line traffic still crosses the Selkirk Divide.

Objectives

Prompted by the resurgence of interest in these questions today, the first objective of this thesis is to undertake a study of these previous comparable decision situations. Such a study will identify the factors which impelled the taking of decisions in each situation, the forces and influences which made the taking of decisions necessary. From the study of these historical situations, the reader will be able to draw his own comparisons with the present decision situation, and will be free to infer his own "lessons to be learned" for the current realignment proposal.

The second objective of this thesis, springing directly from the first, is to allocate an appropriate weighting to the factors which influenced the decisions in each of the historical situations. Historians of CP Rail's operations in Rogers Pass have hitherto always emphasised the influence of avalanches upon the decisions taken, and especially upon the decision taken in 1913 to abandon the Pass in favour of an underground route.[2] The economics of CP Rail's operations in the Pass, and specifically the economics of the decision to construct the Connaught Tunnel, have been consistently neglected. This neglect is especially serious because reference to the primary documentation which surrounded the decision suggests that the occurrence of avalanches over the surface alignment in Rogers Pass is not alone sufficient explanation for the decision to relocate the main line underground. The economics of the rail operation, and in particular the emergence of a major capacity problem in the Pass, appear then, as now, to have been factors of considerable significance in shaping the decision. This thesis will therefore seek to remedy the neglect of those factors. Fresh evidence will be analysed, and appropriate conclusions drawn. The results will be of interest to anyone who has a concern for historical accuracy.

The third and final objective of this thesis is to examine critically the contemporary techniques of appraisal which the Canadian Pacific Railway Company employed in their investment decisions in Rogers Pass during the first thirty-five years of the route's history, and the criteria upon which those decisions were based. The emphasis in this examination will be placed primarily upon the decision to invest in construction of the Connaught Tunnel. Throughout the analysis, however, stress will be placed upon the central and recurring importance of the trade-offs between construction costs and operating costs and between immediate costs and delayed costs, as they applied to rail operations in Rogers Pass. Attention will also be drawn to the manner in which these trade-offs were handled during the course of the study period. The results of this examination of the C.P.R.'s approach to previous investment decisions in Rogers Pass will be of interest to the business historian, and of relevance in a consideration of the evaluation procedures employed by CP Rail today.

Scope Of The Thesis

Previous studies of the history of the C.P.R. in the Selkirk Mountains may be grouped into two general categories, biographical and descriptive. The biographical studies have concentrated upon the personalities involved in the decisions to locate, construct and operate the railway through Rogers Pass.[3] The descriptive studies have tended either to concentrate upon the construction phase of the line,[4] or to treat the line, once built, as an incidental factor in the discussion of regional development.[5]

The present study is essentially analytical in character. It is an historical study of railway economics and their investment implications for a particular operating situation, that of the C.P.R. in Rogers Pass. Therefore, it differs from previous studies in both emphasis and focus.

The emphasis in this study is upon the economic and commercial aspects of railway operation in Rogers Pass, and a quantitative approach is therefore adopted. Such an approach permits integration into the analysis of quantitative data, data which has hitherto received little consideration from historians and analysts, and yet which, as has been indicated above, suggests an alternative interpretation of the C.P.R.'s investment decisions in Rogers Pass to that which is common currency.

The focus of this study is intentionally narrow and highly localised. This is a detailed study of railway economics on a forty-five mile stretch of the Canadian Pacific main line, a line nearly three thousand miles long. The study opens in 1882, the year in which Rogers Pass was selected as part of the route for the transcontinental railway, and it closes in 1916, the year in which the Connaught Tunnel was opened to traffic, marking the abandonment of surface rail operations through the Pass. Throughout that period, railway investment decisions and the economics of railway operations will be analysed and evaluated. Wider historical developments contemporaneous with the study period, such as the economic advance of British Columbia, the opening up of the prairies, and the construction of additional transcontinental routes, by both rail and water, will be considered only insofar as they impinged upon the economics of C.P.R.'s operations in Rogers Pass.

Outline

The thesis is divided into two parts. The first part (Chapters 2 - 4) is primarily concerned with the inception and realisation of a rail link across the Selkirk Mountains, accomplished by means of a surface alignment over Rogers Pass. This section embraces the construction of the original line and the measures taken to consolidate the link as a feasible route for trans-mountain traffic. The second part (Chapters 5 - 9) analyses the forces of change, economic and non-economic, which led to questioning of the appropriateness of the surface alignment, and ultimately to the identification of a decision problem. The analysis proceeds to examine the generation and evaluation of alternative solutions to the problem, and concludes with an appraisal of the achievement of the alternative which was implemented, that of relocating the line underground through the Connaught Tunnel.

Part One begins with a "layman's guide" to the engineering problems of locating railway lines through mountainous terrain, and to the implications of those problems for the economics of railway operations. Pertinent engineering concepts are elucidated. The nature of the critical trade-off between construction costs and operating costs is explained.

Chapter 3 describes the physical and climatic characteristics of the Selkirk Mountains, and the implications of these characteristics for railway location and operation. The reasons for the selection of Rogers Pass as the route by which the C.P.R. would cross the Selkirk Mountains are explained. The expectations of the railway builders for both construction and operation through the Pass, expectations which led to the adoption of the route, are made explicit.

In Chapter 4, the realities of construction and operation over the surface alignment are described, and the gaps between expectations and realities are highlighted. Measures intended to close these gaps are reviewed, and their success evaluated.

Part Two commences, in Chapter 5, with an analysis of the influence of avalanches in Rogers Pass upon the decision to relocate the main line underground. The widely accepted interpretations of the 1910 avalanche disaster in particular and of the snowslide problem in general are presented. These interpretations are then challenged, and as a result of this challenge an alternative interpretation is offered of the influence of avalanches upon the decision to abandon the surface alignment.

Chapter 6 contains an analysis of traffic developments through the mountains of B.C. The analysis includes consideration of changes in traffic volume and composition, competitive pressures, and the cumulative results of improvements undertaken elsewhere on the C.P.R. system. The analysis suggests the increasing inadequacy of the surface alignment over Rogers Pass to cope with these developments: a decision problem is identified and specified.

Chapter 7 reviews the alternative solutions which were generated for this decision problem, and presents the results of the screening of these alternatives.

In Chapter 8, a detailed evaluation of the preferred alternative is carried out. This alternative was a realignment which included the boring of the Connaught Tunnel. The project was modified during implementation: the scheme as conceived and the scheme as completed are both appraised.

In the final chapter, the conclusions of the thesis are presented, and suggestions are offered for further research.

Data Sources And Limitations

This thesis is based upon three primary sources of unpublished data. The first is the Letterbooks and inward correspondence of the C.P.R. Presidents. The Letterbooks have been microfilmed, but the inward correspondence is available only at the Canadian Pacific Corporate Archives in Windsor Station, Montreal. Although these Archives were only recently established, and although the task of indexing the vaults of corporate records is not far advanced, two complete files on

"The Rogers Pass Tunnel" have been assembled. Whilst weak in quantitative content, the files provide invaluable insight into the objectives of the project and the stages of its implementation.

The second source is the collection of C.P.R. records and correspondence which is held at the Revelstoke City Museum, B.C. This miscellaneous collection, withheld from the Canadian Pacific Corporate Archives, was comprehensively indexed in 1976. It includes complete monthly records of traffic volumes on the First District of the British Columbia Subdivision, of which Rogers Pass was a part, for the years 1910 and 1911, and sporadic records of expenditures on snow sheds and snow clearance for certain months between 1912 and 1914.

The third source is the personal notebooks and diaries of Thomas Kilpatrick, "The Snow King," who ended a thirty-year career with the C.P.R. in the mountains of B.C. as Superintendent of the Mountain and Shuswap Sections from 1901 to 1912. His papers are now held by his son, Mr. Donald Kilpatrick, as part of a private collection preserved in Vancouver, B.C. The documents contain many fascinating details of railway maintenance and operations in the mountains throughout the study period. Of particular value in the preparation of this thesis was a monthly record, maintained uninterrupted throughout the years 1906 to 1908, of the number of main-line trains per day, their weights and transit times.

In comparison with the inter-war period, the years prior to the First World War are rich in documentary sources concerning the management of the C.P.R. Nevertheless, it is a sad fact that much information has been destroyed. The loss is particularly serious for a sharply focussed project such as the present thesis which attempts to apply quantitative techniques to the analysis of an investment decision which was undertaken some seventy years ago. Detailed information on the costs of operating trains over Rogers Pass may never have existed. If it did, it has certainly not survived, and neither has detail of the anticipated costs and benefits of the several realignment schemes which were proposed in 1912. Similarly, very little data exists concerning traffic flows through the mountains either by volume, commodity or direction of movement.

Assembly of the extant data was a piecemeal and painful process, drawing from many diverse sources. Many gaps remain. Where possible, the gaps have been filled by inference and assumption; where not, they have simply been identified and recorded. It is to be hoped that this thesis will at least prevent the gaps from widening any further.

FOOTNOTES

[1] "Midweek Report," Vancouver Province, April 16, 1980, p. D 1.

[2] See chapter 5.

[3] See, for example, W. Vaughan, The Life And Work Of Sir William Van Horne, New York: The Century Co., 1920; H. Gilbert, Awakening Continent, Aberdeen: Aberdeen University Press, 1965, and, The End Of The Road, Aberdeen: Aberdeen University Press, 1977; C. A. Shaw, Tales Of A Pioneer Surveyor, Toronto: Longman, 1970.

[4] See, for example, O. S. A. Lavallee, Van Horne's Road, Montreal: Railfare Enterprises, 1975; P. Berton, The Last Spike: The Great Railway 1881-1885, Toronto: McClelland and Stewart, 1971.

[5] See for example, J. S. Marsh, "Man, Landscape And Recreation In Glacier National Park, British Columbia, 1880 to present," PhD thesis, University of Calgary, 1971; W. W. Bilsland, "A History Of Revelstoke And The Big Bend, " MA thesis, University of British Columbia, 1955.

PART ONE

UP AND OVER

This part of the thesis is concerned exclusively with the surface alignment of the C.P.R. main line through Rogers Pass. A brief introduction is provided to the engineering and commercial problems of locating and operating railways in mountains. Then, the specific engineering and commercial problems of locating and operating the C.P.R. main line over the summit of the Selkirk Mountains are analysed. The analysis compares the expectations and the realities of the C.P.R. for specific areas of concern along the surface alignment, and evaluates measures undertaken in order to promote correspondence between those expectations and realities. Part One concludes with a consideration of the extent to which such correspondence was achieved.

The analysis in Part One spans the selection, construction and operation of the Rogers Pass route until the turn of the century, that is, prior to the occurrence of the 1910 avalanche disaster. Consideration of this disaster initiates the analysis in Part Two. A division of the thesis prior to the 1910 disaster is maintained in deference to previous historians of the C.P.R.'s operations in Rogers Pass. Most of these historians identify the 1910 disaster as a turning point in C.P.R. management's perception of the viability of the surface alignment. The validity of this identification is challenged directly in Part Two. However, the foundation for this challenge is provided by the results of the analysis in Part One.

There are three advantages of structuring the analysis in this way. First, it permits establishment in Part One of the extent of the gaps between the expectations and realities of the C.P.R.'s concerns with the surface alignment, before proceeding in Part Two to consider changes in operating conditions which may have widened these gaps. Second, it permits both the avalanche problems and the other operating problems of the line to be considered each as a continuum, stretching from the opening of the surface alignment to the opening of the Connaught Tunnel. Both the avalanche and the operating problems are shown to have changed in severity but not in nature throughout the years of the summit route. Third, it permits the remedial measures undertaken in response to the avalanche problems and the other operating problems to be considered as continua also. Thus, it highlights the extent of substantive changes in the responses of the C.P.R. to the changes in operating conditions over time.

It is therefore possible, as a result of adopting this structure, to determine whether or not the 1910 avalanche disaster was indeed a turning point, and whether or not it is at all even meaningful to talk of "turning points" in the context of the C.P.R.'s investments in improving the surface alignment over Rogers Pass.

CHAPTER 2

RAILWAYS AND MOUNTAINS

This chapter provides a theoretical underpinning to the character of the investment decisions which are analysed in the remainder of the thesis. The chapter begins with an explanation of the two generic types of investment solution to the problem of penetrating mountainous terrain with railway tracks. The fundamental engineering principles involved in each type of solution are described, and the implications of these principles for the economics of railway construction and operation are considered. The inverse relationship between construction costs and operating costs is explained, and criteria are suggested for the trade-off decision between the two types of costs.[1]

2.1 The Two Solutions

The physical barrier which mountains pose to all forms of human communication translates into an economic barrier, as the cost of providing and maintaining communication across mountainous terrain. For rail, the essence of the physical barrier is that the low level of friction between wheel and rail, which affords economic advantage in traffic movement over an even alignment, manifests itself as a low level of adhesion on an adverse gradient, and is therefore turned to economic disadvantage since the payload which can be hauled by a single locomotive is reduced in proportion to the increase in the adversity of the gradient. The following table, adapted from A. M. Wellington's authoritative "The Economic Theory Of The

<u>Location Of Railways,"</u> demonstrates the reduction in payload which is caused by increasingly adverse gradients. The payloads are those which were capable of being hauled by a single "Standard Heavy Consolidation" steam locomotive, as recorded in 1915[2]:

Gradient (per cent.)	Payload (tons)
Level	2,920
0.2	1,920
0.4	1,420
0.6	1,120
0.8	920
1.0	777
1.2	670
1.4	587
1.6	520
1.8	465
2.0	420
2.2	382
4.5	165

Conceptually, there are two ways in which the physical barrier of mountains may be overcome by railway operation. On the one hand, the ratio of motive power to payload may be adjusted, in order to ensure that traffic can be hauled over the existing adverse gradient. Such an adjustment is effected, either by increasing the number and power of the locomotives which haul the train, or by reducing the weight of the train, or by a combination of these approaches.

On the other hand, the existing adverse gradient may be eliminated, in order to ensure that no reduction in the level of adhesion between wheel and rail occurs, and therefore, that no adjustment in the ratio between motive power and payload is necessary. An elimination of adverse gradient is effected, either by reducing the absolute height over which the traffic must be lifted (through tunnelling, cutting, or curvature around the summit) or by reducing the rate at which that height is attained (through "development" of the line, that is, the insertion of length, and usually of curvature, over the summit) or, again, by a combination of these approaches.

In order to explore the implications of these engineering solutions for the economics of the railway operation, it is appropriate to classify the solutions according to economic concepts. The first solution, of adjusting the ratio between motive power and payload, may be characterised as a "Low capital cost, high operating cost" solution, and the second solution, that of eliminating the adverse gradient, may be characterised as a "High capital cost, low operating cost" solution.

2.1 (a) "Low Capital Cost, High Operating Cost" Solution.

The capital requirement for construction of a line of railway may be decreased by locating the tracks over the natural alignment of the terrain in a route which minimises the necessity for man-made structures. In mountainous regions, location in accordance with this principle may involve either steep gradients or protracted curvature or both. Nevertheless, once the location has been decided, the construction period, over which capital disbursements are spread, will be short relative to the period over which interest on the capital will be repaid, or relative to the period over which railway operations will be carried out upon the line. The capital cost of constructing the line may therefore be regarded as an "immediate" cost: it is the cost which is "immediately" incurred in providing the rail facility.

When construction of the facility has been completed, and railway operations have commenced, every train which traverses the route is required to negotiate the steep gradients and protracted curvature, and thereby incurs higher operating costs than would have been incurred with lesser gradients and curvature. Hence, the operating costs of the facility may be regarded as being inversely related to its construction costs. The higher operating costs will be spread over the entire period during which rail operations are carried out over the low-capital-cost alignment. These operating costs may be regarded as "delayed," not only until construction is completed, but until it is necessary to run a train over the line. In the extreme case, if no trains are run over the line, the higher operating costs are "delayed" for perpetuity.

It is important to note that although the operating costs of the facility are inversely related to its construction costs, the <u>level</u> of operating costs which is associated with a particular level of investment in construction is not necessarily uniform. The level of operating costs is also related by a more complex function to the volume of traffic which uses the facility. It is helpful to portray the costs of the facility as a U-shaped curve, the locus of which is determined by variations in traffic volume.

For even the most cheaply built railway, the level of operating costs may at first decline with increasing traffic, as surplus line capacity is absorbed, equipment better utilised, and the costs of providing motive power and manpower and of maintaining lineside structures are spread over a greater volume of business. However, as traffic continues to increase, and as the surplus capacity provided by the opening of the facility is absorbed, operating costs may begin to rise with the expansion of business, and the marginal rate of increase of the operating costs may exceed the marginal rate of increase of the traffic volume. This behaviour of the operating-cost curve may result from three factors, which may obtrude singly or simultaneously.

First, existing resources of locomotives and traincrews may not be sufficient to handle an increase in traffic. Therefore, the marginal increase in traffic entails increases in motive power and manpower which may be particularly severe on a low-capital-cost, steeply graded alignment where the ratio of motive power to payload is initially low.[3] Second, the increase in traffic may cause congestion of the facility, particularly in the case of a low-capital-cost, single-track railway where through speeds are low and where limited passing accommodation is provided. This congestion will increase fuel consumption and power requirements, and limit the absolute volume of traffic handled by the facility. As congestion increases further, the operating-cost curve may bend back upon itself, with the cost of operations continuing to escalate while the volume of business conducted declines below that which it would have been on an uncongested facility. Third, the cost of maintaining lineside structures such as trestle bridges and snowsheds may increase as the structures are subjected to greater weights and frequencies of trains. There may be many such structures on a low-capital-cost, rapidly constructed alignment, and the wear upon them due to pounding from locomotives may be particularly great where the ratio of motive power to payload is low.[4]

Regardless of these fluctuations in the volume of traffic, the relative level of operating costs which is associated with a low-capital-cost alignment is generally higher than the level of operating costs associated with a capital-intensive alignment. There are two reasons for this, which are related to the gradients and the curvature of the alignment.

i) Gradients

In order to appreciate the impact of gradients upon the costs of operation over a particular facility, the concept of "gradient systems" must first be understood. Trains are assembled, and motive power allocated, according to the length and steepness of particular gradients along the line. The line is therefore divided into segments, or "divisions," which embrace gradients of a particular length or steepness. In order to ensure optimal utilisation of motive power over a particular division, the divisional boundaries must be drawn in such a manner as to concentrate all gradients of similar severity into a single division. The assembly of trains and allocation of motive power takes place at the commencement and termination of each division, that is, at "divisional points." The amount of adjustment of train weight and motive power which is required at each divisional point is determined by the relationship between the severity of the gradients on the divisions adjacent to the divisional point. Minimum adjustment of train weight and motive power is commensurate with minimum cost for the operation over the contiguous divisions. Thus, "The grades of a division are very definitely related to each other in their effect on operation, and when considered in this connection may be termed the grade system of the division."[5] The efficacy of the gradient system on the entire line is clearly dependent upon the efficacy of the gradient systems within the constituent divisions. The present analysis distinguishes between three types of gradient, the maximum gradient, the ruling gradient, and the pusher, or helper, gradient.

The maximum gradient is simply the steepest gradient on the line. Operations over the maximum gradient may be conducted either by momentum, or by means of pusher locomotives, or by balancing traffic in such a manner that the heavier flow always descends the maximum gradient.[6]

The ruling gradient is that gradient which, "...by its length or steepness, limits the weight of train that can be hauled by one locomotive over the division on which it occurs."[7] It should be noted that,

> The ruling gradient may or may not be the maximum gradient on a division. In the event that helper engines are used over the maximum grades, or momentum grades are employed...the next steepest grade becomes the ruling grade.[8]

The importance of the ruling gradient in the economics of railway operation is twofold. It determines not only the maximum train load which a single locomotive can haul over a particular division, but also the amount of motive power which is in effect "wasted" on those sections of the division which are not ruling gradients. Thus,

> ...it is not so much the direct cost of power that makes heavy ruling grades so objectionable, but rather the fact that this power which must be available wherever the ruling grade occurs cannot be used to advantage over other portions of the line.[9]

Therefore, it is the ruling gradient rather than the maximum gradient which is the crucial determinant of operating expenses over a particular division. For it is the ruling gradient, its angle, length and frequency of incidence on the division, which together determine the amount of motive power which is provided over the entire division in excess of that required to move the train between the portions of ruling gradient. Alternatively, it is the ruling gradient which determines the amount of payload which must be left off the train over the entire division in order to ensure that a single locomotive can continue to haul the train whenever the ruling gradient occurs.

The excess of motive power, or the loss of payload, may be minimised by the concentration of ruling gradients of similar severity within a particular division. Such concentration ensures that when a train is assembled to match the ruling gradient of the division, the motive power provided is fully utilised for as long as possible in crossing the division.

A <u>pusher</u> or <u>helper gradient</u> is any gradient where an assisting locomotive is attached to the train in order to "help" the train ascend the gradient. Pusher locomotives are required wherever the gradient of a section of the line exceeds the ruling gradient of the division.[10] The assisting locomotives may be inserted into the train at any point along its length. However, the number of pushers which may be attached at any single point is limited by the strength of the drawbar of the car immediately before and the car immediately behind the pusher units, since it is upon these two drawbars alone that the full forces of buffing and pulling respectively are exerted. (The drawbar is that part of the locomotive or car which couples the vehicle to adjacent vehicles.) Moreover, with steam traction, as was operated over the Selkirk Mountains until the 1950's, co-ordination of locomotives in multiple is more difficult to achieve than with diesel and electric traction. Also, with steam traction, each additional locomotive requires its own train crew of at least two personnel, whilst diesel and electric locomotives may be operated in multiple by a single train crew.

Pusher gradients, like ruling gradients, are expensive to operate, not simply because of the direct cost of supplying the additional power where it is needed, but because of the opportunity cost of being unable to utilise this additional power on portions of the line where it is not needed.[11] Like ruling gradients, therefore, pusher gradients must be concentrated as much as possible. The steepness of the pusher gradient must also approximate as closely as possible the steepness of the maximum gradient negotiable by the number of locomotives in the train. In this manner, the maximum benefit is derived from the "push," for if the pusher gradient is only slightly steeper than the ruling gradient, then much of the work of the pusher locomotives is not required in order to move the train.[12], [13] Finally, the pusher gradient must be sufficiently long,[14] and the traffic sufficiently dense,[15] to ensure full utilisation of the pusher locomotive or the pusher fleet.

ii) Curvature

Curvature may be inserted into a line either in order to avoid a summit completely, or in order to moderate the gradient by which a summit is attained, or in order to avoid investment in a tunnel or cutting through the summit. In each case, the implications of the insertion of curvature for both construction and operation are identical. This analysis identifies two implications, those of resistance and distance, which are, however, interrelated in their impact upon constructional and operating costs.

The resistance with which a train meets when travelling over straight track is increased when a curve is encountered, since the natural motion of the train is in a straight line. The increase in resistance due to curvature is identical in effect to the increase in resistance which results from an increase in gradient. Therefore, if curvature is inserted on the ruling gradient of a division, without reducing the gradient, the increase in resistance which this curvature entails is identical in effect to an increase in the ruling gradient: it necessitates either the attachment of additional motive power to each train which negotiates the curve, or the reduction of the payload of each train.

These expedients of additional motive power and payload reduction can only be obviated if the curvature is "compensated," that is, if the increase in resistance which the curvature entails is compensated by a decrease in the gradient, in order to ensure a constant level of resistance over both tangent and curvature.[16] Thus, a gradient of "2.2 per cent. compensated" is a gradient on which the resistance encountered by a train is equivalent in amount to the resistance which the train would have encountered in ascending a 2.2 per cent. gradient on straight track. However, the actual angle of ascent will be less than 2.2 per cent., because some of the resistance encountered on the ascent will be due not to the gradient, but to the incidence of curvature. The angle of ascent is usually reduced, or "compensated," by 0.04 per cent. per degree of curvature.[17] Thus, when a ten-degree curve is located on a gradient of 2.2 per cent., the actual angle of ascent over the curve must not exceed 1.8 per cent., for if it does, the train will stall, as the resistance due to the ascent, compounded by the resistance due to the curvature, will exceed the resistance of the ruling gradient of the division. The necessity to compensate gradients in order to avoid the stalling of trains implies increased distance, for either the angle of curvature must be reduced, or the angle of ascent must be decreased.

The increase in <u>distance</u> which the insertion of curvature entails will increase either the immediate cost of construction or the delayed cost of operation. Each of these cost increases is particularly severe in mountainous terrain, where construction costs per mile are initially high, and where very little local traffic can be generated by the lengthening of the line.[18]

Since the insertion of curvature may entail either increased distance at construction time or increased operating costs afterwards, it is not clear that curvature can always be regarded as a "Low capital cost, high operating cost" solution rather than a "High capital cost, low operating cost" solution to the problem of breaching mountainous terrain with rail. Its appropriate classification will always be determined by the specific circumstances in which it is adopted. The inference must be drawn that where curvature is adopted in practice, it represents the least-total-cost solution in comparison with either constructing a tunnel or operating over steep inclines.

This analysis of "Low capital cost, high operating cost" solutions has demonstrated that the construction costs of overcoming mountains by rail, that is, the immediate cost of providing a railway facility through mountains, can only be reduced at the expense of incurring relatively higher operating costs once the facility has opened. These higher operating costs are incurred only when traffic is required to be transported over the facility. The costs are either direct costs consequent upon the deployment of more motive power, or opportunity costs consequent upon the foregoing of payload. It is appropriate to contrast the results of this analysis with an analysis of the obverse solution, that of "High capital cost, low operating cost."

2.1 (b) "High Capital Cost, Low Operating Cost" Solution.

In the period of construction of a railway line through mountains, large sums of capital may be invested in order to eliminate an adverse gradient from the alignment by either tunnelling or cutting. The outlay is incurred "immediately," that is, before any traffic can flow through the facility. However, once the facility has been completed, and the gradient eliminated, the cost of operating traffic over the line is less for every train than it would have been had the traffic been obliged to negotiate the steeper gradient, since the need to deploy more motive power or forego payload is averted.

The high capital cost of gradient reduction represents a "lumpy" investment. Not only must the entire cost be borne "immediately," during the period of construction, but the investment project must be entirely completed before any savings in operating costs can be realised. Moreover, the rate of return on the investment is determined strictly by the volume of traffic which uses the facility. In the extreme case, if no trains are run over the line, the fact that traffic can be moved at a low operating cost will be of no benefit in securing a return on the investment. Thus, the investment of large sums of capital per mile is not alone sufficient to ensure operating savings: traffic must be available in order to take advantage of the low operating costs.

2.2 The Trade-off

The engineering and economic characteristics of alternative solutions to the problem of locating and operating railways in mountainous terrain require a trade-off between "construction costs" and "operating costs," and between "immediate costs" and "delayed costs." In order to determine the appropriate trade-off, that is, in order to choose between alternative engineering schemes, the two questions posed in the Introduction have to be answered.[19] First, what is the alignment which is appropriate to the traffic flows through the mountains?

Where traffic flows are uncertain, or where there is an expectation that flows will be light, an alignment which entails high construction costs in order to obtain low operating costs will not be appropriate, for the benefit of the low operating costs will not accrue with sufficient frequency to offset the high interest charges on the capital invested in construction. The early North American transcontinental railways, built under uncertainty, or with the expectation of initially light traffic, therefore adhered to the "Low capital cost, high operating cost" solution: the first lines were built quickly and cheaply, in order to minimise interest charges for the future, and in order the sooner to generate revenues with which to upgrade the line and reduce operating costs as traffic developed. Immediate construction costs were diminished, and higher operating costs accepted in the short run.[20]

As long as the traffic volume remains low, the "Low capital cost, high operating cost" alignment continues to be appropriate. However, as the traffic volume increases, and as operating costs escalate as a proportion of total costs, such an alignment becomes less appropriate, and the trade-off decision between capital costs and operating costs becomes less clear-cut. Ultimately, when the traffic volume increases to such an extent that the expected cost of operating trains over the alignment in the future exceeds the cost of constructing an alternative, less severe alignment, then it may be concluded that the "Low capital cost, high operating cost" alignment has become inappropriate for the volume of business which it is required to support. Capital must be invested in order to obtain a more appropriate alignment.

In answering the second question, that is, what is the appropriate level of investment which should be undertaken in order to secure the appropriate alignment, it is instructive to consider the principle advanced in 1906 by the C.P.R. engineer who would later be charged with the task of locating a double track for the C.P.R. main line from Calgary to the West Coast:

> "The question of reducing grades over a certain section should be considered advantageous or economical when the saving effected in operating per annum over the section, due to grade reduction, more than represents the interest on the capital outlay necessary to make the reduction. . .
>
> "Figuring on the traffic being the same before and after the revision, the most economical location to make is the one which will require the least outlay for construction, and which will reduce operating expenses by an amount more than sufficient to pay interest on this outlay."[21]

This principle, which may be regarded as indicative of the C.P.R.'s own criteria for making the trade-off decision between construction and operating costs, and between immediate and delayed costs, is deceptively simple, especially when applied to the problem of investing in railways through mountainous terrain, where the trade-off decision is rendered particularly difficult in practice by three factors.

First, constructional and operating characteristics differ markedly between alternative alignments through mountains. This phenomenon in turn has two ramifications. First, the absolute level of investment required in order to obtain gradient reductions of any significance is likely to be high. Concomitant interest charges will also be high, therefore, and in order to offset these high interest charges, the possibility must exist of making large savings in operating costs. This possibility will exist only if the proposed gradient reduction project is drastic, or if the volume of traffic forecast to benefit from the reduction in operating costs is considerable. Second, the range of alternative projects from which to choose is not likely to be "continuous." Thus, if the railway company is just unable to afford the investment in its "most preferred" alternative, the "next most preferred" alternative may offer significantly fewer benefits than the "most preferred" alternative in terms of construction costs and operating savings.

The second factor which renders the trade-off decision difficult to make in practice is the necessity for the accurate estimation of construction costs, since the alignment should be adopted only if the operating savings relative to alternative investments will outweigh the cost of the initial investment. Clearly, the difficulty of accurately forecasting costs is a problem which pervades all project evaluations. However, the difficulty is particularly acute in the field of mountain railway location, where contingencies are often difficult to foresee, and cost overruns easy to incur.

The final factor which renders the trade-off decision difficult to make in practice is the necessity for the accurate estimation of operating savings. This in turn requires the accurate forecasting of future traffic volumes over the proposed alignment. Again, this is a difficulty common to all project appraisal. Again, too, however, the difficulty is particularly acute in the field of mountain railway location, where the scale of investment costs which must be recovered is usually large, and where flexibility to cope economically with extremes of traffic levels is difficult to incorporate into the proposed facility.

The role of these three factors in shaping the trade-off decisions which were made by the C.P.R. through the Selkirk Mountains will be described and discussed in the remainder of this thesis. This analysis will discern and appraise the answers which the C.P.R., as revealed by their investment decisions, appear to have reached on the two questions posed above. The issue of "appropriateness," as elicited in response to each question, clearly involves more than simply engineering principles and economic costs and benefits. It involves the crucial matter of timing. When, and for how long, is an alignment to be considered "appropriate"? When should the investment be undertaken which is intended to secure a "more appropriate" alignment, and for how long is it intended that this alignment should be "more appropriate"? In analysing the nature and rationale of the trade-off decisions made in Rogers Pass, this thesis must perforce examine the manner in which the

C.P.R. addressed this crucial issue of timing.

FOOTNOTES

[1] This discussion has no pretensions to be a comprehensive review of the engineering principles of mountain railway construction and operation, nor is it intended as such. For a thorough and contemporaneous treatment of the field of railway engineering, see, for example, A. M. Wellington, The Economic Theory Of The Location Of Railways , New York, John Wiley & Sons, Inc., 6th edition, 1915; C. C. Williams, The Design Of Railway Location, New York, John Wiley & Sons, Inc., 1st ed., 1917; W. L. Webb, Railroad Construction, Theory And Practice, New York, John Wiley & Sons, inc., 8th edition, 1926.

[2] Wellington, op. cit., Table 170, pp. 544-551.

[3] See below, pp. 21-23.

[4] "Considerably over half of the deterioration of track comes from the passage of engines over it, and the remainder only from the passage of cars, which may weigh ten or twenty times as much." Wellington, op. cit., p. 701.

[5] Williams, op. cit., p. 219.

[6] Ibid., p. 265.

[7] Ibid., p. 219. My italics.

[8] Ibid.

[9] Ibid., p. 220.

[10] Unless the gradient is operated either by momentum or by balancing traffic. See note (6) above.

[11] "It is a truth of the first importance, that the objection to high gradients is not the work which engines have to do on them, but it is the work which they do NOT do when they are thundering over the track with a light train behind them, from end to end of a division, in order that the needed power may be at hand at a few scattered points where alone it is needed." Wellington, op. cit., pp. 589-590.

[12] Williams, op. cit., pp. 266-7.

[13] "The rate of grade should be such as to require the full power of the pusher engine in addition to that of the regular engine to handle the maximum load over the balance of the section, as this will reduce the length of the pusher grade and consequently the pusher engine mileage." F. F. Busteed, "The Saving Effected By Grade Reductions," in, C.P.R. Co., "Proceedings Of The Meeting Of Western Lines Officials Held At Field, B.C., February twelfth and thirteenth nineteen hundred and six." Public Archives of British Columbia, Victoria, B.C.

(henceforth "PABC,") NWp 971B C225pr. p. 62.

[14] "The maximum efficiency in operating pusher engines is obtained when the pusher engine is kept constantly at work, and this is facilitated when the pusher grade is as long as possible, that is, when the heavy grades and the great bulk of the difference of elevation to be surmounted is at one place. For example, a pusher grade of three miles followed by a comparatively level stretch of three miles and then by another pusher grade of two miles cannot all be operated as cheaply as a continuous pusher grade of five miles." Webb, op. cit., pp. 580-81.

[15] "...the condition that the pushers must be kept busy and be always on hand to have them economical must be remembered. The larger the traffic of the road the more easily can this be assured, and consequently the more frequently can pushers be used." Wellington, op. cit., p. 606.

[16] Williams, op. cit., p. 296.

[17] Webb, op. cit., p. 563.

[18] It should be noted that compensation is also required in railway tunnels which are located on gradients. Here, the increase in resistance is due to damp rails and increased air resistance within the tunnel.

[19] See above, p. 3.

[20] "Whereas European engineers inclined to a permanent type of construction, American railroads were often best built when most cheaply built, with light rails, sharp curves and steep grades. Only such roads could expect to earn interest on their investment, in view of the scant population of the country and the pioneer character of many of the early enterprises." S. Daggett, Principles Of Inland Transportation, New York, Harper, 4th edition, 1928, pp. 63-64.

[21] F. F. Busteed, op. cit., p. 62.

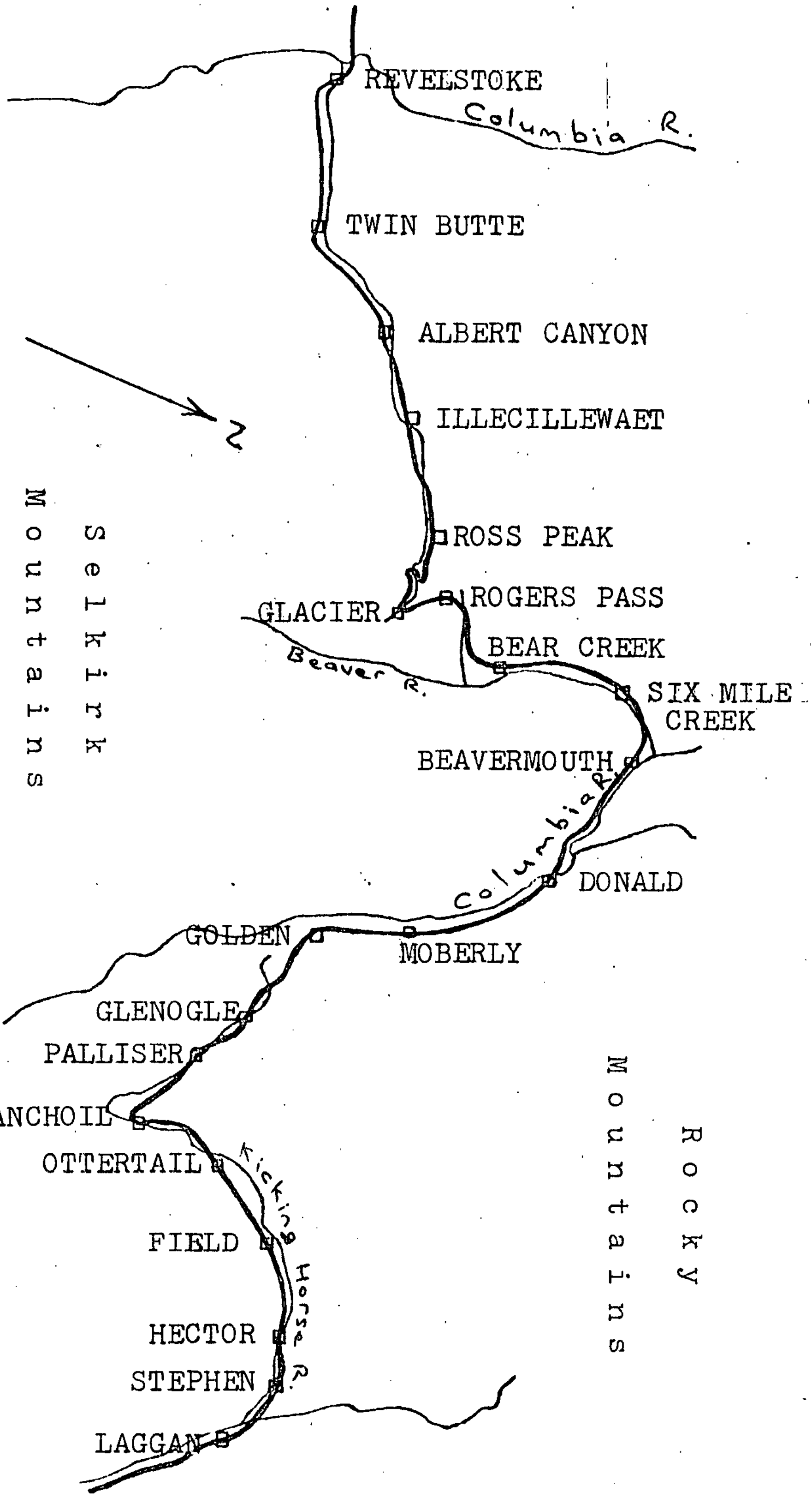
CHAPTER 3

RAILWAYS AND ROGERS PASS

The purpose of this chapter is to relate the engineering and economic concepts of the previous chapter to the specific circumstances of railway construction and operation in Rogers Pass, B.C. The chapter is divided into three sections. The first section describes the physical and climatic characteristics of the Selkirk Mountains, and considers the implications of these characteristics for railway location and operation. The second section explains why Rogers Pass was selected from the alternative routes available for the location of the transcontinental main line through the mountains of B.C. The third section examines the specific expectations which the C.P.R. harboured for the impact of these characteristics upon prospective constructional and operating conditions in the Pass.

3.1 Rogers Pass

The direct route west from the foot of the Kicking Horse Pass crosses the northerly flowing Columbia River, and is then faced by the great mass of the Selkirk Mountains (See Map I). These mountains pose a number of problems for the construction and operation of railways. These problems are related to the location, the topography and the climatic characteristics of the Selkirk Mountains.



MAP I: C.P.R. MAIN LINE FROM REVELSTOKE TO LAGGAN.

a) Location

> The Selkirk Mountains form a chain lying to the west of the Rocky Mountains. They are divided from them by the Columbia Valley, running approximately north and south, and through which the river of the same name flows. This river sweeps round the northern extremity of the Selkirk chain, forming what is called the 'Big Bend,' and then flows southerly into Oregon Territory, scooping out a deep valley, which divides the Selkirks from the Gold Range, lying further to the west. The Selkirks are thus bounded on either side, and enclosed at their northern end, by the Columbia Valley. Their length is about 250 miles in Canadian Territory, and width from 50 to 80 miles.[1]

Situated just inside, and parallel with, the eastern border of B.C., the Selkirks are the second of four great mountain ranges, the Rockies, the Selkirks, the Gold Range and the Coast Range, which stand astride southern Canadian routes from the prairies to the west coast.

b) Topography

> In general character (the Selkirks) are lofty, rugged, and steep; intersected and diversified by narrow passes, and precipitous, rocky canons [sic]. The height of the highest peaks is ten or eleven thousand feet above the sea; long parallel ridges of not much inferior elevation may be frequently observed in close proximity, forming between them a narrow V shaped valley, whose sides extend upwards, at an even and very steep slope, for five or six thousand feet, and along the bottom of which there flows a turbulent mountain stream.[2]

A "low capital cost" railway location, intending to follow the natural alignment of the terrain,[3] would necessarily seek these narrow passes as corridors through the mountains. However, the valley floors in the Selkirks are poorly drained, marshy, and densely overgrown.[4] Even today, the Trans - Canada Highway is compelled to skirt these areas by taking to the valley sides. Thus, even where level valley floors exist, and where they are wide enough to accommodate even a single line of railway, no track can be laid without massive investment in ground clearance and drainage. Instead, track must be thrown up the valley sides, clear of the area prone to flooding.

Moreover, where the valley floors are drained, the streams descend very steeply towards the major rivers, too steeply to be followed by railway lines. In seeking less precipitous descents, tracks necessarily diverge from the river valleys and are thrown high up the valley sides.[5] They must then be "developed" in order to reach the valley floors by practicable gradients, thereby incurring increased distance and curvature.

The necessity of abandoning the valley floors and seeking the mountain sides, whether induced by the narrowness of the valley, poor drainage or steeply flowing rivers, has six consequences adverse to railway construction and operation. First, it entails steep gradients, in order to reach the refuge of the valley sides and then return to the valley floor where possible. Second, it involves construction through the densely forested valley sides, which would be scarcely less expensive to clear than the dense undergrowth of the marshy valley floors. Third, it entails extensive cutting into the side of the mountain above the valley floor, in order to carve out a "bench" upon which to lay the rails. The extent of this cutting is increased by "development" of the line. Fourth, it involves increased expenditure upon the securing of a stable foundation for the line over these "benches," since in the Selkirks, "the rock being for the most part...clay and slate shales...crumbles and degrades easily under the action of the weather, and large masses of debris are thus constantly gathering in the valley bottoms, while the mountain sides are deeply scarred by gullies and fissures."[6] Fifth, it involves bridging these gullies and the many mountain streams, all of which are avoided in an alignment along the valley floor.[7] The bridges may be short, but the crossings will be high above the gullies and streams, and the bridging will therefore be expensive and complex. Moreover, allowance must be made, in both the length and the strength of the bridges, for the violent flooding of these many streams. This flooding, the result of warm weather melting "the snow-fields and ice masses..., may occur at any period of the summer months, and may last for days, or perhaps weeks."[8] Finally, location along the mountain side leads the tracks perpendicularly across the paths of avalanches descending from the peaks above to the valley floor beneath. This problem of avalanches will be examined further in the consideration of climatic characteristics below.

c) Climate

> The Selkirk chain forms, as it were, a lofty wall running north and south. Being very much higher than the mountains to the west, it is the first and chief barrier that the moisture laden currents of air from the Pacific Ocean encounter on their eastward passage. This warm air is intercepted and the moisture condensed by contact with the cold Selkirks, entailing heavy rain in summer and deep snow in winter...[9]

The average annual snowfall ranges from thirty to fifty feet,[10] falling mostly between October and April,[11] and falling much more heavily upon the western slope than upon the eastern slope.[12] The heavy snowfall, coupled with high winds and the steep, fissured profile of the mountains, creates a severe avalanche danger. The severity of the danger lies in the velocity of the avalanches, the volume of snow which slides, and the weight of that snow. Hard-packed and frozen, the snow alone may weigh from 25 to 38 lbs. per cubic foot, and the force of the slides may tear down whole trees or rocks and carry them into the valleys with the avalanche.[13]

> The time of year when slides are largest and most frequent is from the middle of January to the latter part of February. These are 'winter slides,' formed of large masses of quite dry snow. In March and April there are numerous 'sun slides,' caused by the melting of the snow and ice, but these are not of any importance as compared with the others.[14]

The incidence of these slides poses a considerable seasonal hazard to both the construction and the operation of transportation corridors through the Selkirks, and greatly increases the expense of keeping open those corridors. It has already been noted that in being compelled to abandon valley floors, railway lines would be forced directly across the paths of avalanches on the mountain sides. However, even the valley floors do not necessarily provide a refuge from the avalanches. Many of the valleys are too narrow to permit the slides to "run off" harmlessly, and the larger avalanches acquire sufficient momentum to cross the valley floors and travel considerable distance up the sides of the mountains opposite.

Structures intended to defend railway lines from the slides must be strong enough to withstand not merely the weight of the cumulative snowfall, nor even the strength of the avalanches themselves, but also the weight of the falling rocks and trees which accompany the slides. Clearance of the snow slides alone would be arduous and expensive enough: many of them would cover several hundred feet of line, sometimes to a depth of over thirty feet.[15] The presence of rocks and trees in the debris exacerbates the clearance problem, particularly if mechanical ploughs are used in the clearing operation.

This introduction to the geography of the Selkirk Mountains has highlighted the physical constraints upon railway location and operation in those mountains. The constraints are imposed by the topography and the climate of the Selkirks. It should be noted that these constraints are to a considerable extent peculiar to the Selkirk Mountains. In the Rockies, the valley floors are generally wider, better drained and less overgrown, and are thus eminently suitable to accommodate transportation corridors. Moreover, being situated further east than the Selkirks, they receive a far lesser snowfall, mitigating the problems of avalanches and snow clearance. Even in the Sierra Nevada, which experiences considerable snowfall and avalanches, the problems are far less severe than in the Selkirks, for the snow itself is much lighter, and the snow slides do not generally displace rocks and trees.[16]

Moreover, the constraints are to a considerable extent peculiar to the location and operation of railways. Due to the superior adhesion, acceleration and cornering capabilities of road vehicles, highways may follow the severe gradients of the mountain streams, or may alternatively choose both severe gradients and curvature as means of avoiding avalanche paths, gullies or flooded valleys. These alternatives are available to rail in only limited measure.

This analysis of the implications of the physical and climatic characteristics of the Selkirk Mountains for railway construction and operation has revealed that the nature of the terrain would pose a formidable challenge to the location of a rail corridor from the prairies to the west coast. One may legitimately wonder why and how a transcontinental rail link could be expected to penetrate this awesome natural barrier against communication. The next two sections of this chapter will endeavour to answer these questions.

3.2 The Selection Of Rogers Pass For The First Transcontinental Rail Link

The purpose of this section is to explain why Rogers Pass was selected as one segment of the route by which the C.P.R. would cross the mountains which stood between the prairies and the west coast. As a result of this decision, the C.P.R. would be for ever implicated in the struggle with the adverse physical and climatic characteristics outlined above. It should be noted that the selection of Rogers Pass for the transcontinental link was the consequence of two separate but interrelated decisions. The first decision addressed the question of the general alignment which should be adopted in crossing the western Canadian mountains. The second decision addressed the question of the specific location which should be adopted in crossing the Selkirk Mountains of B.C. This analysis will concentrate upon the second of these questions, partly because the first question has been discussed thoroughly elsewhere,[17] and partly because the second question reveals more than the first question about the manner in which the trade-offs elaborated in Chapter 2 were handled in the particular environment of the Selkirk Mountains.

The need to cross the Selkirk Mountains could have been avoided entirely had the C.P.R. adhered to their original contract and constructed the main line through the Yellowhead Pass via Jasper House. Such a route would have had maximum gradients of one per cent., and would have been free from snow slides.[18] However, shortly after the C.P.R. had been awarded the contract to build the transcontinental main line, in 1881, a search was initiated for a more southerly route across the prairies and through the mountains. By 1883, the Yellowhead Pass alternative had been abandoned.

It is not proposed to reopen the controversy which surrounds the rationale for this abandonment decision. The objective of the C.P.R. in seeking a more southerly route was ostensibly to obtain a shorter line.[19] This saving in distance was equated by the C.P.R. with a reduction in future operating costs,[20] and with an improvement in their capability to compete with American rivals for transcontinental traffic.[21] In order to secure these savings, it appears that the C.P.R. was prepared to sanction higher construction costs on a shorter line through the mountains.[22] However, the decision to abandon the Yellowhead Pass may also have been motivated by political considerations, since a route further south would more readily forestall the economic encroachment of the United States into both the Canadian prairies and southern B.C.[23]

Certainly, the decision to reject an extreme southern crossing of the mountains appears to have been dominated by political considerations. Sir Thomas Shaughnessy, third President of the C.P.R., would later assert that the Company "would have preferred to build via the Crow's Nest, but the Government of the day did not approve this, as the line would be too close to the International Boundary. As a consequence the present route was adopted."[24]

That "present route" would penetrate the Rockies through the Kicking Horse Pass and the Selkirks through Rogers Pass. It was the decision to follow the Kicking Horse Pass which made necessary a decision concerning the appropriate crossing of the Selkirk Mountains. Two alternatives were available. An alignment could be followed around the Big Bend of the Columbia Valley, skirting the northern extremity of the range, or, alternatively, a direct crossing could be sought through the Selkirks.

The C.P.R.'s evaluation of these alternatives will now be assessed. From this assessment, it will be possible to analyse the manner in which the C.P.R. handled the trade-offs explained in Chapter 2. The analysis will be instructive for the appraisal of later trade-off decisions made by the C.P.R., because the trade-offs made in the Selkirks appear not to have been coloured by political considerations, but to have been based purely upon principles of transportation economics.

The length of the Big Bend route was estimated at 140 miles, and it seemed "quite certain that gradients of 80 or 90 feet per mile would have to be used in places."[25] Since the ruling gradient elsewhere on the C.P.R. system was to be 52.8 feet per mile,[26] these sections of the Big Bend route would have to be operated as pusher gradients. Moreover, since the gradients would be short and dispersed, the pusher operation would be difficult to conduct economically. Finally, the adoption of the lengthy alignment around the Big Bend would not necessarily preclude the need for tunnelling, although no estimate has survived of the actual length of tunnelling which might have been required.[27]

When the C.P.R. applied for statutory authority to abandon the Yellowhead Pass, the Big Bend represented a "fail-safe" alternative on the southern route: it could be adopted as a last resort if no direct crossing of the Selkirks could be found.[28] However, if the C.P.R. had been driven to adopt the Big Bend, the potential saving in distance on the southern route, which had induced them to abandon the Yellowhead Pass, would have been eroded to between thirty-five and forty-five miles.[29] It is doubtful that the savings in the cost of operating this distance, particularly over the potentially uneconomical pusher gradients, would have offset the increased construction costs which were anticipated in the Kicking Horse Pass.[30] If adoption of the southern route were to be justified on economic grounds, therefore, the C.P.R. had to be prepared to invest even more heavily at construction time in order to ensure that the distance and cost of operating around the Big Bend would be saved. As the C.P.R.'s General Manager, Van Horne, freely admitted, "'to save this distance work will be undertaken that would ordinarily be considered impracticable on account of expense.'"[31]

It was therefore understood and expected that a direct crossing of the Selkirks would necessitate a heavy "immediate" investment. The exact amount which the C.P.R. was prepared to invest in order to secure the saving in distance is not known, but an interesting revealed-preference function may be deduced, which offers at least a general indication of the extent of that preparedness.

The engineer Walter Moberly, having discovered Eagle Pass through the Gold Range in the 1860's, sought to link it with a pass through the Selkirks, but in 1871 he had abandoned his surveys with the conclusion that such a pass "would be impracticable for a railway unless a long tunnel, probably 14 to 15 miles in length, should be excavated through the Selkirk range."[32] The report of the necessity for this length of tunnelling probably expedited the Federal Government's decision in favour of the Yellowhead Pass, announced while Moberly was in Victoria, having returned from his 1871 explorations.[33]

Ten years later, when the C.P.R. requested permission to adopt a southern route, the expectation was still that "some long tunnels" would be required in order to secure a direct crossing of the Selkirks.[34] Although, as has been noted above, the C.P.R. was prepared to undertake "work...which would ordinarily be considered impracticable on account of expense," it is not clear that they regarded this amount of tunnelling as acceptable, for they continued to reserve the option of building around the Big Bend.[35]

The amount of tunnelling which the C.P.R. was prepared to accept appears to have been a maximum of 2 1/2 miles, for it was only at the end of the 1882 surveying season, after Major A. B. Rogers had established that no more tunnelling than this would be required if a route through Rogers Pass were to be adopted, that the C.P.R. applied specifically for permission to locate the line directly across the Selkirks.[36] When even this amount of tunnelling proved not to be necessary in order to secure acceptable gradients, the direct crossing via Rogers Pass became clearly preferable to the circuitous passage around the Big Bend, saving some seventy-seven or eighty-seven miles of mountain railway construction.[37]

The sketching of this preference function has offered some insight into the extent to which the C.P.R. was prepared to undertake "immediate" investment in order to secure future operating savings. It is necessary now to establish the extent of the operating savings which the C.P.R. would require in return for its willingness to accept higher construction costs. Again, no quantitative data is available. Again, too, however, it is possible to obtain some insight into the trade-off from the evidence of preferences, both revealed and explicit.

Evidence of revealed preference is available in the C.P,R.'s preparedness to accept gradients steeper than initially projected on the Rogers Pass route. Rogers, when surveying the Selkirks in 1881, had initially reported "a grade not to exceed sixty-six feet to the mile between Kamloops and the North Fork of the Illi-cille-want [sic], and from thence to the summit of the Selkirks not to exceed eighty feet to the mile."[38] After the following year's surveys, he was compelled to revise these estimates upwards, locating "a line ascending westerly for a distance of twenty miles to the summit of the Selkirks at the rate of 105 6/10 feet per mile, and descending the western slope at the same rate for the same distance..."[39] Nevertheless, the C.P.R. was clearly aware of this gradient system when they applied for permission to exploit Rogers Pass, and was clearly prepared to accept it.[40]

When Rogers later recommended that the gradients again be revised upwards, to 116 feet per mile,[41] it was still not expected that the revision would negate the advantages of Rogers Pass over the Big Bend. "(I)nasmuch as assistant engines would be required on a grade of ninety feet as well as on one of 116 feet per mile...,"[42] better utilisation could be anticipated from pushers over the Selkirk summit than from pushers on scattered gradients around the Big Bend. Therefore, the savings in distance would not be offset by the costs of having to operate over the steeper gradients.

Evidence of explicit preference is available from Van Horne's own retrospective explanation of the trade-off decision. In his evaluation, Van Horne assumed that no pusher gradients at all would be required on the Big Bend. Therefore, the savings in distance over Rogers Pass would be offset by the full cost of the pusher operation which would be required on the summit route. Even under this assumption, however, the Rogers Pass alternative was still preferred. Explicitly, the anticipated savings in distance would offset the cost of operating over steeper gradients.[43] Implicitly, from the above evidence of revealed preference concerning construction costs, it may be inferred that the savings in distance were also expected to offset the potentially higher cost of construction through Rogers Pass.

From the evidence of both revealed and explicit preference, it is clear that the prime factor in influencing the decision to adopt Rogers Pass was the anticipated saving in operating costs, and in particular, in the operating cost of distance. Insofar as this saving in the operating cost of distance was equated with an improved capability to compete for through traffic, the manner in which the trade-off decision was handled in the Selkirk Mountains was consistent with the stated objectives which had prompted the search for a more southerly location.[44]

This analysis explains why the main line of the first Canadian transcontinental railway was located through Rogers Pass. The decision to dismiss the Yellowhead Pass and Crow's Nest Pass alternatives was based at least partly upon political grounds. Nevertheless, it is by no means clear that this decision was inconsistent with a decision which would have been based purely upon principles of railway economics. With the selection of Rogers Pass, it appeared that the objectives which the more southerly location was intended to achieve had been fulfilled, and that the trade-off which the C.P.R. had been prepared to make, that of incurring higher construction costs immediately in order to save operating costs later, had been made. Indeed, when Rogers Pass was selected from the alternatives, it was not at all clear that construction costs would be higher in building through the Pass than they would have been in building around the Big Bend, for although the C.P.R. had been prepared to accept 2 1/2 miles of tunnelling if it had had to, in practice there were virtually "no tunnels necessary."[45] Moreover, although the C.P.R. had been prepared to accept that the cost of the pusher operation over Rogers Pass would offset some of the saving in distance, in practice it is likely that the cost of the pusher operation over Rogers Pass was actually less than the cost would have been of the pusher operation which would certainly have been required around the Big Bend.

The selection of Rogers Pass, therefore, was not merely a necessary expedient. It was not an alternative forced upon the C.P.R. by the Company's blind decision to enter the Rockies via the Kicking Horse Pass with no sure knowledge of its means of exit.[46] Rather, it was a positive choice. It represented a sound solution to the problem of crossing the Selkirk Mountains by rail. The C.P.R. was well pleased,[47] and expectations were high. It is appropriate now to consider the nature of these expectations, and the foundations for optimism.

3.3 <u>The Expectations Of The Builders</u>

The purpose of this section is to examine further the expectations which the C.P.R. harboured for construction and operating conditions over Rogers Pass, prior to the actual construction and inception of the transcontinental link. The examination highlights the gap between the C.P.R.'s expectations of the route, and the realities which will be examined in the following chapter. The analysis of the C.P.R.'s specific expectations in Rogers Pass will examine five distinct areas of constructional and operational concern. These areas are the character of construction work, the cost of construction, the time required for construction, the methods of operation, including forecasts of traffic volumes, and the necessity for protection of the facility from snow slides.

a) <u>The Character Of Construction Work</u>

On first traversing the Pass in 1882, Rogers himself had felt "entirely safe in reporting a practicable line through this range," although he expected that the work would be "very heavy and expensive."[48] The following year, after further surveys, Rogers again reported optimistically: "Through the Selkirks the work is more uniformly distributed than through the Rockies and presents no special engineering difficulties and for mountain work may be considered moderate, the percentage of rock being unusually small."[49] Tunnelling was expected not to exceed 1,200 lineal feet on the entire distance across the Selkirks, in comparison with 1,800 feet on the Upper Kicking Horse, 1,400 feet on the Lower Kicking Horse and 2,200 feet in the Columbia Canyon.[50] In a "Memorandum of the General Character of the Work," prepared in February 1884, the C.P.R.'s Chief Engineer observed that,

> From the east foot of Selkirks to mouth of Eagle Pass:- The work may be considered moderate for mountain work, being largely composed of gravel."[51]

Again this contrasted with conditions in the Rockies, where, on the west slope, in the Chief Engineer's estimation, "The work may be classed as generally heavy, with some short distances very heavy."[52] In September 1884, mere months before construction through the Selkirks commenced,[53] S. B. Reed, the engineer who had located the mountain section of the Union Pacific Railroad, reported that,

> The line over the Selkirk Mountains, a distance of sixty-three miles, is remarkably easy to construct, there being comparatively little rock excavation, and but one short tunnel. The great bulk of the work will be in earth and loose rock.[54]

b) <u>The Cost Of Construction</u>

Few specific forecasts of construction costs in the Selkirks survive.[55] In February 1884, the House of Commons of Canada had been informed that the C.P.R.'s estimate for the entire distance from the summit of the Rockies to Kamloops was $12 million,[56] an average of $44,776 for each of the 268 miles. When Reed travelled the route in August 1884, he calculated that, "between the summit of the Gold Range and the summit of the Rocky Mountains...this section of the road can be constructed at an average cost not exceeding thirty three thousand dollars ($33,000) per mile."[57] Reed's glowing conclusion was that,

> In view of the rugged mountain country, through which the line passes, from Savonna [sic] Ferry to the summit on the main range of Rocky Mountains, a distance of two hundred and ninety miles...you have an exceedingly cheap line to build, costing far less per mile than the mountain work of the Union and Central Pacific roads."[58]

The more conservative estimates which the C.P.R. formulated for submission to the Federal Government the next month forecast an average cost for this same section of some $37,000 per mile, and the forecast cost of construction across the Selkirks was actually slightly below this average.[59] Even if it is assumed that the Big Bend could have been operated as cheaply as the direct crossing, construction costs around the Columbia River would have had to have been less than $20,000 per mile for the Big Bend route to have represented a cheaper overall solution than the Rogers Pass route to the problem of crossing the Selkirk Mountains by rail.[60]

c) Time Required For Construction

In their original contract with the Federal Government, the C.P.R. had been committed to complete the entire transcontinental facility within ten years, that is, by May 1891. Rapid progress across the prairies was doubtless a major factor in enabling this deadline to be brought forwards, but the location of a direct route through the Selkirks, and the optimistic projections of its engineering feasibility, must also have contributed to the revision of the target. When the C.P.R.'s President, Sir George Stephen, reported the discovery of Rogers Pass to the Marquis of Lorne in September 1882, he volunteered: "Expect to have the whole line from Montreal to Pacific Ocean open by January first, 1887,"[61] over four years sooner than the contracted deadline. By December 1882, even this expectation had been revised. Stephen stated that the C.P.R. expected "to complete their own work across the mountains" during 1885.[62] Up to this time, the Lake Superior section was expected to be the last completed, being scheduled to open during 1886.[63] These expectations were unchanged a year later, when the C.P.R. concluded a contract for financial assistance from the North American Railway Contracting Company which stipulated completion of the mountain section by December 31, 1885, and completion of the Lake Superior section by December 31, 1886.[64] When this contract lapsed, and the Federal Government again intervened with loans to the C.P.R., the expectations were revised. The C.P.R. undertook completion of the entire project by May 1886, thus buying time in the mountains at the expense of time on Lake Superior.[65] In May

1884, Van Horne confided to Major Rogers, "(W)e hope that the men on construction from the East will reach the second crossing of the Columbia and possibly Eagle pass by the end of this year..."[66] Slow progress down the western slope of the Rockies[67] only slightly tempered this confidence. In September 1884, Van Horne assured the Directors, "I think there will be no difficulty in completing the mountain section within a year from this date..."[68]

d) Operating Methods And Traffic Forecasts

As the above analysis demonstrated,[69] the C.P.R. was aware when Rogers Pass was discovered that whether the main line followed the Big Bend or traversed the Pass, a pusher operation would be required for either alternative. Several arguments were advanced in favour of the pusher operation over Rogers Pass. The pusher gradients would be concentrated within twenty miles on either side of the Selkirk summit,[70] permitting intensive utilisation of the pusher fleet. The summit itself was "represented as being admirably adapted for the location of a depot for marshalling trains, being practically level for a distance of about three quarters of a mile."[71] Moreover, "considering the fact that the heavy grades in the Selkirk Range are embraced within a comparatively short distance, their disadvantage is very little as compared with the great savings in through distance."[72] Less pusher capacity would be wasted over Rogers Pass than on the lighter pusher gradients around the Big Bend.[73] Finally, since the only other pusher gradient was expected to be for twenty miles on the west slope of the

Rockies,[74] the pusher gradients in the Selkirks complemented the gradient system of the entire transcontinental railway, a system which compared favourably with those of the Central and Union Pacific Railways, the standards of which had provided the model for the C.P.R.[75]

It is likely that these arguments alone would have sufficed to persuade both the C.P.R. Directors and the Federal Government that the pusher operation over Rogers Pass would not be detrimental to the movement of traffic through the mountains of B.C., but rather, in conjunction with the saving in distance, would be a strength of the southern route. Two further arguments in favour of the pusher operation were presented by the C.P.R.

The first was that traffic requiring transit through the mountains would be light "for a number of years to come."[76] Therefore, a small fleet of pusher locomotives would suffice to handle the business. In the Rockies, Van Horne forecast that "three, or at most four, trains each way per day will carry all the business to be done...,"[77] and expressed the belief "that in the case of passenger trains double locomotive service will seldom be required; ordinarily the substitution of a heavy for a light locomotive will answer the purpose."[78] The forecasts of traffic volume appear internally inconsistent with the boasts of timber and mineral resources vaunted by both Stephen[79] and Van Horne.[80] Nevertheless, Van Horne was confident that such traffic as was carried through the mountains would be carried profitably.[81]

The second argument was "that the preponderance of through traffic across the continent (would be) largely west bound, and that the two heavy gradients rising eastward might therefore be still heavier without material disadvantage."[82] This forecast flatly contradicted those generated by members of the B.C. Board of Trade, which emphasised eastbound flows from B.C.[83] However, the argument does highlight the "system" implications of the pusher gradients over the Selkirks. On the entire C.P.R. transcontinental "system," a westbound preponderance of traffic was preferable, since this was revenue traffic, and the trains conveying revenue traffic would have to be tailored to only one restrictive ruling gradient, while longer trains of empties, generating zero direct revenue, could be hauled against the two adverse eastbound ruling gradients.[84] Thus, the traffic imbalance would actually reduce the total joint cost of the operation. Within the Selkirk Mountains themselves, however, since the pusher gradients were expected to be of approximately equal length, a perfect balance of flows would be optimal, in order to ensure even utilisation of motive power on either side of the summit. An imbalance in favour of either direction would be equally costly, but the actual direction of the imbalance would be irrelevant to the economics of the pusher operation.

e) Snowslide Protection

The C.P.R. had long been aware of potential avalanche problems in crossing the Selkirks directly.[85] They had accepted Rogers' recommendation that gradients through Rogers Pass be increased from 105.6 feet per mile to 116 feet per mile, "in order to avoid some points where dangerous snow slides are to be feared."[86] This recommendation had been relatively "cheap" to implement,[87] but further gradient increases in order to avoid slides were impracticable, since they would entail a costly increase in the ruling gradient of the system, and breach of their original contract, which had stipulated maximum gradients of 2.2 per cent. compensated. Tunnelling in order to avoid avalanches does not appear to have been considered at construction time.[88] Instead, where avalanche paths could not be avoided, the C.P.R. intended to protect the main line with snow sheds. When Rogers had first traversed the Pass, he had felt "assured that the distance in which difficulties may be expected in crossing the Selkirk Range will be reduced to ten or twelve miles."[89] As late as August 1884, Reed, making the same crossing, would report that "evidences of snow slides were seen at and near Roger's [sic] Pass, in the Selkirk Range, also near the summit of the main range of the Rocky Mountains, but the aggregate distance on which these occur does not exceed fifteen miles."[90] He admitted that, "A number of snowsheds will probably be required for the protection of the track," but pointed out that "nearly fifty miles of these are in successful use on the Central Pacific road."[91] Thirty-two miles of these sheds had cost $1,731,000 in the 1860's.[92] In March 1885, the C.P.R. estimated that $450,000 would be required for the construction of snowsheds in the mountains[93]: if they were expecting to be able to construct their sheds for the same cost as the Central Pacific had incurred, they could expect to completely cover with snowsheds at least eight miles of those fifteen troublesome miles identified in the mountains.

This detailed investigation of the specific expectations which the C.P.R. harboured for construction and operating conditions over Rogers Pass prior to the actual commencement of work in the Selkirks reveals the particular grounds upon which rested the Company's satisfaction in securing a location through Rogers Pass and their confidence in contemplating future operations over the Selkirks. Construction was expected to be relatively easy and significantly less costly than alternative routes. Adoption of the Rogers Pass route would enable early completion of the entire transcontinental facility, and the rapid generation of revenues from through traffic with which to support subsequent improvements to the line. The pusher operation over the Selkirk summit would complement the gradient system of the entire transcontinental facility, and it was expected that the avalanche problem, which did not appear unduly burdensome when set against conditions experienced by rival railways, would be effectively eliminated by a modest capital outlay at construction time.

The results of this investigation reinforce the conclusion reached in the second section of this chapter, that the Rogers Pass route appeared to offer a positively sound rather than a merely expedient solution to the problem of breaching the Selkirk Mountains by rail. The C.P.R. had been prepared to undertake heavy "immediate" investment in order to obtain operating savings in the future. Yet not only did the operating costs over Rogers Pass appear likely to be far less than operating costs around the Big Bend, but it seemed that a heavy "immediate" investment of capital would not be necessary in order to obtain the savings in operating costs. Thus, although the C.P.R. had been prepared to make a trade-off between construction costs and operating costs, it seemed that they would not in practice have to make such a trade-off, for the Rogers Pass route represented the least-capital-cost and least-operating-cost solution.

Moreover, the decision to adopt Rogers Pass in preference to the Big Bend was much less controversial than the decision to adopt the Kicking Horse Pass in favour of the Howse Pass through the Rockies. The engineers Fleming, Hogg, Rogers and James Ross were each independently dispatched through the Howse Pass in various attempts to establish the feasibility of that alternative. It was not until November 1883, after the railhead had already advanced far to the west of Calgary, and after even more surveys through Howse Pass had been undertaken, that Ross, the manager of construction in the mountains, would admit to feeling "quite satisfied that we have secured beyond doubt the best line through the Mountains."[94] The wrangling with the Ministry of Railways and Canals which accompanied the submission of the C.P.R.'s location plans for the western slope of the Rockies[95] and the Kamloops Lake sections[96] was completely absent from the submission of the profiles of the alignment over Rogers Pass. These latter plans were approved and returned quietly, quickly and without question during the autumn of 1884,[97] in ample time for the commencement of construction through the Selkirks the following spring.

FOOTNOTES

[1] G. C. Cunningham, "Snow Slides in the Selkirk Mountains," Transactions of the Canadian Society of Civil Engineers, Vol. I, Part II, October-December 1887, p. 18.

[2] Ibid., pp. 18-19.

[3] See above, pp. 17-18.

[4] For a graphic description of the difficulties of penetrating the Selkirks on foot, see, S. Fleming, England and Canada. A Summer Tour between Old and New Westminster, with Historical Notes, Montreal, Dawson Brothers, 1884, pp. 271-94. In three full days of marching, Fleming's party managed barely ten miles through the Selkirks.

[5] Cunningham, op. cit., p. 19.

[6] Ibid.

[7] Ibid.

[8] W. S. Vaux, Jr., "The Canadian Pacific Railway from Laggan to Revelstoke, B.C.," Reprinted from the Proceedings of the Engineers' Club of Philadelphia, Vol. XVII, No. 2, May 1900, p. 72.

[9] Cunningham, op. cit., pp. 19-20.

[10] A. C. Dennis, "Construction Methods for Rogers Pass Tunnel," Proceedings of the American Society of Civil Engineers, Vol. XLIII, No. 1, January 1917, p. 6.

[11] T. C. Keefer, "The Canadian Pacific Railway," Transactions of the American Society of Civil Engineers, Vol. XIX, No. 394, June 1888, pp. 83-84.

[12] Cunningham, op. cit., p. 20.

[13] Ibid., pp. 20-24.

[14] Ibid., p. 24.

[15] For an analysis of the frequency and mass of avalanches on major avalanche paths in the Selkirk Mountains from 1909 to 1979, see, B. B. Fitzharris and P. A. Schaerer, The Frequency of Major Avalanche Winters, Ottawa, National Research Council Of Canada, Division of Building Research, June 1979. Cunningham himself recorded one snow slide standing forty feet deep on the roof of a C.P.R. snow shed. Cunningham, op. cit., p. 30.

[16] For an account of snow problems in the Sierra Nevada, see, G. M. Best, Snowplow: Clearing Mountain Rails, Berkeley,

California, Howell-North Books, 1966. See also Cunningham, op. cit., p. 25.

[17] See, for example, W. Kaye Lamb, The History of the Canadian Pacific Railway, Toronto, Macmillan, 1977, pp. 79-81; J. H. E. Secretan, Canada's Great Highway: From the First Stake to the Last Spike, London, John Lane, 1924, pp. 247-8; C. A. Shaw, op. cit., pp. 10-11; R. G. MacBeth, The Romance of the Canadian Pacific Railway, Toronto, The Ryerson Press, 1924, p. 85; N. Thompson and J. H. Edgar, Canadian Railroad Development from the Earliest Times, Toronto, The Macmillan Company of Canada, 1933, p. 138; M. Sprague, The Great Gates: the story of the Rocky Mountain passes, Boston, Little, Brown, 1964, p. 293; G. P. de T. Glazebrook, A History of Transportation in Canada, Toronto, The Ryerson Press, 1938, p. 275; A. J. Johnson, "The Canadian Pacific Railway and British Columbia, 1871-1886," MA Thesis, University of British Columbia, 1936, pp. 151-155.

[18] E. E. Pugsley, The Great Kicking Horse Blunder, Vancouver, 1973, pp. v-vi.

[19] A C.P.R. engineer in the west would recall the day that, "Van Horne sent for me, and announced in a most autocratic manner that he wanted "The shortest possible commercial line" between Winnipeg and Vancouver..." Secretan, op. cit., p. 99.

[20] "...the Canadian Pacific Railway company propose to carry their railway far to the South of Edmonton if a practicable line can be found by the Kicking Horse Pass that will shorten the distance very considerably and thereby reduce the cost of operating it." Marcus Smith to Collingwood Schreiber, Chief Engineer of the C.P.R., April 10, 1882, Department of Railways and Canals, Railway Branch, Central Registry Files, Public Archives of Canada, Ottawa, (henceforth "PAC"). RG 43 A 2 (a) 6710 Vol. 223.

[21] "The importance of the great saving in distance by this line cannot be overestimated. It affords a line across the continent materially shorter than that from New York to San Francisco by way of the Union and Central Pacific Railways, and places beyond a doubt the ability of this Company to compete successfully for the trans-continental freight and passenger traffic." Charles Drinkwater, C.P.R. Co. Secretary, to Sir Charles Tupper, Minister of Railways and Canals, February 21, 1883, Dominion Sessional Papers, Ottawa, (henceforth "DSP,") Vol. XVI, 1883, 27e p. 173.

[22] "'Major Rogers reports that there is no question about feasibility of good line with easy grades through Kicking Horse Pass although work will be very expensive.'" Van Horne, Telegram to Drinkwater, cited by Tupper, Official Report of the Debates of the House of Commons of the Dominion of Canada, Ottawa, (henceforth "HoC Debates,") April 17, 1882, p. 953.

[23] W. Vaughan, op. cit., p. 80.

[24] Sir Thomas Shaughnessy to R. Douglas, Secretary, Geographic Board, Ottawa, March 23, 1921, Department of Railways and Canals, Railway Branch, Central Registry Files, PAC. RG 43 A 2 (a) 6710 Vol. 223. In the same letter, Shaughnessy averred that "the first Directors and the Executive of the Canadian Pacific considered the route via the Yellowhead Pass too far to the North and involving undesirable length of line." See also, J. L. McDougall, Canadian Pacific: A Brief History, Montreal, McGill University Press, 1968, p. 69; Shaw, op. cit., p. 11; Sprague, op. cit., p. 296.

[25] Van Horne to Tupper, DSP, Vol. XVI, 1883, 27 l p. 7.

[26] Ibid.

[27] "The river has its canons [sic], and in places washes the base of the mountains, so that heavy work and possibly some tunnelling would have been encountered on the longer route." Keefer, op. cit., p. 75. Vaux, op. cit., p. 73, goes so far as to claim that it was "the cost of tunnelling and bridging" alone which persuaded the C.P.R. to seek a direct route across the Selkirks. Published evidence does not support this view. See, Van Horne to Tupper, op. cit.

[28] "'The worst that can happen in case of failure to cross Selkirk is, that the line may be forced round the great bend of the Columbia, which would considerably increase distance..." Van Horne, Telegram to Drinkwater, op. cit.

[29] Van Horne estimated the distance around the Big Bend at 140 miles, and the distance by the direct crossing over Rogers Pass at 63 miles, yielding a saving in distance via the latter of 77 miles. Van Horne to Tupper, op. cit., p. 7. Howard Palmer estimated the distance around the Big Bend at 150 miles, and, using the estimate of 63 miles over Rogers Pass, obtained an estimate for the savings via the direct route of 87 miles. Palmer also estimated that the distance from Winnipeg to Kamloops via Edmonton, the Yellowhead Pass and the Albreda Pass was 1,346 miles, against an estimate of 1,224 miles via Calgary, the Kicking Horse Pass, Rogers Pass and Revelstoke, yielding a saving for the southerly route of 122 miles if Rogers Pass were adopted, and of 35 miles if the Big Bend were followed. H. Palmer, "Early Explorations for the Canadian Pacific Railway," Bulletin of the Geographical Society of Philadelphia, Vol. XVI, No. 3, July 1918, p. 78.

[30] See note (22).

[31] Van Horne, Telegram to Drinkwater, op. cit.

[32] W. Moberly, "The Introductory Chapter in the History of the Canadian Pacific Railway," Moberly Papers, Vancouver City Archives, (henceforth "VCA,") p. D915.

[33] Ibid. Moberly himself proposed for the following year, "A trial survey across the Selkirk Range by the valleys of the Gold

River and Gold Creek, to ascertain what length of tunnelling would be required to connect those valleys." N. Robinson, Blazing the Trail Through the Rockies: The Story of Walter Moberly, Vancouver, News - Advertiser, printers, 1913, p. 75.

[34] "'The crossing of the Selkirk Range is the only thing in doubt, but explorations have progressed sufficiently to justify belief that they can be crossed by use of some long tunnels.'" Van Horne, Telegram to Drinkwater, op. cit.

[35] Ibid. See note (28).

[36] Drinkwater to Tupper, September 15, 1882, DSP, Vol. XVI, 1883, 27, p. 25.

[37] Ibid.

[38] Stephen to J. H. Pope, Acting Minister of Railways and Canals, September 29, 1882, DSP, Vol. XVI, 1883, 27e, p. 168.

[39] Ibid.

[40] Drinkwater to Tupper, September 15, 1882, op. cit.

[41] Rogers, Engineer, Mountain Division, to Van Horne, January 10, 1883, DSP, Vol. XVI, 1883, 27e, p. 171.

[42] Van Horne to Tupper, April 18, 1883, DSP, Vol. XVI, 1883, 27 l, p. 6. The C.P.R. would use this reasoning to defend an even more drastic upward revision on the western slope of the Rockies, from ninety feet per mile to 116 feet. Ibid., pp. 6-7.

[43] Ibid., p. 7.

[44] See notes (20) and (21).

[45] Stephen, Telegram to Marquis of Lorne, September 1882, quoted in Pugsley, op. cit., p. vi.

[46] As Howay, and particularly Pugsley, maintain that it was. See F. W. Howay, British Columbia From the Earliest Times to the Present, Vol. II, Vancouver, S. J. Clarke Co., 1914, p. 424; Pugsley, op. cit., p. 11.

[47] See, for example, Drinkwater to Tupper, February 21, 1883, op. cit.

[48] Rogers to Van Horne, op. cit.

[49] Rogers to Van Horne, November 20, 1883, DSP, Vol. XVII, 1884, 31f, p. 40.

[50] Ibid.

[51] "Memorandum of the General Character of the Work, Prepared from the Last Information at Command," Schreiber, February 1,

1884, DSP, Vol. XVII, 1884, 31f, p. 43.

[52] Ibid.

[53] The railhead crossed the Columbia in October 1884, and reached Beavermouth in November. Lamb, op. cit., p. 119.

[54] Reed to Van Horne, September 9, 1884, DSP, Vol. XVIII, 1885, 25n, p. 5.

[55] As late as February 1884, one member of the House of Commons would complain that no cost estimates had been submitted for any of the work west of the summit of the Rockies. HoC Debates, February 18, 1884, p. 359.

[56] Ibid., p. 458.

[57] Reed to Van Horne, op. cit., p. 5.

[58] Ibid.

[59] $36,927.08 per mile for the entire section, compared with $36,557.38 per mile across the Selkirks. The former average is calculated from an estimate of $10,635,000 for the 288 miles from the summit of the Rocky Mountains to Savona's Ferry. This estimate is contained in "Schreiber's Estimate, Summit of Rocky Mountains to Middle of Eagle Pass," enclosed with, Ross to Van Horne, October 7, 1884, "Van Horne Letterbooks," Vol. 7, p. 928. The latter average, from the same source, is based on an estimate for the total cost of construction between Miles 1,039 and 1,100, west of Winnipeg, of $2,230,000. Ross presumed that these estimates were "intended to be entirely safe." Ibid., p. 927.

The estimates per mile for each section may be calculated from Schreiber, op. cit., as follows:- Mile 963 (summit of Rockies) - 966, $26,250; 967 - 975, $155,555.56; 976 - 1,024, $37,755; 1,025 - 1,038 (the crossing of the Beaver River, the point at which the rail line diverged from the Columbia River), $60,714.28; 1,039 - 1,057 (summit of Rogers Pass at 1,054), $35,789.47; 1,058 - 1,072, $36,666.66; 1,073 - 1,100 (Revelstoke, the point at which the Columbia River was rejoined), $35,714.24. Ibid. These estimates correspond exactly with those contained in "Progress Estimate No. 56, Central Section, Eastern Division," November 4, 1884, DSP, Vol. XVIII, 1885, 25a, p. 90, except for the estimate of the cost of the section between Miles 967 and 975. In the Dominion Sessional Papers, the estimate for the total cost is given as $400,000, yielding an average cost per mile of $44,444.44. Schreiber's estimate for the total cost of the nine-mile section is quite distinctly stated as $1,400,000, yielding an average cost per mile of $155,555.56.

[60] This capital cost includes an estimate of $450,000 for snowsheds on the direct crossing. See note 93. The capital invested on the Big Bend route would have had to have been less

than $2,680,000 (i. e. $2,230,000 + $450,000). If the distance around the Big Bend were 140 miles, the cost per mile would have had to have been less than $19,142.86. If the distance were 150 miles, the cost would have had to have been less than $17,866.67. These rates would have been unprecedented for mountain railway construction to main-line standards.

[61] Stephen to Lorne, op. cit.

[62] "Official Memorandum Respecting the Position and Prospects of the Canadian Pacific Railway," Sir George Stephen, December 12, 1882, DSP, Vol. XVI, 1883, 27n, p. 5.

[63] Ibid.

[64] DSP, Vol. XVII, 1884, 31g, pp. 52-53.

[65] DSP, Vol. XVII, 1884, 31z, pp. 250-54.

[66] Van Horne to Rogers, May 23, 1884, "Van Horne Letterbooks," Vol. 6, p. 251.

[67] O. S. A. Lavallee, op. cit., p. 174.

[68] Van Horne to C.P.R. Directors, DSP, Vol. XVIII, 1885, 25n, p. 2.

[69] See above, p. 44.

[70] "-- a distance which, as everyone familiar with railway management knows, is extremely convenient for the application of a pilot engine." Tupper, HoC Debates, May 4, 1883, p. 960. See also, Drinkwater to Tupper, September 15, 1882, op. cit., and, Rogers to Van Horne, January 10, 1883, op. cit.

[71] Drinkwater to Tupper, September 15, 1882, op. cit.

[72] Stephen to Pope, op. cit.

[73] See note (42).

[74] Van Horne to Tupper, op. cit., p. 8.

[75] "The heavier gradients, which will in no case exceed those of the Central Pacific Railway, will be confined to the mountain section, and within a space of 150 miles.

"It is also to be noted that the entire mountain section is embraced within a distance of less than 550 miles from the Pacific coast, while that of the Central and Union Pacific Railways covers about 1,250 miles and lies at a much greater elevation." "Official Memorandum," by Stephen, op. cit.

[76] The phrase is Van Horne's, used in describing the adequacy for traffic purposes of the "temporary" 4.5 per cent. gradient on the western slope of the Rockies. Van Horne to Minister of

Railways and Canals, May 19, 1884, DSP, Vol. XVIII, 1885, 25a, p. 10.

[77] Ibid., p. 11.

[78] Van Horne to Tupper, op. cit., p. 7.

[79] "Official Memorandum," by Stephen, op. cit., p. 9.

[80] Van Horne to C.P.R. Directors, op. cit., p. 2.

[81] "I do not hesitate to say...that every part of the line, from Montreal to the Pacific, will pay." Ibid., p. 3.

[82] Van Horne to Tupper, op. cit., p. 8.

[83] "I have shown that a large amount of ore or base metal will be shipped from the Kootenay mines over the C.P.R....It will be a valuable trade for that railway, as the transportation will be westwardly, while the bulk of their other freight will be in a contrary direction." G. B. Wright to J. H. Pope, June 11, 1883, British Columbia Board of Trade, Annual Reports, Victoria, 1882-83, p. 31.

"With the fast-approaching completion of the Canadian Pacific Railway, whereby direct and speedy transport eastward will be secured, the food-fish trade of this Province must receive a notable impulse. . .A large demand will necessarily arise throughout the line of the railway, where settlement has been established, and in Manitoba; and eastward again of the last named locality, in Ontario and elsewhere, it is probable that, during the winter season, some of our sea-fishes may prove abundantly attractive, and find a ready and lucrative market." op. cit., 1883-84, pp. 96-97.

[84] Van Horne to Tupper, op. cit., pp. 7-8.

[85] Moberly cited "avalanches of snow and rock" as a principal reason for eschewing direct crossing of the Selkirks. Moberly Papers, op. cit., p. D910. He himself recalled running for his life, clad in snowshoes, to avoid interment in a snow slide. Ibid., p. D916. See also Fleming, op. cit., pp. 264-65.

[86] Rogers to Van Horne, January 10, 1883, op. cit.

[87] See note (42).

[88] See below, pp. 70-72.

[89] "Memorandum by Mr. Smellie, Engineer in Chief at Company headquarters, Montreal, dated April 15, 1882," cited by Tupper, HoC Debates, April 17, 1882, p. 954.

[90] Reed to Van Horne, op. cit., p. 6.

[91] Ibid.

[92] Report of Commission for examination of Union and Central Pacific Railroads, October 30, 1869, DSP, Vol. XIV, 1880-81, 23o, p. 119.

[93] Stephen to Minister of Railways and Canals, March 18, 1885, DSP, Vol. XVIII, 1885, 25cc, p. 6.

[94] Ross to Van Horne, November 23, 1883, DSP, Vol. XVII, 1884, 31f, p. 41.

[95] See, for example, DSP, Vol. XVIII, 1885, 25a, pp. 10-16.

[96] See, for example, Schreiber to Bradley, November 13, 1884, DSP, Vol. XVIII, 1885, 25a, p. 32.

[97] DSP, Vol. XVIII, 1885, 25a, pp. 18-22.

CHAPTER 4

REALITIES

The C.P.R. Management:
"This is the climax of mountain scenery."[1]

The C.P.R. Customer:
"It is not too much to say that the Canadian Pacific passage through the mountains is the greatest sermon ever presented to man on the Divine Majesty. The artist is inspired, the lover of nature satiated."[2]

The C.P.R. Employee:
"In the winter it was snow and frost. In the spring it was snowslides, washouts and every other sort of trouble known to railroading, and in the summer it was fires. Just one continual round of pleasure -- if one liked that sort."[3]

The detailed expectations of the C.P.R. for the Rogers Pass route having been analysed in the previous chapter, the purpose of this chapter is to examine the realities which were encountered in Rogers Pass, that is, the actual conditions of both construction and operation which prevailed along the route. Such an examination is necessary to ascertain the existence of gaps between expectations and realities. Once the existence of any gaps has been established, the specific objectives of remedial measures undertaken by the C.P.R. to close these gaps may be more clearly understood, and the success of those measures may be more readily evaluated.

Several compelling narrative accounts have been written of the realities of construction through the Selkirks.[4] Evidence of the methods by which railway operations were conducted through Rogers Pass is, however, more fragmented. In order to preserve the analytical character of the present study, and to facilitate the identification of gaps between expectations and realities, the investigation of realities in this chapter will be similar in structure to the investigation of expectations which was undertaken in the final section of the previous chapter. The same five areas of constructional and operational concern will be explored.

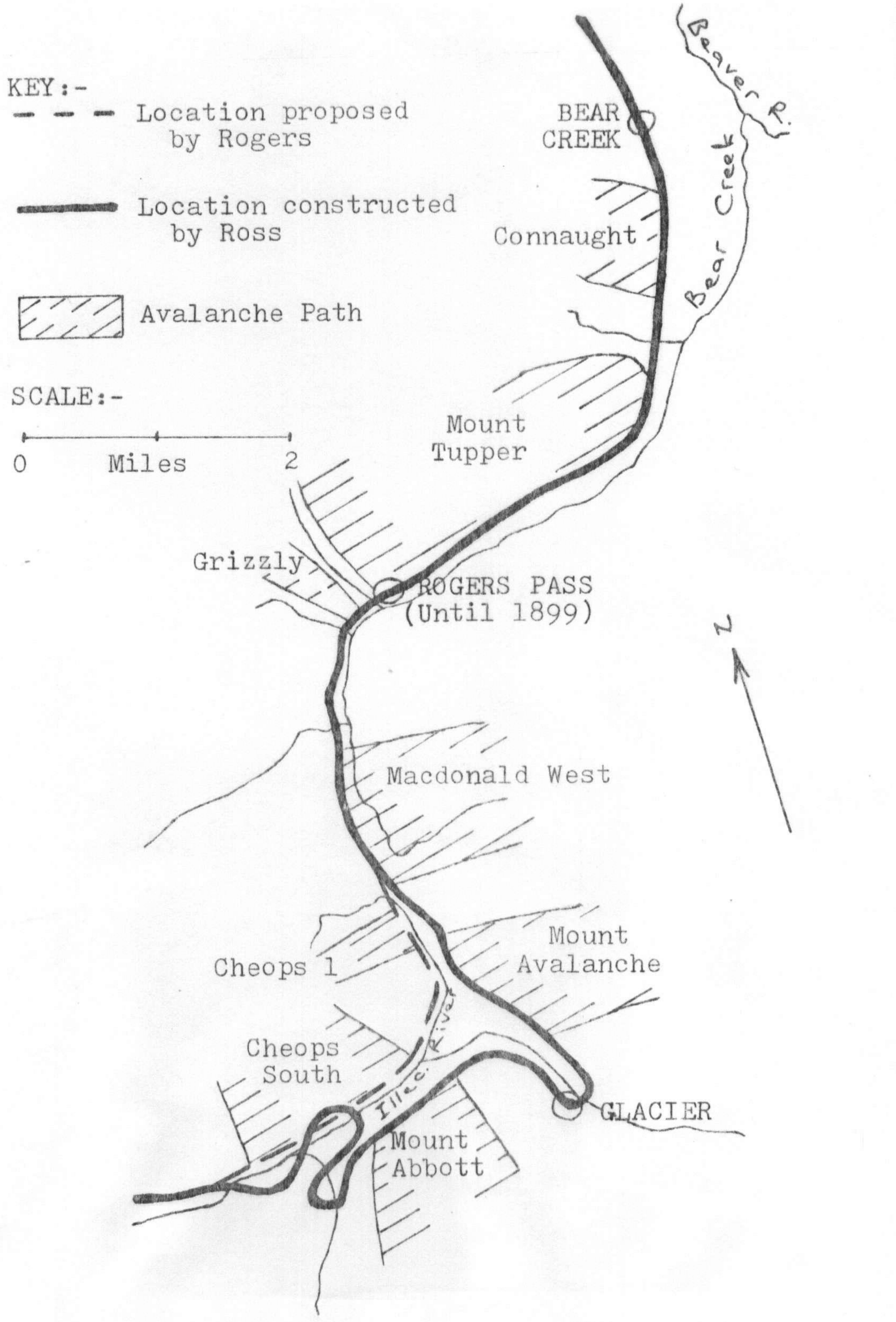
In the consideration of operating realities, the analysis will be extended to include examination of remedial measures adopted by the C.P.R., for it is recognized that, by their very nature, "operating realities" are not static but dynamic in character. They may change with each traffic movement, each technological or managerial innovation, and it is management's unremitting task to seek to narrow those gaps between operating expectations and operating realities as far as they are able. It is therefore appropriate that Part I of this thesis should conclude in this chapter with some consideration of the extent to which those gaps were narrowed by C.P.R. management in Rogers Pass.

a) The Character Of Construction Work

Construction work in the Selkirks was dominated by three constraints, those imposed by snowslides, financial pressure and time pressure. The nature of these constraints will be more closely examined below.[5] This section will concentrate on the impact which these constraints had upon the alignment which was actually followed.

In order to secure cheap and rapid completion of a route over the summit which could be made safe later, as traffic developed, the Construction Manager, James Ross, had intended to undertake "temporary work in the way of building a line that can be thrown further into the hillsides afterwards."[6] On the east slope of the Selkirks, this approach could be implemented successfully.[7] However, Ross was quickly forced to concede that the avalanche problem had been seriously underestimated,[8] and that relocation would be required on the west slope in the interests of safety.[9]

The alignment initially proposed by Rogers had descended the west slope on the north bank of the Illecillewaet River, that is, directly across the south-facing bluffs of Mount Cheops. (See map II.) From observations conducted during the winter of 1884-85, it was discovered that these bluffs, exposed to the sun, "were literally an almost continuous avalanche path."[10] The plan to undertake "temporary work (which) could be used to work into the permanent line" proved untenable.[11] Ross estimated that "it will take 8,350 feet of shedding and about 1400 feet of tunnelling to operate the line with any safety over these...slides."[12] The previous year, in order to avoid the capital cost and delay of building a 1,400-foot tunnel on the west slope of the Rockies, the C.P.R. had obtained the permission of the Federal Government to construct a temporary line with gradients of double the maximum permitted in its contract.[13] A year later, confronted with an even more drastic shortage of capital and an even more pressing need to generate revenue from through traffic,[14] they lacked resources of both time and money to invest in a 1,400-foot tunnel and 8,350 feet of shedding beneath snowslides.



MAP II: LOCATION OF ALTERNATIVE ALIGNMENTS PROPOSED AT CONSTRUCTION TIME ON THE C.P.R. MAIN LINE IN ROGERS PASS.

An alternative location was sought on the south bank of the Illecillewaet. However, in order to reach the valley floor and avoid crossing the highly active Ross Peak slide path, a gradient much steeper than the contractual maximum of 2.2 per cent. compensated would have been required.[15] Even if the C.P.R. had been prepared to increase its ruling gradient, it is doubtful whether the Federal Government, after having so recently acceded to the controversial request for a temporary line in the Rockies, would have granted permission for a second deviation from the contract in the mountains.[16] Instead, Ross developed the line up the valley of Five-Mile Creek, a tributary of the Illecillewaet, and by inserting an elongated loop into the alignment, contrived to reach the valley floor within the contractual maximum gradient.[17]

The south bank of the Illecillewaet was less prone to avalanches than the north bank.[18] Moreover, the "Loop" itself carried the line into the centre of the Illecillewaet Valley by means of five trestles, which had an aggregate length of 4,108 feet.[19] Not only was the new alignment thus clear of slides from both sides of the valley, but construction of the trestles represented a far more rapid and less capital-intensive alternative than tunnelling and snowshedding. Ross estimated that his location would cost "some four to five hundred thousand dollars less to make it a safer line,"[20] and that it had "several hundred degrees less curvature upon it" than upon the original.[21]

However, the sharpest of these curves was 10° 30' at its central angle,[22] which was in excess of the contractual maximum of 10°, and the remainder of the Loop was built at that maximum. The Federal Government had urged that curvature be reduced to eight degrees wherever gradients exceeded sixty feet per mile.[23] Whilst Van Horne had complied on the Kamloops Lake section,[24] Ross warned that in the Selkirks the cost of compliance would be "very heavy."[25] Construction work on the new alignment was "very heavy" too,[26] contrary to the expectation of generally moderate work through the Selkirks. Finally, development of the line had added over three miles to the length of 2.2 per cent. gradient,[27] and all of the additional distance opposed eastbound traffic. Thus, the pusher gradient system within the Selkirks was disequilibrated. Henceforth, the pusher gradient on the west slope would be 24.5 miles long, against 21.5 miles on the east slope.[28] The disequilibrium favoured westbound traffic, the direction forecast by the C.P.R. to preponderate. The extent of the imbalance would not seriously increase the operating cost of eastbound movements relative to westbound movements. Nevertheless, the existence of the imbalance between the pusher gradients meant that, if the relative balance of traffic flows did accord with C.P.R. forecasts, the preponderance of the eastbound flow might eventually pose a capacity problem which would be more acute than it would have been had the pusher gradients themselves been balanced.

The influence of capital and time constraints, which had dictated the relocation west of the summit, was also manifest in the character of the bridge- and tunnel-work undertaken through the Selkirks. Bridging, with "good but uncreosoted timber,"[29] represented a rapid, low-capital-cost alternative to filling or diverting streams, although it imposed high subsequent maintenance costs.[30] In the 46.1 miles between Beavermouth on the east slope and Albert Canyon on the west, there were no less than 207 bridges, with an aggregate length of 19,349 feet.[31] Five of these were each over one thousand feet long.[32] However, perhaps more indicative of the margin at which the C.P.R. were prepared to trade off immediate construction costs against delayed operating costs is the fact that eleven of these bridges were only six feet long, and 118 were sixteen feet long or less.[33]

The unforeseen necessity for tunnelling on the north bank of the Illecillewaet having been avoided by the location of the Loop, tunnelling requirements were largely as expected. No tunnels were necessary on the east slope of the Selkirks.[34] On the west slope, where a maximum of 1,200 feet had been projected,[35] two tunnels, the Laurie Tunnels,[36] aggregating 1,251 feet in length, were eventually constructed between Rogers Pass and Albert Canyon.[37] Due to the time and capital constraints, the side-drift method of construction was adopted in order to secure more rapid completion of the first of these,[38] and the second may not have been completed until at least a year after the main line opened.[39]

Although, as will be demonstrated below, construction work proved both more capital-intensive and more time-consuming than anticipated, in practice neither the work which was undertaken nor the alignment which was adopted appear to have differed greatly from expectations. The single exception was the unforeseen necessity to relocate the line over the Loop immediately west of the summit. Ross, at least, would have preferred not to have been obliged to make the trade-off between construction costs and operating costs in this way.[40] Nevertheless, the Loop alignment was less capital-intensive than the original location, and did, therefore, represent a solution to the trade-off decision which was consistent with the construction policy dictated to the C.P.R. by financial circumstances.[41] Moreover, the Loop, unlike the "Big Hill" on the west slope of the Rockies, was never perceived as being merely a "temporary" alignment, intended to be improved as soon as the flow of revenue traffic permitted. Rather, it was seen as a satisfactory solution in itself to the trade-off decision, and as permanent a solution as the remainder of the alignment across the Selkirks. Thus, the C.P.R. would claim that, "the general alignment, outside the loop was much improved,"[42] and that, "the line as now located is as favourable as any that can be obtained crossing the Selkirks."[43] The latter statement can only be accepted in the context of the predominant capital and time constraints which will be examined below. For taken at face value, the statement implies that the trade-offs between construction costs and operating costs would have been handled in exactly the same manner had no such capital and time constraints prevailed.

b) The Cost Of Construction

The C.P.R.'s entire mountain section, from the Rockies westward, was constructed under conditions of severe capital rationing. These conditions were already in effect when the railhead reached the Rockies,[44] but they were at their most severe during the period of construction across the Selkirks. It was not primarily the capital cost of the actual construction across the Selkirks which was responsible for intensifying these conditions. Three other factors were responsible. These were the capital cost of construction across the Rockies, the inopportune timing of federal loans to assist the C.P.R., and the deliberate reallocation of capital by the C.P.R. from the mountain section to the Lake Superior section in order to accelerate completion of the latter.

In March 1884, with the railhead at the summit of the Rockies, a $22.5 million federal loan had been granted to the C.P.R.[45] By November 1884, however, with the railhead at Beavermouth, the base of the east slope of the Selkirks, the C.P.R. were again "lamentably hard up for money."[46] In March 1885, the Company was briefly unable to meet its wage obligations,[47] and relief, in the form of a further federal loan, was not secured until July 20th,[48] by which time the railhead had almost crossed the Selkirk summit.[49] Meanwhile, completion of the Lake Superior section was accorded priority as a means of obtaining further financial assistance.[50] Capital savings of some four million dollars were effected on construction work in B.C.,[51] and diverted from the mountain section to be "rapidly absorbed on the Lake Superior Section."[52] Only after completion of the latter, in May 1885, could the entire capital resources of the C.P.R. be concentrated upon construction of the remaining sections in the Selkirks and the Gold Range.

The intensification of capital rationing across the Selkirks fostered the propensity to trade off construction costs against operating costs in a manner which would minimise the immediate requirement for capital. Cuttings were reduced to widths less than those on the sections built directly by the Federal Government,[53] against the standards of which Van Horne would rail in later years. Ballasting was omitted, and bridges were built entirely of timber, without masonry or iron support.[54]

Despite the conditions of capital rationing, however, and despite the deliberate management policy of minimising immediate construction costs, the estimate of capital requirements for construction across the Selkirks was exceeded. The excess was incurred chiefly upon the west slope. Between the Beaver River and the summit on the east slope, the actual cost corresponded closely with the estimate of November 1884. From the summit to the first crossing of the Illecillewaet on the west slope, however, the November 1884 estimate of $550,000 was exceeded by some $200,000, or over one third. This increase was incurred not so much because of an increase in the capital cost of the work per mile, but rather because three additional route miles had to be inserted into the section at the Loop. Thus, the per-mile cost of $41,666.66 exceeded the per-mile estimate of $36,666.66 by only fourteen per cent. A similar margin of error prevailed on the section between the first crossing of the Illecillewaet and the second crossing of the Columbia, where the length of railway constructed corresponded with the length estimated. Thus, the expected cost, one million dollars for the twenty-eight miles, was exceeded by $130,000, or thirteen per cent. The total cost of construction from the Beaver River to the Columbia River, as assessed after completion of the entire transcontinental main line, was $2,560,000. This was $330,000, or fifteen per cent., more than the last estimate submitted before construction across the Selkirks began.[55]

Certainly, as James Ross admitted, "It has cost more than it should."[56] Certainly too, Ross had had "to strain every point to so change the location as to save every dollar."[57] Nevertheless, it appeared that this was successfully accomplished. For example, had the location of the Loop not obviated the expenditure of a further $500,000, the actual cost would have exceeded the expectation by some $830,000, or over thirty-seven per cent. C.P.R. management's policy in railway construction across the Selkirks had been overtly to "build the road, in all respects, with the least immediate outlay necessary to insure safety in operation, leaving as much as possible to be done in the future."[58] This policy had been dictated by financial expediency. Yet it was the construction policy which was most appropriate for the C.P.R. as it sought to open up a link between east and west across the mountains of B.C.; and the policy was successfully implemented.

c) <u>Time Required For Construction</u>

Van Horne's hope to reach the second crossing of the Columbia by the end of 1884[59] was frustrated by the nature of the construction work which was encountered on the west slope of the Rockies. The railhead did not reach Beavermouth, ten miles west of the first crossing of the Columbia, until November 1884.[60] Nevertheless, Van Horne's forecasted date for completion, September 1885,[61] was actually brought forwards by a month in October 1884,[62] perhaps in anticipation of easier work in the Selkirks, or perhaps in an attempt to spur Ross to even greater efforts.

Considerable pressure was exerted upon Ross in order to accelerate completion.[63] However, work was delayed early in 1885 by avalanches, the first to be experienced directly by Ross and the C.P.R., and as a result of the experience, the Construction Manager counselled Van Horne to "anticipate a delay in construction."[64] In June 1885, the forecasted date for completion was set back again by two months, to the end of September.[65] Heavy summer rainfall further delayed the work, and by late September the railhead had progressed only as far as Albert Canyon, twenty-four miles west of the Selkirk summit, having advanced scarcely fifty miles in six months.[66] The "Last Spike" was not driven until November 7th, in Eagle Pass.

Even then, however, the line was not opened to through traffic for another eight months. No snowsheds had been provided in either the Selkirks or the Gold Range at the time of construction, and no rail operations were attempted until further research had been undertaken into the incidence of avalanches in the mountains. Only when the slide season was over, and after the damage to the permanent way had been repaired, was the line opened for revenue traffic, in June 1886. This delay in opening the line had been fully anticipated by the C.P.R., and both shareholders and the Federal Government had been forewarned.[67]

Although the erection of snowsheds to protect the permanent way would continue until 1890, the through line itself had indeed been completed only two months behind the schedule anticipated when the railhead reached the Selkirks. The circumstances causing delay, the snowslides and inclement weather, might possibly have been foreseen. Nevertheless, the delay was trivial in comparison with the saving achieved over the deadline initially contracted. Moreover, the date of actual completion was safely within the limits of the revised contract of 1884. No specific value for "construction-time saved" was adduced in the west.[68] However, the time savings were clearly accorded an implicit value, for certain construction decisions, notably the location of the Loop and the building of bridges using timber only, were motivated by the desire to secure time savings as well as by the desire to secure capital savings. Both types of savings had to be traded off against the increase in subsequent operating costs, and it appears that in the Selkirks, trade-offs intended to secure time savings were successful. In order to save one year of construcion time in the Rockies, the C.P.R. were compelled to locate thirteen miles of explicitly "temporary" track, and to operate over its 4.4 per cent. gradients until a permanent line was built.[69] In contrast, no part of the route across the summit of the Selkirks was ever regarded as "temporary" at construction time: when the C.P.R. secured time and capital savings in the Selkirks, they did so without incurring any tacit obligation to undertake subsequent relocation.

d) Operating Methods And Traffic Flows

Gradients across the Selkirk summit nowhere exceeded the 116-feet-per-mile maximum which had been anticipated by the C.P.R. The 2.2 per cent. compensated ruling gradient commenced on the east slope at Beavermouth, 21.5 miles from the summit, and on the west slope at Albert Canyon, 24.5 miles from the summit. Trains were hauled by a single road locomotive westbound from Field to Beavermouth and eastbound from Revelstoke to Albert Canyon.[70] When these trains were too heavy to be hauled over the 2.2 per cent. ruling gradients by the single road locomotive, pusher locomotives were attached in order to avoid the expense of cutting and remarshalling the trains. One pusher locomotive was attached to each ascending train, and provided assistance as far as the yard at Rogers Pass on the summit of the Selkirks.[71] Here, while the road locomotive conducted the train on the descent of the opposite slope, the pusher locomotive was detached, turned in the Rogers Pass roundhouse and returned light down the gradient, to be turned again on a "Y" at Beavermouth or Albert Canyon and held to await the next ascending train.

The level of the variable cost of hauling traffic over the pusher gradients was determined by the number of pusher locomotives required in the mountain locomotive fleet, and by the number of trips obtained from each pusher locomotive. These latter variables were in turn functions of the volume of traffic requiring transit over the pusher gradients, and the volume of traffic which the locomotives could haul per unit of time, as conditioned by their tonnage ratings and speeds, and by the spacing of meeting and passing sidings along the route.

The C.P.R. had expected light traffic for several years after the opening of the transcontinental line, and it appears that they were able to provide sufficient pusher capacity to move the available traffic until at least the turn of the century. Scheduled passenger service was provided by a single passenger train daily in each direction until 1902.[72] Passenger trains comprised five or six cars,[73] and by 1891, observation cars were being attached through the mountains.[74] However, the heaviest of all passenger vehicles, dining cars, were not attached until 1909.[75] The speed of passenger trains through the Selkirks was not determined by the tonnage rating of the road locomotive, but was regulated to coincide with a mealbreak at the Glacier Hotel, two miles west of Rogers Pass.[76] Pusher locomotives were therefore rarely required on passenger duty.

Data limitations inhibit accurate estimation of the volume and direction of freight movements over the Selkirks. However, an impression of low traffic volume and surplus rail capacity may be gleaned. Throughout the summer of 1888, when seasonal freight activity might have been expected to have been at its highest for the year, there were no westbound freight trains scheduled out of Donald at all, and only two per day eastbound.[77] Admittedly, most freight trains were run as specials, without scheduling. Yet in 1889, the Superintendent of the Pacific Division observed that "there will be some days without any trains whatsoever over the road, and others, after the arrival of a steamship [i.e. in Vancouver], there will be a constant quick succession of trains for several days together."[78] During one such local peak, in a single week of July 1888, the Donald Truth boasted of "seventy car-loads of tea" destined eastbound through the mountains.[79] Even this, however, would amount to scarcely one train per day.[80] Movements of the other principal traffic from the Orient, silk, may not have been of sufficient volume to generate a demand for more trains: adequate surplus capacity existed on the passenger trains to permit attachment of cars of silk to their rear.[81] When avalanches in the Rockies disrupted transcontinental service for three days in December 1888, only one special freight and two tea trains were delayed.[82] As late as June 1896, total train movements between Donald and Kamloops, including summer passenger and freight specials as well as mixed trains, amounted to 268, an average of four and a half trains per day in each direction.[83]

The maximum length of trains over the Selkirks appears to have been at least thirteen cars when the line first opened.[84] By 1898, the maximum length of a train with a single pusher locomotive was certainly eighteen cars,[85] and this maximum continued until at least 1900.[86] Eighteen loaded cars were equivalent to 846 tons, the haulage capacity of a single "Consolidation" locomotive on a 1.6% compensated gradient.[87] Over the Selkirks, therefore, where the gradients were 2.2% compensated, pusher locomotives may have been required for any train of greater weight than approximately 420 tons, or about nine loaded cars. It is not known how frequently in practice trains were assisted to the summit. However, evidence suggests that by the 1890's, the operating cost of the pusher service was decreasing, and that this trend continued until the turn of the century. By 1893, the average length of freight and mixed trains on the entire Pacific Division had risen beyond nine cars, the approximate payload for which pusher service was required, to 10.95 cars. One year later, this had increased to 11.31 cars,[88] and in September 1894 it reached 12.13 cars.[89] Although these data are for average conditions only, they indicate that payloads per train were continuing to increase beyond the point at which pusher service became necessary, and therefore that the cost of the pusher service on each train was being spread over more revenue traffic.[90] Moreover, the C.P.R. does not appear to have experienced any difficulty in providing the requisite pusher capacity. When the line had opened for traffic in 1886, two locomotives had been appointed for pusher duty on either slope of the Selkirks.[91] By August 1898, it had still not been found necessary to increase the size of this pusher fleet.[92]

Train speeds over the Selkirks were low. The first scheduled passenger trains averaged less than twelve miles per hour for the seventy-nine-mile journey between Revelstoke and Donald.[93] By 1902, the eastbound "Imperial Limited," the fastest C.P.R. train through the mountains, still required almost four and a half hours for the crossing, averaging less than eighteen miles per hour.[94] The scheduled Third Class "Fast Freight" services averaged just over eleven miles per hour for the journey in 1902.[95] It is unfortunate that little is known of the speeds at which the "extra" freight trains negotiated the Selkirk gradients, for it was these services which conveyed the majority of traffic through the mountains. The evidence of passenger-train timetables is unrepresentative of typical train speeds over the Selkirks. These services were rigorously scheduled, and received priority over all other traffic. Their meets were carefully synchronised, and their speeds through the entire mountain region were governed to ensure timely arrival for breakfast, lunch and dinner at the C.P.R. hotels in North Bend, Glacier and Field. This regulation of their speed, and the fact that several minutes could generally be found for a stop to admire the Illecillewaet River at Albert Canyon,[96] suggest that there was little difficulty in pathing the "extra" freight trains among the scheduled services between Beavermouth and Albert Canyon.

Van Horne had forecast that in the early years, the flow of traffic would be predominantly westbound. Although at first more trains were scheduled to run eastbound than westbound, and although the tea and silk flows which have been so highly visible to subsequent commentators[97] were also always eastbound through the mountains, it appears that Van Horne's forecast was accurate for at least several years after the transcontinental facility opened. In July 1888, the Donald Truth lamented that the C.P.R. could not be made to "see that it would be better for it to haul loaded cars east to Winnipeg, rather than empty ones."[98] The Vancouver Board of Trade recorded that in 1889, 38,895 tons of freight arrived in Vancouver by rail from the East, and 21,441 tons were shipped by rail to the East. In 1890, the respective volumes were 50,773 tons and 13,973.5 tons.[99] It is unlikely that this westbound predominance was reversed until the "take-off" of the lumber trade between B.C. and the prairies after the turn of the century.[100]

With the volume of traffic, the length and speed of trains and the frequency of train movements detailed above, it appears that siding capacity on the main line over the Selkirks was quite adequate for the extent of operations which the C.P.R. was required to undertake. By August 1889, there were certainly crossing points for trains at Bear Creek and Glacier, five miles respectively on the east and west slopes from the yard at Rogers Pass.[101] Table 1, taken from the earliest available comprehensive list of sidings on the Pacific Division, compiled in 1896, indicates that, despite the nature of the terrain, the C.P.R. contrived to locate passing sidings at regular intervals on the main line, and that each of the sidings could easily accommodate the longest trains operated through the mountains. The frequency of sidings and the ratio of siding length to length of running line on the C.P.R. in 1896 compared favourably with those on the Canadian Northern main line when the latter opened through the Yellowhead Pass in 1915.[102]

TABLE 1

SIDING ACCOMMODATION IN THE SELKIRK MOUNTAINS, C. 1896

Section	Length Main Line (Miles)	Length Side Track (Feet)	Car-lengths Of Storage (36' Per Car*)
Revelstoke East			
	5 1/2	800	22
Twin Butte West			
	5	-	-
Twin Butte East			
	5	-	-
Albert Canyon West			
	5 1/2	2,645	73
Albert Canyon East			
	5	2,785	77
Illecillewaet West			
	5	-	-
Ross Peak West			
	5	1,150	31
Ross Peak East			
	5	12,016**	333
Glacier			
	5	3,850	106
Rogers Pass			
	5	2,000	55
Bear Creek			
	5 1/2	1,000	27
Six-Mile Creek			
	5	1,000	27
Beaver West			
	6	7,171	199
Beaver East			
	6	17,012	472
Donald			

* Standard length of C.P.R. box-car. See, "Hunting-Merritt Lumber Company versus Canadian Pacific and British Columbia Electric Ry. Companies, 20, Canadian Railway Cases, 181 at 184

** Includes 9,500 feet of summer track

Source:- Abbott to Shaughnessy, September 15, 1896, PIC, CPCA

The C.P.R.'s expectations for operating conditions and traffic flows through the Selkirks proved accurate once the line opened. The volume of traffic was low, and a small fleet of pusher locomotives was sufficient to provide assistance over the summit. Despite slow speeds and the necessity for returning pushers light against ascending trains, traffic levels were sufficiently low, and siding accommodation sufficiently spaced, to permit the pathing of trains through the Rogers Pass corridor with little apparent difficulty. Although it is not known how intensively the available pusher capacity was utilised, it seems that paths for additional trains could have been found had increasing traffic made them necessary and had the pusher fleet been enlarged accordingly. It is therefore concluded that there was surplus line capacity on the C.P.R. route over the Selkirk Mountains. It appears from this analysis that that surplus capacity endured until at least the turn of the century.

e) <u>Snowslide Protection</u>

In adopting the location through Rogers Pass, the C.P.R. had expected to encounter snowslides for some ten to twelve miles, and had expected to solve the problem by building snowsheds. During construction of the transcontinental line, however, in the C.P.R.'s first winter in the Selkirks, Ross admitted candidly that he had underestimated the danger from the slides,[103] although he reassured Van Horne that conditions in the Selkirks that winter were exceptional.[104] The C.P.R.'s realisation of the magnitude of the threat may have been further postponed due to the fact that in the following winter, that of

1885-86, when they sent observers into the Selkirks to monitor slide paths, the slides were "certainly less in bulk" than they had been the previous winter.[105] In the winter of 1886-87, conditions were far worse than they had been in either of the previous two years,[106] and even these conditions may have been surpassed in adversity by those of 1887-88.[107]

While Ross acknowledged the gap between the expectations of snowslides and the realities, he was confident that the gap could be closed with modest immediate cost,[108] and that, "With some additional expense over estimate every point can be made perfectly secure for operation."[109] He proposed to minimise the investment in snowshedding, the immediate cost, by maintaining an increased section force who would dig out the slides "as you would an ordinary drift."[110]

However, not only was the gap between expectations and realities underestimated, but so was the cost of closing that gap. Even after the experience of the first winter's observations, Van Horne informed the Ministry of Railways and Canals that, "A comparatively small expenditure will be required to make the line entirely safe."[111] When, as a result of these observations, the General Superintendent of the Pacific Division submitted estimates for the cost of snowshedding, Van Horne was forced to admit that, "Your estimate of cost...is far beyond any previous estimate and far beyond our expectations, and for financial reasons it is somewhat appalling."[112] The General Manager, consistent with his expectation that the line would be lightly used for several years, intended to reduce the immediate cost of closing the gap, and to postpone further investment in snowslide protection, until traffic volumes had increased. He was prepared to countenance risk in order to make the trade-off in this way. He informed his General Superintendent that,

> We can't afford to cover every place where a slide may occur. If we provide now for such as have occurred within record years we will probably be justified in taking some chance of interruption by the others.[113]

The fact that this was the C.P.R.'s trade-off policy in providing protection from snowslides makes even more remarkable the magnitude of the sums of capital which were invested in the construction of snowsheds during the years immediately following the completion of the through line. After Ross's reports during the winter of track-laying, the C.P.R. had estimated that $450,000 would suffice for snowsheds in the mountains.[114] During 1886, the first summer after observation of the avalanches, the C.P.R. spent $1,477,510 on snowsheds in the Pacific Division.[115] The following year, having estimated that a further $504,565 would be required,[116] the C.P.R. was in fact forced to invest $691,062,[117] and in 1888 the Company disbursed another $136,401.[118] Perhaps because of the magnitude of the costs, or perhaps because the C.P.R. might have argued that investment in snowsheds was a social welfare measure, it seems that by April 1888, the Company had applied for, or was at least hopeful of, a Federal Government grant for snowshedding work.[119] However, there is no record of such a grant having been approved.

Two factors may explain why the C.P.R. was unable to contain investment in snowshed construction within target levels, and why its trade-off policy broke down in the provision of avalanche protection. The first factor was the extent of snowshed construction. After the first winter's observations, thirty-five sheds were constructed.[120] In 1887, a further 15,388 feet of shedding were proposed, 8,568 feet of which were to be located in the Selkirks.[121] By June 1888, a total of 31,764 feet of sheds had been built on the entire Pacific Division, of which 30,403 feet, or 5 3/4 miles, were situated between Beavermouth and Albert Canyon in some forty-three separate sheds.[122]

The second factor was the quality of construction which was required if the sheds were to function satisfactorily. In order to withstand the force of avalanche material weighing from 25 - 45 lbs. per cubic foot,[123] the protective structures, sheds and glance-cribs, had to be far more heavily built than those on the American transcontinental railways. Snowsheds on the Central Pacific had cost an average of $10.25 per lineal foot in the 1860's.[124] In 1918, the renewal cost of sheds on the Southern Pacific would be between twelve and fourteen dollars per lineal foot.[125] The average cost of the C.P.R. sheds and cribs by 1888 was around seventy dollars per lineal foot.

The need to upkeep this quantity of shedding imposed severe maintenance costs upon the C.P.R., which will be considered in more detail in the following chapter. This extent of shedding also created operating problems of its own, however. Each shed had to be patrolled constantly by section men, in winter on account of avalanche damage, and in summer on account of fire damage, to which the sheds were peculiarly susceptible.[126] The longer sheds were equipped with hydrants every four hundred feet.[127] Due to the steep main-line gradients, handcars could rarely be used in fire-fighting,[128] and eventually a fleet of locomotives had to be adapted for this purpose.[129] During routine operations, the accumulation of smoke rendered the brakesmen's duties hazardous,[130] and in winter the rails were prone to icing and the permanent way deteriorated.[131]

As the C.P.R. acquired experience of the slide paths, they undertook bridge improvements and piecemeal diversions as alternative means of preventing the avalanches from obstructing the main line through the mountains. The trestle bridge at Snow Bank was swept away in February 1886,[132] and again in January 1887.[133] New bridges were installed here and at Cut Bank, enabling avalanches to pass beneath the railway tracks.[134] When the bridges were again removed by slides, Cut Bank in 1900 and Snow Bank in 1904,[135] the respective ravines were filled, and the main line diverted in each case. Diversion at Williamson's Creek, some two hundred yards east of Cut Bank, as part of the Cut Bank project, cost $1,242.57 in 1900.[136] Two years previously, a diversion at Illecillewaet had cost $9,429.91.[137] These cost data suggest that diversion was adopted where it clearly represented a less costly means of avalanche defence than the snowsheds. However, these investments in bridge improvements and diversions must not be accounted entirely as costs of snowslide protection. Rather, they may have been the result of a greater availability of capital once transcontinental operations had commenced, and they may have formed part of the policy, clearly envisaged at the time of construction, of investing in the upgrading of the line once traffic had begun to flow.[138] These investments in improvements, which had the effect of mitigating the avalanche problem, were therefore entirely consistent with the manner in which the

C.P.R. had sought to handle the trade-off between construction costs and operating costs from the very outset of work in the Selkirks.

Where diversions were too costly, and where the snowsheds failed, the line was cleared by snowploughs and the efforts of the section gangs. The first winter of operations proved that the conventional wing ploughs were "entirely insufficient and almost unworkable" in the Selkirks,[139] and the C.P.R. was compelled to invest in the more expensive rotary snowploughs. The first was delivered to the Selkirks and tested in November 1888.[140] It was, however, required to perform duty not only in the Selkirks, but in Eagle Pass too.[141] The single plough appears to have been inadequate for the burden of these snowclearing duties. Nevertheless, C.P.R. management clearly accorded greater priority to the clearing of the Lake Superior section, and refused requests for a second rotary plough for the mountains "until it is known what difficulties are likely to be encountered this winter on the North Shore."[142] It was not until February 1890 that a rotary was transferred from the Lake Superior section to the Mountain Division, by which time, "Want of a second rotary ha(d) seriously delayed operations in clearing snow slides."[143] The rotaries alleviated the difficulty of finding convenient dumping grounds for the cleared snow,[144] but the early models were nevertheless useless for clearing avalanches containing timber and rocks, and these had still to be cleared manually. Assembling an adequate labour force in the mountains could be a task in itself.[145]

Certainly, the C.P.R. underestimated both the demand for snowslide protection in the Selkirks and the cost of meeting that demand. Nevertheless, within five years they had implemented a comprehensive avalanche defence system intended for the protection of their main line. This system had preventitive components, diversion of the line, snowsheds and patrols, and curative components, snowploughs and section gangs. Moreover, the system was successful. The C.P.R. itself claimed that the sheds "answered their purpose admirably," and that during the winter of 1889-90, the first in which the defensive system was fully operational, the C.P.R. "was the only one of the transcontinental lines that enjoyed immunity from blockades."[146] Available evidence reinforces these claims.

Daily records of the arrival time of the C.P.R. passenger service in Vancouver reveal that from November 1888 to January 1890, only two trains were cancelled "on account of obstructions in the mountains."[147] Two others were more than twelve hours late in reaching their destination.[148] From January to December 1891, three trains were more than twelve hours late, all in late April, and in December one train was cancelled, although it is not known whether this cancellation was due specifically to avalanche problems in the Selkirks.[149] The Minister of Railways and Canals assured the House of Commons in May 1888 that,

> ...the means adopted by the (C.P.R.) Company for dealing with the avalanches of snow in the Rocky Mountains [sic] were found to be absolutely perfect, the snow-shedding, which is upon a scale that would astonish hon. gentlemen if they were to see in the solidity of construction, allowing these avalanches to come down from the Rocky Mountains and the Selkirks and elsewhere to pass over them without the slightest difficulty or without the slightest disturbance."[150]

Even Walter Moberly, who spent a lifetime deploring the adoption of the Kicking Horse Pass and Rogers Pass in preference to the Howse Pass and the Big Bend, was forced to concede that,

> The most direct line is unquestionably the one taken by the C.P.R. along the Illecillewaet river. Its disadvantages are the heavy grades and liability to snow and land slides. Substantial snowsheds are overcoming one of these difficulties.[151], [152]

Moreover, it should be remembered that slide problems at least equal in severity to those in the Selkirks were encountered elsewhere through the mountains. In January 1887, Abbott reported that, "the difficulties with the snow have occurred where we least expected them, viz. at Eagle Pass,"[153] and after the 1887 slide season, he accompanied his estimate for snowshed requirements with a recommendation that,

> If the Company decide upon building a portion only of these sheds, I would suggest that those in Eagle Pass should be first provided, so as to confine the trouble to the line between Revelstoke and Donald, and that the worst of the slides in the Selkirks should then be provided for, according to the amount that may be appropriated for this purpose.[154]

A list of delays to passenger trains submitted in March 1889 indicates that rock slides between Vancouver and Kamloops were responsible for most of the lost time, whilst in the Selkirks, "the glance cribs, fences, sheds &c. have all stood the test and are doing the work, for which they were intended, admirably."[155] In November 1892, Abbott would report forty-eight mudslides in a single day on the Thompson and Cascade sections,[156] and when, in 1894, the year of the C.P.R.'s darkest fortunes, their main line through B.C. was closed for forty-one days, it was not avalanches in the Selkirks which were responsible, but flooding in the Fraser.[157]

The preceding analysis of the areas of constructional and operational concern to the C.P.R. reveals a close correspondence between expectations and realities. The gap between expectation and reality in the nature of construction work west of Rogers Pass did not translate into a significant gap in terms of either cost or time. Operations were conducted, and traffic conveyed, much as expected. The only serious gaps between expectations and realities emerged over the incidence of avalanches and the cost of measures to protect against them. The analysis reveals that in undertaking these remedial measures, the C.P.R. endeavoured to handle the trade-off decision in providing snowslide protection exactly as they had handled it in construction of the line as a whole: that is, they sought to minimise capital investment at the outset, and to undertake measures of improvement as operations over the line developed. To this extent, the extremely high capital cost of snowslide protection should be regarded as an indication, not that the route over the Selkirks was fundamentally unsafe, but simply that the C.P.R.'s trade-off policy was, in the specific context of avalanche defences, inappropriate. The policy broke down. There was no effective solution to the snowslide problem which was not capital intensive. Thus,

> It was deemed best to carry out these works in the most durable and substantial manner, in order that the safety of the line might be placed beyond doubt.[158]

Even though the C.P.R. had been forced to abandon their intended trade-off policy, they had made, as it were, the minimum concession. Having once grasped the magnitude of the snowslide problem, and the cost of solving it, the Company was faced with four alternatives. They could abandon the Rogers Pass route entirely, and build around the Big Bend; they could follow the Rogers Pass alignment, but undertake tunnelling beneath the snowslides, presumably to the extent of the 2 1/2 miles which they had been prepared to sanction in order to secure a direct crossing; they could persist with the alignment as built, but abandon operations during the winter months;[159] or they could persist with the alignment as built, and invest substantially in snowsheds for its protection.

To have either abandoned the Rogers Pass route entirely or to have undertaken tunnelling would have imposed demands upon the capital resources of the Company, and indeed upon the capital resources of the country, which quite simply could not have been met in 1885, nor in the years immediately afterwards. There is no evidence that the Company ever considered these alternatives. There is no evidence that the Federal Government ever asked them to consider the alternatives. The Federal Government, indeed, would not even contribute to the cost of the snowsheds.

To have closed the line in winter would have meant foregoing the revenue from all traffic which might have traversed the line during the months of closure. It would also have entailed investment in the spring in order to repair the damage inflicted by the avalanches of the winter. After the closure of 1885-86, the damage to the unprotected line had not been repaired until the following August.[160] Not only might the investment in repairs be high, therefore, but interruption to traffic as a result of leaving the line unprotected might not have been confined to the winter months alone. The fact that the C.P.R. rejected this alternative suggests that they believed that the direct cost of repairing the line after closure, combined with the opportunity cost of interrupting the flow of traffic, together outweighed the cost of constructing and maintaining avalanche defences in order to keep the line open throughout the winter months.

Therefore, the Company proceeded to invest heavily in snowsheds. A gap between expectations and realities had existed. Remedial measures were taken. These measures were successful. The gap was narrowed. Indeed, insofar as the line was never disrupted for more than a month once the avalanche defence system was implemented, the gap must be regarded as having been almost entirely closed, and the trade-off decision must be regarded as having been largely successful.

There is one final implication of the result of the C.P.R.'s selection from among the four alternatives outlined above. The decision to attempt to keep open the line over the summit of the Selkirks on a perennial basis implicated the C.P.R. in a high fixed investment in snowsheds. The investment was particularly high, and particularly fixed, in comparison with other investments undertaken by the C.P.R. in construction through the Selkirks. Even discounted back to 1885, at four per cent.,[161] the amount invested in snowsheds by 1888 still represented $2,180,869, almost as much again as the investment in the main line itself between the Beaver and Columbia rivers, and as much as the C.P.R. had expected to pay for construction through the Selkirks. This fixed investment had been undertaken, and annual maintenance charges would accrue, regardless of the volume of traffic which actually took advantage of the line's being open during those winter months on behalf of which the costs were incurred.

The implication must be that, in the years immediately following completion of the transcontinental link, the C.P.R. was in a decreasing-cost situation in the Selkirk Mountains. Specifically, the more traffic that could be carried through the Selkirks, the wider the fixed cost of snowshed maintenance could be spread, and the lower the total cost of each individual traffic movement would be. Moreover, given the low initial volume of traffic travelling over the line, additional traffic could be handled without incurring congestion costs. Therefore, the reduction of total costs effected by spreading the snowshed costs over an increased volume of traffic would not be offset by the addition of more trains. Thus, although the C.P.R. had handled trade-off decisions in a manner intended to ensure low capital costs, it commenced operations in a situation where it could absorb additional traffic without incurring increased operating costs.

FOOTNOTES

[1] Canadian Pacific Railway Company, "The Canadian Pacific; the new highway to the East, across the mountains, prairies and rivers of Canada," Montreal, 1888, p. 25.

[2] J. B. Ker, "The Progress of Vancouver," in, Vancouver Board of Trade, Annual Reports, Vancouver, 1892, p. 23.

[3] Alex Forrest, quoted in E. E. Pugsley, "Pioneers of the Steel Trail. Four: Fighting the Snow Menace," Maclean's Magazine, August 15, 1930, p. 16.

[4] Perhaps the most compelling is that of O. S. A. Lavallee, Van Horne's Road, op. cit., pp. 194-214.

[5] See sections (e), (b) and (c) respectively.

[6] Ross to Van Horne, March 4, 1885, quoted in Lavallee, op. cit., p. 196.

[7] Five years after the line opened, one traveller would record ascending the east slope "along a track cut in the side of the mountain..." Francis Mollison Black, "Down the Selkirks on the Cowcatcher: A Story of Rogers Pass," MSS, VCA, July 1891, p. 1.

[8] "I find that the snowslides on the Selkirks are much more serious than I anticipated, and I think are quite beyond your ideas of their magnitude and of the danger to the line." Ross to Van Horne, February 19, 1885, quoted in Lavallee, op. cit., p. 194.

[9] "I can see quite plainly that the present location of the line will not be safe -- more particularly so on the west slope where the slides this season already aggregate more than two miles in width." Ibid.

[10] Proceedings of the Canadian Society of Civil Engineers, op. cit., p. 27.

[11] Ross to Van Horne, February 19, 1885, quoted in Lavallee, op. cit., p. 196. ...to get any kind of line we have to go in for heavy work which would in no way serve our purpose in throwing the snow..." Ibid.

[12] Ibid.

[13] DSP, Vol. XVIII, 1885, 25a, pp. 10-14.

[14] The C.P.R. was on the verge of bankruptcy by March 1885, and relief in the form of federal aid was not forthcoming until July. Lamb, op. cit., pp. 128-132, H. A. Innis, A History Of The Canadian Pacific Railway, Toronto: McClelland and Stewart, 1923, pp. 125-6.

[15] Haldane estimated "the natural slope of the line" on the south bank as one in 17 1/2, equivalent to an uncompensated gradient of 5.7 per cent., or approximately 300 feet per mile. J. W. C. Haldane, 3,800 Miles Across Canada, London: Simpkin, Marshall, Hamilton, Kent & Co. Ltd., 1900, p. 216.

[16] Vaux implies that the Federal Government did in fact refuse to sanction the steeper gradient. Vaux, op. cit., p. 84.

[17] DSP, Vol. XIX, 1886, 35a, p. 11.

[18] "On my way west, I noticed on the other side of the Ille-Cille-Wait [sic] that there were no large slides or any marks of very dangerous ones..." Ross to Van Horne, March 4, 1885, quoted in Lavallee, op. cit., p. 199.

[19] The length of the trestles was as follows: First Crossing, Five-Mile Creek, 331 feet; Second Crossing, Five-mile Creek, 1,006 feet; First Crossing, Illecillewaet, 601 feet; Second Crossing, Illecillewaet, 1,061 feet; Third Crossing, Illecillewaet, 1,109 feet. "List of Bridges," Kilpatrick MSS, Vancouver, 1893. The map in "Snow War, A guide to the history of Rogers Pass, Glacier National Park," Ottawa: Dept. of Indian and Northern Affairs, Parks Canada, 1978, p. 8, erroneously labels the First Crossing of the Illecillewaet east of Glacier House. According to the "List of Bridges," this bridge was called "Glacier Creek," and was 211 feet long. The "List of Bridges" quite clearly records the First, Second and Third Crossings of the Illecillewaet as west of the two crossings of Five-Mile Creek.

[20] Ross to Van Horne, March 25, 1885, quoted in Lavallee, op. cit., p. 199.

[21] Ibid.

[22] Ross to Van Horne, June 18, 1885, ibid., p. 205.

[23] Schreiber to Bradley, February 8, 1883, Department of Railways and Canals, Railway Branch, Central Registry Files, PAC. RG 43 A 2 (a) 6710 Vol. 223.

[24] DSP, Vol. XVIII, 1885, 25a, p. 32.

[25] "The Government should be asked to accept ten degrees as the minimum to Station 1200 West of the Summit, otherwise the increased cost will be very heavy." Ross to Van Horne, February 19, 1885, Presidents' Inward Correspondence, Canadian Pacific Corporate Archives, Montreal, (henceforth 'PIC CPCA,').

[26] Schreiber to Bradley, July 6, 1885, DSP, Vol. XIX, 1886, 35a, p. 7.

[27] 20,006 feet, according to Lavallee, op. cit., p. 199.

[28] C.P.R. Co., "Pacific Division Time Table No. 1, to take

effect One O' Clock Saturday, July 3rd, 1886." Calgary Tribune Print.

[29] Lavallee, op. cit., note to Plate 299, p. 183.

[30] See below, p. 92; pp. 243-4.

[31] "List of Bridges," op. cit.

[32] Three were trestles in the Loop. The others were Mountain Creek Bridge, 1,086 feet, and the Fifth Crossing of the Illecillewaet, 1,091 feet. Ibid.

[33] Ibid.

[34] Rogers to Van Horne, November 20, 1883, DSP, Vol. XVII, 1884, 31f, p. 39.

[35] Ibid.

[36] Lavallee, op. cit., footnote to p. 205.

[37] "Tunnels on Pacific Division," n. d., Kilpatrick, Add Mss 323, PABC.

[38] Ross to Van Horne, June 18, 1885, quoted in Lavallee, op. cit., p. 205.

[39] Ross employed the side-drift method on the 565-foot tunnel. Ibid. (This tunnel is shown on the list of "Tunnels on the Pacific Division, op. cit., as 564 feet long.) He reported that he was "running a temporary line around" the other. Lavallee, op. cit., p. 205. On November 10, 1886, the General Superintendent of the Pacific Division reported a runaway incident, with three fatalities and six injuries, "on the middle of the temporary steep grade west of the summit at Rogers Pass." Abbott to Van Horne, November 10, 1886, PIC, CPCA. This "temporary steep grade" may have been Ross's "temporary line" around the second Laurie Tunnel.

[40] "For my own part I regret being obliged to submit this line but there are so many objectionable features on the present location and the more you examine them, the less you like them..." Ross to Van Horne, March 25, 1885, quoted in Lavallee, op. cit., p. 199.

[41] See below, pp. 75-78.

[42] Schreiber to Bradley, October 10, 1885, DSP, Vol. XIX, 1886, 35a, p. 11.

[43] Schreiber to Bradley, July 6, 1885, ibid., p. 7.

[44] It appears that the rate of construction across the prairies was faster than optimal. Lamb argues that austerity dictated changes in the proposed alignment west from Calgary as early as

mid-1883. Lamb, op. cit., p. 104.

[45] DSP, Vol. XVII, 1884, 31z, pp. 250-254.

[46] Van Horne to John Ross, November 29, 1884, "Van Horne Letterbooks," Vol. 8, p. 888.

[47] Lavallee, op. cit., pp. 199-204.

[48] Lamb, op. cit., pp. 129-132; McDougall, op. cit., pp. 61-63.

[49] The railhead crossed the Selkirk summit on August 17, 1885. Lavallee, op. cit., p. 209.

[50] "...there is still much lack of faith on the part of the Government and in financial circles of our ability to finish our work within the amount of the Government loan and we will be utterly unable to get any financial relief from outside until the last spike is driven in the Lake Superior section, and the lie is given to all the slanderous reports that have been circulating." Van Horne to John Ross, op. cit., pp. 892-3.

[51] Blake, HoC Debates, June 20, 1885, p. 2749.

[52] Van Horne to John Ross, October 19, 1884, quoted in Lamb, op. cit., p. 127. See also Stephen to Minister of Railways and Canals, March 18, 1885, DSP, Vol. XVIII, 1885, 25cc, p. 3.

[53] Van Horne to H. J. Cambie, July 14, 1885, "Letterbooks," op. cit., Vol. 6, pp. 919-920.

[54] Van Horne to Schreiber, December 1, 1884, "Letterbooks," op. cit., Vol. 8, pp. 951-2.

[55] "Central Section, Western Division, Progress Estimate No. 87, November 28, 1885," DSP, Vol. XIX, 1886, 35a, p. 152.

[56] Ross to Van Horne, April 16, 1885, quoted in Lavallee, op. cit., p. 204.

[57] Ibid.

[58] Van Horne to H. J. Cambie, op. cit., p. 920.

[59] See above, p. 54.

[60] Lamb, op. cit., p. 119.

[61] See above, p. 54.

[62] "We ought to be able to complete all the grading by the first of July and to connect the track by the first of August." Van Horne to John Ross, October 20, 1884, "Letterbooks," op. cit., Vol. 8, p. 229.

[63] For example, before Ross had even completed work on the west

slope of the Rockies, and with only two months remaining of 1884, Van Horne wrote to him, "I presume upon reaching the Columbia you will be able to lay track, not alone to the mouth of the Beaver, but up as far as the first of the high trestles. It is important that every inch possible should be made this year." Van Horne to Ross, ibid., p. 222.

[64] Ross to Van Horne, February 19, 1885, quoted in Lavallee, op. cit., p. 194.

[65] Canadian Pacific Railway Company: Report of the Directors of the C.P.R. Co. submitted at the adjourned Annual General Meeting of the Shareholders, June 13, 1885. Canadian Pacific Railway Company, Annual Reports, Montreal, 1885, p. 18.

[66] Lavallee, op. cit., p. 209.

[67] As early as March 18, 1885, Stephen had forecast to the Minister of Railways and Canals "the opening of the through line in the spring of 1886." Stephen to Minister of Railways and Canals, March 18, 1885, DSP, Vol. XVIII, 1885, 25cc, p. 1. C.P.R. shareholders were assured in January 1885 that, "by the early spring of next year the through line from Montreal to the Pacific Ocean...will be finished and in perfect condition..." C.P.R. Co., Annual Report, op. cit., 1885, p. 18. In October 1885, with only thirty-six miles of track remaining to be laid, Schreiber informed the Ministry, "I do not think it is the Company's intention to operate (the road) through the mountains this season; in fact I should not consider it wise to attempt to do so until the road is thoroughly completed, which will scarcely be before spring." Schreiber to Bradley, October 10, 1885, DSP, Vol. XIX, 1886, 35a, p. 11.

[68] Unlike on the Lake Superior section, where "Mr. Stephen estimates the financial advantage of connecting the track in March instead of May at $500,000." Van Horne to John Ross, op. cit., pp. 894-5.

[69] Van Horne to Minister of Railways and Canals, May 19, 1885, DSP, Vol. XVIII, 1885, 25a, pp. 10-11.

[70] Lavallee is incorrect in stating that pusher locomotives were provided from Revelstoke to Rogers Pass. Lavallee, "Rogers' Pass: Railway to Roadway," Canadian Rail, Canadian Railroad Historical Association, No. 137, October 1962, p. 155. See Marpole to Shaughnessy, February 15, 1898. PIC, CPCA.

[71] The pusher locomotive was generally attached at the rear until 1907. This arrangement of the motive power ensured even distribution of the pulling and buffing forces throughout the train. It may also have permitted attachment of the pushers "on the fly." See T. H. Crump, "The Big Hill and the Mountain Section," October 21, 1940, reprinted in Canadian Rail, No. 275, December 1974, p. 356. The change to double-heading in 1907 was ordained by G. T. Bury as General Manager of Western Lines, ostensibly in the interests of safety and passenger comfort. The

rearrangement of motive power per se appears to have had a negligible impact upon the economics of the pusher operation. Sir George Bury, "The Making of a Railway Man II. From Superintendent To Vice-President," Maclean's Magazine, January 15, 1926, p. 14.

[72] Province, April 21, 1902, p. 1.

[73] Crump, op. cit., p. 356.

[74] F. M. Black, op. cit., p. 1.

[75] "Diary, 1909," Kilpatrick MSS, Vancouver, December 9, 1909.

[76] C.P.R. Co., Time Table, July 3rd. 1886, op. cit.

[77] Donald Truth, July 7, 1888, p. 8, and November 3, 1888, p. 3.

[78] Abbott to Van Horne, January 5, 1889, PIC, CPCA.

[79] Donald Truth, July 14, 1888, p. 5.

[80] Six trains per week, assuming thirteen cars per train, and four trains per week, assuming eighteen cars per train. See below, notes (84) and (85).

[81] "(The steamship Aberdeen) had several carloads of silk, one of which went through Donald on yesterday's express, another going through today." Donald Truth, July 28, 1888, p. 5.

[82] Whyte, Telegrams to Van Horne, December 18, 19 and 21, 1888, PIC, CPCA.

[83] Tait to Shaughnessy, July 29, 1896, PIC, CPCA.

[84] Donald Truth, October 6, 1888, p. 1.

[85] Marpole to Shaughnessy, February 15, 1898, PIC, CPCA.

[86] Tye to Shaughnessy, April 2, 1900, PIC, CPCA.

[87] Ibid.

[88] Memorandum by Thomas Tait to Shaughnessy, October 24, 1894, PIC, CPCA.

[89] Shaughnessy to all General Superintendents, October 23, 1896, "Letterbooks," op. cit.

[90] The data do not necessarily imply the availability of surplus capacity, or underutilised "push," on each train. Although the data which is based on averages indicate that pusher locomotives were required for the "average" train, and that the marginal payload for which the pusher was required was only, for example, 1.95 cars or 92 tons in 1893, it is possible that the payloads of the trains to which pushers were attached may have been far

greater than 10.95 cars, while the payloads of those trains which were conducted by a single locomotive may have been far less than nine cars. Under these conditions, the "push" would be more fully utilised where provided, even though the data for average payload appears to indicate otherwise.

[91] Report of H. Abbott, quoted in Lavallee, Van Horne's Road, op. cit., p. 244.

[92] "Appropriations, Year 1898," Kilpatrick MSS, p. 55. The total haulage capacity of the fleet may have been increased during this period if stronger locomotives were introduced into mountain service. Unfortunately, this hypothesis cannot be tested until the appearance of a comprehensive work on C.P.R. motive power, currently in preparation by O. S. A. Lavallee. However, since the numerical strength of the pusher fleet certainly did not increase during this period, it is likely that the increment in total pusher capacity obtained from the introduction of stronger locomotives would not have been dramatic.

[93] C.P.R. Co., "Timetable No. 1, 1886," op. cit.

[94] Canadian Pacific Railway Company, "Timetable Number 1, Taking Effect at 24.01 O'Clock, Sunday, June 15th, 1902," Montreal, n.p.

[95] Ibid.

[96] C.P.R. Co., "The Canadian Pacific: the new highway to the East," op. cit., p. 27.

[97] See, for example, Lavallee, op. cit., p. 280; N. R. Hacking, History of the Port of Vancouver, Vancouver, n. d., n. p.

[98] Donald Truth, July 28, 1888, p. 4.

[99] Vancouver Board of Trade, Annual Reports, op. cit., 1889, p. 31; 1890, p. 24.

[100] See chapter 6.

[101] Abbott to Shaughnessy, August 2, 1889, PIC, CPCA.

[102] The average spacing on the C.P.R. between Albert Canyon and Beaver East was one siding every 5.8 miles in 1896, and the ratio, "length of siding: length of main line" was 1: 8.17. Between Lucerne and Blue River, west of the Yellowhead Pass on the Canadian Northern main line, the average spacing was one siding every 8.5 miles, and the ratio, "length of siding: length of main line" was 1: 15.33. Sessional Papers of the Province of British Columbia, Victoria, 7 Geo. 5, 1917, Report of Department of Railways, p. D12. This does not of course indicate that the C.P.R. had "more capacity" than the C.N. The above comparisons take no account of such crucial variables as average train weight and average train speed.

[103] Ross to Van Horne, February 19, 1885, quoted in Lavallee, op. cit., p. 194.

[104] "From all reports the snow is exceptionally deep this season." Ross to Van Horne, March 4, 1885, PIC, CPCA.

[105] Cunningham, op. cit., p. 21.

[106] "Journal of Observations in camp three miles east of Selkirk Summit, Winter 1885-86, kept by Granville C. Cunningham, Engineer-in-Charge (and by J. S. Vindin after April 18th); Observations at Cascade Camp, Winter 1886-87, kept by J. E. Griffith." PABC, pp. 46-57. On February 28, 1887, six C.P.R. employees were killed in an avalanche off Mount Carroll. ibid., p. 54. The following day, the entire distance from snowshed No. 5 to Rogers Pass, some five miles, was "one continuous slide." ibid., p. 55. The line was closed from February 26 to March 23. Ibid., p. 56.

[107] Marpole, Telegram to Van Horne, December 17, 1887, PIC, CPCA.

[108] "In [sic] the east slopes slides occur in two places, but very little shedding will be necessary as the increased section force will dig out any of them quickly, the snow keeping soft will do no damage. On the west slopes slides mostly come down in gulches, so it will be necessary to throw the line more into the hill side so as to pass the snow over the track." Ross, Telegram to Van Horne, March 4, 1885, PIC, CPCA.

[109] Ibid.

[110] Ross to Van Horne, March 4, 1885, quoted in Lavallee, op. cit., p. 196.

[111] Van Horne to Bradley, May 6, 1886, Letterbooks, op. cit.

[112] Van Horne to Abbott, July 4, 1886, ibid.

[113] Ibid.

[114] See chapter 3, note (93).

[115] C.P.R. Co., Annual Reports, 1886, p. 36.

[116] "Statement of Proposed Snowshed work," enclosed in Abbott to Van Horne, April 15, 1887, PIC, CPCA. Of this amount, $386,515 were earmarked for the section between Donald and Revelstoke.

[117] C.P.R. Co., Annual Reports, 1887, p. 25.

[118] C.P.R. Co., Annual Reports, 1888, p. 23. In 1889, a further $3,975.95 was invested, and in 1890, $159.25, bringing the total expenditure on snowshed construction on the Pacific Division in the first five years of the line's history to $2,309,108.69.

[119] Abbott submitted a calculation of the amount of money necessary for snowshedding in the event of the Company's obtaining a grant from the Dominion Government. Abbott to Van Horne, April 17, 1888, PIC, CPCA. Unfortunately, the calculation has not been preserved, so there is no way of knowing how the Company proposed to allocate the grant.

[120] Keefer, op. cit., p. 68.

[121] "Statement of Proposed Snowshed work," op. cit.

[122] Keefer, op. cit., Plate V.

[123] Engineering News, Vol. XIX, January 21, 1888, p. 38.

[124] See chapter 3, note (92).

[125] Engineering News-Record, Vol. LXXX, January 3, 1918, p. 45.

[126] In the Selkirk Mountains, eleven watchmen were allocated exclusively to snowshed patrols: two each to Sheds 1-6, 7-11 and 16-20, and one each to Sheds 12-15, 21-26, 27-31, 35-38 and 39-42. "Timekeeper's Force Return, Donald - Revelstoke, w/e July 13, 1889." PIC, CPCA.

[127] Engineering News, Vol. XIX, January 21, 1888, p. 39.

[128] Abbott to Van Horne, July 31, 1889, PIC, CPCA.

[129] Keefer, op. cit., p. 70.

[130] Ibid., p. 69.

[131] Abbott to Van Horne, January 5, 1889, PIC, CPCA.

[132] "Journal of Observations," op. cit., p. 27.

[133] Ibid., p. 49.

[134] Abbott, Telegram to Van Horne, January 28, 1888; Abbott to Van Horne, January 29, 1890, PIC, CPCA.

[135] Canadian Pacific Railway Company, "Old Bridge Record and Section Maps, Mountain Subdivision," Mount Revelstoke and Glacier National Parks, File No. 1758, p. 14.

[136] Ibid.

[137] C.P.R. Co., Annual Reports, 1898, p. 19.

[138] "I feel sure that in a number of places -- particularly on the section from the Selkirk Summit eastwards five or six miles and from the Summit westwards towards Glacier Creek -- the track will have to be thrown far into the face of the slope before it can be fully protected and these possible changes should be kept in view in building sheds." Van Horne to Abbott, July 4, 1886,

op. cit.

[139] Abbott to Van Horne, April 15, 1887, op. cit.

[140] Donald Truth, November 24, 1888, p. 1.

[141] Abbott to Shaughnessy, November 29, 1889, PIC, CPCA.

[142] Ibid.

[143] Marpole, Telegram to Shaughnessy, February 13, 1890, PIC, CPCA.

[144] Abbott to O. W. Petri, April 24, 1889, PIC, CPCA.

[145] During February 1890, Abbott reported that, "in order to get the necessary force we had to call upon tie-makers, bridge gangs, Siwashes and every man we could find, as men were extremely scarce at that time on this Division." Abbott to Shaughnessy, May 22, 1890, PIC, CPCA.

[146] C.P.R. Co., Annual Report, 1889, p. 13.

[147] Vancouver Board of Trade, Annual Reports, 1890, p. 21.

[148] Ibid., pp. 22-23; 1889, p. 32.

[149] Ibid., 1892, pp. 45-46.

[150] Tupper, HoC Debates, May 11, 1888, p. 1337. It should be noted that there were no snowsheds, and very few avalanches, on the C.P.R. main line through the Rocky Mountains.

[151] Letter from Walter Moberly to the Editor of the "Winnipeg Call," August 24, 1888. Reproduced in the Donald Truth, September 1, 1888, p. 2.

[152] See also, Engineering News, Vol. XXII, December 14, 1889, p. 570.

[153] Abbott to Van Horne, January 11, 1887, PIC, CPCA.

[154] Abbott to Van Horne, April 15, 1887, op. cit.

[155] Abbott to Van Horne, March 2, 1889, PIC, CPCA.

[156] Abbott to Van Horne, November 29, 1892, PIC, CPCA.

[157] C.P.R. Co., Annual Report, 1894, p. 10.

[158] C.P.R. Co., Annual Report, 1886, p. 11.

[159] There is some evidence that this alternative was considered. Perhaps after the C.P.R.'s experience of its first winter in the Selkirks, the Calgary Daily Herald may have considered that the Company had no other choice: "The town [i. e. Rogers Pass] is

built right in the track of the avalanches and after November will be subject to the disturbance of these mountain horrors. At the beginning of December all the inhabitants will move out in a body and Roger's [sic] Pass will be desolate until another summer spreads her mantle on the scene, etc." Calgary Daily Herald, August 6, 1886. Van Horne must have considered discontinuing passenger services during the winter of 1886, either in the immediate interests of passenger safety, or because he was reluctant in the coming months to undertake the full cost of making the line safe for passenger travel, or perhaps simply because of lack of patronage of the passemger service. On December 9, 1886, he informed Abbott, "We have decided on continuing the daily through passenger service for the Winter." Van Horne to Abbott, December 9, 1886, Letterbooks, op. cit.

[160] Engineering News, Vol. XV, May 8, 1886, p. 303.

[161] This was the rate of discount adopted by the C.P.R. in the evaluation of alternative tunnelling projects through the Selkirk Mountains in 1912. See Chapters 7 and 8. It is unlikely that the discount rate would have been significantly less in 1885 than it was in 1912.

PART TWO

THE BIG BORE

The C.P.R. had made its decision. It had evaluated alternative routes through the mountains, and had opted for a short, direct crossing. In the Selkirks, this entailed construction and operation over Rogers Pass, with its steep gradients and exposure to snowslides. The decision to secure a direct route had been taken in 1881 and fully implemented by 1885. It would commit the C.P.R. to surface operations in Rogers Pass for the next thirty years.

What were the consequences for the C.P.R. of being committed to this alignment? One of the principal consequences was that the C.P.R. became engaged in a protracted and costly battle to protect its traffic against avalanches. This consequence has attracted the most scrutiny from previous historians of the C.P.R.'s operations in Rogers Pass. Many of these historians assert that the C.P.R. lost the battle. The 1910 avalanche disaster, in which 62 C.P.R. employees were buried alive, is regarded as a turning point in C.P.R. management's perception of the viability of the surface route through Rogers Pass. The C.P.R.'s decision, taken in 1913, to abandon the surface route and construct the Connaught Tunnel beneath the summit of the Selkirks, is regarded as an acknowledgement of defeat, a strategic withdrawal in reaction to the intractability of the avalanche hazard.

How tenable is an explanation of the decision to construct the Connaught Tunnel which addresses only the snowslide problems? For another principal consequence of the C.P.R.'s commitment to a surface route through Rogers Pass was the necessity to haul all trains over 46 miles of 2.2% gradients and severe curvature. The variable cost of routine operations was therefore high. Moreover, the steep gradients, the single-track configuration of the main line, and the scarcity of locations suitable for sidings, all imposed constraints upon the capacity of the facility to absorb increases in traffic.

The Connaught Tunnel was double-tracked, and secured a large increment in main-line capacity. It was accompanied by gradient revisions which reduced the variable cost of operations and enhanced the increment in line capacity provided by the tunnel. Analysis reveals that traffic forecasts generated by the C.P.R. in 1913 identified an urgent requirement for increased capacity through Rogers Pass, and that investment in the Connaught Tunnel was undertaken with a view towards expected future operating requirements, and not just in response to past avalanche experiences.

The second part of this thesis examines the question of why the surface route through Rogers Pass was abandoned in favour of the Connaught Tunnel. The answer is sought by an analysis of operating conditions at the summit of the Selkirks throughout the thirty years of surface railroading. This section begins with a re-examination of the nature of the avalanche hazard which has been accorded so much attention by previous railway historians. An attempt is made to establish the actual extent and cost of snowslide problems on the surface route. Then, traffic developments through the B.C. mountains are examined, with particular emphasis upon previous investments undertaken by the C.P.R. to improve operating conditions in Rogers Pass, and upon the implications of traffic growth and traffic forecasts for the future adequacy of the surface route. When the C.P.R. deemed that its surface alignment was no longer appropriate for its operating requirements, it considered several alternative alignments, and ultimately decided to construct the Connaught Tunnel. The C.P.R.'s evaluation of these alternative alignments is described, and the reasons for the selection of the preferred alternative are discussed. Finally, the conclusions of the thesis are presented.

CHAPTER 5

AVALANCHE PROBLEMS

The purpose of this chapter is to analyse the role played by avalanche problems in the decision of the C.P.R. to abandon the surface alignment through Rogers Pass. Previous historians of C.P.R. operations in the Selkirks have maintained that the role played by snow problems was crucial, and they have made little attempt to look beyond this aspect of operating conditions for an explanation of the decision to construct the Connaught Tunnel. This chapter will attempt to determine whether or not the snow problem in Rogers Pass was indeed sufficiently severe to justify abandonment of the original route over the Selkirks, and whether or not it was indeed the desire to avoid the danger and expense of avalanches which spurred the C.P.R. to invest in an alignment underground.

The analysis is divided into two parts. The first part concentrates exclusively upon the role of the 1910 avalanche disaster in motivating the decision to relocate the main line. This concentration is justified because certain authorities attribute the decision entirely to the influence of that particular disaster.[1] In the second part of the analysis, the focus is widened to include consideration of the snowslide problem in general, the extent of the problem and the impact which it had upon the investment decisions taken by the C.P.R. in Rogers Pass.

5.1 The 1910 Disaster

On the evening of March 4, 1910, a C.P.R. snow-clearing crew was working at the south end of Shed 17, one mile west of Rogers Pass station at the summit of the Selkirks. The crew was removing a slide which had descended during the afternoon from Mount Cheops, to the west of the main line. Half an hour before midnight, the crew was struck by a much larger avalanche descending from Mount Avalanche, east of the main line. Sixty-two C.P.R. employees were killed,[2] of whom thirty-two were "Japs and Hindoos."[3]

There were several alarming aspects of the disaster, besides the enormity of the death-toll. The snow-clearing crew had been working on a two-mile portion of the main line which had been relocated less than three years before. The relocation, motivated by the desire to increase yard accommodation rather than by any necessity for avoiding snowslides over the original location,[4] had been undertaken in the belief that the new route was quite safe from snowslides. Indeed, the C.P.R. had undertaken additional investment in widening the cuttings on the diversion,[5] in order to secure greater protection.[6] The incident might have been regarded as an indication that no surface alignment through the Pass could escape the avalanche danger, or that no expansion of capacity could be secured without increasing the vulnerability of the operation to disruption by avalanches. Moreover, whilst no members of the public had suffered injury in the incident, the westbound passenger train No. 97 had been less than ten miles away when the fatal avalanche had struck,[7] and had fortunately been running slightly late, having been delayed by a smaller snowslide east of the Selkirk summit.[8] The train would be imprisoned in the mountains for two and a half days until the major avalanche could be cleared.[9] Less than a week before, over eighty passengers on the Great Northern's Spokane Express had been killed at Wellington, Washington, when an avalanche had swept the train into a 150-foot gorge.[10]

If the 1910 disaster is to be linked directly with the decision, taken more than three years later, to abandon Rogers Pass, then proponents of the direct linkage must believe that the incident precipitated a change in C.P.R. management's perception of the viability of the route through the Selkirk Mountains. For when the disaster occurred, the C.P.R. had been operating over the surface alignment for some twenty-four years, during which time they had made no serious attempt to seek an alternative route to that through Rogers Pass. In order to establish the extent of any linkage, this analysis will begin by considering the nature of the 1910 disaster itself. Then, the possibility will be investigated that the disaster provoked pressure upon the C.P.R. to undertake investments in improving the safety of its surface alignment. Finally, the actual response of the C.P.R. to the disaster will be examined, for evidence that the incident had indeed prompted a reappraisal of the viability of the surface route.

The 1910 avalanche disaster was in every sense a "freak." The slide followed a path down which there had been no previous record of avalanches.[11] At an inquest into the deaths, it was stated that, "There was timber in the path of this slide which in some places was fifty years old."[12] The slide was also of exceptional magnitude. An employee of twenty years' seniority testified that,

> The old track for considerable distance several hundred feet west of 17 Shed was covered by the slide, as well as the new track. In my experience this has not occurred before.[13]

Finally, the weather in the days preceding the slide was exceptional, even for the Selkirks. "There had been a snowfall of 88 inches in nine days previous to the slide."[14]

There is no evidence to suggest that the disaster provoked any pressure upon the C.P.R. either to undertake improvements to the existing route, or to abandon the route entirely and invest in an alternative. Certainly, the first coroner's jury which was empanelled to investigate the disaster was dismissed on March 12 after failing to reach a verdict.[15] However, the controversy appears to have centred upon the questions of whether or not the C.P.R. actually compelled its snow-clearing crews to work at nights, and whether or not the failure to post look-outs at the site of snow-clearing operations constituted an act of negligence on the part of the Company. At a second inquest, convened on March 14, it was reaffirmed that, "It is not compulsory for men to work at nights."[16] Those who did were paid time-and-a-half.[17] It was moreover agreed that look-outs would be "not much use at nights" in any event.[18]

The findings of the inquests placed no pressure upon C.P.R. management to make a major policy decision. The jury at the second inquest returned a verdict of "Accidental Death." It expressed no condemnation of the C.P.R. Neither did it recommend drastic changes in methods of operating through the Pass, nor expensive investments in improving traffic conditions. Rather, it recommended simply that, "... the Canadian Pacific Railway withdraw their workmen from service at all slides in future during stormy nights."[19] There was nothing new in this: the General Superintendent of the Pacific Division himself had issued instructions to this effect as early as 1888 after a C.P.R. work-train had been struck by an avalanche in the Selkirks.[20]

Neither was any pressure from other institutions exerted upon the C.P.R. to undertake investments in improving its surface alignment. The Federal and Provincial Governments made no allusion to the incident,[21] and the Ministry of Railways and Canals merely noted, without comment, that the deaths were responsible for inflating the annual accident figure for 1910 to an unusually high level.[22] The Labour Gazette reported the incident matter-of-factly in its account of "Industrial Accidents."[23] Whilst a motion to investigate industrial safety was carried in the House of Commons within a year of the 1910 disaster, and whilst the frequent incidence of injuries to railwaymen did spark the debate, neither the 1910 disaster in particular nor the character of the C.P.R.'s operations through Rogers Pass in general aroused comment from the protagonists.[24] Neither was the press critical of the C.P.R. Indeed, the Company emerged with credit, the Revelstoke Mail-Herald carrying a glowing account of the conduct of the C.P.R. officials during the incident,[25] and the Calgary Daily Herald affirming that the C.P.R.'s snow-clearing organization "has been equal to the occasion."[26] Nor did the press recommend investment in the pursuit of greater safety. Only the Revelstoke Mail-Herald suggested that the C.P.R. seek an alternative route and accelerate completion of the Arrowhead and Kootenay line.[27]

The C.P.R.'s own reaction to the disaster sets the incident in its appropriate context as part of the ongoing battle with the snow. The inquests established that there was no question of the C.P.R.'s having omitted to make investments which would have reduced the risk to life and traffic. It had made such investments in the past, and would continue to do so after 1910, without the necessity for major diversions or tunnels:

> The Company have built sheds wherever they thought it necessary, and have built several sheds over which a slide has never passed...
>
> If a shed were thought necessary, expense would not stand in the way.[28]

The C.P.R., of course, refused to acknowledge any responsibility for the incident, although granting compensation to the relatives of the victims.[29] Nevertheless, it appears that the Company was not dissatisfied with its handling of the snow problem. President Shaughnessy wrote privately in the aftermath of the disaster,

> While it would appear that the danger is not passed by any means, and there is still occasion for much apprehension and anxiety, the record up to the present time is most excellent, marred only by the sad catastrophe, that no human agency could prevent or control, in which so many poor workmen lost their lives.[30]

The C.P.R.'s investment response to the disaster confirms the view that the incident did not provoke a change in investment policy on the Selkirk route. The Company had not built a snowshed over the new alignment because it had not considered it necessary: no slide had ever passed over Shed 17, and it was believed that there was sufficient flat land to the east of Shed 17 "to stop any ordinary slide," even considering that, "A slide had never been known on the [east] side for many years."[31] It does not appear that the realignment had in any way entailed increased vulnerability to avalanches as the price of increased capacity. The Resident Engineer at Revelstoke affirmed that,

> A new track 300 or 400 feet to the north would have been reached by this slide.
> A shed over this portion of new track would not have withstood this slide.[32]

Management's investment response to the 1910 slide was the same as it had been to previous slides. "The first thing we will have to do is to build a snow shed at Rogers Pass on the new line," the Vice-President of Western Lines, Sir George Bury, had written to the Chief Engineer on March 15, 1910.[33] The shed was erected during 1910, at a cost of $48,275.97,[34] and the next year some $700 was invested in a shed over the Rogers Pass turntable.[35] Two new rotary snowploughs were ordered, and the existing fleet modified.[36] A piecemeal diversion was undertaken at Bear Creek.[37] The old alignment through Rogers Pass which the C.P.R. had intended to abandon in 1907, and which it had re-connected to the main line two days after the 1910 disaster in order to pass the beleaguered train No. 97,[38] was retained "as emergency track in cases of blockades on the Diversion by snow."[39] However, there was never any question that the disaster would induce the Company to abandon its new alignment through the Pass.[40]

The 1910 disaster may have provoked discussion of the possibility of driving a tunnel beneath Rogers Pass, for in

April 1910, the Revelstoke Mail-Herald reported that,

> ...it is stated a tunnel would soon save its cost in the maintenance and construction of snowsheds, besides avoiding the danger of slides in the pass. A factor in the problem is that the time is at hand when all snowsheds and the extensive cribwork connected with some of them would have to be wholly renewed in any case.[41]

However, there is no evidence to suggest that the C.P.R. regarded such a project as an appropriate alternative to its longstanding policy of avalanche defence. Moreover, analysis of the economics of such a project reveals that in fact the savings in snowshed construction and maintenance would not alone be sufficient to justify investment in a tunnel on the scale which would be required in order to preclude the necessity for shedding through Rogers Pass.[42]

It is undeniable that the C.P.R. did examine the feasibility of an alternative route through the Selkirks during the summer of 1910, undertaking a thorough survey of the Big Bend. Walter Moberly thought that the time for his favoured route was at hand, and believed that, "The Rogers Pass accident may make [the C.P.R.] change their minds."[43] However, the surveys through the Big Bend may have had far grander motives than simply the desire to avoid a repetition of the 1910 disaster. The Victoria Daily Times reported in July 1910,

> That the Canadian Pacific Railway is in earnest in its scheme to open up the Big Bend by railway transportation and build a connecting line between Revelstoke and the Grand Trunk Pacific at Tete Jaune Cache is evident from the fact that a party of locating engineers numbering sixteen have arrived from the east.[44]

Moreover, it was chiefly for developmental reasons, and not because the alternatives offered a safer passage through the mountains, that the Revelstoke Mail-Herald welcomed the prospect of rails through the Big Bend,[45] just as it had welcomed a report of the C.P.R.'s intention to complete the Arrowhead and Kootenay line.[46] It does not appear, therefore, that this survey of an alternative route through the Selkirks was directly linked with the 1910 disaster in Rogers Pass.

Regardless of the normative issue, of whether or not the 1910 avalanche disaster should have precipitated a change in the C.P.R.'s perception of the viability of the surface alignment through Rogers Pass, the positive conclusion of this analysis is that the incident in fact heralded no turning point. It was a serious incident in terms of the number of casualties involved, but the slide itself blocked the main line for only two and a half days, a brief interval when compared with the disruptions of previous years, and when compared with the disruption which would follow later in the spring of 1910. The incident brought no condemnation of the C.P.R., and no pressure upon them to undertake investment in improving safety, either upon its existing alignment or by means of an alternative route. It is unlikely that a single incident of this magnitude would stimulate a change in investment policy as drastic as that which would be involved in abandonment of the surface alignment after a quarter-century of rail operations; and in fact no such change occurred. After the 1910 disaster, as before, the C.P.R.'s investment policy towards the avalanche problem continued to be essentially reactive in character. Snowsheds were repaired and extended, piecemeal diversions undertaken, and snowploughs engaged to clear the line between.

5.2 The Snow Problem In General

Having decisively rejected the hypothesis that it was the 1910 avalanche disaster which induced the C.P.R. to abandon the surface alignment through Rogers Pass, it is necessary still to determine the extent to which the snow problem in general prompted the abandonment decision. Several authorities maintain that it was the apparent worsening of avalanche difficulties during the early years of the 20th Century which persuaded the C.P.R. to undertake investment in a tunnel beneath the summit of the Selkirks.[47] In assessing the accuracy of this interpretation, it is useful to distinguish between two separate aspects of the snow problem before attempting to determine whether or not the avalanche difficulties were in fact worsening. These two aspects are the direct cost of maintaining the avalanche defence system, and the indirect cost of disruptions to traffic consequent upon slides blocking the main line.

a) The Direct Costs Of Maintaining The Avalanche Defence System

Authorities have tended to concentrate upon the direct costs of maintaining the avalanche defence system as the major stimulus to investment in a tunnel. However, quantitative data appertaining to these direct costs do not support this view. Detailed cost data are available for the later years of the surface operation, the crucial years, according to certain authorities, during which the C.P.R. was persuaded "that the savings in snowshed maintenance alone would tip the scales in favour of a five-mile, double-tracked tunnel."[48]

It appears that as the C.P.R. acquired experience of the avalanche problems, and as the Company undertook piecemeal relocations of the line in order to reduce its exposure to snowslides, it was able to reduce the length of snowshedding which had to be provided and maintained. When first constructed across the Selkirks, the line had been equipped with some 30,403 feet of snowsheds,[49] and by August 1898 the length of shedding between Beavermouth and Albert Canyon, Sheds 1 to 43A inclusive, had been increased to 31,558 feet.[50] It was envisaged in 1898, however, that only some 30,866 feet of this shedding would be renewed, in a programme extending until 1904.[51] By October 1904, the last year for which complete data are available, the length of shedding in the Selkirks had been reduced to 29,639 feet,[52] a saving of 1,919 feet since 1898. This reduction in the length of snowshedding may have represented a cost-saving of between $6,865 and $8,077 per year.[53]

Further reductions in the amount of snowshedding on the surface alignment may not have been possible. When the C.P.R. undertook diversion of the main line through Rogers Pass in 1907, it saved another 2,224 feet of sheds,[54] which may have afforded annual cost-savings of between $7,956 and $9,360.[55] However, after the 1910 disaster, the Company was forced to rebuild Shed 17. With the rebuilding of this single shed, some three thousand feet long, the entire reduction in shedding obtained in 1907 was offset, and the new alignment actually required more avalanche protection than the old.

The cost of maintaining and renewing the snowsheds may have escalated rapidly in the last years before the surface route was abandoned. In 1910, the total cost of maintenance and renewals to snowsheds through the Selkirks was $68,481.94.[56] In 1911, the total cost leaped by 75%, or $50,932.05, to $119,413.99.[57] Much of this leap may be explained by the rebuilding of Shed 17, which cost $48,275.97. In turn, however, the reconstruction of Shed 17 might have ensured that maintenance costs would have remained at a high level had the surface route continued in operation: for nine months of 1912 the total maintenance cost was $114,878.66.[58]

Even if this escalation in maintenance costs was entirely due to the rebuilding of Shed 17, which was in turn a consequence of the 1910 disaster, and even if maintenance costs were expected to remain at these high levels for perpetuity, the magnitude of the annual maintenance costs would still not alone have justified investment in a tunnel. In 1912, when the C.P.R. evaluated various tunnelling projects which were intended to supersede the surface alignment, it estimated that 23,760 feet of snowshedding would be rendered obsolete by a tunnel.[59] Savings in the maintenance and renewal costs of this shedding were estimated at between $85,000 and $100,000.[60] In order to obtain these savings, the C.P.R. would not have been justified in investing more than between $2,125,000 and $2,500,000.[61] The lowest estimate for the cost of a tunnel was $5,495,000.[62]

Even when it became clear that the main line through the Selkirks would have to be doubled,[63] the magnitude of the savings which could be derived from avoiding the cost of doubling the existing sheds and maintaining these enlarged sheds would still not alone have justified investment in a tunnel. The

C.P.R. estimated that the cost of doubling 23,760 feet of wooden sheds would be $475,200,[64] and that the maintenance cost of the enlarged sheds would be $125,000 per year. This increase in the maintenance cost of a doubled shed, from between $85,000 and $100,000 to $125,000, suggests that the C.P.R. believed in the existence of economies of scale in the provision of snowsheds. In order to avoid the capital and maintenance costs of doubling the sheds, the Company would still only have been justified in investing some $3,600,200.[65]

Had the C.P.R. merely desired to avoid the costs of maintaining the snowsheds, it could have rebuilt the sheds in reinforced concrete. When this alternative was considered in 1912, however, the estimated cost of double-track sheds in reinforced concrete was $3,801,600.[66] The expense of maintaining the wooden sheds was not sufficiently great to warrant this investment: the potential net benefit of such a project, $3,600,200, did not outweigh the cost.

The cost of maintaining and renewing snowsheds was the largest single component of the total direct cost of maintaining the avalanche defence system. There were other components, for which quantitative data are not available. The cost of certain of these components, for example the cost of snowshed patrols and the cost of section-gangs clearing line blockages, may have been subsumed within the maintenance and renewal costs discussed above. There is little evidence to suggest that these costs were either significant or escalating. The system of patrols does not appear to have been fundamentally modified throughout the entire thirty years of surface operations. In 1912, patrols were still detailed to Sheds 1-6, 7-11, 12-14, 16-20, 21-27, 28-31 and 35-37,[67] much as they had been when the patrol system had been instituted by Van Horne.[68] The hours of patrol duty were longer during the summer months than during the winter months, perhaps reflecting the fact that fire was perceived to be a greater enemy of the sheds than avalanches.[69] At its most expensive, manning of these patrols could cost up to $620 per month.[70] However, even if this rate represented the average for the year, the direct cost of providing the patrol would still only have been $7,440. If this cost were not subsumed within the cost of snowshed maintenance and renewal, it would still amount to less than ten per cent. of the total cost of maintenance and renewal.

The cost of other components, for example the acquisition of snowploughs and the diversion of the main line, should not be allocated entirely to the direct cost of avalanche protection. The snowplough fleet, comprising two wingploughs and two rotaries at Revelstoke and one of each at Rogers Pass in February 1904,[71] had been augmented by two more rotaries at the end of 1910.[72] The new rotaries boasted significant technological advances over their predecessors. They were, therefore, more than simply reinforcements for the fleet: they represented an investment in modernisation too. Their duties were not confined to the Selkirks, but extended to the Eagle range and the Rockies also. Moreover, they performed not only avalanche clearance but routine snow removal in this region of high winter precipitation. They were acquired, not because the snowslides themselves were increasing in magnitude or frequency, but because, "The increasing traffic makes it most necessary that interruptions be at least cut down to the minimum..."[73] The investments were thus motivated, at least in part, by an increase in the volume of traffic over the line. A similar motivation also dictated certain relocations of the main line and bridge improvements which, as has been noted,[74] often afforded other operating advantages besides merely the avoidance of snowslides. The role of traffic increases in motivating investments in the mountains will be investigated more thoroughly in the next chapter.

This analysis of the direct costs of maintaining the avalanche defence system indicates that the anticipated savings in direct costs were not a major stimulus to the investment in the Connaught Tunnel. The quantifiable costs of maintaining the system certainly appear to have risen in the years immediately preceding the decision to abandon the surface alignment. However, there is no evidence to suggest that the C.P.R. expected these costs to continue to rise, and in 1912, the level of maintenance costs was still not sufficiently high to warrant investment in a tunnel. If the decision to abandon Rogers Pass was motivated by the escalation of the direct costs of maintaining the avalanche defence system after 1910, then construction of the Connaught Tunnel represented a very expensive solution to the problem.

The conclusion that construction of the Connaught Tunnel was motivated by the desire to avoid the direct cost of avalanche protection would only be justified if the sum of the expected savings in the quantified and non-quantified costs outweighed the expected cost of a tunnel beneath Rogers Pass.

The maximum quantified saving was $3,600,200. In order to tip the balance in favour of a tunnel, the non-quantified savings, in both direct costs of avalanche defence and indirect costs of traffic disruption, would have had to have exceeded $1,894,800, or over half as much again.[75] Given that rotary snowploughs would still have been required in order to remove the routine snowfall, and given the fact that improvements to the permanent way afforded other operating advantages which became increasingly valuable as traffic volumes increased through the Selkirks, it is unlikely that the non-quantified savings in direct costs alone did exceed this level. The conclusion of this analysis, therefore, is that investment in the Connaught Tunnel was not motivated by the direct cost of maintaining the avalanche defence system. It remains to be proven in the next section that the non-quantified savings in indirect costs of traffic disruption would not tip the balance in favour of a tunnel either.

b) The Indirect Cost Of Disruptions To Traffic

Previous historians of the C.P.R.'s operations in Rogers Pass have rarely accorded explicit credence to the view that investment in a tunnel beneath Rogers Pass was motivated by the desire to save the indirect cost of interruptions to traffic flows consequent upon snowslides blocking the main line. Nevertheless, the argument has intuitive appeal. This section investigates the possibility that the costs of disruption to traffic provoked construction of the Connaught Tunnel. The nature of the disruption costs is explained, and the incidence of disruption is examined. The efficacy of diversionary arrangements is assessed, and an attempt is made to determine whether the extent of disruption to traffic was increasing in the final years of surface operations through Rogers Pass, as traffic volumes increased. The section ends with an analysis of the importance of disruption costs in the financial evaluation of the Connaught Tunnel.

(i) The Nature Of Disruption Costs

If traffic flows through Rogers Pass were increasing in the early years of the 20th Century -- and, as the following chapter demonstrates, they most certainly were, and at a dramatic rate -- then the indirect cost of line blockages must also have increased. This indirect cost may have had several components. It would certainly have included the cost of diverting traffic via alternative routes, and it would certainly have included the opportunity cost of actually having to forego traffic because of the line blockage. Moreover, if traffic levels were sufficiently high, the indirect cost may also have included a congestion cost, as backlogs of traffic which accumulated during the period of the facility's closure would have been moved under congested conditions once the line could be reopened. Each of these indirect costs would increase as traffic volumes increased.

If it is to be argued that the indirect cost of avalanches motivated abandonment of Rogers Pass, it must be proven that the savings to be derived from the avoidance of these indirect costs, either in isolation or in conjunction with savings in the direct cost of maintaining the avalanche defence system, outweighed the anticipated cost of investing in a tunnel. Quantification of these indirect costs would be a difficult accounting problem under any circumstances, but it is rendered particularly exacting in this instance by severe data constraints. There is a paucity of evidence surrounding even the general nature and extent of traffic disruptions consequent upon avalanches, and cost data are virtually non-existent. This analysis, therefore, does not explicitly quantify the indirect cost of disruptions to traffic resulting from snowslides. However, it is at least possible to specify the relationship between disruption costs and investment in avalanche defence.

The optimal level of investment in avalanche defence is determined by two variables: the level of avalanche activity disrupting the line, and the level of traffic requiring transit over the line. An increase in avalanche activity in Rogers Pass, or an increase in traffic during the avalanche season, would both increase the probability of delays to traffic, and could both be expected, therefore, to call forth increased investment in avalanche defence, until a new equilibrium between disruption costs and protection costs was reached. Once the optimal level of investment was attained, however, the marginal cost of securing an additional "degree" of protection would be greater than the economic benefits which could be anticipated from the incremental investment. As has been recounted above, the C.P.R. initially provided some 30,000 feet of snowsheds on the main line across the principal avalanche paths. This length of snowshedding was not significantly extended throughout the thirty years of surface operations, presumably because the marginal cost of extension was not justified by the marginal benefit of the additional degree of protection.

Moreover, there was a marked discontinuity in the avalanche-defence investment-function, at the point where further investment in snowsheds was abjured in favour of the Connaught Tunnel. The analysis in section (a) of this chapter determined that, at least in the very last years before the decision was taken to abandon the surface operation, the C.P.R. did increase its investment in avalanche defence. It may therefore be assumed that the costs of traffic disruption also increased during this period. The increase in disruption costs may have been sufficient to warrant the increased investment in snowsheds. However, the analysis in the remainder of this thesis reveals that the increase in disruption costs was unlikely to have been sufficient to warrant investment in the Connaught Tunnel.

Indeed, it seems likely that avalanche defence exhibited decreasing-cost characteristics throughout the thirty years of surface operations in Rogers Pass. The decreasing-cost nature of avalanche defence is readily explained. If there are only two trains per day over a route, a snowslide may block the line and be cleared again before either of the trains is disrupted. In this case, the provision of a snowshed at the site of the slide averts no disruption, whilst the entire cost of providing the snowshed must be recouped from the revenues of those two trains alone. If, however, there are twenty trains per day over the route, it is unlikely that a snowslide can be cleared before some disruption to traffic occurs. Investment in a snowshed which can withstand the force of an avalanche therefore entirely averts this disruption, whilst the cost of providing the snowshed is spread over all of the twenty trains which travel the route, thus decreasing the total cost of each traffic movement.

At the commencement of surface operations through Rogers Pass, the C.P.R. provided some 30,000 feet of snowsheds. Yet in the winter of 1888, only four trains per day were scheduled to cross the Selkirks.[76] In the winter of 1912-13, the C.P.R. was still providing some 30,000 feet of snowsheds, yet there may have been as many as fourteen trains daily over the line throughout the avalanche season.[77] A greater volume of traffic was thus benefitting directly from avalanche defence, whilst contributing greater revenue towards offsetting the costs of the defence system. Between 1910 and 1912, total annual traffic through Rogers Pass virtually doubled.[78] Even if expenditure on avalanche defence doubled in the same period -- and it is known only that a discrete increase of 75% occurred between 1910 and 1911,[79] corresponding closely to the capital cost of rebuilding Shed 17 -- then the effect of the increased expenditure upon total costs must have been considerably cushioned by the spreading of the expense over the greater volume of revenue traffic.

(ii) The Incidence Of Disruption

Available evidence permits a non-quantitative analysis of both the actual extent of traffic disruptions due to avalanches, and of the manner in which traffic disruptions were perceived by the C.P.R. and by the public. The importance of the manner in which the disruption was perceived should not be underestimated. When C.P.R. management undertook an investment solution to a problem, it was of course reacting to its perception of the problem. As the analysis in section (a) above revealed, the C.P.R. does not appear to have been dissatisfied with the perceived return which it obtained from its investment solutions to the avalanche problem.

Neither does the press, insofar as it reflected, through its editorial and correspondence columns, the public's perception of traffic disruptions due to avalanches, appear to have been dissatisfied with the effectiveness of the C.P.R.'s avalanche-defence investments in reducing the experience of disruption in the Selkirks. In the wake of the 1910 disaster, the Vancouver Province reported that,

> It had almost become a byword that although occasional slides occurred the existence of snowsheds and a perfect system of patrolling the tracks near unprotected spots had hitherto, with rare exceptions, prevented any serious accident. No passenger or freight trains were ever swept away and no passenger ever lost his life.[80]

Although the 1910 disaster was followed by a succession of slides which interrupted traffic for almost two weeks,[81] not all of these slides were in the Selkirks.[82] Moreover, the C.P.R.'s handling of the disruption drew favourable press comment, for example from the Calgary Daily Herald:

> Now that the heaviest engagements of the trouble have been passed, the mountain staff are able to find in their achievement nothing but that which reflects creditably upon themselves...[83]

With passenger traffic forming a high proportion of total train movements through Rogers Pass,[84] the C.P.R. must have been acutely sensitive to the manner in which the public perceived the extent of traffic disruption due to avalanches. Yet it does not appear that the public was sufficiently alarmed for the C.P.R. to have been pressured by public opinion.

The actual extent of traffic disruption may be established slightly more concretely than the perceived extent of disruption. The following analysis will first assess the extent of direct disruption to both passenger and freight traffic which was consequent upon avalanches, as reflected in data concerning train movements through the mountains. The analysis will then consider the efficacy of diversionary arrangements which were intended to palliate the disruption caused by snowslides. Finally, the analysis will attempt to determine whether the avalanche problem was increasing in severity in the years prior to the decision to abandon the surface alignment.

In assessing the actual extent of disruption to passenger services, it must be conceded that there are at least four recorded incidents of passenger trains having been struck by avalanches in Rogers Pass prior to construction of the Connaught Tunnel. Two of these incidents occurred in the mid-1890's,[85] one in January 1912,[86] and one in April 1913,[87] after the decision to abandon the surface alignment had been taken. No casualties were reported in any of the incidents. There were tales of miraculous escapes,[88] and as soon as the 1911 slide season began, with the memory of the previous year's disaster presumably still fresh in the public's mind, the C.P.R. had to move rapidly to quash rumour of "a heavy snowslide at Rogers Pass."[89]

Nevertheless, disruption to passenger services was generally in the form of delay rather than of physical damage or diversion: the standard operating procedure was to "hold" trains until it could be ascertained that the line was clear. Incidence of delays may have been quite frequent, but it cannot be proven that those delays were any more serious than delays caused by other operating problems encountered in providing the transcontinental service. The only complete record of passenger train performance through the Selkirks which is extant is that for 1908, and this is presented in table 2. The table records on a monthly basis the aggregate time gained and lost upon schedule of the daily transcontinental service whilst crossing the Mountain Subdivision of the C.P.R. main line. Train No. 96 was the eastbound service, or "Atlantic Express," which had a morning path across the Selkirks, departing from Revelstoke at 0830 and arriving in Donald at 1433. Train No. 97 was the westbound service, or "Pacific Express," which had an afternoon path, departing from Donald at 1405 and arriving in Revelstoke at 1925.[90]

TABLE 2

PASSENGER TRAIN RECORD, MOUNTAIN SUBDIVISION, 1908.

Month	Time Gained Per Train Per Month (Hrs.-Mins.) Train No. 96	97	Time Lost Per Train Per Month (Hrs.-Mins.) 96	97
Jan.	1-39	27-16	-40	-55
Feb.	7-36	31-30	4-10	-45
March	7-32	30-28	5-05	6-04
April	7-07	17-13	59-07	54-15
May	7-25	11-09	nil	3-13
June	7-29	28-32	4-15	-38
July	7-45	26-26	4-55	2-32
Aug.	4-37	33-29	5-48	4-58
Sept.	7-35	37-46	1-50	4-58
Oct.	8-35	11-40	11-40	4-20
Nov.	12-51	1-20	13-55	2-30
Dec.	4-49	17-12	2-54	8-51
Total Per Train	85-00	280-01	124-19	93-54

Total Time Gained Per Year, All Trains: 365 hrs. 01 min.

Total Time Lost Per Year, All Trains: 217 hrs. 13 mins.

Source:- "Notebook," Kilpatrick MSS, Vancouver, n.p., n.d.

The table demonstrates that, in 1908 at least, there was as much potential for the service to recover time while crossing the Selkirks as there was for it to lose time. Losses incurred on the Mountain Subdivision averaged much less than an hour per day throughout the year, except in April, which appears to have been the peak month for slide activity in 1908. Even in April, however, losses still averaged less than two hours per day throughout the month. Except in April, the distribution of losses was not markedly skewed towards the winter months, but was generally uniform throughout the year. The fact that net gains outweighed net losses by some forty per cent. suggests that passenger trains were often already late when received onto the division.

Performance data are available for all traffic on a monthly basis during the years 1906-08. The data for the average number of trains per day on both the Mountain and Shuswap sections, eastbound and westbound, are reproduced as table 3. From this table, it can be seen that, except in 1907, more trains per day were put through the Mountain Section than through the Shuswap Section during each period of the year. The number of trains per day shows no sharp change from month to month, although if snowslides had indeed imposed a constraint upon traffic movements through Rogers Pass during certain months of the year, then some discontinuity between the monthly totals might be expected. It may be inferred that the number of trains operated over the Mountain Section was determined by the availability of traffic rather than by the availability of paths between avalanches. When the demand for train movements was comparable between the Mountain and Shuswap Sections, the Mountain Section could meet the demand at least as adequately as the Shuswap Section. The stochastic probability of any particular train being delayed on the Mountain Section was not sufficient to induce the C.P.R. to run trains with less frequency over the Mountain Section than over the Shuswap Section.

TABLE 3

AVERAGE NUMBER OF TRAINS PER DAY, MOUNTAIN AND SHUSWAP SECTIONS, 1906-1908.

Mountain Section

	Westbound 1906	1907	1908	Eastbound 1906	1907	1908	Total 1906	1907	1908
J	2.66	1.93	1.8	2.78	2.07	1.6	5.44	4	3.5
F	3.21	2.15	2.7	3.14	2.18	2.2	6.35	4.33	4.9
M	4.03	3.77	2.29	4.29	3.77	2.29	8.32	7.54	4.58
A	4.63	3.27	2.26	4.73	3.5	2.1	9.36	6.77	4.36
M	4	4.5	2.4	4.5	4.6	2.6	8.5	9.1	5
J	5.6	3.8	2.3	5.6	4.4	2.4	11.2	8.2	4.7
J	5	3.9	2.8	5	4	3.5	10	7.9	6.3
A	5	3.9	3.3	5.2	4	3.5	10.2	7.9	6.8
S	4.1	3.4	3.15	4.7	3.79	3.36	8.8	7.19	6.51
O	4.3	3.2	3.16	4.4	3.5	3.3	8.7	6.7	6.46
N	3.8	3.3	2.8	4	3.1	2.7	7.8	6.4	5.5
D	2.89	2.58	2.8	3.06	2.6	2.7	5.95	5.18	5.5
Average number of trains daily, all year:	4.1	3.3	2.7	4.3	3.5	2.7	8.4	6.8	5.4
% +/- in all-year average number of trains daily, over previous year:		-19.5	-18.2		-19.2	-22.0		-19.3	-20.1
Average number of trains daily, January-April:	3.6	2.8	2.3	3.7	2.9	2.1	7.4	5.7	4.3
% +/- in slide-season average number of trains daily, over previous year's slide season:		-22.2	-17.9		-21.6	-27.6		-23.0	-24.6

TABLE 3 (Cont.)

Shuswap Section

	Westbound			Eastbound			Total		
	1906	1907	1908	1906	1907	1908	1906	1907	1908
J	2.43	2.19	1.5	2.43	2.13	1.5	4.86	4.32	3
F	3.03	2.71	1.8	3.03	2.03	1.9	6.06	4.74	3.7
M	3.7	4.03	1.87	4	4	2	7.7	8.03	3.87
A	3.9	3.8	1.9	4.3	4.16	2	8.2	7.96	3.9
M	3.4	4.8	1.9	3.6	4.5	2	7	9.3	3.9
J	4.7	4	1.96	4.7	4.4	2.2	9.4	8.4	4.16
J	4.2	3.6	2.2	4.2	4.4	2.5	8.4	8	4.7
A	4.8	3.9	2.5	4.8	3.6	2.4	9.6	7.5	4.9
S	3.79	3.79	2.3	4.2	3.6	2.6	7.99	7.39	4.9
O	4	3.48	2.5	4.5	3.7	2.7	8.5	7.18	5.2
N	3.8	3.2	2.6	4	3	2.4	7.8	6.2	5
D	3.06	2.5	2.2	3.2	2.6	2.2	6.26	5.1	4.4
Average number of trains daily, all year:									
	3.7	3.5	2.1	3.9	3.5	2.2	7.6	7.0	4.3
% +/- in all-year average number of trains daily, over previous year:									
		-5.4	-40.0		-10.2	-37.3		-7.9	-38.7
Average number of trains daily, January-April:									
	3.3	3.2	1.8	3.4	3.1	1.9	6.7	6.3	3.6
% +/- in slide-season average number of trains daily, over previous year's slide season:									
		-3.0	-43.8		-8.8	-38.7		-6.0	-42.9

Source:- "Notebook," Kilpatrick MSS, Vancouver, n.p., n.d.

Table 4 contains data for the average equivalent gross tonnage handled per trip on both the Mountain and Shuswap Sections, eastbound and westbound. Two features of this table should be noted. First, there is no sharp change from month to month in average train weights on the Mountain Section, although discontinuities might again be expected if snowslides were a constraint. Second, train weights on the Mountain Section were consistently less than train weights on the Shuswap Section, at all times of each year, except during the winter months of 1907. This suggests that the seasonal avalanche hazard did not exercise influence over the average weight of trains: the consistent difference between train weights on the two sections may be explained by the fact that the gradient system on the Mountain Section was more severe than that on the Shuswap Section.

TABLE 4

AVERAGE WEIGHT OF TRAINS,
MOUNTAIN AND SHUSWAP SECTIONS, 1906-1908.
(Equivalent Gross Tons Per Trip)

Mountain Section

	Westbound					Eastbound				
	1906	1907	%+/-	1908	%+/-	1906	1907	%+/-	1908	%+/-
J	618	509	-18	802	+58	571	658	+15	739	+12
F	565	677	+20	749	+11	610	592	-3	723	+22
M	539	635	+18	785	+24	658	727	+10	787	+8
A	554	677	+22	820	+21	665	688	+3	798	+16
M	500	657	+31	684	+4	658	720	+10	830	+15
J	481	657	+37	777	+18	671	732	+10	837	+14
J	495	621	+25	775	+25	671	755	+13	828	+10
A	497	677	+36	607	-10	685	741	+8	734	-1
S	538	683	+27	667	-2	704	735	+4	797	+8
O	557	668	+20	699	+5	712	748	+5	806	+8
N	582	790	+36	809	+2	710	734	+3	802	+9
D	530	765	+44	746	-2	695	716	+3	764	+7
Average Train-weight Per Trip:										
	539	668	+24	743	+11	668	712	+7	787	+11

TABLE 4 (Cont.)

Shuswap Section

	Westbound					Eastbound				
	1906	1907	%+/-	1908	%+/-	1906	1907	%+/-	1908	%+/-
J	631	498	-21	835	+68	659	630	-4	732	+16
F	541	563	+4	907	+61	700	633	-10	760	+20
M	559	603	+8	882	+46	712	730	+3	833	+14
A	626	638	+2	911	+43	731	709	-3	918	+29
M	530	687	+30	844	+23	721	741	+3	1030	+39
J	509	634	+25	938	+48	720	728	+1	977	+34
J	527	669	+27	916	+37	735	736	-	1005	+37
A	491	681	+39	760	+12	718	757	+5	966	+28
S	515	675	+31	753	+12	719	768	+7	984	+28
O	546	619	+13	800	+29	726	751	+3	979	+30
N	575	765	+33	897	+17	721	750	+4	982	+31
D	513	714	+39	958	+34	688	773	+12	957	+24
Average Train-weight Per Trip:										
	547	647	+18	867	+34	712	725	+2	927	+28

Source:- "Notebook," Kilpatrick MSS, Vancouver, n.p., n.d.

Table 5 records the total equivalent gross tonnage per month which was transported in either direction over the Mountain and Shuswap Sections during the years 1906-08. Again, there are no systematic discontinuities between the monthly totals on the Mountain Section, as there might have been if snowslides had been a constraint. It may be inferred that the monthly variation in tonnages on the Mountain Section, and the monthly differences between the tonnages on the Mountain Section and those on the Shuswap Section, were due to the varying availability of traffic, that is, to varying demand, rather than to the varying availability of train paths during the avalanche season.

TABLE 5

TOTAL EQUIVALENT GROSS TONNAGE PER MONTH, MOUNTAIN AND SHUSWAP SECTIONS, 1906-1908.

Mountain Section

Westbound

	1906	1907	%+/- in Total	1908	%+/- in Total
Jan.	50,960	30,453		44,752	
Feb.	50,782	40,755		58,647	
March	67,337	74,212		55,727	
April	76,951	66,414		55,596	
May	62,000	91,652		50,890	
June	80,808	74,898		53,613	
July	76,725	75,079		67,270	
Aug.	77,035	81,849		62,096	
Sept.	66,174	69,666		63,032	
Oct.	74,248	66,266		68,474	
Nov.	66,348	78,210		67,956	
Dec.	47,483	61,185		64,753	
Total	796,851	810,639	+2	712,806	-12

Eastbound

	1906	1907	%+/- in Total	1908	%+/- in Total
Jan.	49,209	42,224		36,654	
Feb.	53,631	36,136		46,127	
March	87,507	84,964		55,869	
April	94,365	72,240		50,274	
May	91,791	102,672		66,898	
June	112,728	96,624		60,264	
July	104,005	93,620		89,838	
Aug.	110,422	91,884		79,639	
Sept.	99,264	61,520		80,338	
Oct.	97,117	81,158		82,454	
Nov.	85,200	68,262		64,962	
Dec.	65,928	57,710		63,947	
Total	1,051,166	889,014	-15	777,264	-13

Year	Total Tonnage	%+/- Over Previous Year
1906	1,848,017	
1907	1,699,653	-8
1908	1,490,070	-12

TABLE 5 (Cont.)

Shuswap Section

Westbound

	1906	1907	%+/- in Total	1908	%+/- in Total
Jan.	47,533	33,809		38,828	
Feb.	45,898	42,720		47,345	
March	64,117	75,333		51,130	
April	73,242	72,732		51,927	
May	55,862	102,226		49,712	
June	71,769	76,080		55,154	
July	68,615	74,660		62,471	
Aug.	73,061	82,333		58,900	
Sept.	58,556	76,748		51,957	
Oct.	67,704	66,778		62,000	
Nov.	65,550	73,440		69,966	
Dec.	48,663	55,335		65,336	
Total	740,570	832,194	+12	664,726	-20

Eastbound

	1906	1907	%+/- in Total	1908	%+/- in Total
Jan.	49,642	41,599		34,038	
Feb.	59,388	35,980		41,876	
March	88,288	90,520		51,646	
April	94,299	88,483		55,080	
May	80,464	103,370		63,860	
June	101,520	96,096		64,482	
July	95,697	100,390		77,888	
Aug.	106,838	84,481		71,870	
Sept.	90,594	82,944		76,752	
Oct.	101,277	86,140		81,942	
Nov.	86,520	67,500		70,704	
Dec.	68,250	62,304		65,267	
Total	1,022,777	939,807	-8	755,405	-20

Year	Total Tonnage	%+/- Over Previous Year
1906	1,763,347	
1907	1,772,001	+0.5
1908	1,420,131	-20

Source:- Tables 3 and 4. Average no. of trains per day x days per month x equivalent gross tonnage per trip. (1908 leap year).

In table 6, tonnages moved during the slide seasons (January to April) are compared with tonnages moved on an annual basis over the Mountain and Shuswap Sections. From this table, it appears that in the first third of each of the years 1906-08, slightly less than one third of the annual total tonnage of traffic was conducted over the Mountain Section. A similar proportion of total annual business was conducted over the Shuswap Section during the first four months of the year. In absolute terms, greater tonnages were conveyed over the Mountain Section than over the Shuswap Section during the slide seasons of two of the three sample years. Moreover, although traffic volumes over both sections were generally declining throughout the three-year period, column (vi) of table 6 suggests that the rate of decline on the Shuswap Section was faster during the slide season than on an annual basis. The difference between slide-season and annual rates of decline was not as great on the Mountain Section, and in 1908, indeed, the rate of decline was less during the slide season than the average annual rate of decline.

TABLE 6

COMPARISON OF TRAFFIC ON MOUNTAIN AND SHUSWAP SECTIONS, SLIDE SEASONS (JANUARY-APRIL), 1906-1908.

(i) Year	(ii) Tonnage Moved Jan.-April	(iii) % (ii) Of Annual Tonnage	(iv) %+/- Over Jan.-April of Previous Year	(v) %+/- Over Annual Tonnage Of Previous Year	(vi) (iv)-(v)
Mountain Section					
1906	530,741	28.7			
1907	447,398	26.3	-15.7	-8	-7.7
1908	403,646	27.1	-9.8	-12	+2.2
Shuswap Section					
1906	522,407	29.6			
1907	481,176	27.2	-7.9	+0.5	-8.4
1908	371,870	26.2	-22.7	-20	-2.7

	% Mountain Tonnage Greater Than Shuswap Tonnage During Slide Seasons	% Annual Total Mountain Tonnage Greater Than Annual Total Shuswap
1906	1.6	4.8
1907	-7.5	-4.3
1908	8.5	4.9

Source:- Tables 3, 4 and 5.

The data must be treated circumspectly, for several trend factors operated concurrently across the period. It is difficult to determine whether the C.P.R. countered the risk of traffic disruption due to avalanches between January and April by running fewer but heavier trains. Again, it is difficult to determine whether gross tonnages transported between January and April were low because traffic was disrupted by avalanches during these months, or because the traffic, for example lumber,[91] was seasonal in character. Indeed, it may be possible to explain some of the seasonality of the traffic, not only in terms of its composition, but in terms of the expectation of avalanche disruption _per se._

Monthly data are available for the aggregate gross ton mileage of all train movements over the Mountain Subdivision for the years 1910 and 1911. These data are particularly valuable in analysing the extent of disruption due to avalanches, as they span the slide seasons which several authorities believe to have been crucial in motivating the decision to abandon the Rogers Pass route. The data embrace the period of the 1910 avalanche disaster, and the two weeks of disturbance which followed. They also extend to within months of the decision to survey an underground route through the Selkirks, and include the penultimate winter of surface operation, one of the winters which, Lamb argues, "showed that slide hazards continued to be high," and persuaded the C.P.R. "that drastic action was essential."[92]

The data, aggregating the gross ton mileage of all passenger and freight trains, are presented in table 7, and a comparison of train performance between the years 1910 and 1911 is presented in table 8. The caveats expressed in the analysis of the 1906-08 data are equally applicable to analysis of the 1910-11 data. Again, however, certain inferences may be drawn.

TABLE 7

TOTAL EQUIVALENT GROSS TON MILEAGE PER MONTH, MOUNTAIN SUBDIVISION, 1910 AND 1911.

	1910	1911
Jan.	53,348,399	48,946,968
Feb.	50,058,868	60,621,556
March	60,162,544	81,423,638
April	72,008,888	89,572,739
May	79,289,709	98,883,576
June*	86,061,150	92,546,832
July	85,431,095	99,277,235
Aug.	83,407,130	102,947,877
Sept.	78,025,943	95,277,584
Oct.	80,259,054	95,710,487
Nov.	69,494,910	77,880,170
Dec.	64,499,788	77,035,828
Total	862,047,978	1,019,124,490

* No record of June ton mileages in RCM. Ton-mileage figures shown have been calculated from available figures for Total Train Miles in June, multiplied by estimate of average train weights in June. Average train weights for June are averages of train weights for May, July and August of respective years.

Source:- C.P.R. Co., "Statement of Train Locomotive and Actual Gross Ton Mileage, First District, British Columbia Division," Form S.O. 46, RCM.

TABLE 8

COMPARISON OF EQUIVALENT GROSS TON MILEAGES,
MOUNTAIN SUBDIVISION, 1910 AND 1911.

		Gross Ton Mileage	% Of Annual Total Conveyed Jan-April
1910	Jan-April	235,578,699	27.3
	Total Annual	862,047,978	
1911	Jan-April	280,494,901	27.5
	Total Annual	1,019,124,490	

%+/- Between Jan-April 1910 and Jan-April 1911: +19.1
%+/- In Total Annual Gross Ton Mileage, 1910-1911: +18.2

Source:- Table 7.

The proportions of total annual business which were conducted during the slide seasons of 1910 and 1911 were not markedly less than those of 1906-08. Indeed, the proportion of annual business carried during the slide season of 1911 may have been greater than the proportion for any year since 1906. (See table 6, column (iii)). The absolute volume of business conducted during the slide season of 1911 increased by 19.1% over the corresponding period of 1910, slightly more than the increase in the absolute volume of business on an annual basis, which was 18.2%. During these two years of increasing traffic, the main line continued to conduct slightly less than one third of the total annual business during the first one third of the year. Nevertheless, the proportion of total annual business which was conducted during the slide season of 1911 did increase slightly over that conducted during the slide season of 1910, from 27.3% to 27.5%. This evidence suggests that, within one year of its decision to abandon the surface alignment, the C.P.R. could still meet additional demand, where required, by increasing the volume of traffic conveyed over the mountains between January and April.

The evidence highlights the difficulty of convincingly apportioning influence upon the volume of business conducted in March 1910 between demand factors and avalanche factors. Despite the fortnight's interruption during March 1910, business increased by 20% over the previous February, and would increase by a further 20% in April. The volume of business conducted in March 1910 was greater than it had been for at least three months, greater than it would be in January 1911, and almost as great as it would be in February 1911. However, it must be conceded that the volume of business which was conducted in March 1911 was over 35% greater than the volume of business conducted in the corresponding month of 1910. This increase between the March figures of 1910 and 1911 was almost double the annual increase over the respective years (35% against 18.2%). Moreover, in 1911, a less troubled season, traffic increased by 34% between February and March, and by only 10% between March and April. This suggests that the blockages of March 1910 may have retarded the rate of growth in traffic volume which could usually be expected to prevail between February and March. It suggests also that the relatively high rate of growth which prevailed between March and April 1910 may have been due to a "catching-up" process, in which a backlog of traffic was cleared as soon as mountain access was restored. Nevertheless, the very difficulty of convincingly allocating weightings between demand factors and avalanche factors in part refutes the thesis that the "disastrous" 1910 slide season was a decisive influence in motivating the abandonment of the surface alignment.

This analysis of train movements, spanning years of both declining and increasing traffic volumes, does not establish conclusively that avalanche disruptions to traffic flows through the Selkirks seriously limited monthly traffic movements. The analysis does not reveal whether the relative increase in train movements which occurred during the slide seasons of certain years fully satisfied the demand for train movements in those seasons. Equally, however, the analysis does not prove that the C.P.R. would have been justified in abandoning its surface alignment through Rogers Pass purely because of the extent of actual disruption to traffic from snowslides. Only if it could be proven, first that the demand for train movements through the Selkirks between January and April could not be met, and second that it could not be met because of interruptions from avalanches, could it be concluded that the extent of disruption to traffic which was caused by snowslides prompted the C.P.R. to undertake investment in an alternative route across the mountains. The evidence of this analysis offers no such proof. Instead, it proves that the demand could be met with no more difficulty in the Selkirks than in the Gold Range, and suggests that avalanches were not a decisive factor in preventing the demand for traffic movement through the Selkirks from being satisfied.

(iii) Diversionary Arrangements

In assessing the efficacy of diversionary arrangements intended to mitigate the disruption due to avalanches, it must be remembered that until completion of the Canadian Northern main line through the Yellowhead Pass in 1915, there was no all-rail alternative to the C.P.R. main line through the Rockies and the Selkirks. Moreover, until 1914, the only alternative route which did exist entailed diversion through both the Rockies and the Selkirks, even when the C.P.R. main line was blocked through only one of these mountain ranges. For two weeks in March 1910, when the main line was blocked by slides in the Rockies and the Selkirks,[93] and again for at least three days in September 1913, when the main line was blocked by slides in the Rockies,[94] all traffic, "passenger, mail, baggage and express," had to be completely diverted between Calgary and Revelstoke. Westbound traffic was diverted via the Crow's Nest Pass railway to Kootenay Lake, conveyed by barge from Kootenay Landing to Nelson or Procter, thence by rail to Slocan, by barge across Lake Slocan, by rail to Nakusp, by barge again across the Upper Arrow Lake to Arrowhead, and thence by rail to Revelstoke. Eastbound traffic followed the route in reverse. Up to six transhipments were involved in either direction. It was not until 1914, with the opening of the Kootenay Central from Golden to Colvalli,[95] linking the main line through the mountains with the Crow's Nest Pass line, that it became possible for the C.P.R. to divert traffic around the Selkirks without also having to divert it around the Rockies. Transhipment at Kootenay Landing would continue to be necessary until 1930.[96]

Diversionary arrangements were therefore cumbersome and expensive. In 1910, at least, they were also inadequate. The Revelstoke Mail-Herald reported that,

> Freight sent round by the Crow's Nest has been much delayed owing to the barge equipment on Slocan Lake not being capable of handling the immense quantity of congested freight which had accumulated during the past two weeks.[97]

The inadequacy of the diversionary arrangements, together with the "awful disaster at Rogers Pass" and "the danger to passengers," prompted the Mail-Herald to urge completion of the Arrowhead and Kootenay Railway, "so as to give the C.P.R. an alternative route over the mountains under any conditions."[98]

The question of the desirability of alternative routes to the C.P.R. main line through the Selkirks will be discussed in chapter 7. It has already been noted that the Revelstoke Mail-herald was interested in the Arrowhead and Kootenay line chiefly for developmental reasons, and not because of its value as a safe alternative to the C.P.R. main line. The editor of the Mail-Herald claimed that,

> The immense sum which the present disaster, and the extensive slides which accompanied it, has cost the company, would complete the forty miles of the Arrowhead and Kootenay railway remaining to connect the main line with the Crows Nest road, and this would give the C.P.R. practically as short a route across the mountains as the main line, while on the Arrowhead and Kootenay railway there is not a snowslide...[99]

The C.P.R. clearly did not share his conviction: the Arrowhead and Kootenay was not completed until 1930.

Diversionary arrangements were only required on those occasions when the avalanche defence system on the main line failed. The diversions of March 1910 and September 1913 are the only recorded occasions of such failure. Even if diversion was cumbersome, expensive and inadequate when required, evidence suggests that it was not required sufficiently frequently to justify the channelling of investment from the main-line avalanche defence system into the construction of an alternative route through the Selkirks.

(iv) Was Disruption Increasing?

In analysing the role of traffic disruption in motivating the decision to construct the Connaught Tunnel, it is important to determine whether the extent of disruption due to avalanches was increasing in the years immediately prior to the abandonment of Rogers Pass. Certain authorities maintain that it was avalanche experiences in these years which induced the C.P.R. to discontinue surface operations.[100] Moreover, contemporaries may have perceived that the threat from avalanches was increasing in intensity. In the wake of the 1910 disaster, the editor of the Revelstoke Mail-Herald wrote thus:

> ...we understand from railway men, who know what they are talking about, that these slides are getting worse every year, and will continue to do so, as the remains of the forests which formerly protected a great part of the road, but were destroyed by fire during and since construction, rot away, thus giving clear sweep to slides from the deep snow banks which cover the mountains in winter.[101]

The previous analysis of train movements suggests that disruption did not increase throughout the period 1906-11. The proportion of total annual traffic which was conveyed through the Selkirks during the slide season remained almost constant at around 28%. This proportion actually increased when the total volume of traffic increased. Whilst this evidence cannot be considered conclusive, since it is impossible to discriminate the influence of seasonal demand factors from avalanche factors upon the volumes of traffic conveyed in various months of the year, further evidence is consistent with the view that disruption did not increase, either with the passage of time, or with increasing traffic volumes.

By February 1911, the C.P.R. had experienced its largest snowfall for sixteen years in the Selkirks.[102] Nevertheless, in the Engineering Department's annual report for the year ending June 30, 1911, the Chief Engineer, Sullivan, reported that, "During the winter the only slide of importance was one at M.B. 93, Mountain Subdivision, which covered one end of the shed delaying traffic six hours."[103] The corresponding report for 1912 noted:

> Small snowslide on January 14th at Mileage 113, Albert Canyon, carried out three cars from wrecking train...killing one man. The same morning at Shed No. 11, Colonist Car No. 14 was cut out from the train, but no one was hurt.[104]

By this time, the decision had already been taken to double track through the Selkirks, and the way was paved for the abandonment of Rogers Pass.

A list of avalanche occurrences in the Selkirks, recorded by the C.P.R. between 1909 and 1918 confirms that the years 1911 and 1912 were unremarkable for their slide activity, and that the extent of such activity would not be sufficient to cause disruption warranting investment in an alternative route. For 1911, the list records simply, "Nothing." Throughout the avalanche season of 1912, the list records two slides on January 14, and then only one more slide, over two months later, which apparently required only "1 hr. 30 min. to clear."[105]

Certainly, there was disruption to traffic in the years immediately before construction of the Connaught Tunnel, and this disruption was caused by slide activity. However, much of the slide activity did not occur in Rogers Pass at all. In November 1909, eastbound passenger train No. 2 was cut off by slides at front and rear in the Fraser Canyon,[106] and the main line was blocked for two days between Barnet and Lytton, whilst in the Selkirks and the Rockies, "the C.P.R. sustained no damage."[107] In January 1911, the main line was closed for a week by slides east of Field.[108] In April 1912, a passenger train was struck by a slide at Savona's Ferry, causing the only recorded avalanche-induced casualties in passenger service over the entire C.P.R. main line through the mountains prior to construction of the Connaught Tunnel. Even then, the fatalities were traincrew, not passengers.[109] In August 1913, the C.P.R. experienced a "series of blockades...in the mountain sections" which was "unparalleled in the history of the company. Never before have such a number of slides come down so many different points."[110] Again, however, most of the disruption was in the Kicking Horse Canyon, which would be rendered no less vulnerable to disruption from slides by the construction of a tunnel beneath the Selkirk Mountains.

The results of this analysis suggest that the extent of disruption to traffic due to avalanches may not actually have been very great, and was unlikely to have been sufficient to justify abandonment of the surface operation over the Selkirks. The extent of disruption does not appear to have warranted investment in diversionary facilities as an alternative to the route through Rogers Pass. Neither does the extent of disruption appear to have increased, either with the passage of time, or with increasing traffic volumes.

(v) Disruption Costs And The Abandonment Decision

Since this analysis makes no attempt to quantify the cost of disruptions to traffic due to avalanches, it is not possible to assess the relative importance of disruption costs in motivating the decision to construct the Connaught Tunnel. It is possible, however, to estimate how high those disruption costs would have had to have been in order to justify investment in a tunnel.

The analysis of the direct cost of maintaining the avalanche defence system revealed that the potential benefit of discontinuing the system, $3,600,200, was outweighed by the potential cost of tunnelling, at least $5,495,000. Cost outweighed benefit by some $1,894,800. If the benefits of tunnelling were to have outweighed the costs, the potential benefit of avoiding disruption to traffic from avalanches, combined with the non-quantified direct cost of maintaining the avalanche defence system, would have had to have been at least $1,894,800. Discounted at four per cent., these non-quantified costs would have had to have exceeded $75,000 per year,[111] in addition to the $125,000 per year expended in maintaining the avalanche defence system. If the non-quantified benefits were expected to be so high -- sixty per cent. of the quantified benefits of discontinuing the avalanche defence system -- it is reasonable to suppose that the C.P.R. would have included them in an evaluation of the forecasted cost savings of constructing a double-track tunnel which would obviate disruption from avalanches. The Company published an evaluation of the project in 1914,[112] which sought to justify construction of a double-track tunnel entirely by reference to the magnitude of the cost savings of the project, without any explanation of the costs which would have to be incurred in order to obtain those savings. Yet even with this bias, the evaluation makes no allusion to anticipated benefits from reduced traffic disruption. One interpretation of this omission might be that the magnitude of savings which could be derived from a reduction in traffic disruption was not sufficiently great to influence the decision of whether or not to construct a tunnel beneath

Rogers Pass.

This analysis of snow problems in the Selkirks raises serious doubts about the adequacy of the explanation that the surface alignment through Rogers Pass was abandoned because of the severity and the intractability of the avalanche hazard. Neither the 1910 disaster in particular, nor the snowslide problem in general, with its concomitant costs in defence and disruption, appears to have motivated the decision to construct the Connaught Tunnel. Nevertheless, the view that the tunnel was constructed in response to avalanche problems remains thoroughly entrenched. Any of three reasons may explain its endurance.

The first may be that the cost-savings approach by which the C.P.R. sought to justify the tunnel investment in retrospect accorded paramount importance in the outcome of the evaluation to the role of savings in the avalanche defence system. Thus:

> The figures would not have been very decisive one way or the other were it not for the fact that there is now 4 1/2 miles of wooden snow sheds on the present location which will all be done away with on the new location. The maintenance and cost of renewals of these sheds cost between $85,000 and $100,000 per year. To maintain and renew a double track wooden shed would probably cost at least 50% more than the above, so that with a saving of about $125,000 per year in maintenance and renewals of snow sheds and a calculated saving in operation and maintenance of $171,271.22 on a traffic that surely will be reached in the near future, there was no doubt as to the proper course to pursue.[113]

If the anticipated savings in snowshed costs had indeed constituted such a high proportion of the benefits of the project -- almost three-quarters of the benefit which was expected to accrue from operating savings -- then it might reasonably be asserted that the savings in snowshed maintenance did tip the balance in favour of the abandonment of Rogers Pass. However, as will be explained more fully in chapter 8, the evaluation which the C.P.R. published omitted all consideration of congestion costs and of the opportunity costs of traffic which would have to be foregone if the single line over Rogers Pass was not doubled. These omissions lend a downward bias to the estimate of operating savings accruing from the project, and this in turn lends an upward bias to the contribution of savings in snowshed maintenance towards the total benefits of the tunnel.

The second reason may be that Sir George Bury, who was instrumental in the decision to tunnel beneath Rogers Pass, himself emphasised in retrospective correspondence the role of avalanches in motivating the decision. Thus, two years after construction of the tunnel was commenced, Bury wrote,

> The big problem we had, of course, was to get the tunnel built as fast as possible, not only to avoid the continual expense of renewing the present snow sheds, and pay interest and overhead charges on a long delayed job, but to get away from the dangers of snow which is [sic] greater or less, depending on the season.[114]

As will be explained more fully in chapter 7, however, Bury himself offered a different rationale at the time when the decision was actually made. In June 1913, he wrote quite simply that,

> Regarding the necessity of this tunnel, I may say that the traffic over Rogers Pass has become so great that it is necessary to double track the line.[115]

He then proceeded to calculate an annual saving in traffic operating costs from the tunnel of $150,000 within four years.

The final reason is the obvious one, that savings in both snowshed maintenance and disruption to traffic from snowslides did accompany construction of the tunnel, since rail operations ceased to be conducted on the exposed surface of Rogers Pass.

The analysis in this chapter indicates that snow problems in the Selkirks were a matter of ongoing concern to the C.P.R., but that they were not a crucial factor in motivating the abandonment decision. As long as the service was operated over Rogers Pass, the potential for disaster was always present. Both the C.P.R. and the general public were well-informed about the nature of the avalanche hazard, and were prepared to accept the risks in order to maintain the service. Routinely, the service was maintained without incident. As the Calgary Daily Herald observed in the winter of 1910,

> Snowslides are looked for in season, as a matter of course, and under ordinary conditions they are attended with no special danger or delay to traffic. In these regions the battle with the snow is a commonplace feature of the winter's work. The organization and equipment are prepared for it.[116]

Occasionally, the potential for disaster was realised. However, the mere incidence of disaster would not necessarily precipitate a major change in policy: it would not necessarily dictate the cessation of rail operations through Rogers Pass. Whether or not the incidence of disaster would precipitate a major policy change would depend not upon the magnitude of the disaster itself, but upon the crucial question of how much the public or the railway company would be prepared to spend in order to avoid a repetition of the disaster. This was clearly perceived and understood by contemporaries: at the second inquest into the 1910 disaster, the C.P.R.'s Resident Engineer in Revelstoke asserted that,

> To make the road absolutely safe from slides, we

> would have to have a continuous shed through the mountains -- which is impracticable.[117]

The evidence of this analysis suggests that the C.P.R. was not prepared to spend the amount which would be required for a tunnel beneath the Selkirks, merely in order to avoid either the actual cost of operating services through hazardous avalanche paths, or the potential for disaster. Indeed, the analysis indicates that the C.P.R. <u>should</u> <u>not</u> have been prepared to spend that amount, for the benefits which it could expect to obtain from avoiding actual costs and potential disasters would not have offered the Company a return on its investment. Yet the C.P.R. did invest in a tunnel beneath the Selkirks, and when that tunnel opened, the Company did cease operating services through Rogers Pass. Clearly, if the benefits to be derived from avoiding avalanche problems did not alone justify investment in a tunnel, then the project must have been undertaken in the expectation of benefits from another source. Moreover, these latter benefits, aggregated with the former, must have been expected to justify the cessation of surface operations through Rogers Pass, operations which had been conducted for almost thirty years. The remaining chapters of this thesis will examine the nature and extent of these other benefits, and their influence upon the realignment schemes which were proposed.

FOOTNOTES

[1] See, for example, P. Berton, op. cit., p. 335; P. Mason, "89 Over The Top," Canadian Rail, No. 257, June, 1973, p. 175; Snow War, op. cit., p. 10.

[2] There is some controversy over the actual number of victims. It was initially feared that over one hundred railwaymen had been buried. T. Kilpatrick, tel. to G. T. Bury, March 5, 1910. Revelstoke City Museum, (henceforth "RCM,") File No. 76.15.171-9223.2. However, the Vancouver Province of March 5, 1910 reported 61 dead, and the next day, the Calgary Daily Herald reported that, "All the men in the section gangs in that vicinity have been checked up and the total number missing is 62. There is no question that this is the total death list." The toll reported to the Board of Railway Commissioners was 58. Board of Railway Commissioners, Annual Report, 1911. DSP Vol. XLVI, 1912, 20c, p. 45. The last body was not recovered until over a month after the disaster. T. Kilpatrick, tel. to G. T. Bury, April 18, 1910. RCM, ibid.

[3] Toronto Globe, March 7, 1910, p. 1.

[4] Province, June 22, 1907, p. 1.

[5] Dept. of the Attorney General, "Inquisitions, 1862-1918," No. 72, "James Moffat and Others, March 14, 1910," p. 10. PABC.

[6] Kilpatrick testified that, "The diversion east of Rogers Pass has been very expensive, as extra precaution had been taken against slides." Revelstoke Mail-Herald, March 12, 1910, p. 1.

[7] Province, March 8, 1910, p. 1.

[8] Revelstoke Mail-Herald, March 16, 1910, p. 3.

[9] Province, March 8, 1910, p. 1.

[10] Toronto Globe, March 2, 3, and 4, 1910.

[11] "Inquisitions," op. cit., p. 19.

[12] Ibid., p. 20.

[13] Ibid., p. 8.

[14] Ibid., p. 15.

[15] Calgary Daily Herald, March 14, 1910, p. 1.

[16] "Inquisitions," op. cit., p. 5.

[17] Ibid., p. 24.

[18] Ibid., p. 10.

[19] Ibid., p. 1.

[20] Abbott to Van Horne, January 4, 1888. PIC, CPCA. Either the instructions were ignored, or they lapsed with time, for a bridge carpenter at the second inquest into the 1910 disaster testified that, "We were doing just the same as we had always done, in working on slides at night." "Inquisitions," op. cit., p. 25. Only one employee was killed in the 1888 incident, although Robert Marpole, later to become General Superintendent himself, had a narrow escape.

[21] On March 7, 1910, the B.C. Legislative Assembly carried a motion of sympathy for the victims of the "deplorable accident." Journals Of The Legislative Assembly Of The Province Of British Columbia, Victoria, Vol. XXXIX, 1910, p. 91. Clearly, they could not be expected at this time to prejudice the outcome of the forthcoming inquest.

[22] DSP, Vol. XLV, 1912, 20c, p. 45.

[23] Labour Gazette, Journal of the Department of Labour, Ottawa, Vol. 10, April, 1910, p. 1177.

[24] HoC Debates, Vol. XCIX, "Accidents on Canadian Railroads," February 20, 1911, pp. 3922-47.

[25] Revelstoke Mail-Herald, March 16, 1910, p. 3.

[26] Calgary Daily Herald, March 7, 1910, p. 1.

[27] Revelstoke Mail-Herald, March 12, 1910, p. 4.

[28] "Inquisitions," op. cit., pp. 19-20.

[29] For example, on June 17, 1911, the C.P.R. paid $500 to Fredrik Vilhelm Carlsson as compensation for the death of his brother, Vic. "It is distinctly understood, however, that the Company does not admit but disputes legal liability for the accident, the amount being given as a gratuity and for the sake of peace." RCM 76.15.165-91.

[30] Shaughnessy to Bury, March 15, 1910. Letterbooks, op. cit.

[31] Revelstoke Mail-Herald, March 12, 1910, op. cit. The Resident Engineer, J. P. Ford, stated that the flat land was "on south side." At this point, however, the main line is running in a north-south direction, and the Engineer means "east."

[32] "Inquisitions," op. cit., p. 17.

[33] Reported in, Bury to Shaughnessy, March 18, 1910. PIC CPCA.

[34] RCM 76.15.165-57.

[35] $667.02 was paid to the Manitoba Bridge and Iron Works Company in April, 1911. Ibid., 76.15.139-64.

[36] Bury to Shaughnessy, March 15, 1910, PIC CPCA.

[37] Revelstoke Mail-Herald, April 30, 1910, p. 9.

[38] Province, March 8, 1910, p. 1.

[39] Whyte to Shaughnessy, April 13, 1911, PIC CPCA.

[40] "Inquisitions," op. cit., p. 15.

[41] Revelstoke Mail-Herald, April 13, 1910, p. 9.

[42] For further discussion, see below, Chapters 5.2 and 8.

[43] "Draft of letter from Walter Moberly re. double-tracking of the C.P.R. west of Winnipeg, and the danger of Rogers Pass." n.d., Moberly MSS, p. D946.

[44] Victoria Daily Times, July 6, 1910, p. 14. Earlier in the year, an editorial in the Revelstoke Mail-Herald commented that, "While everybody is glad to see the initial steps taken to open up the Big Bend by a railway, the policy of tieing [sic] up the whole of the Canoe and Columbia valleys between Revelstoke and the Yellow Head Pass is all nonsense, and it is to be hoped these reservations will not be kept long in force." Revelstoke Mail-Herald, April 30, 1910, p. 4.

[45] Revelstoke Mail-Herald, June 11, 1910, p. 1.

[46] Revelstoke Mail-Herald, April 13, 1910, p. 4.

[47] See, for example, Lamb, op. cit., p. 265; O. S. A. Lavallee, "Rogers Pass: Railway to Roadway," Canadian Rail, op. cit., p. 155; J. A. Beatty, "CP Rail's Connaught Tunnel," Canadian Rail, No. 271, August 1974, p. 227; Pugsley, op. cit., p. 47.

[48] Lavallee, ibid.

[49] By June, 1888. See Chapter 4.

[50] Statement of Snowsheds, "August, 1898," 6 pages, Kilpatrick Add Mss 323, PABC.

[51] Ibid.

[52] "C.P.R. Co. District No. 1, Pacific Division, Length of Snowsheds, October 8th 1904," ibid.

[53] Assuming that the maintenance cost of 23,760 feet of snowshedding was $85,000-$100,000 per annum. See Chapter 7.

[54] The C.P.R.'s plan of the relocation, dated October 19, 1908, shows that Sheds 15, 15A and 16, 426 feet, 89 feet and 353 feet

long respectively, were rebuilt; a new shed, 750 feet long, was required between Sheds 15A and 16, and the old Shed 17, 3,101 feet long, was replaced by a shed only 127 feet long. PABC, Maps Division, R-R 1, #9054.

[55] See note (53).

[56] C.P.R. Co., "Comparative Statement of Expenses, 1911 and 1910, First District, B.C. Division," RCM 76.15.140.

[57] Ibid.

[58] For the months of March, and May-December, 1912. C.P.R. Co., "B.C. Bridge and Building Dept., Distribution of Labour and Material," RCM 76.15.135-23; 76.15.128-34; 76.15.158-25; 76.15.130-25; 76.15.138-84; 76.15.131-30; 76.15.125-26; 76.15.167-78; 76.15.123-29.

[59] See Chapter 7.

[60] Sullivan to Bury, op. cit.

[61] Ibid.

[62] Ibid.

[63] Ibid.

[64] Ibid.

[65] ($125,000/4%) + $475,200.

[66] Sullivan to Bury, op. cit.

[67] See, for example, C.P.R. Co., "B.C. Bridge and Building Dept.," op. cit., RCM 76.15.135-23.

[68] See Chapter 4, note (126).

[69] "B.C. Bridge and Building Dept.," op. cit.

[70] Ibid., June, 1912. RCM 76.15.158-25. The expenditure upon "Watching" was $619.03.

[71] "Appropriations 1902-3 (Field Book 360)," Kilpatrick MSS, Vancouver, p. 42.

[72] Canadian Railway And Marine World, Toronto, April, 1911, No. 158, p. 323.

[73] Bury to Shaughnessy, March 15, 1910, op. cit., PIC CPCA.

[74] See above, pp. 92-93.

[75] $5,495,000 - $3,600,200. See note (65).

[76] In addition to the daily transcontinental passenger trains, two eastbound freight trains were scheduled, at least until November. Donald Truth, November 3, 1888, p. 3.

[77] In 1908, 7% of the total annual number of trains crossed the Mountain Section during March. See table 3. In 1912-13, the total annual number of trains through Rogers Pass was 6,162. Cornell Civil Engineer, op. cit., p. 81. 7% of this total would have represented 14.42 trains per day during a 31-day month.

[78] See table 11.

[79] See above, note (56).

[80] Province, March 5, 1910, p. 1. See also, Calgary Daily Herald, March 7, 1910, p. 1.

[81] Disruption continued until at least March 15. Calgary Daily Herald, March 15, 1910, p. 1.

[82] Slides occurred at Field, Palliser and Glenogle in the Rockies, and at Three Valley in Eagle Pass. Revelstoke Mail-Herald, March 9, 1910, p. 8. One of the slides was 100 yards long and 50 or 60 feet deep. Calgary Daily Herald, March 7, 1910, p. 1.

[83] Calgary Daily Herald, March 12, 1910, p. 9.

[84] See below, pp. 191-195.

[85] Tait, Memoranda to Shaughnessy, February 20, 1895 and February 29, 1896. PIC CPCA.

[86] Bury to Shaughnessy, "Engineering Department, Annual Report for year ending June 30, 1912," September 7, 1912, PIC CPCA.

[87] J. M. McKay, Superintendent, Revelstoke, to W. H. D'Arcy, General Claims Agent, Winnipeg, February 7, 1914, RCM 76.15.100-014872.

[88] See, for example, Revelstoke Mail-Herald, March 9, 1910, p. 8.

[89] Province, January 12, 1911, p. 1.

[90] C.P.R. Co., "Annotated Timetable, corrected to January 10, 1908," Montreal.

[91] See Chapter 6.

[92] Lamb, op. cit., p. 265.

[93] Province, March 9, 1910, p. 1.

[94] Province, September 8, 1913, p. 15.

[95] Innis, op. cit., pp. 154-155.

[96] Lamb, op. cit., p. 212.

[97] Revelstoke Mail-Herald, March 16, 1910, p. 3.

[98] Revelstoke Mail-Herald, March 12, 1910, p. 4.

[99] Ibid.

[100] Lamb, op. cit., p. 265; Frontier Guide to the Incredible Rogers Pass, Frontier Book No. 8, Calgary, 1963, p. 42.

[101] Revelstoke Mail-Herald, March 12, 1910, p. 4.

[102] Whyte to Shaughnessy, February 8, 1911, PIC CPCA.

[103] Whyte to Shaughnessy, "Engineering Department Annual Report for year ending June 30, 1911," September 7, 1911, PIC CPCA.

[104] Bury to Shaughnessy, "Engineering Department Annual Report for year ending June 30, 1912," op. cit.

[105] "Avalanche Occurrences 1909-1918, as recorded by the C.P.R.," Mount Revelstoke and Glacier National Parks, Revelstoke, B.C., File No. 1779.

[106] Victoria Daily Colonist, November 30, 1909, p. 1.

[107] Province, November 29, 1909, p. 1.

[108] Province, January 11, 1911, p. 2; January 12, 1911, p. 1.

[109] Victoria Daily Times, April 11, 1912, p. 1.

[110] Province, September 8, 1913, p. 15.

[111] $1,894,800 x 0.04 = $75,792 per year.

[112] Cornell Civil Engineer, December, 1914, op. cit.

[113] Ibid., p. 84.

[114] Bury, Memorandum to Shaughnessy, July 23, 1915, PIC CPCA.

[115] Bury to Shaughnessy, June 16, 1913, PIC CPCA.

[116] Calgary Daily Herald, March 12, 1910, p. 1.

[117] "Inquisitions," op. cit., p. 16.

CHAPTER 6

CAPACITY PROBLEMS

After the turn of the century, there was a considerable increase in the volume of traffic requiring haulage over the Selkirks. For railways traversing mountainous regions, substantial increases in traffic volumes may entail significant changes in operating procedures, and major investments intended to obtain increments in line capacity. At issue in Rogers Pass, then, is the question of whether main-line capacity was adequate to meet the requirements of burgeoning traffic in the early years of the 20th Century. The analysis begins with a consideration of the capacity of the main line through Rogers Pass. Then it considers changes in the traffic demands which were imposed upon the line, and changes in the competitive pressures which the C.P.R. confronted in meeting these demands through the mountains of B.C. Next, improvements which the C.P.R. undertook on its system in response to these changes are analysed, and the financial resources of the C.P.R. to undertake further system improvements are appraised. Finally, forecasts of traffic flows through the mountains are examined, and the implications of these forecasts for main-line operations through the mountains are assessed.

6.1 The Capacity Of The Main Line

The capacity of a railway line is the weight of traffic which can be transported over the line per unit of time. There are two crucial determinants of line capacity. The first is train weight; that is, the maximum weight of traffic which can be conveyed over the line by a single train. The second is the number of train paths which the line can supply; that is, the maximum number of trains which can be passed over the line in a given unit of time.

a) Train Weight

As was explained in chapter 2, the maximum weight of trains which can be conveyed over a line segment or a division is determined by the ruling gradient of that line segment or division. Over the line segment between Beavermouth and Rogers Pass on the east slope of the Selkirks, the ruling gradient against westbound traffic was 2.2% compensated for 20.8 miles. Over the line segment between Albert Canyon and Rogers Pass on the west slope, the ruling gradient against eastbound traffic was 2.2% compensated for 25.3 miles.[1] Table 9, containing tonnage ratings for a single locomotive through the Selkirk Mountains from Revelstoke to Field, demonstrates the influence of these gradients upon the weight of traffic which could be hauled in a single train through Rogers Pass. With the motive power which was available in 1913, any train travelling in either direction with an equivalent gross weight exceeding 508 tons required the attachment of a pusher locomotive for the entire distance of the ascent.[2]

TABLE 9

TONNAGE RATINGS FOR SINGLE 210% LOCOMOTIVE BETWEEN STATIONS ON MOUNTAIN SUBDIVISION, PRIOR TO JUNE 1913.

Westbound Rating (tons)	Station	Miles	Eastbound Rating (tons)
	Field		
Downgrade		8.2	1,224
	Ottertail		
Downgrade		4.4	2,100
	Wapta		
1,398		4.4	2,100
	Leanchoil		
Downgrade		18.2	554
	Golden		
2,100		16.3	2,100
	Donald		
2,100		11.7	1,283
	Beavermouth		
508		20.8	Downgrade
	Rogers Pass		
Downgrade		25.3	508
	Albert Canyon		
Downgrade		20.9	1,108
	Revelstoke		

Source:- F. J. Fisher to J. M. McKay, Superintendent, Revelstoke, May 25, 1913. RCM 76.15.188-45693.6.

Even with a pusher, however, the maximum weight of a freight train on either side of the summit was restricted to 1,016 tons, still significantly less than could be hauled on adjoining sections through the mountains. More than one pusher was rarely attached to a train. It is not known whether this was because the C.P.R. was chronically short of locomotives with which to supplement its pusher fleet;[3] whether it was because the incremental drawbar stress imposed by the additional locomotives would have fractured the car-drawbars;[4] or whether it was because of the difficulty of co-ordinating more than two steam locomotives. Whatever the reason, the fact that only two locomotives were generally allocated to any single train meant that trains exceeding 1,016 tons in equivalent gross weight had to be "cut" to this weight and forwarded in sections. In turn, this decreased the payload per locomotive-movement, and increased the number of train paths required for the movement of the traffic. Moreover, it set a ceiling on the extent to which an increase in the total volume of traffic requiring transit through the mountains could be accommodated simply by increasing the weight of trains. An increase in total volume above this ceiling would require more trains, and proportionately more locomotives, simply in order to match the capacity of adjoining sections. More trains, on a single line, and with the need to return pushers light through the increased opposing traffic, would, beyond a certain point, impose congestion costs additional to the direct operating costs of the train movement.

The addition of a pusher locomotive, and the addition of an entire train, both represent "lumpy" investments. That is, the investment produces the same fixed increment in capacity regardless of whether there are five tons or five hundred tons of additional traffic to be moved. Table 10 presents average train weights through the Selkirks for the period 1906-13. In the years 1906-08, "Consolidation" locomotives were deployed as pushers in the Selkirks. Since these locomotives had a rating of 490 tons,[5] the fixed increment in capacity which was obtained from the addition of one pusher was 490 tons. The maximum train weight which could be handled by two locomotives was thus 980 tons. From the increase in average train weights which occurred between 1906 and 1908, it may be deduced from table 10 that this fixed increment in capacity was being absorbed rapidly during these years. After 1910, the introduction of N-3's, each with a rating of 508 tons, increased the fixed increment in capacity obtained from the addition of one pusher to 508 tons, and raised the maximum train weight over the Selkirks to 1,016 tons. With the increase in average train weights recorded in table 10, it appears that this further fixed increment in capacity had been almost completely absorbed by 1913, and that there was renewed pressure for a further increment in train capacity. Such a conclusion is reinforced by the fact that in the summer of 1913, that is, actually after the decision to build a double-track tunnel beneath Rogers Pass had been taken, but before the tunnel could be brought on stream, the C.P.R. undertook intensive dynamometer tests on the Mountain Subdivision in order to examine the possibilities for increasing train weights on the restricted sections. Figure 1 presents a profile of the alignment between Revelstoke and Beavermouth, and shows the tonnage ratings which prevailed over the route both before and after the tests.

TABLE 10

AVERAGE TRAIN WEIGHTS, MOUNTAIN SUBDIVISION, 1906-1913.
(Equivalent Gross Tons)

Year	Westbound		Eastbound
1906	539		668
1907	668		712
1908	743		787
1910		737*	
1911		790*	
1912-13	898		950

* Average for both directions.

Sources:-

1906-08: "Notebook," Kilpatrick MSS, Vancouver, n.p., n.d.

1910-11: Actual Gross Ton Miles Per Month/Total Train Miles. C.P.R. Co., "Statement of Train Locomotive and Actual Gross Ton Mileage, First District, British Columbia Division," Form S.O. 46, RCM.

1912-13: Cornell Civil Engineer, Vol. 23, No. 3, December 1914, p. 80.

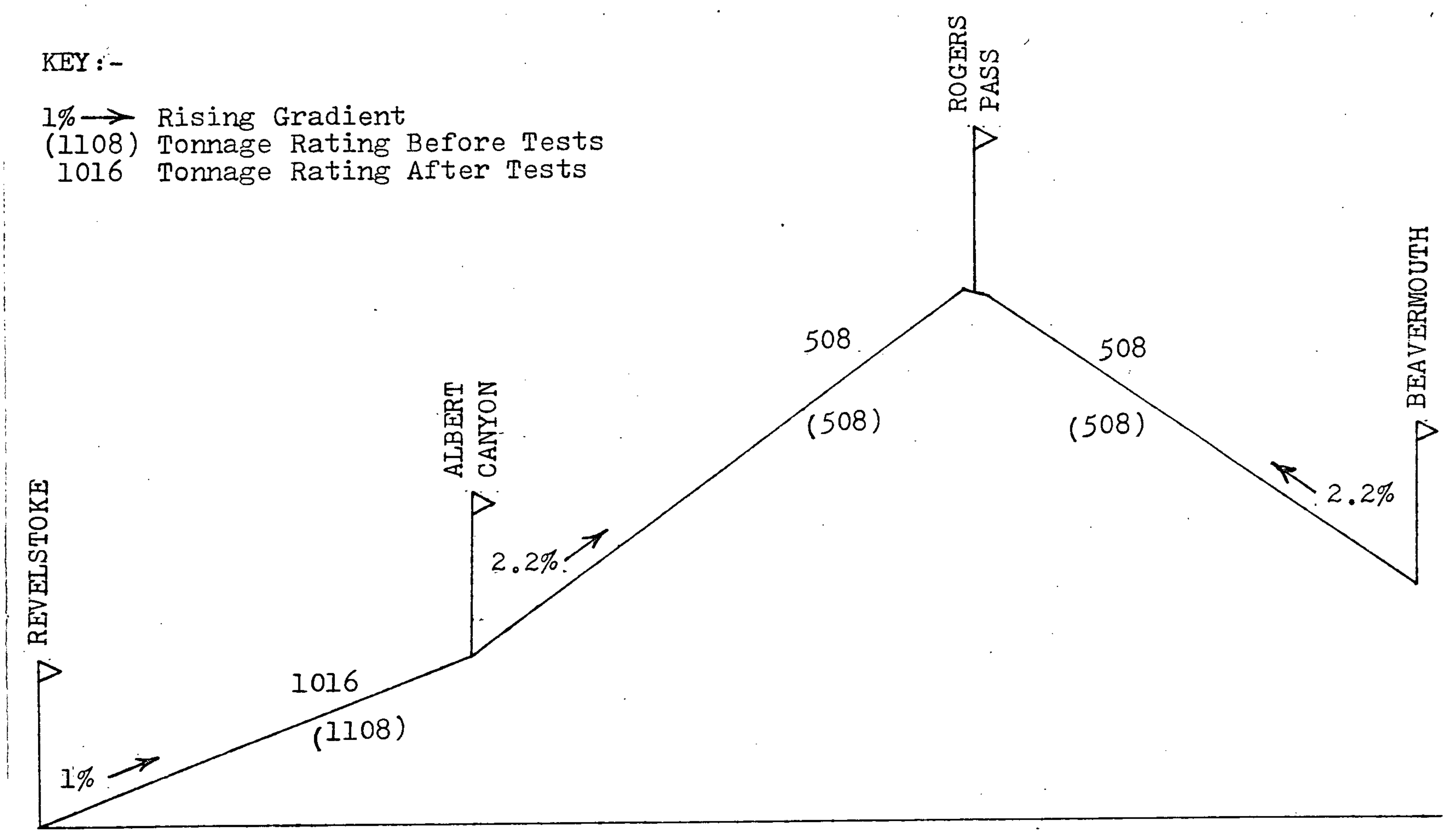


FIGURE 1: PROFILE OF C.P.R. MAIN LINE BETWEEN REVELSTOKE AND BEAVERMOUTH, SHOWING TONNAGE RATINGS FOR SINGLE 210% LOCOMOTIVE BEFORE AND AFTER DYNAMOMETER TESTS, MAY 1913. (Ratings in Tons)

Source:- F. J. Fisher to J. M. McKay, Superintendent, Revelstoke, May 25, 1913.
RCM 76.15.188-45693.6

During the tests, which were held in summer conditions, "43 more tons was handled from Beavermouth to Rogers Pass at an average speed of 8 1/2 miles per hour,"[6] but the "Engine slipped badly going through snowsheds."[7] Eastbound, "35 more tons was handled Albert Canyon to Rogers Pass." However, since motive power was doubled on this latter section, as on the Beavermouth - Rogers Pass section, the rating between Revelstoke and Albert Canyon had to be double the rating between Albert Canyon and Rogers Pass in order to ensure full utilisation of the single locomotive which would haul the train out of Revelstoke. This was found impossible to achieve, since the tests revealed that the existing rating between Revelstoke and Albert Canyon was already too high. The rating between Albert Canyon and Rogers Pass was therefore maintained at 508 equivalent gross tons, and the rating between Revelstoke and Albert Canyon was revised downwards to 1,016 tons.[8] A train of 508 tons might comprise as few as ten loaded and two empty cars,[9] and even these ratings may have been reduced by five per cent. during the winter months.[10]

The tests demonstrated that the possibilities for increasing train weights over the summit of the Selkirks were extemely limited with existing motive power. Increments in train weight were offset by a severe penalty in train speeds, which at full throttle were already well below ten miles per hour for the heaviest freight trains. Moreover, the reduction in train speeds in turn curtailed the supply of train paths. However, since train weights could not be increased, the only way in which an increase in the total traffic volume could be accommodated was by increasing the frequency of trains. This in turn increased the demand for train paths.

b) Train Paths

Estimation of the number of train paths which a single line of railway can supply is an imprecise science. The estimate is a complex function of transit time, which is in turn a function of motive power, train weight, train speed, opposing train movements and spacing of sidings; and of headways, which are in turn a function of the method of signalling, as well as of motive power, train weight and train speed. Computer simulation would be required in order to generate an accurate estimate of the capacity of the Rogers Pass line to supply train paths. Nevertheless, data are available for the demand for train paths in the years preceding abandonment of the surface route.

Table 3 records the demand for train paths on both the Mountain and the Shuswap Sections during the years 1906-08. The period was one of declining traffic, and this table, with table 4, indicates that the decline in traffic was met by an increase in train weights, which in turn decreased the demand for train paths. Table 3 indicates that in 1906, the average demand for train paths was slightly over four per day in each direction. The table also indicates, however, that the demand for train paths through the Selkirks was highly seasonal, and more sharply peaked than demand on the Shuswap Section.[11] In the summer peak, demand could reach almost six paths per day in each direction.

By 1912, traffic volumes had increased to such an extent that the average demand for train paths was over eight per day in each direction,[12] and in the summer peak, the average demand may have reached almost eleven paths per day.[13] Moreover, in 1912, the volume of traffic requiring transit through the mountains was forecast to double again within the next four years.[14] An increase in traffic volume of such magnitude implied an increase in the demand for train paths to an average of sixteen per day in each direction,[15] with seasonal peaks of almost twenty-two per day. It was because of these forecasts of future traffic volumes that the C.P.R. decided that its entire main line from Calgary to the West Coast would have to be doubled. Since other, less steeply graded portions of the main line were expected to be inadequate to handle this volume of traffic, it is reasonable to conclude that the alignment over Rogers Pass, with its forty-six miles of 2.2% gradient, was also deemed incapable of meeting the potential demand for train paths.

From the available data on train weights and train paths, an approximate measure of the capacity of the main line may be calculated. There are three assumptions. First, it is assumed that the annual total of trains through Rogers Pass in 1912-13, the years upon which the C.P.R.'s evaluation of the Connaught Tunnel was based, represented the maximum number of train paths sustainable by the facility. Second, it is assumed that an increase in passenger traffic could have been accommodated by increasing only the weight, and not the frequency, of passenger trains: thus, an increase in passenger traffic would not decrease the number of train paths available for freight. Third, it is assumed that every freight train in either direction conveyed the maximum tonnage operable by two locomotives, 1,016 tons. With these assumptions, it can be calculated that the maximum volume of freight which could have been conveyed by the 3,477 freight trains through Rogers Pass was 3,532,632 tons. In 1912-13, the C.P.R. actually conveyed 3,212,748 tons of freight through the Pass. This volume represented 91% of the calculated maximum tonnage which the facility could handle.[16]

This analysis demonstrates that the route over Rogers Pass imposed a potential bottleneck upon the flow of traffic through the mountains. This bottleneck was created by restrictions upon both train weights and the number of train paths available through the Pass. As traffic volumes increased, the surplus capacity which was available on individual trains was absorbed, until most trains were operated over the Selkirks at their maximum permissible weight, 1,016 tons. Since train weights could not be increased beyond this level, further increases in traffic volume had to be handled by increasing train frequency. The maximum number of train paths which the single line over Rogers Pass could supply appears to have averaged between eight and sixteen per day in each direction. The latter represents a non-sustainable average, since, by the time the demand for train paths reached this level, the C.P.R. expected that it would have to have double-tracked its main line through the mountains. The potential bottleneck appears to have been on the verge of becoming an actual bottleneck. This impression is reinforced by an analysis of traffic flows through Rogers Pass.

6.2 Traffic Flows

This analysis will first consider total traffic levels through Rogers Pass, and then changes in specific traffic flows. Consideration of C.P.R. estimates of future demand will be deferred until section (6.6) of this chapter, although data concerning forecasted traffic levels are incorporated into the appropriate tables for purposes of comparison.

a) Total Traffic Levels

Table 11 presents the secular trends in the total tonnage of traffic requiring transit through Rogers Pass between 1904 and 1912, broadly disaggregated into freight and passenger volumes. Table 12 expresses these trends as annual rates of change.

From the tables, it can be seen that passenger traffic, reacting less markedly to the recession of 1906-08, maintained a steady rate of increase throughout the years prior to the decision to abandon Rogers Pass. The volume of passenger traffic increased by 117% between 1908 and 1912. Over the same period, the volume of freight traffic, which had declined during the recession, increased by 123%. In gross tonnage terms, passenger traffic increased by 675,000 tons, while freight traffic increased by 2,575,000 tons. The tables indicate that in 1911-12, the rates of increase in traffic were the highest since 1908-09, the year of recovery from the recession. Moreover, in 1912, the year of the decision to double track through the mountains, the volumes of both passenger and freight traffic surpassed all previous records.

TABLE 11

GROSS TONNAGE OF PASSENGER AND FREIGHT TRAFFIC OVER EACH MILE OF ROAD, MOUNTAIN AND SHUSWAP SUBDIVISIONS, 1904-1913.
(Equivalent Gross Tons)

Year	Passenger	% Passenger Of Total	Freight	% Freight Of Total	Total
1904	0.325	21.7	1.175	78.3	1.5
1905	0.425	21.8	1.525	78.2	1.95
1906	0.475	17.0	2.325	83.0	2.8
1907	0.55	23.9	1.75	76.1	2.3
1908	0.575	27.1	1.55	72.9	2.125
1909	0.775	27.2	2.075	72.8	2.85
1910	0.875	26.5	2.425	73.5	3.3
1911	1.025	26.8	2.8	73.2	3.825
1912	1.25	26.6	3.45	73.4	4.7
1912-13*	2.002	30.9	4.471	69.1	6.473
1915-16**	4.314	32	9.155	68	13.469

* Average for two years, total tons over Rogers Pass. Cornell Civil Engineer, Vol. 23, No. 3, December 1914, p. 80.

** Forecast. Sullivan to Bury, October 22, 1912, PIC CPCA.

Source:- Histogram enclosed in, Bury to Shaughnessy, April 21, 1913, PIC CPCA (except 1912-13 and 1915-16).

TABLE 12

ANNUAL RATES OF CHANGE IN GROSS TONNAGE PER MILE, MOUNTAIN AND SHUSWAP SUBDIVISIONS, 1904-1913.
(% change)

Year	Passenger	Freight	Total
1904-05	+30.7	+29.8	+30.0
1905-06	+11.8	+52.5	+43.6
1906-07	+15.8	-24.7	-17.9
1907-08	+4.5	-11.4	-7.6
1908-09	+34.8	+33.9	+34.1
1909-10	+12.9	+16.9	+15.8
1910-11	+17.1	+15.5	+15.9
1911-12	+22.0	+23.2	+22.9
1912-1912/13	+60.2	29.6	+37.7

Source:- Table 11.

Whilst freight traffic declined as a proportion of total volume, the absolute magnitude of the increase in freight tonnage, and the distribution of traffic between freight and passenger, which was heavily skewed towards the former, had serious implications for rail operations over Rogers Pass. An increase in passenger traffic might have been accommodated to some extent by adding cars to passenger consists and absorbing the surplus capacity which was available on passenger trains. By 1912, however, such an alternative was not available for freight operations. In 1912-13, every freight train which crossed the Selkirks required assistance. If traffic continued to increase, additional train paths and additional motive power would be required. In contrast, over one quarter of all passenger trains were still conducted by single locomotives, and could have borne some increase in tonnage without requiring an increase in paths.[17]

Table 13 presents the balance of traffic flows through Rogers Pass in those years between 1889 and 1913 for which disaggregated data are available. During the early years of operation, consistent with the C.P.R. forecasts made at construction time, westbound flows predominated. By the early years of the 20th Century, however, the balance had swung until the eastbound flows slightly outweighed the westbound. This pattern endured at least until the year of the decision to abandon Rogers Pass. Reversal of the C.P.R.'s forecasts would have implications for the C.P.R. system which are discussed below.[18]

TABLE 13

BALANCE OF TRAFFIC FLOWS THROUGH ROGERS PASS, 1889-1913.
(Tons)

Year	Westbound Tonnage	% Of Total	Eastbound Tonnage	% Of Total	Total Tonnage
1889*	38,895	64	21,441	36	60,336
1890*	50,773	78	13,974	22	64,747
1906	1,081,891	43	1,427,176	57	2,509,067
1907	1,100,610	48	1,207,021	52	2,307,632
1908	967,782	48	1,055,297	52	2,023,079
1910-11**	1,710,779	47	1,922,756	53	3,633,535
1911-12**	2,037,320	46	2,371,856	54	4,409,176
1912-13	3,191,488	49	3,281,890	51	6,473,378
1915-16#	6,734,660	50	6,734,660	50	13,469,320

* Net tons of freight forwarded and received at Vancouver by rail, to and from the East.

** The equivalent gross tonnages of traffic given in Sullivan's letter to Bury have been disaggregated into passenger and freight volumes according to the averages of the percentages of each for the years 1910 and 1911 and 1911 and 1912 respectively, according to table 11. The resulting passenger tonnages have been divided by 50 to yield estimates of the number of cars, and these estimates have been divided by 6.5 to yield estimates of the number of passenger trains. This was the basis upon which Sullivan himself projected future passenger traffic. The resulting freight tonnages have been divided by 508 to yield estimates of the number of freight trains. These estimates of the numbers of passenger trains and freight trains have been multiplied by 175 tons and 181 tons respectively, the weights of passenger locomotives and pushers (see Cornell Civil Engineer, op. cit., p. 80) in order to yield estimates of the weight of motive power which traversed the Pass. These estimates have been added to Sullivan's estimates of equivalent gross tonnages of traffic in order to yield estimates of total equivalent gross tonnages in each direction through Rogers Pass.

Forecast.

Sources:- 1889-90: Vancouver Board of Trade, Annual Reports.
1906-08: Kilpatrick MSS, Vancouver, n.p., n.d.
1910-12 and 1915-16: Sullivan To Bury, October 22, 1912, PIC CPCA.
1912-13: Cornell Civil Engineer, Vol. 23, No. 3, December 1914, p. 80.

Within the Selkirks, partly because of the greater length of 2.2% gradient and curvature on the west slope than on the east, the time required in order to pass an eastbound train over the Mountain Section exceeded that required to pass a westbound train by some 20%.[19] This may have aggravated the effect of the imbalance between eastbound and westbound traffic flows. The greater elapsed-time requirement for eastbound flows may have been symptomatic of actual congestion in the eastbound direction. However, there is no evidence to suggest that the existence of the imbalance between relative traffic volumes in itself caused the C.P.R. any concern. Neither does it appear that the C.P.R. expected any chronic imbalance in the future to exert pressure upon main-line capacity in a single direction only.

Although it is not known whether actual congestion was experienced on the main line through Rogers Pass prior to construction of the Connaught Tunnel, it is certain that the C.P.R. encountered some difficulty in handling existing traffic volumes. The Company's investment response to the 1910 avalanche disaster was motivated, not by an explicit desire to save human life in future, but by a recognition of the need to protect the expanding traffic. Thus, Bury had informed the Assistant Chief Engineer of Western Lines, F.F.Busteed:

> The way traffic is increasing on our main line, we must take steps to at least reduce delays, and it is necessary for you to prepare plans looking to minimizing trouble from slides.[20]

Bury echoed these sentiments to his President: "The increasing traffic makes it most necessary that interruptions be at least cut down to the minimum."[21] It was not only during the slide season, however, that difficulty was experienced: for almost two weeks during the summer peak of 1912, motive power had to be transferred from work-train to freight-train duty, and every locomotive on the Pacific Division, with the exception of four which were detailed to essential ballasting, was used to clear freight traffic.[22]

The nature and extent of the increases in total traffic levels through Rogers Pass may be more clearly understood by an analysis of changes in specific traffic flows.

b) Changes In Specific Traffic Flows

This analysis will examine changes in the following types of traffic through Rogers Pass:- passenger, lumber, grain, fish, other transcontinental traffic, and local traffic.

(i) Passenger

Few statistics are available concerning the actual number of passengers conveyed over the C.P.R. main line prior to construction of the Connaught Tunnel. Some impression of the magnitude of the increase in passenger volume which occurred during the period of surface operations through Rogers Pass may be gained from table 14, which contains the available data on passenger volumes for specific months between 1893 and 1908.

TABLE 14

PASSENGER VOLUME THROUGH ROGERS PASS, VARIOUS MONTHS, 1893-1908.

Month	Year	Number Of Passengers
April	1893	4,609
April	1894	4,160
May	1895	2,549
May	1896	2,722
Oct.	1907	31,620
Nov.	1907	24,055
Dec.	1907	17,358
Oct.	1908	25,916
Nov.	1908	19,384
Dec.	1908	16,932

Sources:- 1893-94: Tait, Memorandum to Shaughnessy, May 8, 1894. PIC CPCA
1895-96: Tait, Memorandum to Shaughnessy, June 5, 1896. PIC CPCA
1907-08: "Notebook," Kilpatrick MSS, Vancouver. n.p., n.d.

It was the weight and frequency of passenger trains, rather than the actual number of passengers carried, however, which exercised the most important influence upon main-line capacity. Early transcontinental trains usually comprised a baggage-mail-express, coach, Colonist and sleeping car.[23] By 1902, the only change to this consist was the addition of an observation car.[24] In 1909, following gradient revision on the "Big Hill" and the introduction of larger motive power, the first dining cars were attached to consists through the Rockies and the Selkirks,[25] and by 1913, passenger trains were generally nine cars long,[26] and averaged 443 tons in weight.[27] Although a single road locomotive could haul a train of such weight, by 1913 three-quarters of all passenger trains were being pushed through the Selkirks in order to increase speeds and thus reduce line occupation.[28] By 1916, however, the average speed of the fastest passenger service through the Selkirks, the eastbound train No. 2, was still less than twenty miles per hour,[29] scarcely 1 1/2 miles per hour faster than it had been in 1902.

Passenger train frequency also increased. During the summer of 1902, the single daily passenger service was augmented by an additional train in each direction on three days per week.[30] In 1906, the double-daily service had to be introduced a month early because of increased demand,[31] and it was maintained until October.[32] During 1907, a third transcontinental service was added on three days per week,[33] and this became a daily service during the summer of 1909.[34] Until 1909-10, passenger service had always been pared to a single train daily between Calgary and Vancouver during the winter months. Although the C.P.R. had intended to maintain a double-daily service throughout the winter of 1909-10,[35] this was cut back from January to March 1910 between Vancouver and Calgary and between Winnipeg and Montreal.[36] During the winter of 1912-13, however, the C.P.R. maintained its full complement of passenger services,[37] and in the summer of 1913 increased the regular service to four transcontinental trains daily in each direction.[38] It is likely that the number of passenger specials over the mountains, although unrecorded, also increased throughout the period, especially during the summer months.

Thus, not only did the total number of passenger trains through Rogers Pass increase, but the seasonality of the scheduled traffic declined. Since passenger trains enjoyed priority over all other traffic on the main line, this increase in the number of passenger trains increased the probability that freight trains, also increasing in frequency, would have to be recessed in the limited siding accommodation, both ascending and descending the Pass, whilst awaiting "meets." Moreover, the probability was now extended into the winter months. Data for the transit times of "extra" freights is insufficient to permit analysis of the frequency and duration of recessing. Nevertheless, if the journey of an "average" train eastbound across the Mountain Section in 1908 required 12 hours 55 minutes,[39] while the scheduled passenger trains made the crossing from Revelstoke to Donald in 6 hours 3 minutes, it is likely that the elapsed time for the journey of an "extra" freight would have exceeded 16 hours. Some of this prolongation in elapsed time may therefore have been attributable to the creation of congestion as the volume of passenger traffic increased.

(ii) Lumber

Table 15 presents a record of the principal commodity flow through Rogers Pass by volume, that of lumber. Throughout the study period, the direction of the flow was almost exclusively eastbound, from the B.C. Coast and Interior mills to the Prairies, and, by 1909, as far east as the Great Lakes.[40] The C.P.R.'s eastern lumber market began to develop in 1897-98,[41] and provided an accurate index of crop conditions on the prairies. After the poor prairie crop of 1900-01,[42] the years 1902 to 1907 were ones of marked expansion in eastbound lumber shipments by rail.[43] By 1904, the trade was generating an average of 500-800 carloads per month, or at least one or two trainloads daily.[44] The trade experienced recession in 1907-08,[45] a fact which may explain much of the decline in freight volumes over the Mountain and Shuswap Sections during this period (see tables 11 and 12). However, the years 1910 to 1912 were marked by a dramatic increase in eastbound lumber shipments. This increase, unlike those of earlier years, which had been due to B.C.'s achievement of an increased market share in the prairies, was chiefly due to a large absolute increase in the volume of lumber consumed in the eastern provinces.[46] Mirroring the trend in total freight traffic, the lumber flow peaked in 1912, the year of the decision to double-track the main line, and the rate of increase in the flow during the year preceding the decision surpassed all previous records.

TABLE 15

LUMBER TRAFFIC THROUGH ROGERS PASS, VARIOUS YEARS, 1900-1918.

Year	Total Board Feet Shipped By Rail From B.C. (Millions)
1900	26*
1906	360
1907	190*
1908	280**
1909	not available
1910	640
1911	761
1912	912
1913	756
1914	548
1915	562
1916	836
1917	537*
1918	530*

* Rail shipments from B.C. Coast mills only.

** Annual output of Interior mills only.

Source:- Vancouver Board of Trade, Annual Reports, except 1906.
1906: Victoria, B.C., Board of Trade, Annual Report, 1906-07.

The lumber traffic was a key factor in the economics of the Rogers Pass route for four reasons. First, its sheer magnitude, in terms of both absolute volume and rate of increase, rendered it the most important of the trans-mountain freight flows, and a vital influence upon the capacity and the prosperity of the main line through Rogers Pass.[47] Second, it was a distinctly seasonal flow, peaking in the summer months of constructional activity on the prairies, when main-line train paths through Rogers Pass were already at a premium on account of the summer peak in passenger traffic. Third, the loaded lumber movement was principally eastbound, against the greater length of 2.2% gradient. It was, therefore, more costly than westbound loaded movements, and imposed greater demands on main-line capacity since greater elapsed time was required in order to complete an eastbound crossing of the Selkirks. Finally, satisfaction of the demand for the loaded eastbound movement entailed a substantial movement of cars westbound. Since there was generally insufficient traffic with which to fill these cars, most were hauled empty, and as the demand for cars for the lumber trade increased, empties were hauled to B.C. from as far east as Fort William and beyond.[48] Not only did the substantial, and expanding, empty westbound movement impose further pressure on main-line capacity through Rogers Pass, but it raised the joint cost of the total movement considerably. This increased cost was passed on to B.C. shippers in the form of higher rates, to an extent which goaded appeals from the shippers to the Board of Railway Commissioners on at least three occasions.[49]

(iii) Grain

Grain shipments from the prairies westbound were negligible during the late 19th Century, due to crop failures[50] and to the lack of markets accessible via the western route. By 1903, however, the C.P.R. had shipped "several grain cargoes" to South Africa and Australia,[51] and was competing to supply Japan and China.[52] By 1909, markets had been developed in Mexico, the Philippines and Alaska,[53] and the Tehuantepec Railway across Mexico was increasing in importance as a route by which grain shipped west from the prairies could penetrate the European market.[54] The key stimulus to westbound grain shipments, however, was the westerly advance across the prairies of the grain production-frontier, which was extended beyond Medicine Hat in 1904.[55] This afforded to westbound grain movements from the prairies to tidewater an increasing advantage over the hitherto predominant eastbound movements in terms of length-of-haul, car-cycle time, and therefore cost. By 1905, the Calgary Board of Trade calculated that, "grain from...Swift Current can be taken to Vancouver as cheap [sic] as to Fort William, probably for considerably less."[56]

The potential for westbound grain shipments, as a major commodity flow in themselves, and as a backhaul traffic which could offset the high joint costs of lumber movements through the mountains of B.C.,[57] had early been foreseen. In 1902, the Edmonton Board of Trade had raised the question of Vancouver's suitability as a point of export for Alberta grain.[58] Presentations canvassing the advantages of the western route were submitted to the Royal Commission on Transportation in

1905,[59] and to the Royal Grain Commission in 1906,[60] and both Commissions were convinced. The former concluded that, "a very material increase in westbound traffic from the whole province of Alberta may be expected."[61] The latter was even more unequivocal:

> There is no doubt...that a very large trade with the Orient could be developed if there were transportation facilities at reasonable rates to the Pacific coast, and proper terminal facilities there for handling the grain. Considering the benefit that would arise out of this trade with the Orient to the grain producers of Alberta and Western Saskatchewan, we think the [federal] government would be justified in assisting the development of this trade.[62]

Until 1907, there were no grain elevators in B.C.: by 1913, there was storage capacity for 562,000 bushels.[63]

TABLE 16

GRAIN TRAFFIC THROUGH ROGERS PASS, VARIOUS YEARS, 1903-1917.

Year	Bushels	%+/- Over Previous Year
1903	202,000	
1907	774,790	
1908	969,570	+25
1909	2,664,700	+175
1910	3,163,610	+19
1911	3,057,175	-3
1912	4,827,175	+58
1913	4,048,475	-19
1914	2,811,100	-44
1915	1,766,050	-59
1916	1,079,700	-64
1917	973,797	-11

Notes:- 1903: Number of carloads of domestic grain inspected at Winnipeg, destined for Vancouver by C.P.R., year ending September 1, 1903. One carload = 1,000 bushels.
1907-17: Grain shipments from Calgary going West.

Source:- Board of Grain Commissioners, Annual Reports, DSP, except 1903.
1903: Labour Gazette, Vol. 4, March 10, 1904, p. 285.

Table 16 shows grain flows through Rogers Pass from 1903 to 1917. The secular increase in the volume of the shipments prior to 1914 is evident. Moreover, as with the eastbound lumber traffic, grain shipments peaked in 1912, while the rate of increase during the preceding year surpassed all previous records. The grain traffic did represent a principal westbound flow, contrary to the direction of lumber shipments. Nevertheless, it was not of sufficient magnitude prior to the First World War to offset the massive movement of empties which the lumber traffic entailed. In 1912, the absolute volume of the westbound grain shipment was only one-eighth of the volume of the eastbound lumber movement, and since grain loads far more densely than lumber, the disproportion between the respective number of carloads which each traffic generated was probably even greater. Moreover, the seasonality of the grain and lumber shipping patterns may not have coincided. Whilst lumber shipments were concentrated into the summer months, the flow of grain did not commence until September,[64] and the westbound movement may indeed have been concentrated into the period from January to April, when the freezing of the Great Lakes precluded eastern exports. Such a shipment pattern would have eased pressure upon main-line capacity during the summer peak, but if the westbound grain traffic did furnish cars for the return-loading of lumber, substantial inventories of empties must have accumulated in the west during the months between the cessation of grain traffic and the commencement of eastbound lumber shipments. There is no evidence that such inventories did accumulate.

(iv) Fish

Data on fish traffic are sparse, but nevertheless reinforce the impression of rapid secular growth in the demand for freight movements through Rogers Pass. Table 17 records the annual pack of the B.C. salmon canneries from 1887 to 1918, and, for the period during which data are available, that between 1887 and 1906, indicates the proportion of this output which was conveyed "overland." Overland shipments to the United Kingdom competed directly with ocean transportation and fluctuated according to shipping conditions. It was the increase in rail shipments to the Eastern Canadian market which was largely responsible for the increase in the absolute volume of total overland shipments throughout the period, although overland shipments remained fairly stable as a proportion of total output, as shown by column (viii) of the table.

TABLE 17

B.C. SALMON PRODUCTION AND TRADE, 1887-1918. (Tons)

(I) Year	(II) Annual Pack	(III) To U.K. Overland	(IV) % (III) Of (II)	(V) To Eastern Canada Overland	(VI) % (V) Of (II)	(VII) Total Overland	(VIII) % (VII) Of (II)
1887	4,898	0	0	1,109*	22.6	1,109	22.6
1888	4,417	57**	1.3	1,108*	25.1	1,165	26.4
1889	9,943	14	0.1	1,014	10.2	1,028	10.3
1890	9,827	0	0	1,886*	19.2	1,886	19.2
1891	7,557	77	1	1,463*	19.4	1,540	20.4
1892	5,483	0	0	1,424	26.0	1,424	26.0
1893	14,165	659	4.7	2,755	19.4	3,414	24.1
1894	11,865	490	4.1	1,824	15.4	2,314	19.5
1895	14,423	1,576	10.9	1,903	13.2	3,479	24.1
1896	14,438	492	3.4	1,225	8.5	1,717	11.9
1897	24,371	1,040	4.3	3,140	12.9	4,180	17.1
1898	10,634	330	3.1	2,109	19.8	2,439	22.9
1899	17,578	765	4.4	2,754	15.7	3,519	20.0
1900	14,050	1,686	12.0	1,900	13.5	3,586	25.5
1901	29,668	1,586	5.3	3,165	10.7	4,751	16.0
1902	15,024	41	0.3	3,259	21.7	3,300	22.0
1903	11,368	11	0.1	3,660	32.2	3,671	32.3
1904	11,181	441	3.9	3,846	34.4	4,287	38.3
1905	28,019	2,631	9.4	3,651	13.0	6,282	22.4
1906	15,107	142	0.9	2,764	18.3	2,906	19.2
1907	13,139						
1908	13,025						
1909	23,230						
1910	18,293						
1911	22,775						
1912	23,918						
1913	32,494						
1914	26,665						
1915	27,201						
1916	23,882						
1917	37,380						
1918	38,788						

Notes:- Unless otherwise stated, "Overland" and "Via Rail" are assumed to be by C.P.R. Co.
* Mode and route unspecified.
** By Northern Pacific Rail Road.

Source:- Vancouver Board of Trade, <u>Annual Reports.</u>

Canned salmon was not a principal flow through Rogers Pass. In 1905, a peak year, the traffic may have generated less than one loaded car per day.[65] Nevertheless, the direction of the flow was again predominantly eastbound, and again, the flow increased in absolute magnitude, at least until 1906. Moreover, the total output of the B.C. canneries continued to increase after 1906, and the canneries continued to sustain high levels of annual output despite the natural four-year cycles of the salmon run. Canning began in Victoria after 1904, and stimulated a new trade in spring salmon, shipped to Europe in cold storage.[66] Although it is not clear that this particular traffic was railborne, it is nevertheless likely that these developments together generated increases in both the magnitude and the consistency of eastbound salmon shipments through Rogers Pass after 1906.

The opening of the transcontinental rail link also stimulated the development of fresh fish traffic. An eastern market for fresh salmon had been opened by 1888.[67] Markets for fresh halibut were developed in Boston and New York by 1894,[68] halibut shipments to Boston alone averaging four cars per week by 1902.[69] The fresh fish traffic may have matched the canned salmon traffic in volume: total shipments of the former reached six million pounds in 1902, and again in 1905.[70]

Like the lumber and canned salmon flows, the direction of fresh fish shipments was overwhelmingly eastbound. In the early years of the trade, at least, fresh fish shipments were concentrated in the winter months, when the fish could be packed in ice. Thus, the traffic did not compound the summer peaks of passenger and lumber movement through Rogers Pass. However, it is not known whether this seasonal pattern endured, nor even whether the flow itself persisted in any volume after 1905.

(v) Other Transcontinental Traffic

Little quantitative data is available concerning other transcontinental traffic flows through Rogers Pass, although, again, the general impression is of increasing absolute volumes. It is known that the first carload of strawberries to be forwarded from Vancouver was shipped to Calgary and Winnipeg in the summer of 1908,[71] and that Japanese oranges and carload shipments of bananas were being imported into Vancouver by 1909.[72] Some of these latter may have been forwarded eastwards through Rogers Pass. Moreover, a considerable sugar traffic may have developed prior to the First World War: during a four-month period in the summer of 1912, 16,100 tons, or perhaps three carloads per day, were forwarded by the C.P.R. to Alberta and Saskatchewan.[73] It should be noted that all these flows were eastbound. Trade with the Orient increased "by leaps and bounds" after the turn of the Century,[74] and two steamers were added to the C.P.R.'s Pacific fleet of five vessels in 1913.[75] Meanwhile, the trans-Atlantic link in the "All-Red" route from Britain to the Orient was completed in 1903, with the purchase of Elder Dempster.[76] Neither the direction, nor the composition, nor the volume of trade along the route is known, however.

(vi) Local Traffic

Although the Lake Superior Division enjoyed the dubious distinction of generating the least local traffic per mile of line on any part of the C.P.R.,[77] it appears that local traffic through Rogers Pass was also negligible. This was affirmed in 1908,[78] and again in 1911.[79] The major reason for the dearth of local traffic was the sparsity of settlement along the main line through the Selkirks.[80]

These analyses of total traffic levels and of specific commodity flows through Rogers Pass reveal that there was a rapid growth in traffic during the early years of the 20th Century. The rate of increase was particularly great following the recession of 1906-08, and peaked in the year of the decision to double-track the main line from Calgary to the West Coast. Absolute traffic levels also peaked in that year. Tonnage levels in both directions increased proportionately, and there is no evidence to suggest that capacity problems unique to either direction were experienced by trans-mountain traffic. However, much of the westbound freight traffic continued to comprise empties on zero-revenue "positioning" hauls into B.C. for the servicing of the eastbound lumber trade. This imbalance in the movement of revenue traffic, combined with the fact that the predominant eastbound revenue-traffic flows confronted the longer pusher gradient through the Selkirks, influenced both the variable costs of the freight movements and the concomitant level of rates imposed by the C.P.R. for trans-mountain traffic, as will be demonstrated in the following section.

6.3 Competitive Pressures

This analysis will begin with a brief consideration of the rate scheme which governed traffic movements through Rogers Pass. It will then examine three sources of potential competitive pressure upon the C.P.R.'s trans-mountain traffic. These sources were the Canadian Northern Railway, the Grand Trunk Pacific Railway, and the Panama Canal. Finally, the manner in which the C.P.R. perceived these pressures will be examined, in order that the impact of the pressures upon the decision to abandon the route through Rogers Pass may be assessed.

a) C.P.R. Rates In The Mountains

There was little dispute that the costs which the C.P.R.'s rates were required to recover in the mountains were much greater than elsewhere on the transcontinental system. Construction costs had been three times higher than on the prairies.[81] In 1914, the cost of "Maintenance of Way and Structures" on the B.C. Division was double that on the prairies, and the cost of "Transportation" per train mile was greater by thirty per cent.,[82] even excluding provision for "overhead expenses, such as taxes, insurance, or capital charges."[83] Moreover, contrary to the earliest forecasts of Van Horne, the predominant freight movement was eastbound, while in 1904, for example, "One-third of all the loaded cars that go East from Vancouver return to the same point empty," mostly from "East of Winnipeg."[84]

The C.P.R. sought to pass on these higher costs to its shippers in the form of higher rates. Throughout the entire period of surface operations in Rogers Pass, the Company enjoyed the regulatory freedom to do this. Prior to 1904, "There was practically no rate regulation in Canada."[85] Until 1914, the Board of Railway Commissioners sanctioned a tariff structure of five standard scales, one of which, the "Mountain Scale," applied to traffic movements on C.P.R. lines west of the Crow's Nest and Canmore. On this scale, "one mile is counted as two prairie tariff miles for distances up to 220 miles." For hauls between 220 and 750 miles, the maximum haul for mountain territory, this double rate was reduced upon a sliding scale until the rate per mile for the maximum haul was approximately 46 2/3 per cent greater than the prairie rate. This rate differential was sanctioned explicitly because of "the greater cost of construction and operation in British Columbia."[86]

In practice, it appears that the C.P.R. did not generally cross-subsidise any traffic flows through the B.C. mountains, either by drawing funds from more profitable sections of the system, or by drawing funds from more profitable particular flows within the mountains. The only specific service on the B.C. Division which was internally subsidised was the local passenger service.[87] Nevertheless, profitability on the Division may have been substantially less than elsewhere on the system: in 1908, for example, the operating ratio on the Pacific Division was 0.88, compared with 0.565 on the Central Division.[88]

Moreover, there were instances when traffic was foregone because the C.P.R. could not pass on to its shippers the higher rates required to cover the cost of the freight movement. The circumstances under which traffic was foregone are, however, vague in character and lacking in quantitative substantiation. In 1888, the British Columbia Board of Trade argued that, because of the high C.P.R. rates, "A large proportion of British Columbia freight continues to be carried by foreign competing lines."[89] This traffic was generally transcontinental, however, and moved under transcontinental tariffs of which the rate through the B.C. mountains was merely one component. During the Parliamentary debate on the National Transcontinental Railway, several Members expressed the view that certain freight, particularly lumber and grain, was not being moved at all, and explicitly adduced the heavy gradients of the C.P.R. main line through the B.C. mountains, and its concomitant high rates, as explanation for the non-movement. It was the gradients through the Kicking Horse Pass, rather than those through Rogers Pass, which were perceived as the chief obstacle to freight movement, however,[90] and the Kicking Horse gradients would be halved in 1909. The question of whether or not the B.C. mountains were the only obstacle to the development of a westbound grain trade will be addressed later.

Throughout the entire period of surface operations in Rogers Pass, it appears that the C.P.R. was generally successful in passing on to its shippers the high cost of routine traffic movement over the mountains in the form of higher rates. The Company enjoyed the regulatory freedom to do so. This freedom was never in jeopardy before the First World War. The Company also enjoyed the commercial freedom to forego traffic which it did not regard as offering sufficient contribution above the marginal cost of the movement. Such traffic would either move by competing lines in the United States, or it would not move at all. By 1912, however, this commercial freedom would be seriously threatened by changes in competitive circumstances through the mountains of B.C.

b) The Sources Of Competitive Pressure

The first source of pressure to the C.P.R. was the Grand Trunk Pacific Railway Company, which, in July 1903, was authorised to extend its main line to the West Coast of B.C. The extension was scheduled for completion in 1911. The new transcontinental route would breach the Rockies through the Yellowhead Pass, and would terminate at Prince Rupert, one day's sailing closer than Vancouver to Yokohama, Japan. It therefore posed a direct threat to the C.P.R.'s Oriental trade,[91] and was expected to play a major role in conveying the grain of the former North-West Territories westbound for export.[92] Unlike the main line of the C.P.R., which had been laid as quickly and cheaply as possible throughout its length, and subsequently upgraded as revenues were generated, the Grand Trunk Pacific's main line was, from the outset, "substantially built, with a view to heavy traffic and economical operation."[93] Its maximum gradient from Saskatchewan to the West Coast was 0.4% in either direction, except for twenty miles of one per cent. gradient in the Rockies. Even this, however, was situated on the west slope of the mountains, and would therefore not oppose the movement of loaded grain cars to the Coast. Maximum curvature across the prairies was three degrees, and in the mountains six degrees. A single locomotive would be able to haul 2,041 tons between Edmonton and Prince Rupert on the Grand Trunk Pacific, over four times as much as the C.P.R. could haul across its main line through the mountains.[94]

In practice, the Grand Trunk Pacific incurred severe penalties, in terms of both capital costs and time required for completion, in order to secure this first-class alignment. By 1908, it was already obvious that the line would not open in 1911.[95] Track was laid through the Yellowhead Pass in December 1911,[96] and in December 1912 completion was forecast, correctly, for the autumn of 1914.[97] By the time that the line opened, however, the railway had accumulated massive debts in order to meet its construction costs,[98] while the outbreak of world war, with its heavy toll on merchant shipping, delayed the development of a westbound grain trade. After receiving a series of federal loans between 1916 and 1918, the railway was finally placed in the receivership of the Ministry of Railways pending post-war reorganisation.[99]

The second source of pressure was the Canadian Northern Pacific Railway. By the terms of an agreement with the provincial government of B.C. in 1910, the Canadian Northern was authorised to extend its main line from the eastern border of the province through the Yellowhead Pass and Kamloops and into the heart of Vancouver. The Canadian Northern expected to make inroads into the lumber market,[100] and to wean transcontinental tourists to the new route through the Rockies.[101] The maximum gradient of the Canadian Northern through the mountains would be 0.7%. This gradient would be twenty-eight miles long, and, like the maximum gradient on the Grand Trunk Pacific, would oppose eastbound traffic. Westbound, the maximum gradient would be 0.5%, and a single locomotive would be able to haul 2,400 tons in this direction.[102]

The line was scheduled for completion in July 1914, and the threat to the C.P.R. of rival service into Vancouver persisted throughout the later years of the C.P.R.'s surface operation in Rogers Pass. In June 1911, the C.N.R.'s Vice President projected completion by autumn 1914.[103] In 1912, the target was brought forward to "the end of 1913,"[104] but in January 1913, the prediction for passenger service out of Vancouver was once more set back, to August 1914.[105] Transcontinental service was in fact inaugurated in November 1915,[106] by which time, again, world war had overtaken economic events.

The third source of pressure was the Panama Canal, superseding the Tehuantepec Railway as the route by which traffic from the west coast of North America would be shipped to Europe. The Canal would not actually open until 1915. However, throughout the later years of the C.P.R.'s surface operation across the Selkirks, completion of the Canal posed both a threat and an opportunity to the C.P.R.

It posed a threat to the C.P.R.'s transcontinental traffic by reducing the cost of ocean competition, which had traditionally dictated rate levels for transcontinental traffic.[107] The C.P.R., operating one of the most costly sections of main-line railway in North America through the mountains of B.C., and compelled to derive some contribution towards these costs from transcontinental traffic, was less favourably equipped than its rivals to revise rates downwards in order to meet the threat of ocean competition.

Moreover, the Panama Canal, by reducing the cost of ocean transportation between the Pacific and the Atlantic, paved the way for grain exports from the west coast of North America to the massive markets of Europe. In addition to following its traditional pattern of eastbound shipment from the prairies to the Atlantic ports, grain destined for Europe could now flow westwards, through the Rocky Mountains to the Pacific coast. The C.P.R. would either increase its market share of westbound grain shipments, which had developed steadily during the first decade of the 20th Century, or it would lose its market share to the new competitors, with their superior alignments between the prairies and the ports.

The Grand Trunk Pacific, the Canadian Northern and the Panama Canal each represented a competitive threat to the C.P.R. Each of the threats alone might have been serious enough to a company which had enjoyed a twenty-five year monopoly of transcontinental traffic in Canada. By 1910, however, the C.P.R. was facing all three threats simultaneously. The crucial issue in determining the nature of the C.P.R.'s investment response to the competitive situation, and indeed, in determining whether the Company responded at all to the changes in competitive circumstances, is the manner in which the C.P.R. perceived these pressures in the years prior to the decision to abandon Rogers Pass.

c) The C.P.R.'s Perception Of The Pressures

The Vancouver Province adduced competitive pressure as the reason for the C.P.R.'s decision to double track between Calgary and the West Coast.[108] Certain authorities have placed primacy upon the changes in competitive circumstances as specific explanation to drive the Connaught Tunnel.[109]

The C.P.R. certainly perceived very clearly indeed the competitive threats posed by the Grand Trunk Pacific and the Canadian Northern. Both the initial decision to seek gradient reductions in the B.C. mountains, and the specifications of the gradient reductions which were sought, were beyond doubt determined to a considerable extent by the potential pressure of rail competition. When Sullivan, the C.P.R.'s Chief Engineer, was instructed to study the economics of providing a second track through the mountains,

> "he...came to the conclusion that we [the C.P.R.] should double track our present main line, making the grade, after passing over the first small summit west of Revelstoke, four-tenths of one percent from there to the Coast. This, with the other grade reductions possible between Revelstoke and Calgary, including the construction of a tunnel about five miles in length under the Selkirks,...would enable us to operate much cheaper than the Grand Trunk Pacific and slightly less than the Canadian Northern.[110]

The objective of securing a competitive edge over the rival railway companies must also have been stressed before V. G. Bogue, a consulting engineer from New York who was commissioned to verify Sullivan's conclusions. For Bogue's interim conclusion was,

> that the completion of our plans will give us the best transcontinental line, and that we will be able to handle traffic over it more economically than either the Canadian Northern or Grand Trunk Pacific.[111]

Vice-President Bury himself later confirmed that one of the reasons for seeking gradient revision in the mountains was the necessity "to be able to move traffic at a cost competitive with the new Canadian transcontinental lines with their low grades, now rapidly nearing completion."[112]

The C.P.R.'s response to the pressure caused by the imminent opening of the Panama Canal was less unequivocal. Both the Vancouver press and the Vancouver Board of Trade relished the prospects of the Canal's opening, and of export grain pouring through the mountains into Vancouver.[113] Press reports suggest that the C.P.R. perceived the Canal purely as an opportunity, a means for increasing its share of grain traffic. They also suggest that improvements which were undertaken in the mountains were a direct response to the potential of westbound grain shipments. Thus, the Victoria Daily Times reported in 1912:

> It is stated that the company will proceed with [the] work of double tracking in order to have the easy grades available for the handling of the wheat crop westward when the opening of the Panama Canal comes in three years.[114]

It is certainly true, moreover, that it was the westbound gradients which the C.P.R. sought to reduce to levels competitive with those of the Grand Trunk Pacific and the Canadian Northern.[115] The gradients against eastbound traffic, 2.2% for some twenty miles on the west slope of the Selkirks and for almost thirteen miles on the west slope of the Rockies, far in excess of the eastbound gradients of the C.P.R.'s competitors, would be virtually unaffected by the proposed revisions.

Yet if the improvements to its westbound gradients betokened the C.P.R.'s intention to be ready for the westward shipment of grain, the Company seems to have been remarkably sceptical about the prospects of such future grain shipments. The 1905 Royal Commission on Transportation noted "the wish of the Canadian Pacific Railway Company to develop the trade in winter wheat for the purpose of the oriental market," but not before a C.P.R. representative had stated before the Commission, "I do not think there is any prospect of developing any shipment of grain to the Pacific coast from east of Alberta."[116] At this time, Alberta was producing scarcely three million bushels of wheat per year, less than one-tenth of the output of either Saskatchewan or Manitoba.[117] In September 1909, when the enthusiastic Council of the Vancouver Board of Trade was accorded a special interview with C.P.R. President Shaughnessy, and duly raised the question of facilities for westbound grain shipments, the President merely replied "that when the necessity arises the grain question will be amply provided for."[118]

The C.P.R.'s scepticism of westbound grain shipments persisted into the First World War. The Company's expectations of future grain flows do not appear to have been sufficient by 1912 that the decision to double-track the main line could be interpreted purely as a response to the potential of the grain business. The C.P.R.'s Chief Engineer, in rationalising the need for a tunnel through the Selkirks in October 1912, assumed merely that, "in a few years the wheat traffic west will increase sufficiently to make eastbound and westbound traffic balance." According to his own calculations, since the eastbound equivalent gross tonnage was 1,688,230, and the westbound was 1,450,115, and since both were expected to double, the increase which the Chief Engineer anticipated could not have exceeded 480,000 tons over four years, including the weight of the grain cars themselves.[119] By 1912, the C.P.R. was already shipping 150,000 tons of grain westbound, exclusive of the weight of the cars. It appears, therefore, that the Company did not expect grain traffic to increase even as rapidly as its other business.

Lamb has already publicised the remarkable miscalculation of President Shaughnessy in this matter: as late as October 1913, after boring of the Connaught Tunnel had commenced, Shaughnessy expressed privately the belief that "it could 'be taken as an accepted fact' that no vessels would come to British Columbia 'merely for the purpose of getting a load of grain.'"[120] In late 1914, Mr. W. B. Lanigan, the Assistant Freight Traffic Manager of the C.P.R., before delegates of the Grain Committee of the Vancouver Board of Trade, "had deprecated the idea of ever sending grain Westward at the present rates of water carriage." By this time, ocean rates had been inflated by the prevalence of war conditions. Nevertheless, the Grain Committee must have been impressed with the contrast between Lanigan's cautious stance and the posture of the Canadian Northern, about which it was informed at the same meeting:

> A letter [was read] from Mr. G. H. Shaw, General Traffic Manager, Canadian Northern Railway, stating that this Company hoped to do business in the wheat trade in the Westward route through the Panama Canal.[121]

The C.P.R.'s caution must have been widely perceived. Two weeks after this meeting, and in the wake of his superior's circumspection, the Divisional Freight Agent of the C.P.R. felt it necessary to conciliate the Board of Trade:

> Mr. Larmour pointed out to the Committee that he wished to remove the impression that seemed to have gained hold of the public of Vancouver, that the Canadian Pacific Railway Company was opposed to the movement of grain Westward. On the other hand the Officials of that Company would be pleased to see grain moving Westward through Vancouver, if an economic arrangement of cars and traffic could thereby be obtained.[122]

The inference must be that even in December 1914 the C.P.R. was not convinced that the westbound grain trade would enable "an economic arrangement of cars and traffic." The Company's scepticism may have been due to its inability to obtain a rate which would compensate it for the cost of grain haulage over the mountains. This, however, is extremely unlikely. If the rate did not compensate the C.P.R., this was not because the statutory rates were in themselves non-compensatory: the MacPherson Commission on Transportation would years later be informed that grain traffic was remunerative until 1946.[123] Moreover, from 1903 until the end of the First World War, the C.P.R. rate on grain was actually ten per cent. below the Crow rate.[124] Rates on export grain westbound were between twenty and thirty-one per cent. higher than the corresponding rates eastbound,[125] and it had been during the period in which these rates were prevalent that the C.P.R. had initiated the development of its markets for westbound grain.[126] It is unlikely that, in circumstances of regulatory freedom, the C.P.R. would have continued to carry the traffic and to expand its volume of the business in the absence of a compensatory rate. It is unlikely, too, that in circumstances of competitive pressure, the traffic would not have been remunerative when the C.P.R. was continuing to lift empty cars over the east slope of the Selkirks in order that lumber traffic could be raised over the more severe gradients on the west slopes of both the Selkirks and the Rockies.

The promise of the westbound grain trade would not be fulfilled until the mid-1920's. MacGibbon, in The Canadian Grain Trade, has offered several factors in explanation for the delay: the historic orientation of the grain trade eastwards, the high level of ocean rates during and after the First World War, and the doubt that Canadian grain could survive transit through the tropics.[127] The argument that the railway companies derived more revenue from the longer transit eastwards, and were therefore reluctant to divert shipments westwards because "grain shipped westward would entail a certain sacrifice in revenue,"[128] was as applicable to the Canadian Northern and the Grand Trunk Pacific as to the C.P.R. It does not appear that the route of the latter's main line through Rogers Pass formed a significant barrier in itself, either physically or economically, to the westbound movement of grain.

This analysis of competitive pressures indicates that the C.P.R. did perceive, in the imminent completion of the Canadian Northern and the Grand Trunk Pacific, a commercial threat to its freedom to recoup the higher costs of its mountain operations through higher rates. The investments in gradient improvements between Calgary and the West Coast which the C.P.R. undertook prior to the outbreak of the First World War, including the investment in the Connaught Tunnel beneath Rogers Pass, were certainly motivated, at least in part, by perception of the need to respond to the threat of competition. The threat may have been perceived to be more acute in the westbound direction, for it was in this direction that the C.P.R. sought gradients which were competitive with those of the Grand Trunk Pacific and the Canadian Northern. However, it does not appear that the investments in gradient reduction which the C.P.R. proposed could have been justified by the potential increase in westward grain shipments alone. Grain was merely one component of a total traffic mix which was already increasing dramatically in volume. The C.P.R.'s forecast of the magnitude of the increase in westbound grain shipments was not in itself sufficient to warrant an investment response, and neither would the increase in westbound grain which was forecast create an imbalance between eastbound and westbound flows that would require investment in restructuring the gradient system through the B.C. mountains. Competitive pressure, therefore, while certainly one factor in motivating improvements to the C.P.R. main line across the mountains, offers only a partial explanation of the decision taken in 1913 to abandon the alignment through Rogers Pass.

6.4 "System" Improvements To The C.P.R.

This section will analyse certain important investments which the C.P.R. undertook throughout its system prior to construction of the Connaught Tunnel, and will set the construction of the tunnel into a context of investments intended to improve main-line operations system wide. The analysis will first consider certain large-scale investments which were undertaken by the Company beyond the Selkirk

Mountains. It will then examine smaller-scale improvements undertaken within the Selkirk Mountains, and appraise the extent to which the possibilities for such smaller-scale improvements had been exhausted by 1913.

a) Large-Scale Improvements Beyond The Selkirks

The trade-off policy which the C.P.R. had pursued in the Selkirks at construction time had also been applied elsewhere in the B.C. mountains: time and capital requirements had been minimised, and the level of subsequent variable costs was high. As revenues were generated, investments were undertaken in order to reduce this level of variable costs. During the first decade of the 20th Century, a series of such investments was undertaken in the Rocky Mountains.

(i) The Ottertail Diversion

The first such investment was undertaken in 1902 at Ottertail, where the original line had for several miles climbed out of the Kicking Horse valley west of Field.[129] Pusher locomotives were based at Field in order to assist eastbound trains up the 4.4% "Big Hill" to Hector. However, these pushers were often compelled to run light as far west as Golden in order to assist trains over the Ottertail gradient, which was much shorter and lighter than the Big Hill.[130] The Ottertail gradient was thus expensive to operate, and the earliest increases in eastbound lumber shipments may have sufficed to trigger investment in improvement. In 1902, the main line was diverted into the Kicking Horse valley for seven miles between Field and

Ottertail, eliminating the pusher gradient between these stations at a cost of $82,278.[131]

(ii) The Palliser Tunnel

A second major investment in the Rockies was that which was undertaken near Palliser, some fourteen miles west of Ottertail. Here, the Kicking Horse River curved in a horseshoe-shape around a south-facing clay bluff. The original line had pierced this bluff through a five-hundred-foot tunnel. The tunnel was unstable, and although lined throughout with timber,[132] it collapsed in 1887.[133] The main line was then diverted around the bluff on the south bank of the river. The alignment curved through 331 degrees in less than a mile,[134] with gradients against eastbound traffic of 0.65% for 925 feet, one per cent. for 850 feet and 1.3% for 250 feet.[135] There were three ten-degree curves,[136] and the central angle of the horseshoe was over twenty-two degrees.[137] Originally, all cars had had to be uncoupled and then chained together in order to prevent derailment, and although the necessity for this was quickly remedied,[138] passenger cars had still to be clamped together in order to prevent uncoupling on the curve.[139] Originally, too, the outer rail had been superelevated by six or seven inches, but by 1895 the superelevation had had to be removed because of excessive grinding,[140] and instead, the gauge was spread to 4' 10" around the horseshoe.[141] This alignment was intended to be merely temporary, but, perhaps as a result of these remedial measures, it was deemed satisfactory for C.P.R. requirements until the early 20th Century.

The decision to replace the horseshoe with a new tunnel was not taken until the autumn of 1905,[142] and although the new alignment did not open until September 1906,[143] plans for the realignment had been prepared as early as November 1903.[144] This timing suggests that, as with the Ottertail diversion, the impetus for improvement may have been the increase in traffic flows, both of loaded and of empty cars, which accompanied the development of lumber shipments eastbound from B.C. after 1900. Moreover, the realignment eased the gradient against eastbound traffic, replacing the original gradients with 1,100 feet at 0.7% and the remainder at less than 0.95%.[145] The new main line pierced the clay bluff through a 694-feet tunnel, which was concrete-lined throughout. The relocation reduced the length of the main line from 2,880 feet to 1,687.8 feet,[146] eliminated two of the ten-degree curves and eased the third to eight degrees, the maximum for the realignment.[147] However, the C.P.R. may have seriously underestimated both the nature and the cost of the project. It appears that, as originally conceived, the new tunnel would have been only 310 feet long, less than half the length of the tunnel which was actually built.[148] Moreover, the cost of the project, including the longer tunnel, was estimated in February 1906, before construction began, at $100,000.[149] On completion, the cost was estimated at $150,000.[150]

(iii) <u>The Spiral Tunnels</u>

A third major investment in the Rockies, and perhaps one of the most famous which was ever undertaken by the C.P.R., was that in the Spiral Tunnels between Field and Hector on the west slope. Here, at construction time, in order to avoid the capital cost and one-year delay that would have been entailed in driving a 1,400-feet hard-rock tunnel, the C.P.R. had obtained permission to build a "temporary line."[151] This temporary line, the "Big Hill," was nine miles long, with an average gradient against eastbound traffic varying from 3.5% to 4% compensated, and a maximum gradient of 4.5% compensated for some three miles.[152] Three safety switches were provided in order to prevent runaway incidents. Maximum curvature on the line was 11 1/2 degrees.[153] The steep gradients, and the operating procedures devised to ensure safe working over them, together imposed a severe restriction on main-line capacity. In 1895, the load-limit for a descending freight train was twelve cars,[154] and by 1902, the limit was fifteen cars in daylight hours and ten cars at nights.[155] By 1904, engines were prohibited from operating snowploughs down the gradient with more than five cars attached,[156] a regulation which must have severely curtailed westbound capacity during the winter months. By 1908, four of the largest locomotives on the C.P.R. were required in order to haul 710 tons eastbound up the ascent.[157] At that time, while the route through Rogers Pass was averaging less than ten trains per day, the single line over the Big Hill, because of the necessity for cutting trains to the 710-ton limit, was averaging a daily total of twenty.[158]

The C.P.R. had obtained permission to construct the alignment over the Big Hill on the explicit understanding that the line would be "temporary." The C.P.R.'s Chief Engineer had assured the federal government that, "The temporary line will be replaced by a permanent line, upon which the maximum gradient will be 116 feet to the mile,"[159] the same as in the Selkirks. However, he gave no indication of the proposed timing of the replacement decision, and in fact, operations would be conducted over the "temporary line" for the next twenty-five years. This was partly because the line itself had been thoroughly built:

> ...as some years might be necessary to determine the disputed questions regarding the permanent line, it was decided to make the temporary line available for operation for as long a time as might be necessary, making the gradients uniform, the curvature as light as practicable, and constructing the line substantially.[160]

It was also because the benefits to be derived from replacement were not expected to offset the high costs of constructing a permanent line. Reed, having inspected the temporary line in 1884, had concluded that it would be "unwise to expend any money on the intended permanent line, until the traffic really demands it,"[161] while the C.P.R. estimated that the cost of driving the tunnel for the permanent line would be between $800,000 and $1,000,000. In the House of Commons, C.P.R. opponent Edward Blake, having asked whether or not the Company had any plans for completing the temporary line, was informed that, "the engines they have working upon the grade now are doing very well, and they may not for some little time make the tunnel as proposed."[162] Until 1895, the C.P.R. faithfully recorded its heaviest gradient, 237' 6" per mile, as "temporary" in its annual reports to the Minister of Railways and Canals. After 1895, however, the designation "temporary" was dropped. It appears that external pressure upon the Company to replace the "temporary" location with a permanent, less severely graded line had ceased. Moreover, since the C.P.R. made no attempt in practice to eliminate the gradient, it is reasonable to assume that, at least until the end of the 19th Century, the Company regarded the temporary line, however expensive and dangerous it may have been to operate, as appropriate for its requirements.

There was no renewal of external pressure upon the C.P.R. prior to the elimination of the Big Hill in 1908. It is doubtful, therefore, that it was belated acknowledgement of its outstanding contractual obligations which prompted the C.P.R. to drive the Spiral Tunnels. A more pressing motive for the investment may have been concern for passenger safety. Although Shaughnessy had considered surveying a completely new main line through the Kootenays in 1906, his Vice-President of Western Lines was particularly anxious that the Big Hill be eliminated first:

> ...I do not consider that we should allow this [Kootenay] line to interfere with the grade reduction on the Hill, as it should be gone on with on account of the risk to passenger traffic in any case.[163]

The consulting engineer, Bogue, and the C.P.R.'s own engineers in Winnipeg may have shared this view. However, a C.P.R. officer in Vancouver, unfortunately anonymous, dissented:

> I cannot agree that the element of safety is the only one that enters into the consideration of the revision of the grade. We have operated the hill for years and with improved safety switches and the installation of safety devices now in operation and the proposed staff system I think the hill can be operated without accident.[164]

For this officer, the crucial factor in motivating investment in gradient improvement was the variable cost of moving traffic over the existing alignment:

> The question of getting traffic and increasing traffic over the hill is the main question and getting it over at the lowest cost the especial one.[165]

Reassessment of the trade-off between construction costs and operating costs on the Big Hill was dictated not only by the high initial level of variable costs incurred in the movement of traffic over 4.5% gradients, but by the fact that total variable costs were increasing as more traffic travelled over the facility. The C.P.R. had a very clear notion of congestion costs, and as congestion costs accounted for at least some of the increase in variable costs, it may be concluded that there was _de facto_ congestion on the existing facility. As the C.P.R. officer in Vancouver observed in 1907, "On the present grade every train that is put on increases the percentage of operation, because of the time taken and delays caused."[166]

One of the factors which contributed to the increase in the level of variable costs was the volume of passenger traffic. This volume increased in 1907 with the inauguration of the thrice-daily transcontinental service on three days per week, but it also reduced the availability of paths for freight trains, and deprived the latter of motive power:

> At the very least we are going to lose six hours per day on account of the passenger trains put on this season and with power short we cannot handle the traffic quickly or economically.[167]

The decisive factor in influencing the abandonment of the "temporary line," however, may once again have been the increase in the eastbound lumber traffic, which, like other traffic, incurred the high cost of ascent of the Big Hill, but which also may have imposed congestion costs on that other traffic as the volume of lumber shipments increased. The increase in these lumber shipments began in 1900, and the first surveys for an alternative route to that over the Big Hill were undertaken in 1902.[168] Further surveys, undertaken in 1905, enabled the location of a twenty-mile loop with a gradient of only one per cent. against eastbound traffic,[169] but this alternative was not adopted. Only after more surveying in 1906 was the final location approved.

This location reduced the maximum gradient from 4.5% compensated to 2.2% compensated, the latter gradient extending for 12.7 miles against eastbound traffic in the Rockies.[170] The gradient reduction was achieved by development of the main line, the length of which was increased from 4.1 miles to 8.2 miles by location through two spiral tunnels, 3,200 feet and 2,890 feet long. Curvature within the two tunnels was ten degrees, the maximum for the new alignment, and the gradient within the tunnels was compensated accordingly by 0.06% per degree to 1.6%.[171] The project also entailed the driving of a straight tunnel 170 feet long, and construction of four short bridges over the Kicking Horse River.[172]

The C.P.R. underestimated by one-third the length of time required for the completion of the project. The contract was let in August 1907,[173] and work commenced in September.[174] The project was scheduled for completion fourteen months later, in November 1908.[175] However, due to problems with water, bad ground and frost, the tunnelling was not completed until seven months after this deadline, in June 1909.[176] The recession in traffic through the mountains, which had set in after 1906, may have mitigated the effects of this delay in completion upon the incidence of congestion over the Big Hill. Moreover, it does not appear that the delay seriously affected the actual cost of the project, which, at $1,121,660.94,[177] was in fact 12% below the cost forecast by the C.P.R. in January 1908, of $1,270,000.[178]

The chief benefit which was derived from the project was the increase in payload made possible by the gradient reduction. In comparison with the four locomotives which had previously been required to haul 710 tons over the Big Hill, two similar locomotives would henceforth be able to haul 980 tons.[179] This represented an increase in the haulage capacity of each locomotive of 176%, and an increase in the ratio of motive power to payload from 1 : 1.15 to 1 : 3.18.

The project was adopted in the recession year of 1907. It was perhaps because of this recession that, at the time when the project was adopted, the anticipated savings in operating costs were not alone sufficient to justify the investment in the Spiral Tunnels. It appears that the balance was tipped in favour of adoption by non-quantifiable benefits, one of which was passenger safety:

> The amount saved on account of reducing this grade at the time the estimate was prepared was not in itself sufficient to warrant the expenditure; but taking into account the question of handling passenger traffic so much more safely, as well as allowing longer trains to be operated, besides doing away with the terminal at Laggan, the terminal of the Western division being moved to Field, it was decided to go on with the work.[180]

The severe gradients of the Big Hill, like the avalanches of Rogers Pass, were always a potential threat to passenger safety. In neither location was the potential ever realised in practice. Supersession of the respective alignments by improved locations would of course eliminate the threat to passenger safety in each instance, and improved passenger safety was, therefore, highly visible as a benefit of the respective realignment projects. However, in the abandonment of the Big Hill, at least, it was explicitly recognised that removal of the threat to passengers was merely one of several benefits appertaining to the operating methods by which traffic would be conducted over the C.P.R. main line.

(iv) C.P.R. Investment Strategy In The Rockies

This analysis has appraised three investment projects undertaken by the C.P.R. in the Rockies during the first decade of the 20th Century. Quantitative data concerning operating costs over the original and improved lines are not available. Therefore, it is not possible to estimate rates of return-on-investment for the three projects, and in turn, it is not possible to establish whether or not the investments were undertaken according to rate-of-return criteria. Nevertheless, analysis of the three projects is instructive for an understanding of the investment in the Connaught Tunnel, which followed early in the next decade.

The timing of the projects is consistent with the lifting of capital-budgeting constraints. Table 18 records total C.P.R. investment in "Additions and Improvements" to its system during the years 1901-13, and shows the proportions of that total investment which were channelled into the prairies and the mountains. From the table, it can be seen that the amount of capital which was available for investment in the mountains increased throughout the period, and that the amount of capital which was invested in improvements through the mountains also increased, although it remained far below the amount which was invested annually in the prairies.

TABLE 18

THE ALLOCATION OF INFRASTRUCTURE INVESTMENT ON THE C.P.R., 1901-1913

Year	Main-Line Investments ($)				Non Main-Line Investments ($)		Total Investment ($)
	Port Arthur to Laggan	% of Total	Laggan to Pacific Coast	% of Total		% of Total	
1901-02	560,665	29	495,680	26	556,378	29	1,917,274
1902-03	1,669,612	46	459,264	15	840,431	21	3,637,649
1903-04	4,114,444	65	627,864	10	697,564	11	6,343,536
1904-05	5,490,362	70	661,739	8	1,153,928	15	7,898,205
1905-06	4,341,923	56	842,271	11	2,120,550	24	7,783,031
1906-07	5,547,306	58	548,688	7	2,978,497	30	9,518,980
1907-08	7,827,932	55	1,477,841	11	3,310,346	22	14,130,303
1908-09	3,532,464	39	1,160,524	13	3,562,380	38	9,178,764
1909-10	2,348,572	34	1,260,516	18	2,328,942	35	6,856,308
1910-11**	3,582,476	30	2,242,712	19	4,881,762	40	12,103,471
1911-12	5,175,667	35	2,419,087	16	6,212,740	41	14,967,264
1912-13	11,639,246	40	4,002,118	14	9,686,848	35	28,740,987

*This category includes investments in branch lines and acquired railways, telegraph extensions, and hotels. It does NOT include investments upon the main line between Quebec and Port Arthur, which have been omitted from this table.

**After 1910, the divisional point was moved from Laggan to Field.

Source: C.P.R. Co., Annual Reports, "Details of Expenditure on Additions and Improvements".

Throughout the first decade of the 20th Century, then, the C.P.R. demonstrated its preparedness to invest in the mountains in order to improve operating conditions which were the legacy of the trade-off policy pursued by the Company at construction time. The timing of the investments was consistent with a "bottleneck" criterion of project evaluation: the Company undertook investment only after, and in reaction to, perception of a "bottleneck" in its system. Increases in traffic, which commenced with the turn of the century, may have highlighted and aggravated potential bottlenecks.

Nevertheless, the severity of any particular bottleneck was not in itself sufficient motivation for investment in its removal. The timing of the projects suggests that the C.P.R. removed the cheapest and simplest bottlenecks first, and postponed larger-scale investments for as long as possible. Thus, as successive improvements were made, the cost of obtaining further improvements became increasingly high. That is, the investments became more and more "lumpy," and the level of savings which had to be derived from the improvements had to be accordingly greater in order to justify the initial investment. The capital costs of the three projects discussed in this section were each higher than those of their predecessors, and the improvements which the projects effected were each more far-reaching in scope.

As traffic increased, and as capital became available for investment in improving operating conditions, the C.P.R. systematically removed bottlenecks along its main line through the mountains. Once the bottleneck on the Big Hill had been alleviated, the next most obvious bottleneck in the mountains was the alignment through Rogers Pass. This was explicitly recognised by contemporaries when construction of the Connaught Tunnel commenced. The Railway Age Gazette reported that:

> Following the completion of the work between Field and Hector, the portion of the line at Rogers Pass has presented the greatest difficulties in the operation of...trains.[181]

The Vancouver Province set the investment in the Spiral Tunnels in a context of main-line improvements throughout the mountains:

> For many years the railway company has been gradually effecting a reduction of its gradients and improving its main line generally in preparation for a big expansion of business and the development of the grain traffic westward from the prairies. In connection with this progressive policy, the C.P.R....bored two spiral tunnels...in the Rocky Mountain range, eliminating...the "Big Hill" between Field and Hector.[182]

After the opening of the Spiral Tunnels, the maximum gradient on the main line through the Rockies was 2.2% compensated for 12.7 miles against eastbound traffic and for 5.1 miles against westbound traffic.[183] By comparison, the maximum gradient in the Selkirks was 2.2% compensated for 25 miles against eastbound traffic and for 21 miles against westbound traffic.[184] Investment in the Spiral Tunnels may have been intended primarily to expedite lumber shipments eastwards. However, there is no doubt that the elimination of the Big Hill rendered the gradient system through the Rockies far superior to that through the Selkirks, not only for the movement of eastbound lumber, but also for the conduct of the prospective grain business westbound.

After 1909, then, the alignment through Rogers Pass was the next most obvious target for investment in the mountains. The nature of the terrain and the operating conditions at the summit of the Selkirks would ensure that this investment would be even more costly than preceding investments in the mountains, and that its consequences would be even more far-reaching.

b) Smaller-scale Improvements Within The Selkirks

These smaller-scale improvements may be divided into improvements to rolling stock and improvements to infrastructure. Analysis of the former will address motive power and car capacity. Analysis of the latter will include consideration of improvements to permanent way, bridges, signalling, maintenance facilities and sidings.

(i) Improvements To Rolling Stock

The locomotives deployed in the Selkirks had always been amongst the most powerful on the entire C.P.R. system.[185] Due to this requirement for particularly powerful locomotives, and due to the fact that pushers were required for routine traffic movement, a separate locomotive fleet was maintained exclusively for mountain duty. Those units which operated through the Selkirks were based at Rogers Pass and Revelstoke. The numerical strength of the fleet had to be increased as traffic levels rose. In the summer of 1898, the fleet detailed to the Selkirk section comprised twelve locomotives, of which two were allocated to passenger, four to freight, four to pushing duties and two to work-trains.[186] By July 1908, the Rogers Pass fleet had been increased to eighteen locomotives, of which five were allocated to passenger, eight to freight and five to pushing duties.[187] When construction of the Connaught Tunnel commenced, the average number of pusher locomotives alone which were based at Rogers Pass had increased to eleven.[188]

The early years of the 20th Century were ones of prodigious expansion in the entire C.P.R. locomotive fleet. Between 1902 and 1908, the fleet had averaged an increase of one locomotive every three days,[189] and Gibbon has calculated that the Company added 952 locomotives between 1907 and 1914.[190] It cannot be inferred, therefore, that the need to supply locomotives to the mountain fleet necessarily strained the resources of the C.P.R., although it is certain that in the peak of 1912, the fleet was barely adequate to handle the traffic available.[191]

It was not the quantity of motive power demanded in the Selkirks which posed problems to the C.P.R., but the quality. Specifically, powerful locomotives were required which could haul the increasing volumes of traffic quickly, economically and safely over the single line through the mountains, with its severe gradients, sharp curvature, heavy snowfall and greasy rails. In 1898, the rated capacity of the passenger locomotives in the Selkirks had been 280 tons, and that of the freight locomotives 315 tons. The pusher fleet comprised two of each type. The total tonnage rating of the Selkirk fleet was then 3,010 tons, excluding the locomotives detailed to work-trains.[192] By 1908, most freight and pushing duties were performed by "Consolidation" locomotives, each with a rating of 490 tons. The total tonnage rating of the Selkirk fleet may then have been 7,945 tons,[193] representing an increase in haulage capacity of 164% over the previous decade. In 1909, the C.P.R. designed a locomotive specifically for pusher duties in the B.C. mountains. This was the Mallet compound, an articulated steam locomotive, the largest hitherto introduced on the B.C. division. It was tested over the Selkirks in May and June 1910, when it stalled in attempting to haul 663 tons westbound and 724 tons eastbound over Rogers Pass.[194] Although the Mallets promised an increase in haulage capacity of some 30% over the "Consolidations," they were expensive to maintain, and Lamb, at least, believes that they did not provide a satisfactory solution to operating problems in the mountains.[195] By 1912, the haulage capacity of the largest locomotives in regular freight and pusher service over the mountains, the N-3's, was 508 tons, a rating which extensive dynamometer tests in 1913 failed to improve.[196] It appeared that, pending the introduction of a new breed of motive power, the limits of haulage capacity for a single locomotive over the Selkirks had been reached by 1913.

Improvement in the ratings was made possible only by the conversion of the energy source of the mountain locomotive fleet, from coal to oil. The earliest locomotives through the mountains had burned wood, but this had proved to be an unsatisfactory fuel because of the propensity of woodburning locomotives to emit sparks when struggling at the mountain gradients. These sparks ignited fires in snowsheds, on the trestle bridges and throughout the adjacent forests which proved expensive to contain. Conversion to coal therefore came early in the mountains,[197] and coalburning continued until 1912. The C.P.R. considered converting to oil between Revelstoke and Field at least as early as 1910. At that time, however, the additional cost of using oil instead of coal, even when calculated according to two different oil-price scenarios, of 80c. and 90c. per barrel, militated against conversion.[198] The decision to convert the mountain locomotive fleet to oil, which was taken less than two years later, was motivated primarily by the desire of the C.P.R. to reduce manpower costs. However, the decision was also prompted by the difficulty of finding firemen capable of feeding coal to the increasingly heavy locomotives with sufficient rapidity to avert stalling on the 2.2% gradients.[199] Conversion was announced in June 1911,[200] oil storage tanks were built at seven locations on the Mountain and Shuswap Divisions, including Rogers Pass and Revelstoke,[201] and during 1912, at least seventy-six locomotives, including all of the Mallet compounds and forty-one N-3's, were experimentally converted to oil.[202] The experiment proved successful, and in December 1913, the entire B.C. Division from Vancouver to Field was converted to oil.[203]

By this time, the cost of oil had risen to $1 per barrel, 10c. above the "most-expensive" scenario envisaged in 1910. Nevertheless, the C.P.R. calculated that, even with a coal price as low as $3 per ton (the Company had assumed a price of $4.60 per ton in evaluating the Connaught Tunnel the previous year[204]) conversion to oil was justified because it "removes the necessity for maintaining a fire patrol along the railway, which is required of coal burning roads by provincial statute."[205] A further benefit of consuming oil as the principal energy source was the fact that oil injection permitted a constant steam pressure to be maintained in the locomotive cylinders, and this in turn enabled an increase in the tonnage ratings of the converted locomotives. This was not regarded as the key benefit of conversion, however, and it appears not to have been even perceived by the Assistant General Superintendent in Vancouver until over two years later.[206] It was not until April 1915, and only after more extensive dynamometer tests, that the tonnage rating over the Selkirks was successfully raised, and this by only seventeen tons per locomotive, or one car for each assisted train, and in the eastbound direction only.[207] By this time, construction of the Connaught Tunnel was already two years advanced, and complete abandonment of the surface alignment was scarcely eighteen months away.

Whilst the haulage capacity of the available motive power was slowly expanded, an increasingly severe weight penalty was incurred. In 1897, the weight of the "SR" and "SE" classes of locomotives in the mountains was less than 60 tons.[208] The "Consolidations" deployed by 1908 weighed 154 tons,[209] the N-3's in service by 1913 weighed 181 tons,[210] and the Mallets weighed 195.5 tons.[211] More serious, because of its ramifications for rail wear, was the concomitant increase in locomotive axle-weights. The maximum weight on the driving wheels of the "SR" and "SE" classes was slightly over 14 tons.[212] On the Mallets, it was 21.8 tons.[213] Moreover, the ratio between the weight of motive power per train and the weight of payload was declining in the later years of surface operation through Rogers Pass. A single Consolidation was able to haul 490 tons over the 2.2% gradients, yielding a ratio of 1 : 3.18. The weight of an N-3 was 17.5% more, yet it yielded an increase in payload of only 3.7%, to 508 tons, yielding a ratio of 1 : 2.81. Even after conversion to oil, which enabled a further 3.3% increase in payload at no penalty in locomotive weight, the ratio was only 1 : 2.9. Had the Mallets been able regularly to haul 622 tons over the Selkirks, the ratio between weight of motive power and weight of payload would still have been no higher than it had been for the Consolidations. In addition to increasing fuel consumption and maintenance, there may have been a further cost attached to the deployment of larger locomotives: in December 1914, the Brotherhood of Locomotive Firemen and Enginemen were agitating for the tying of traincrew wage-rates to the weight on the driving wheels of the locomotives which they manned.[214]

Increases in car capacity paralleled those in haulage capacity. Gibbon has calculated that the Company added 1,304 passenger cars and 47,685 freight cars to its fleet between 1907 and 1914,[215] and in 1912 alone, the Company placed orders for 12,500 freight cars, at a cost of $14 million.[216] The crucial increase, however, was not in numerical strength, but in the carrying capacity of the individual cars. System-wide, Lamb has estimated that the total carrying capacity of C.P.R. freight cars increased tenfold between 1901 and 1914.[217] By far the greatest part of this increase was achieved after 1911, the year in which the Company commenced massive escalation of its 80,000-lb. boxcar fleet. In June of that year, the fleet boasted 5,915 80,000-lb. boxcars, compared with 24,655 60,000-lb. boxcars. The next year, the number of 80,000-lb. boxcars more than doubled, to 12,385, and the following year it doubled again, outstripping the number of 60,000-lb. boxcars in the fleet. By June 1914, the fleet boasted 38,956 80,000-lb. boxcars, compared with 25,517 60,000-lb. boxcars.[218]

Specific information concerning increases in car-carrying capacity within the Selkirks is sparse. However, it is certain that a considerable economy of scale was achieved in the eastbound shipment of lumber, the principal freight flow through Rogers Pass. In 1904, the C.P.R. had estimated that only 15,000 lbs. of lumber could be shipped per car.[219] By 1909, the average weight of lumber shipped per car was 39,879 lbs., an increase in per-car loading of 166% in five years.[220]

Nevertheless, increases in car capacity are otiose unless motive power is available in order to haul the heavier cars. In the Selkirks, where the number of main-line train movements was already restricted by the limitation on train paths, it appeared that by 1912 the haulage capacity of the existing motive power had been reached. Changes in fuel source and the introduction of the unconventional Mallet locomotives failed to increase this capacity significantly. Indeed, the next major increment in haulage capacity would not be achieved until 1929, with the introduction of the oil-fired 2-10-4 "Selkirk" locomotives. Not until the advent of diesel-electric traction in the 1950's could a substantial increase in haulage capacity be effected economically, by means of fully co-ordinated multiple-heading without the concomitant multiple-crewing.

(ii) Improvements To Infrastructure

Consistent with the C.P.R.'s trade-off policy at construction time, the main line through the Selkirks had been provided with minimal infrastructure. The need for subsequent investment in improvements was thus recognised from the beginning. The only exception to this minimisation of initial infrastructure costs was the provision at the outset of 70-lbs.-per-foot iron rail on the main line through the Selkirks.[221] This was heavier than the 56-lb. iron laid across the prairies,[222] presumably in anticipation of the heavy weight and peculiar pounding of locomotives over the 2.2% gradients. In June 1890, more heavy rail had been installed "between Beaver and the Summit,"[223] but after this, it appears that the Selkirk main line ceased to receive priority for the allocation of heavy rails.

Lamb asserts that by 1897, the standard renewal on C.P.R. main lines was 80-lb. steel.[224] However, in 1898, the entire main line from Albert Canyon to Beavermouth was still laid with 70-lb. iron, and the main-line renewals which were undertaken in the Selkirks during that year -- thirteen miles, all west of Albert Canyon -- consisted entirely of 73-lb. steel.[225] It was not until 1901 that 80-lb. steel was shipped into the Selkirks.[226] By December 1903, out of almost 106 miles of track in the Mountain Section, only 60 miles were laid with 80-lb. steel, including the sixteen-mile stretch from Albert Canyon to Ross Peak on the west slope, and the fifteen-mile stretch from Beavermouth to Bear Creek on the east slope. For thirteen miles of 2.2% gradient over the summit of Rogers

Pass, the main line was still cast in 70-lb. iron.[227] The 80-lb. replacement programme was still proceeding apace on the Mountain Section in 1906,[228] and it was not until April of the following year, during the 1906-08 traffic recession, that the entire main line from Laggan to Vancouver was completely relaid.[229] The next year, 1908, 85-lb. steel became the standard renewal,[230] but again, it was not until 1912 that the heavier rails were allocated to the Pacific Division,[231] by which time almost one thousand miles of the new rail had been laid elsewhere on the C.P.R. system.[232]

The main line between Donald and Revelstoke had not been ballasted until three years after the track had first been laid,[233] and even then, the following year, "It took to about the middle of June to get the slime out of the track."[234] As part of the general upgrading programme of 1912 in the B.C. mountains, however, rock-crushing plants were constructed at Chase, Donald and Craigellachie,[235] and by the following year, "the rock ballasting through that section [was] one of the most permanent in track building that has ever been accomplished."[236]

In construction across the entire C.P.R. system, time and capital had been spared in bridging by the erection of timber trestles, which had an expected life-span of seven or eight years.[237] Replacement with masonry and steel structures began in earnest in 1890,[238] but as in the rail-renewal programmes, the route over the Selkirks was accorded low priority. In 1891, C.P.R. shareholders were informed that, "At the present rate of progress...practically all of the timber structures in the

Company's principal lines will be permanently replaced within two or three years."[239] In 1895, the Company duly reported that "by far the greater part of the original bridge structures have been replaced with permanent works," and stated that its objective was to dispose of the remainder, "including a few of an expensive character," within four years.[240]

It is certainly true that in 1894, the 286-feet tall structure at Stoney Creek was replaced with a steel arch, at a cost of $96,000.[241] It is also true that between 1897 and 1902, the 1,086-feet long crossing at Mountain Creek was partially filled and replaced with masonry and steel spans aggregating 585 feet in length,[242] the steel erected in the first year alone costing nearly $22,000. Nevertheless, it appears from table 19, which provides a chronology of bridge improvements on the original main line across the Selkirks, that many of the investments in bridge replacement were postponed until after the turn of the century. Moreover, it appears that the bridge replacement programme, like the rail replacement programme, was still proceeding apace in 1906, for in that year, 110 bridges on the Pacific Division were rebuilt, compared with 36 on the Western Division and 28 on the Central Division.[243] One of the last bridge improvement projects was that of the Loops, implemented just prior to the commencement of the 1906-08 recession. Italian masons were hired to replace the trestle at the first crossing of Five-Mile Creek with three stone pillars, and the trestle at the second crossing with five pillars.[244] The total cost was nearly $110,000.

TABLE 19

BRIDGE IMPROVEMENTS IN THE SELKIRK MOUNTAINS, 1893-1909.

Date	Name Of Bridge	Improvement	Cost $
1893	Stoney Creek	Steel/masonry	**96,000
1896	5th Xing, Illecillewaet	"	
"	6th " "	Renewed	
1897	Surprise Creek	Steel/masonry	
"	Cedar Creek	"	
1898	Cascade Creek	Built over slide path	
"	2nd Xing, Illecillewaet*	Steel/masonry	***1,815
"	5th " "	Steel	***2,634
"	7th " "	"	
"	11th " "	"	***2,620
1898-1904	8th "	Steel/masonry	***2,554
1898-1902	Mountain Creek	Steel/masonry/ filling	***21,784
1900	4th Xing, Illecillewaet	Steel/masonry	
"	Cut Bank	Filled	
"	Williamson's Creek	"	1,243
"	Mud Chute	Masonry	4,791
"	Bryant's Creek	"	6,752
1901-05	2nd Xing, Five-Mile Creek*	Steel/masonry	
1902	Cougar Creek	Rebuilt	
1904	Snowbank Creek	Filled	
1904-06	2nd Xing, Five-Mile Creek*	Steel	76,763
1906	1st Xing, Illecillewaet*	"	45,093
"	2nd " " *	"	17,769
"	5th " "	Steel/masonry	6,756
"	1st Xing, Five-Mile Creek*	"	32,843
"	No. 437A (not named)	Replaced by culvert	2,627
"	" 437B "	Masonry	5,271
1906-07	Glacier Creek*	Steel/masonry	13,198
c. 1906	No. 411B (not named)	Steel/culvert	4,480
"	" 414B "	Steel	4,504
"	3rd Xing, Five-Mile Creek*	Culvert	9,881
"	Cascade Creek	Masonry	15,597
"	Raspberry Creek	"	
1907	Cariboo Creek	Steel	3,852
"	No. 410B (not Named)	Replaced by culvert	1,644
1909	Cache Creek	Replaced	

* Denoted in "Record" as "Retired by 1916 diversion."
** Engineering News, November 28,1895, p. 355.
*** "Diaries," 1900, 1901 and 1905, Kilpatrick MSS, Vancouver. (Mountain Creek cost is for 1898 only.)

Source:- C.P.R. Co., "Old Bridge Record and Section Maps, Mountain Subdivision," Mount Revelstoke and Glacier National Parks, File no. 1758.

Until at least the turn of the century, all trains were dispatched over the Selkirk summit by telegraph. In January 1902, main-line telegraphers were located at Beavermouth, Rogers Pass, Glacier, Illecillewaet and Albert Canyon.[245] From this assignment of staff, it may be surmised that the pusher gradient on the east slope of the Selkirks was operated as a single section, telegraphers at Beavermouth and Rogers Pass controlling access to the only two sidings in the section, short passing sidings at Six-Mile Creek and Bear Creek. Responsibility for the pusher gradient on the west slope was divided. The Glacier telegrapher may have been responsible for the 9,500 feet of summer track and 2,500 feet of sidings at that location, and the Illecillewaet telegrapher may have controlled access to the 2,800-feet side track between Glacier and Albert Canyon.[246]

The relationship between this signalling system and the capacity of the main line is not easily determined. It is possible that control of the eastbound pusher gradient was shared because the number of revenue-earning trains requiring regulation was greater eastbound than westbound. Again, control may have been shared because the configuration of the main line permitted greater scope for regulating operations on the west slope than on the east. If greater operating flexibility did prevail on the west slope, this may imply that the alignment through the Selkirks could more easily absorb an increase in eastbound traffic than in westbound traffic. However, no quantitative data concerning the relationship between signalling and capacity are available.

On October 26, 1911, train dispatching by telephone was inaugurated between Field and Revelstoke, and the functions of eight telegraph dispatchers were henceforth performed by a single dispatcher based at Revelstoke. The quantitative impact of this investment upon the safety, cost and capacity of main-line operations through the mountains is not known, but it may be assumed to have been positive in each aspect. More certain, however, is the fact that the Mountain Section was one of the last stretches of the C.P.R. main line to be equipped with telephone dispatching. The line between Newport and Montreal had been thus equipped in 1908, and the routes between White River and Fort William, Winnipeg and Brandon, and Swift Current and Medecine Hat were all equipped in 1909. It was not until October 1, 1911 that the system was extended from Medecine Hat to Calgary and thence to Field, and after the telephone circuits through the Selkirk Mountains had been installed, only that section of the main line between Kamloops and Vancouver remained to be integrated into the national network during 1912.[247]

Expansion of the maintenance facilities and sidings in the Selkirks was most rapid after the lifting of the 1906-08 recession. In 1909, the C.P.R. built a new locomotive shop at Revelstoke.[248] The following year, a new locomotive shop was built at Kamloops,[249] and the engine houses at Field and Rogers Pass were extended,[250] the capacity of the latter increasing from four to six locomotives.[251]

The first major extension of siding capacity in the Selkirks appears to have been undertaken in 1898, when $1,550 were appropriated for the addition of 1,200 feet between Donald and Beaver.[252] Each of these sidings would have been able to store over thirty standard freight cars. The next major investment in siding extension was undertaken at Rogers Pass itself in 1908. Some $69,600 were appropriated in January of that year for diversion of the main line some 100 feet to the east.[253] The investment may have had multiple objectives. It effected a considerable gradient reduction. The length of gradient in excess of 1.6% on the approaches to the summit was reduced by 3,700 feet, and at the summit, the length of gradient below 1% was extended from 2,500 feet to 5,800 feet. Moreover, the investment permitted a saving in snowshedding of some 2,224 feet over the 4,000 feet which had protected the original line.[254] However, the primary objective of this diversion was "that more yardage accommodation may be secured there."[255] The diversion enabled the length of sidings to be increased from 3,850 feet to approximately 13,200 feet, even excluding 1,500 feet of the former main line which remained linked with the new system.[256] Storage capacity may thus have quadrupled from 106 to over 400 standard freight cars. The 1910 avalanche disaster attenuated the benefits of snowshed reduction, but the overall advantages of the relocation endured. Before 1912, the C.P.R. had invested in a further 1,200 feet of yardage at the Pass, increasing total siding accommodation, including that offered by the former main line, to 15,900 feet, storage capacity for some 450 cars.[257]

(iii) C.P.R. Investment Strategy In The Selkirks

It is possible to discern two distinct waves of infrastructure investment in the Selkirks between construction of the original facility and the decision to abandon the surface alignment through Rogers Pass. The first wave commenced at the turn of the century, and terminated around 1906. The second wave commenced about 1909, and terminated around 1912 with the decision to double-track the main line from Calgary to the West Coast. The two waves were separated by the recession of 1906-08. Both these waves may be interpreted simply as responses to a secular increase in traffic through the mountains. According to this interpretation, the 1906-08 recession, which offered a respite in the traffic increase, may have tempered the urgency of the need for improvements to the infrastructure, and may therefore have caused a postponement of infrastructure investments, including that in the Connaught Tunnel, for at least two years.

Traffic did increase through the mountains, particularly after 1900. Whilst the investments which were undertaken after 1908 were explicitly motivated by the increase in traffic through the Selkirks, there is less explicit evidence that the infrastructure improvements which were effected prior to 1906 were prompted by an increase in traffic. An alternative explanation for the two waves of investment may therefore be appropriate.

The C.P.R. had undertaken system-wide programmes of rail renewal, bridge replacement and telephone dispatching. In each case, the route through the Selkirks had been one of the last sections of the main line to benefit from the improvements. The timing of these investments may therefore be interpreted simply as a consequence of the geographical unfolding of a nationwide modernisation programme from eastern to western Canada. According to this interpretation, the extension of the improvements into the Selkirks was merely a quest for "symmetry," that is, the pursuit of a uniformly modernised rail system. However, only the investment in telephone dispatching, which occurred in the second wave of improvements, may be convincingly explained in this way. This investment, although made within the Selkirks, assisted in the completion of a uniform communications mode throughout the system, with the concomitant benefit system-wide of improved safety.

The investments in rail renewal and bridge replacement afforded benefits which were much more regional in character. Since it was the gradients which determined the weight of trains through the Selkirks, and not the strength of the rail or the strength of the bridges, the benefits which could be derived system-wide from increasing rail weights and improving bridges within the Selkirks were few. Therefore, before investments in rail renewal and bridge replacement could be justified at all, each of these investments would have had to have afforded a return which satisfied a required rate. The timing of the bridge replacements and the first wave of rail renewal may therefore be interpreted as an indication that these investments did begin to meet the required rate between the turn of the century and 1906.

This interpretation is consistent with both traffic developments and investment patterns in the Selkirks during the period. The absolute volume of traffic through the mountains continued to be far less than that on the prairies. From table 18, it can be seen that the absolute level of investment in the mountains was accordingly much lower than that on the prairies, where a major double-tracking programme was undertaken between 1904 and 1908. However, total traffic volume through the mountains did increase during the period from 1900 to 1906, as described in section (6.2) above, and it can be seen from table 18 that the absolute level of investment in the mountains also increased fairly steadily between 1901 and 1906.

Moreover, in the latter years of this period, at least, the proportion of total C.P.R. system-wide business which was conducted through the mountains increased quite markedly. From table 20, it may be seen that, in the two years after 1904, the proportion of the C.P.R.'s total business which crossed the Selkirks increased from 10.6% to 16.7%. Whilst an increase of comparable magnitude -- from 10.3% to 16.1% -- would occur after the 1906-08 recession, culminating in the decision to drive the Connaught Tunnel, this latter increase would be spread over not two but five years, from 1908 to 1913. In table 21, it is confirmed that between 1904 and 1906, the rate of increase in business was more rapid in the Selkirks than elsewhere on the C.P.R. system. Tonnage through the mountains increased four times faster than total system tonnage, and almost twice as fast as total grain tonnage.

TABLE 20

PROPORTION OF TOTAL C.P.R. FREIGHT TRAFFIC HANDLED OVER SELKIRK MOUNTAINS, 1904-1913.

Year	Tonnage Over Selkirks As % Of Total C.P.R. Freight Tonnage
1904	10.6
1905	12.8
1906	16.7
1907	11.1
1908	10.3
1909	12.5
1910	11.8
1911	12.4
1912	15.3
1912-13*	16.1

* Average of 1912 and 1913.

Source:- Table 11 and C.P.R. Co., Annual Reports.

TABLE 21

ANNUAL RATES OF CHANGE IN REGIONAL DISTRIBUTION OF FREIGHT TRAFFIC, 1904-1913.

Period	% Change In Total C.P.R. Freight Tonnage	% Change In Total C.P.R. Grain Tonnage	% Change In Freight Tonnage Over Selkirks
1904-06	+25	+55	+98
1906-08	+8	+7	-33
1908-13*	+84	+83	+188
1904-13*	+149	+205	+281

* Average of 1912 and 1913.

Source:- Table 11 and C.P.R. Co., Annual Reports.

It seems likely that these increases in both absolute and relative levels of traffic through the mountains prompted the increase in investment in the Selkirks which formed the first wave of infrastructure improvements. The C.P.R., having operated on the "decreasing-cost" slope of the variable-cost curve since the transcontinental line opened, may have begun to experience increasing variable costs in the Selkirks as traffic increased after the turn of the century. As the level of variable costs increased, any investment intended to reduce the level of variable costs would accordingly offer a higher rate-of-return than previously. The potential return on investment in the Selkirks may therefore have risen to meet the rate required by the C.P.R. on investments system-wide, and this increase in the rate-of-return may in turn have called forth increased investment in the Selkirks between 1901 and 1906.

There was a lull in investment in the Selkirks between 1906 and 1908. The increase in the level of variable costs may have been checked, either because the first wave of infrastructure investments was successful in reducing variable costs, or because the economic recession of 1906-08 reduced traffic volume through the Selkirks, and thus held down the level of variable costs. The effect upon investment strategy of the reduction in variable costs was identical in either case: it diminished the expected rate-of-return on further investment, and thus discouraged capital expenditures. From table 20, it can be seen that, during the years 1906-08, the proportion of total system business which was conducted through the Selkirks declined to pre-1904 levels. Moreover, the decline in total business was much more rapid in the Selkirks than elsewhere. Total system traffic and grain traffic continued to increase in 1907, and fell back only slightly in 1908. Both volumes therefore recorded a net increase for the period 1906-08, as demonstrated in table 21. Through the Selkirks, however, business declined markedly in both years. Thus, the recession of 1906-08, which hit most sharply in the mountains, acted most sharply in the mountains as a brake on investment.

After 1908, a second wave of investment began in the Selkirks. This wave witnessed the fruition of further modernisation programmes: ballasting, the installation of 85-lb. steel, and the extension of telephone dispatching. It also witnessed investment in projects specific to the Selkirks: the extension of maintenance facilities and yardage, and, in rolling stock, experimentation with the articulated pusher locomotive. This second wave of investment is much more explicitly related to increases in traffic. The _Daily Colonist,_ for example, reported of the yardage expansion in the mountains during 1910, that,

> The large increase in traffic on the main line necessitates a very large expenditure for sidings and spurs. Extensions will be made to all yards not extended in recent years.[258]

As in the years 1900-06, the increases in traffic were both absolute and relative between 1908 and 1913. The magnitude of the absolute increase is shown in table 11, where it can be seen that traffic tripled in the five years before the decision to abandon Rogers Pass. The magnitude of the relative increase is shown in tables 20 and 21. From table 20, it can be seen that between the years 1908 and 1913, the proportion of total system business which was conveyed through the Selkirks began to return to the levels which had prevailed in the last years of the first wave of infrastructure investment. Moreover, table 21 indicates that, while the rates of increase in each of the categories of freight business were high, the rate of increase in grain traffic was now no greater than the rate of increase in total system business. The rate of increase in freight traffic through the Selkirks, however, was over twice as great as the rates elsewhere on the system.

These increases in absolute and relative levels of traffic precipitated a second wave of infrastructure investment in the Selkirks. From table 18, it may be seen that after 1908, the absolute level of the C.P.R.'s investment in B.C., and the proportion of total expenditures on "Additions and Improvements" which was diverted into B.C., both increased. Moreover, the proportion of total expenditures which was diverted into B.C. did not decrease but rather increased during the years of increased capital rationing between 1908 and 1910. This channelling of rationed capital into the mountains suggests that an increasing number of projects in the mountains was expected to yield the rate of return which the C.P.R. required on its investments.

This rate of return would be realised chiefly from savings in the variable cost of traffic movement through the Selkirks. It appears that the decrease in variable costs which set in after 1906 was short-lived. After 1908, the increases in traffic implied an increase in the level of variable costs, much as the increases which had occurred between the turn of the century and

1906 had done. The C.P.R. responded with a second wave of infrastructure investment, intended to reduce this level. However, during the second wave of infrastructure investment, the increases in traffic volume through the Selkirks were far greater than they had been during the first wave. It is likely, therefore, that the increase in the level of variable costs was also greater during the second wave than during the first. Moreover, it appears that the scope for further small-scale improvements to the C.P.R. system through the Selkirks was almost exhausted by 1912. The main line in the mountains compared with that elsewhere on the system in the quality of its rails, its bridges and its dispatching organisation, and the limits of conventional motive power had been reached. Yet there was no evidence in 1912 that the increase in traffic volumes would abate -- rather the reverse, as is explained in section (6.6). There was therefore no prospect of a reduction in the level of variable costs. Indeed, as congestion costs were incurred, the level of variable costs might rise more rapidly than the volume of traffic. Thus, although the C.P.R. had responded to increases in traffic with increases in infrastructure investment, the investments had not been sufficient by 1912 to effect a long-term solution to the problem of the escalating level of variable costs. Further investment, and a more drastic solution, appeared to be imperative. Its timing would be influenced by the availability of funds.

6.5 The Financial Resources Of The C.P.R.

In almost every parameter, C.P.R. performance improved steadily after 1896, and, except for a temporary reversal between 1906 and 1908, the improvement continued until 1913, gathering momentum furiously after 1909. The tonnage of freight carried by the C.P.R. increased by 312% between 1901 and 1913, from 7,155,813 tons to 29,471,814 tons.[259] Over the same period, freight earnings increased by 372%, from $18,983,186 to $89,655,223;[260] passenger earnings increased by 340%, from $8,083,370 to $35,545,062; and gross earnings per mile increased by 201%. The increases between 1909 and 1913, expressed as percentages, were 78% in freight tonnage, 86% in freight earnings, 76% in passenger earnings and 59% in gross earnings per mile. Reflecting the C.P.R.'s prosperity, its average stock price increased from 102 in 1901 to 178 in 1906, and from 160 in 1908 to 254.5 in 1912. The dividend on common stock increased from 5% in 1902 to 6% in 1904, 7% in 1909 and 10% in 1911.[261]

McDougall has described these years as ones of "almost overwhelming prosperity...with earnings rising, seemingly without limit."[262] In presenting the annual report for the operating year 1911-12, Shaughnessy described that year as "the most prosperous year in the history of the Company."[263] Gross earnings for the year were $123 million, and net profits almost $34 million.[264] Yet even this performance was outstripped in the following year, when gross earnings exceeded $139 million, and the net surplus was $36.6 million.[265] The C.P.R. exploited this strength in order to attract a further influx of capital, issuing new ordinary stock with a par value of $18 million in

January 1912,[266] and realising a further $20 million from preference and debenture issues.[267]

The financial resources of the C.P.R. thus increased dramatically after 1908, and by 1912 there was no indication that this increase would abate. Clearly, the Company did command sufficient resources to undertake major improvement projects, entailing increasing "lumpiness" of investment, in the years immediately before the First World War. Nevertheless, mere possession of these resources did not necessarily imply their investment in the Selkirks, even though this section was by 1912 the most steeply graded portion of the system, and one of the last portions of main line to be operated over single track. Only if the C.P.R. was satisfied that the investment did offer an acceptable rate of return would any part of these resources be channelled into improvement projects in the Selkirks.

6.6 Traffic Forecasts And Their Implications

Absolute volumes of traffic and rates of increase in the flows through the Selkirks between 1904 and 1913 are presented in tables 11 and 12. These data formed the base from which the C.P.R. generated estimates of future demand for the rail facility through the mountains. In October 1912, the forecast generated by the C.P.R.'s Chief Engineer was thus:

> Now assuming that in a few years the wheat traffic west will increase sufficiently to make eastbound and westbound traffic balance, and with these rates of increase, it would take less than four years for the traffic to double. It would seem therefore, as it will take three or four years to build this [tunnel-] line, that it would be a conservative discounting of the future to assume that the east and westbound traffic will be equal and double what the eastbound traffic has been the past year...[268]

Two features of this forecast should be noted. First, the forecast was essentially short-term in character. That is, it envisaged only the eventuality that traffic would double. Doubling was expected to occur within four years, but there is no forecast of the traffic volumes which the C.P.R. expected to handle beyond that horizon. The absence of longer-term forecasts is a severe handicap in the evaluation of a project with an extended payback period, such as investment in a railway tunnel, where benefits will be realised long after the period spanned by a four-year traffic forecast. Moreover, the absence of longer-term forecasts is also a severe handicap in the evaluation of a project where a large proportion of the benefits comprises savings in variable costs due to improved alignment, rather than the savings in fixed costs. The savings in both variable costs and fixed costs in such a project may be long-term in character. However, the savings in variable costs will fluctuate considerably with traffic volume, while savings in certain relatively fixed costs, such as snowshed maintenance and shed- and bridge-patrols, which are invariant to traffic volume, may be comparatively regular and predictable long into the future.

The second feature of the forecast to note is that it was generated by the technique of simple, or linear, extrapolation, based upon the traffic volumes and rates of increase during the years August 1910-11 and August 1911-12. The only provision for deviation from this uniform rate of growth was in the forecast for westbound grain, the single commodity flow for which a specific forecast has survived. In order for the total volume of traffic to have doubled within four years, a rate of increase of approximately 20%, compounded annually, would have been required. As table 12 reveals, this rate was actually slightly less than the rates of increase between 1911 and 1913. Moreover, as table 16 indicates, the actual rate of increase in westbound grain shipments during 1911-12 was 58%. Yet the C.P.R., in projecting an increase in grain traffic of 480,000 tons over four years,[269] from a 1912 base of 145,000 tons of grain, and assuming a minimum of 110,000 tons of rolling stock,[270] must have been anticipating a rate of increase of barely 15%.

It appears, therefore, that the forecast was conservative when set against the actual rates of increase prior to commencement of the tunnel, and was even conservative in comparison with the rates of increase in several years since 1904. In the contemporaneous economic circumstances of Canada, the optimism of the forecast is perhaps understandable. As the President of the Vancouver Board of Trade reported in early 1913,

> It is gratifying...to be able to say that the Dominion of Canada has but recently closed the most prosperous year in its history, the records of the year 1912 exceeding in almost every respect those of any previous year in all that concerns the financial and commercial progress of our country.
>
> There is, too, no special cause for apprehension that this remarkable era of progress is about to receive any great setback...[271]

In fact, however, 1913 began "quietly" in Vancouver and Calgary, and by July 1913 in Vancouver, "It [was] realized by all classes of the community that the outlook for the coming winter [was] graver than for many years."[272] Nevertheless, it seems that the C.P.R. believed the downturn would be shortlived, for despite these adverse economic signals, the Company's forecasts continued to be optimistic. In April 1913, the Vice-President, Sir George Bury, himself applying the extrapolation technique to a data base spanning ten years of traffic flows on the Mountain and Shuswap Sections, forecast a continued increase in traffic through the mountains, and declared his conviction that any setback to growth in the West was "most unlikely, or if it should happen, it could be only of a temporary character..."[273]

The volume of traffic through the mountains had doubled between 1908 and 1912.[274] Based on simple extrapolation from historic growth rates, the forecast for the mountains in 1912 was that volume would double again within another four years. Forecasted expansion of this magnitude and rapidity had grave implications for the adequacy of the C.P.R.'s single-track main line throughout the whole of B.C.

As early as 1911, Bury had dispatched the Chief Engineer to "make a study" of double-tracking the entire C.P.R. main line through the mountains to the West Coast. This study appears to have been motivated by competitive considerations: the desire to secure "the best transcontinental line" in comparison with those of the Canadian Northern and the Grand Trunk Pacific.[275] During 1912, however, the need to increase capacity throughout B.C. became a more compelling motivation for the examination of double-tracking needs. In March 1912, Shaughnessy launched an initiative intended to secure "additional track facilities between Calgary and the Coast," appointing F. F. Busteed "Engineer in charge of grade revision and double tracking, Calgary west," and dispatching five engineering parties into the field.[276] Shaughnessy envisaged that,

> It is probable that for a considerable portion of the distance we shall find it most desirable to double track the present line, but no doubt there are many points where more advantageous grades can be secured by a diversion of the second track.[277]

In July 1912, Shaughnessy apparently conceded that "double tracking the line from Calgary to Vancouver is absolutely necessary in the very near future."[278] Detailed cost estimates prepared in December 1912 projected total outlay of $50,085,993.34 for the entire venture between the Laggan Subdivision and the Coast.[279]

Forecasted traffic expansion, therefore, based on historic trends, stimulated a policy decision in 1912 to double track the entire C.P.R. main line from Calgary to the Coast. The problems posed by double-tracking through the mountains were particularly complex, and were threefold in character. First, the demand for double-tracking was most urgent in the mountains, because the capacity problem was most imminent there. Second, although the demand was most urgent, the gestation period for the provision of double track would be longer there than elsewhere, because of the nature of construction work in the mountains. Third, the provision of a second track would involve greater expense in the mountains than elsewhere. The double-tracking of the existing alignment might involve less capital outlay than construction of an entirely new route, but it would also increase the number of tracks on gradients over which pusher service was required. With a double track, and double the volume of traffic, the Company would be committed to incurring the additional operating expense of the pusher gradients even more irreversibly than it had been when the original single track was laid through the mountains thirty years before. Alternatively, location of an entirely new route, and construction of an entirely new double track, would require an even longer gestation period, during which congestion costs and the opportunity costs of foregone traffic could be expected to escalate rapidly. It would also involve an even more "lumpy" investment of capital, with the concomitantly greater risk that the payback period would be prolonged.

That these problems were simply not as acute elsewhere in the West is well demonstrated by the ordering of the double-tracking work between Calgary and the Coast, and the criteria for that ordering. Surveys for alternative mountain routes had begun in 1911,[280] and even when an alternative route in the Selkirks was selected, it was expected to take "three or four years to build [the] line."[281] In contrast, double-tracking for 24 miles east of Vancouver had been completed by the spring of 1912,[282] and the decision to double track for a further 57 miles east, taken in July 1912, had been carried out by June 1913.[283]

The criteria for undertaking the latter section early in the double-tracking programme were thus:

> There is no Engineering question to be decided...The gradients and alignments are good..., but regardless of how well managed our construction work on the whole line will be, there is bound to be delay and therefore if we can have pieces completed on which we can make up time with our passenger and fast freight trains and our business generally, the Company's reputation would be enhanced and its interests doubly served.[284]

The initial investment was $1,914,264.63, averaging $33,584 per mile, and while the return anticipated in "enhanced reputation" was not quantified, Bury clearly believed that it justified the provision of surplus capacity east of Vancouver:

> Having in view...the advantages that we would gain in this section when the other sections are under construction, I believe that the Company will get better returns from this investment than from any other investment they can make between Calgary and the Coast.[285]

Similarly, the initial criterion for the next sections of double track, from Revelstoke to Taft, from Kamloops east to Pritchard and west to Tranquille, and at the Notch Hill and Walhachin diversions, was that there be "no possibility of causing disturbances that would interfere with traffic while under construction."[286]

Only the first three of these projects were in fact accepted. There is no evidence that any analysis was undertaken in order to determine whether or not these sections should have been double-tracked at all. Available analyses begin with the assumption that double-tracking was necessary in each case, and merely contrast the costs and benefits of incorporating improvements into the double-tracking. Between Revelstoke and Taft, the existing main line was to be doubled, at a cost of $1,450,000 for the 24 miles, or an average of $60,417 per mile. The cost of incorporating improvements between Pritchard and Kamloops was estimated at $126,912, and the benefits of the improvements, $14,000 per annum for perpetuity, were capitalised at 5% to yield a total of $280,000, implying a positive net present value of $153,088. Between Kamloops and Tranquille, the cost of improvements was $65,747, and the benefits $7,000 per annum for perpetuity, or $140,000 at a discount rate of 5%, implying a positive net present value of $74,253. Interestingly, the improvements at Notch Hill and Walhachin, which Shaughnessy rejected, would have yielded positive net present values of

$293,414 and $1,172,130 respectively. However, the respective costs of these double-tracking projects, incorporating improvements, were $2,325,000, or $86,111 per mile for 27 miles, and $1,202,529, or $100,211 per mile for 12 miles.[287] It appears to have been the magnitude of these capital costs, and the associated risk of obtaining positive returns from the outlays, which deterred Shaughnessy.

Even within the mountains, the problems of double-tracking were not as acute in the Rockies as in the Selkirks. Certainly, prolonged gestation and high total cost would ensue regardless of the manner in which the capital cost of double-tracking were to be traded off against subsequent operating costs in the Rockies. It had been only three years since the single-track Spiral Tunnels had opened. There were rumours that the C.P.R. proposed to drive duplicate Spirals,[288] and even to supersede the Spirals with a 16-mile tunnel between Alberta and B.C., which would require seven years for completion and cost $14 million.[289] However, the capacity problem in the Rockies may not have been as severe as in the Selkirks, for the 2.2% gradients through the former extended for only 17.8 miles, compared with 46.1 miles of 2.2% gradient through the Selkirks.[290] Moreover, construction of the Kootenay Central, which had been proceeding since 1910, may have been expected to further mitigate any main-line capacity problems in the Rockies. Although originally intended to serve settlers in the Columbia and Kootenay river valleys,[291] and not intended as an alternative through route, it would, when opened in 1914, link the existing main line at Golden with the Crow's Nest line at

Elko. In practice, therefore, it did complete an alternative route through the Rockies, and may have been perceived by the C.P.R. as a means of delaying the double-tracking of the existing main line.

It was on the main line west of Golden, therefore, that the capacity problem was most acute, and where double-tracking priorities were most urgent.[292] By January 1913, Bury reported that between Golden and Ruby Creek, "we are almost up to the capacity of the present single track." The imminence of the capacity problem here led him "most strongly" to recommend "the immediate double tracking" of this section,[293] and in April, he warned again that it would be "impracticable" to handle traffic over the existing route, "unless it be doubletracked, and that just as fast as we are able to accomplish it."[294] It was in Rogers Pass that the capacity problem was expected to be most severe. Sullivan, having forecast that traffic through the Pass would double within four years, concluded summarily in retrospect that,

> ...the present single track line with double the present traffic would make the business too congested for economical single track operation. Therefore, it was apparent that it was time to study the question of double tracking the present line or seeking a new line for double track.[295]

In 1912, therefore, the traffic forecast for Rogers Pass was that volume would double within the next four years, and the implication of this forecast was that the main line through the Selkirks would have to be double tracked. It should be noted that the traffic growth which made doubling through Rogers Pass essential was expected to involve increased flows in both directions, and that capacity problems were not expected to be more acute in one direction than in the other. Moreover, the decision to double-track the main line through the Selkirks did not in itself imply construction of a tunnel beneath Rogers Pass. Investment in a tunnel would be justified only if the additional cost of providing the improved alignment were to be outweighed by the additional benefits which would accrue from the reduced cost of hauling existing traffic over the improved alignment, and from the reduced cost of hauling all the incremental traffic which would be attracted to the new route by the increase in main-line capacity. The C.P.R. had already undertaken investments elsewhere on its system which were intended to reduce the variable costs of hauling existing and incremental traffic. Only the generation and evaluation of alternative routes would reveal whether or not the C.P.R. would be able, in 1913, successfully to trade off capital costs against operating costs, as it had done recently elsewhere on the main line, and as it had done already at the summit of the Selkirks in 1885.

This chapter leads far away from the interpretation that the driving of the Connaught Tunnel was merely a response to the 1910 avalanche disaster. In the route taken by the original main line through Rogers Pass, capacity constraints were at least as latent as snowslides. These capacity constraints became ever more binding as the demand for main-line capacity increased, and ever more economically intolerable as competitive pressures accumulated. Even though investments were undertaken, both within and beyond the Selkirks, the latent capacity problem over Rogers Pass, rooted in the single-track configuration over severe gradients, remained unresolved. In 1913, the C.P.R. commanded the requisite resources to resolve it, and traffic forecasts provided the impetus for a solution to be sought. The process of demand estimation highlighted the imminence of a capacity problem, and only the generation and screening of alternatives would reveal the most appropriate solution.

FOOTNOTES

[1] These distances are taken from C.P.R. Co., British Columbia District, Timetable 31, taking effect at 24.01 o' clock Sunday, Oct. 29th, 1916, "Mountain Subdivision." This was the last working-timetable published by the C.P.R. prior to the opening of the Connaught Tunnel. The distances differ slightly from those given in Chapter 4 above. The difference is explained by the relocation of Rogers Pass station in 1899. Following its destruction by an avalanche, the station was rebuilt approximately one mile further south, in a slide-free area closer to the summit of the Pass. The change increased the distance between Beavermouth and Rogers Pass stations from 19.8 to 20.8 miles, and decreased the distance between Albert Canyon and Rogers Pass stations from 26.3 to 25.3 miles. Since the change did not affect the gradient system, however, it did not alter the actual distances up which trains had to be assisted on either slope of the Selkirks.

[2] The motive power which was most frequently deployed in service over Rogers Pass was 210% locomotives, numbered in the "3820" to "3870" series. "Dynamometer Car Tests," RCM 76.15.188-45693.6. For further discussion of motive power in the Selkirks, see below, pp. 235-240.

[3] This seems unlikely, because the C.P.R. did take steps to expand its pusher fleet as traffic increased throughout the years of surface operation. See below, pp. 235-6. Shortage of motive power would not alone have motivated investment in a realignment designed to reduce the requirement for pushers: it was far cheaper to build locomotives than to build tunnels.

[4] This is slightly more plausible, although contemporary photographs showing Royal Trains assisted over the Selkirks by up to seven locomotives indicate that drawbars capable of withstanding stress from up to four locomotives in multiple were in use on certain passenger stock.

[5] See note (193).

[6] F. J. Fisher to J. M. McKay, Superintendent, Revelstoke, May 25, 1913. RCM 76.15.188-45693.6.

[7] "Dynamometer Test Report," May 14 and 15, 1913. RCM 76.15.188-45693.6.

[8] Fisher to McKay, op. cit.

[9] "Dynamometer Test Report," May 8 and 9, 1913. RCM 76.15.188-45693.6.

[10] "The freight train winter tonnage rating is five per cent less than that of the summer rating." J. H. Shinnick, Inspector, Calgary, to G. A. Mountain, Chief Engineer, Railway Commission,

February 20, 1918, CTC, Ottawa, File 21029.7 ("Connaught Tunnel, Glacier, B.C."). This was after the opening of the Connaught Tunnel. It is not clear whether the rating was reduced specifically because of the deterioration in rail conditions within the tunnel during the winter months, or whether the reduction was operational prior to the abandonment of the surface alignment.

[11] For the 1906 data, the range of demand on the Mountain Section was 5.76, in comparison with 4.54 on the Shuswap Section. The respective standard deviations were 29.63 and 26.89.

[12] Cornell Civil Engineer, op. cit., p. 80. The Railway Age Gazette set the volume at "four to eight transcontinental passenger trains and an average of about twelve freight trains daily." Railway Age Gazette, Vol. 57, No. 24, December 11, 1914, P. 1082.

[13] In 1906, approximately 10.5% of the annual total traffic was moved in June, the peak month. No data for the monthly distribution of traffic flows is available for 1912. However, assuming that June was the peak month for 1912, and that 10.5% of the annual total of train movements occurred during this month, the average daily demand for train paths in both directions would have been 21.5. ([10.5% x 6,162]/30).

[14] Sullivan to Bury, October 22, 1912, PIC CPCA.

[15] Ibid.

[16] Cornell Civil Engineer, op. cit., p. 80.

[17] Ibid.

[18] See below, pp. 259-268.

[19] The proportions of the imbalance between the time required to pass eastbound and westbound trains are remarkably consistent throughout the years 1906-08, averaging 21.4%. During these years, train weights increased and train speeds decreased, while traffic volumes decreased, and the probability of congestion therefore decreased also. The average elapsed times for all trains eastbound and westbound respectively are:- 1906, 13 hours 41 mins. and 11 hours 17 mins.; 1907, 14 hours 9 mins. and 11 hours 38 mins.; 1908, 12 hours 55 mins. and 10 hours 39 mins. "Notebook: Comparative Freight Train Performance, 1906-08," Kilpatrick MSS, Vancouver.

[20] Bury to Shaughnessy, March 18, 1910, quoting a letter to Busteed of March 15, 1910. PIC CPCA.

[21] Bury to Shaughnessy, March 15, 1910, PIC CPCA.

[22] Province, July 31, 1912, p. 1; August 12, 1912, p. 17.

[23] Van Horne's Road, op. cit., notes to plates 431-2, p. 270.

[24] Province, April 21, 1902, p. 1.

[25] "Diary, 1909," entry for December 9, 1909. Kilpatrick MSS, Vancouver.

[26] "Conductor's Report," enclosed with, McKay to D'Arcy, February 7, 1914, RCM 76.15.100-014872.

[27] Cornell Civil Engineer, op. cit., p. 79.

[28] Ibid.

[29] C.P.R. Co., "Timetable No. 31," op. cit.

[30] Province, April 21, 1902, p. 1.

[31] Province, March 28, 1906, p. 1.

[32] Province, September 12, 1907, p. 1.

[33] Victoria Daily Times, August 30, 1907, p. 1.

[34] Province, February 16, 1909, p. 1.

[35] Province, October 19, 1909, p. 1.

[36] Province, December 27, 1909, p. 1.

[37] Province, October 10, 1912, p. 29.

[38] Province, May 16, 1913, p. 32.

[39] See note (19).

[40] Labour Gazette, Vol. 10, October, 1909, p. 450.

[41] Vancouver Board of Trade, Annual Report, 1897-98, p. 14.

[42] Vancouver Board of Trade, 1900-01, p. 16.

[43] Vancouver Board of Trade, 1902-03, p. 17; 1903-04, p. 15; 1905-06, p. 15; Victoria, B.C., Board of Trade, Annual Report, 1906-07, pp. 59-61.

[44] Canadian Transport Commission, Board of Railway Commissioners, Transcripts of Hearings, Case 103, (British Columbia Lumber And Shingle Manufacturers), RG 46, Box 4, Vol. 9, p. 4087. The estimate of the number of trainloads assumes that each loaded car weighed 40 tons, and that each trainload was 508 tons, as it was in 1913. See table 9. A further impression of the increase in the demand for lumber which occurred between the years 1900 and 1906 may be gathered from the forecast of one Member of Parliament that 425 million feet of lumber would be required on the prairies in 1904 alone. R. G.

MacPherson, HoC Debates, August 20, 1903, pp. 9224-5.

[45] Victoria, B.C., Board of Trade, 1907-08, p. 32.

[46] B.C.'s share of the prairie lumber market increased from 31% in 1905 to 51% in 1906. By 1911, it was 53%. Labour Gazette, Vol. 6, May 1906, p. 1184; Vol. 11, March 1911, p. 914; Victoria, B.C. Board of Trade, 1906-07, p. 61.

[47] Province, August 12, 1912, p. 17.

[48] "British Columbia Pacific Coast Cities v. Canadian Pacific Ry. Co." 7 Canadian Railway Cases (henceforth "CRC") 125 at 133.

[49] Board of Railway Commissioners, Transcripts of Hearings, Case 103, op. cit.; Case 104, (Pacific Coast Cities Case), RG 43, Box 11, Vol. 26, pp. 401-500, and Box 12, Vol. 27, pp. 501-718; Case 105, (Canadian Manufacturers' Association and Vancouver Board of Trade), RG 46, Box 4, Vol. 9, pp. 3815-3872.

[50] A. W. Currie, The Economics Of Canadian Transportation, Toronto: University of Toronto Press, 1954, p. 45.

[51] Vancouver Board of Trade, 1902-03, p. 14. In April 1903, the trade was "greatly retarded" by a strike of C.P.R. employees over recognition of the United Brotherhood of Railway Employees. Labour Gazette, Vol. 3, April 1903, p. 798.

[52] Rt. Hon. Sir W. Laurier, HoC Debates, Vol. LXI, July 30, 1903, col. 7686.

[53] Revelstoke Mail-Herald, April 30, 1910, p. 2.

[54] Vancouver Board of Trade, 1908-09, p. 32; 1909-10, p. 56; Vancouver World, April 29, 1912, p. 10.

[55] Vancouver Board of Trade, 1902-03, pp. 13. For a brief chronology of C.P.R. irrigation projects, see Lamb, op. cit., pp. 252-255.

[56] Quoted in, Report Of Royal Commission On Transportation, December 11, 1905, DSP XL, 1906, 19a, p. 37.

[57] Vancouver Board of Trade, 1902-03, p. 17.

[58] Vancouver Board of Trade, 1901-02, p. 21.

[59] Victoria, B.C., Board of Trade, 1904-05, pp. 48-50.

[60] Vancouver Board of Trade, 1906-07, p. 17.

[61] Report Of Royal Commission On Transportation, op. cit., p. 38.

[62] Report Of The Royal Commission On The Grain Trade Of Canada, October 11, 1907, DSP XLII, 1907-08, 59, p. 20.

[63] *Canada Year Book, 1920,* Ottawa, pp. 466-7.

[64] C. F. Wilson, *A Century Of Canadian Grain,* Saskatoon: Western Producer Prairie Books, 1978, p. 25.

[65] 6,282.1 tons at 30 tons per car would generate 209 cars.

[66] Victoria, B.C., Board of Trade, 1905-06, p. 21; 1906-07, p. 14; 1908-09, p. 23.

[67] Keefer, op. cit., p. 84.

[68] Vancouver Board of Trade, 1889, p. 12; Victoria, B.C., Board of Trade, 1894-95, p. 22.

[69] *Labour Gazette,* Vol. 3, November, 1902, p. 318.

[70] Vancouver Board of Trade, 1902-03, p. 18; 1905-06, p. 34.

[71] *Labour Gazette,* Vol. 9, July, 1908, p. 48.

[72] *Labour Gazette,* Vol. 9, January, 1909, p. 690.

[73] "British Columbia Sugar Refining Company vs. Canadian Pacific Railway Company," 14 CRC 354, at 357.

[74] R. G. MacPherson, *HoC Debates,* Vol. LXI, August 20, 1903, p. 9225. See also, Moberly MSS, pp. D968 and D1005-6.

[75] J. C. Bonar, "The Canadian Pacific Railway Company and Its Contributions Towards the Early Development and to the Continued Progress of Canada," Montreal, 1950, Vol. II, "Contributions of Ocean Steamship Services, etc.," P. 5.

[76] *Labour Gazette,* Vol. 3, April, 1903, p. 722.

[77] "Western Freight Rates Case," 17 CRC 123 at 157.

[78] "British Columbia Pacific Coast Cities Case," op. cit., at 131.

[79] "Dawson Board of Trade vs. White Pass & Yukon Ry. Co.," 11 CRC 402 at 418.

[80] "British Columbia Pacific Coast Cities Case," op. cit., at 138.

[81] Ibid., at 133.

[82] "Western Freight Rates Case," op. cit., at 227.

[83] Ibid., at 229.

[84] "British Columbia Pacific Coast Cities Case," op. cit., at 132-133.

[85] "Western Freight Rates Case," op. cit., at 167.

[86] Ibid., at 218. See also, Currie, op. cit., p. 44.

[87] "Western Freight Rates Case," op. cit., at 227.

[88] "British Columbia Pacific Coast Cities Case," op. cit., at 130.

[89] Victoria, B.C., Board of Trade, 1888-89, p. 34.

[90] HoC Debates, Vol. LXI, pp. 8477; 8678; 8872; and 9135. See also, "Annual Report of the Department of Agriculture of the North-west Territories for 1902," quoted in, Labour Gazette, Vol. 4, November 1903, p. 479.

[91] Vancouver Sun, March 7, 1912, p. 1.

[92] D. A. MacGibbon, The Canadian Grain Trade, Toronto: The Macmillan Company, 1932, p. 278.

[93] Engineering News, Vol. 59, No. 14, April 2, 1908, p. 377.

[94] J. G. Turiff, HoC Debates, Vol. XC, March 31, 1909, p. 3647.

[95] Engineering News, April 2, 1908, p. 377.

[96] The Grand Trunk Railway Company of Canada, Report Of The Directors And Statements Of Accounts, December, 1911, p. 10.

[97] Op. cit., December 1912, p. 10.

[98] Op. cit., December 1918, p. 8.

[99] Glazebrook, op. cit., pp. 331-5.

[100] The Canadian Northern Railway System, Annual Reports, 1916, p. 10.

[101] The Canadian Northern Railway Company, Annual Report, 1912, p. 7.

[102] "Report of the Department of Railways, 1911-1916," Sessional Papers of the Province of British Columbia, Session 1917, Vol. I, pp. D7-9.

[103] Engineering, Vol. XCI, June 9, 1911, p. 774.

[104] Canadian Northern Railway Company, Annual Report, 1912, p. 7.

[105] Province, January 25, 1913, p. 1.

[106] British Columbia Sessional Papers, op. cit., p. D13.

[107] "British Columbia Pacific Coast Cities Case," op. cit., at

129.

[108] Province, April 22, 1912, p. 1.

[109] P. E. Roy, "Railways, Politicians, and the Development of the City of Vancouver as a Metropolitan Centre, 1886-1929," M.A. thesis, Toronto, University of Toronto, 1963, p. 161; J. M. Gibbon, Steel of Empire: the romantic history of the Canadian Pacific, the Northwest passage of today, Toronto: McClelland & Stewart, 1935, p. 367.

[110] Bury to Shaughnessy, January 3, 1913, PIC CPCA.

[111] Ibid.

[112] Bury to Shaughnessy, June 17, 1913, PIC CPCA.

[113] Vancouver Board of Trade, 1908-09, pp. 27-34; 1910-11, pp. 23-24; 1912-13, pp. 45-49; Vancouver World, April 29, 1912, p. 10. The Province awaited, "that opening of future prosperity -- the year 1915." Province, November 14, 1913, p. 26.

[114] Victoria Daily Times, July 8, 1912, p. 1.

[115] "Before going on the ground I was in hopes that we could get a line that would give us grades, not to exceed 1% against westbound traffic..." Sullivan to Bury, op. cit.

[116] "Report of the Royal Commission on Transportation," op. cit., p. 38.

[117] Canada Year Book, 1912, p. 60.

[118] Vancouver Board of Trade, 1909-10, p. 21.

[119] Sullivan to Bury, op cit.

[120] Quoted in Lamb, op. cit., p. 305.

[121] Vancouver Board of Trade, "Special Committee Minutes," Vol. 143, April 23, 1914 to July 20, 1920. Minutes of the meeting of the Grain Committee, December 2, 1914, p. 163.

[122] Ibid., p. 165.

[123] E. P. Reid, "Statutory Grain Rates," in, "Royal Commission on Transportation," Vol. III, July 1962, p. 380.

[124] R. Chodos, The C.P.R.; a Century of Corporate Welfare, Toronto: J. Lewis & Samuel, 1973, P. 61.

[125] Vancouver Board of Trade, Annual Report, 1914-15, pp. 44-45.

[126] See above, section [6.2 (b) (iii)].

[127] MacGibbon, op. cit.,pp. 267-269.

[128] Ibid., p. 267.

[129] Van Horne's Road, p. 181.

[130] Whyte to Van Horne, July 13, 1888, PIC CPCA.

[131] C.P.R. Co., Annual Reports, 1901-02, p. 6; 1903, p. 19.

[132] Van Horne's Road, p. 181.

[133] Ibid., p. 187.

[134] C.P.R. Co., "C.P.R. Original Main Line, etc., June 21, 1905," CP Rail, Vancouver, Engineering Department Maps, No. 8498-2.

[135] C.P.R. Co., "C.P.R. Pacific Division, Change of Location of Main Line, etc., August 31, 1905," CP Rail, Vancouver, Engineering Department Maps, No. 8498-8.

[136] Map 8498-2.

[137] Van Horne's Road, p. 181.

[138] Vaux, op. cit., p. 72.

[139] T. H. Crump, "The Big Hill and the Mountain Section," October 21, 1940. Reproduced in Canadian Rail, No. 275, December 1974, p. 358.

[140] T. C. Clarke, "The Canadian Pacific Railway, as seen by an engineer," Engineering News, Vol. XXXIV, No. 22, November 28, 1895, p. 355.

[141] E. E. R. Tratman, Railway Track and Track work, New York: The Engineering News Publishing Co., 1909, p. 399.

[142] Railway And Marine World, New Series No. 99, May 1906, p. 264.

[143] Ibid., New Series No. 115, September 1907, p. 641.

[144] C.P.R. Co., "C.P.R. Pacific Division, proposed change of line, etc., November 30, 1903," CP Rail, Vancouver, Engineering Department Maps, No. 8498-4. A further sketch of the proposal was drawn up in June 1904. See "Map. Proposed Change of Line East of Palliser, June 20, 1904," ibid., No. 8498-5.

[145] Map 8498-8.

[146] Engineering News, Vol. 57, No. 16, April 18, 1907, p. 424.

[147] C.P.R. Co., "As Constructed, Canadian Pacific Railway, Pacific Division, Change of Location of Main Line, etc., August 31, 1905," CP Rail, Vancouver, Engineering Department Maps, No. 8498-1.

[148] See Maps 8498-1, 8498-4 and 8498-8.

[149] Province, February 3, 1906, p. 1.

[150] Province, October 8, 1906, p. 14.

[151] Van Horne to the Minister of Railways and Canals, May 19, 1884, DSP Vol. XVIII, 1885, 25a, pp. 10-11.

[152] Engineering News, Vol. 59, No. 12, March 19, 1908, p. 316.

[153] Engineering News, Vol. 59, No. 4, January 23, 1908, p. 87.

[154] Engineering News, November 28, 1895, p. 355.

[155] T. Kilpatrick, "Notebook," entry for October 7, 1902. Kilpatrick MSS, Vancouver.

[156] Ibid., entry for January 25, 1904.

[157] Engineering News, January 23, 1908, p. 87.

[158] T. Kilpatrick, "Notebook," entry for June 10, 1907. C.f. table 3, showing an average of 8.2 trains per day on the Mountain Section in June 1907, and an annual average of 6.76 trains per day.

[159] "Canadian Pacific Railway Return -- Subject No. 2 -- Reports on Progress," October 1, 1884, DSP Vol. XVIII, 1885, 25a, p. 36.

[160] Van Horne to the Minister of Railways and Canals, op. cit.

[161] Reed to Van Horne, September 9, 1884, DSP Vol. XVIII, 1885, 25n, p. 6.

[162] A. W. McLelan, HoC Debates, Vol. XXI, April 29, 1886, p. 941.

[163] Whyte to Shaughnessy, October 10, 1906, PIC CPCA.

[164] Personal letter, dated "Vancouver, May 10th, 1907," addressed to "My dear Schwitzer." The xerox copy of this letter, which is held in the reference library of the Mount Revelstoke and Glacier National Parks, is unfortunately incomplete. File No. 1916.

[165] Ibid.

[166] Ibid.

[167] Ibid.

[168] Engineering, Vol. LXXXVIII, September 24, 1909, p. 434.

[169] Province, December 4, 1905, p. 13.

[170] Engineering, September 24, 1909, p. 433.

[171] Engineering News, January 23, 1908, p. 87.

[172] Engineering News, Vol. 64, No. 19, November 10, 1910, p. 512.

[173] Province, August 30, 1907, p. 14.

[174] Province, September 28, 1907, p. 1.

[175] Engineering News, January 23, 1908, p. 87.

[176] Engineering News, November 10, 1910, p. 514.

[177] C.P.R. Co., Annual Reports, 1909, p. 21; 1910, p. 21; 1911, p. 19; 1912, p. 21.

[178] Engineering News, January 23, 1908, p. 87.

[179] Engineering News, March 19, 1908, p. 316.

[180] Engineering, September 24, 1909, p. 433.

[181] Railway Age Gazette, Vol. 57, No. 24, December 11, 1914, p. 1082.

[182] Province, February 14, 1914, p. 17.

[183] Engineering, September 24, 1909, p. 433.

[184] Railway Age Gazette, December 11, 1914, p. 1082.

[185] As early as January, 1889, Abbott had had to contend with "heavy engines in the Selkirks" spreading the gauge of the permanent way. Abbott to Van·Horne, January 5, 1889, PIC CPCA.

[186] Kilpatrick, "Appropriations, Year 1898," p. 55, "Engine Power, 1st August," Kilpatrick MSS, Vancouver.

[187] Kilpatrick, "Notebook," "Engines in Service -- Mountain Section -- District No. 1, July 31, 1908," Kilpatrick MSS, Vancouver.

[188] Railway Age Gazette, December 11, 1914, p. 1082.

[189] President's statement to annual meeting of C.P.R. shareholders, October 7, 1908, reported in Labour Gazette, Vol. 9, November 1908, p. 463.

[190] Gibbon, op. cit., p. 367.

[191] See above, p. 191.

[192] "Engine Power, 1st August," op. cit.

[193] Assuming that the former freight- and pusher-locomotives, each with a rating of 315 tons, were cascaded into passenger service by 1908. "Engines in Service, July 31, 1908," op. cit. The rating for a single Consolidation locomotive on a 2.2% compensated gradient is obtained from Engineering News, March 19, 1908, p. 316.

[194] Railway And Marine World, January 1912, p. 4.

[195] Lamb, op. cit., pp. 270-271.

[196] See above, pp. 177-182.

[197] Perhaps soon after 1887, when Abbott suggested "that coal should be used entirely in the Mountains during the dry season, as there is no doubt that the risks of fire being set by the engines is greater than on ordinary grades." Abbott to Van Horne, April 15, 1887, PIC CPCA. However, a veteran C.P.R. engineer asserts that the last woodburning locomotives in the mountains were withdrawn between 1905 and 1907. Frank W. Anderson, "Interviews on Railroading with W. Pavey and G. Williamson," Revelstoke, August 27, 1963. MSS, Glenbow Alberta Institute, p. 1.

[198] H. H. Vaughan, Memorandum to Shaughnessy, October 1, 1910, PIC CPCA.

[199] Railway And Marine World, June 1911, p. 509.

[200] Ibid.

[201] Railway And Marine World, December 1911, p. 1135.

[202] Railway And Marine World, January 1912, p. 19.

[203] Railway And Marine World, December 1913, p. 579.

[204] Cornell Civil Engineer, op. cit., p. 81.

[205] Railway And Marine World, December 1913, p. 579.

[206] J. M. Cameron, Assistant General Superintendent, B.C. Division, to J. M. McKay, Superintendent, Revelstoke, March 14, 1915. R.C.M., 76.15.188-48300.

[207] McKay to Cameron, April 6, 1915, ibid.

[208] Kilpatrick, "Notebook, 1897," Kilpatrick MSS, Vancouver.

[209] Engineering News, March 19, 1908, p. 316.

[210] Cornell Civil Engineer, op. cit., p. 80.

[211] Railway And Marine World, January, 1912, p. 4.

[212] Kilpatrick, "Notebook, 1897," op. cit.

[213] Railway And Marine World, January, 1912, p. 4.

[214] Railway Age Gazette, December 11, 1914, p. 1085.

[215] Gibbon, op. cit., p. 367.

[216] Province, June 12, 1912, p. 3.

[217] Lamb, op. cit., p. 267.

[218] C.P.R. Co., "Annual Reports to the Minister of Railways and Canals," 1910-14, "Description of Equipment," PAC, RG 46, Vol. 890.

[219] Board of Railway Commissioners, Transcripts of Hearings, Case 103, op. cit., p. 3791.

[220] "Canadian Lumbermen's Association vs. Grand Trunk, Canadian Pacific and Canadian Northern Ry. Cos.," 10 CRC, 306 at 311-312.

[221] Ross to Van Horne, August 14, 1885, PIC CPCA.

[222] Van Horne's Road, p. 100.

[223] Shaughnessy to Van Horne, June 4, 1890, PIC CPCA.

[224] Lamb, op. cit., p. 179.

[225] Kilpatrick, "Appropriations, Year 1898," op. cit., p. 39.

[226] Kilpatrick, "Appropriations, 1902-1903 (Field Book 360)," op. cit., p. 3.

[227] Ibid., p. 40.

[228] See, for example, Whyte to Shaughnessy, July 6, 1906, PIC CPCA.

[229] Railway And Marine World, April, 1907, p. 255.

[230] Lamb, op. cit., p. 308.

[231] Province, January 17, 1907, p. 7.

[232] C.P.R. Co., "Annual Reports to the Minister of Railways and Canals," 1907-1912, "Description of Equipment," op. cit., Vols. 889-890.

[233] Donald Truth, July 21, 1888, p. 8.

[234] Abbott to Van Horne, July 18, 1889, PIC CPCA.

[235] Vancouver Sun, May 30, 1912, p. 4.

[236] Canadian Railway And Marine World, February, 1913, p. 76.

[237] Van Horne to Schreiber, December 1, 1884, "Letterbooks," op. cit., Vol. 8, pp. 951-2.

[238] C.P.R. Co., _Annual Report,_ 1890, p. 10.

[239] C.P.R. Co., _Annual Report,_ 1891, p. 10.

[240] C.P.R. Co., _Annual Report,_ 1895, p. 10.

[241] _Engineering News,_ November 28, 1895, p. 355.

[242] Filling commenced in June, 1897. Vaux, op. cit., p. 84. The spans were completed in 1902. C.P.R. Co., "Old Bridge Record and Section Maps, Mountain Subdivision," pp. 19-1 to 19-9. Mount Revelstoke and Glacier National Parks, File No. 1758.

[243] F. F. Busteed, Assistant Chief Engineer, to Shaughnessy, "Annual Report for the Western Lines to June 30, 1906," PIC CPCA.

[244] M. Daem and E. E. Dickey, _A Short History of Rogers Pass and Glacier Park,_ Revelstoke, B. C., 1965, p. 31.

[245] _Labour Gazette,_ Vol. 2, January 1902, p. 397.

[246] See table 1.

[247] _Railway And Marine World,_ January 1912, p. 10.

[248] _Victoria Daily Times,_ September 20, 1909, p. 14.

[249] _Victoria Daily Times,_ June 25, 1910, p. 18.

[250] _Colonist,_ March 3, 1910, p. 10.

[251] C.P.R. Co., "C.P.R. Plan and Profile of Line Change as Constructed, etc., Montreal, October 19, 1908," PABC, Maps Division, R-R 1, #9054. C.f. C.P.R. Co., "C.P.R. Pacific Division, Rogers Pass, B.C.," Revelstoke, B.C., corrected to December 31, 1910. Mount Revelstoke and Glacier National Park, File no. 1620.

[252] Kilpatrick, "Appropriations, Year 1898," op. cit., p. 24.

[253] Kilpatrick, "Notebook," op. cit., "Appropriations January 1908."

[254] Map R-R 1, #9054.

[255] _Province,_ June 22, 1907, p. 1.

[256] Map, File no. 1620.

[257] C.P.R. Co., "C.P.R. B.C. Division, Rogers Pass," Revelstoke, B.C., December 2, 1912, Mount Revelstoke and Glacier National Park, File no. 1619.

[258] Colonist, March 3, 1910, p. 10. Note that this article was written two days before the avalanche disaster at Rogers Pass. Already, irrespective of snowslides, the C.P.R. was confronted by the problem of increasing operating costs, and was seeking investment solutions to that problem.

[259] C.P.R. Co., Annual Reports.

[260] Innis, op. cit., p. 211ff.

[261] Ibid., p. 284.

[262] McDougall, op. cit., p. 6.

[263] Labour Gazette, Vol. 13, November, 1912, p. 435.

[264] C.P.R. Co., Annual Report, 1912, p. 3.

[265] C.P.R. Co., Annual Report, 1913, p. 5.

[266] Labour Gazette, Vol. 12, January, 1912, p. 623.

[267] C.P.R. Co., Annual Report, 1912, p. 24.

[268] Sullivan to Bury, op. cit.

[269] See above, p. 259.

[270] Assuming that all grain moved in 80,000 lb. cars, each with a tare weight of 60,000 lbs. This estimate of the weight of rolling stock is conservative, because it entirely ignores the weight of the locomotives which would have been required to haul the traffic. The C.P.R. forecasts explicitly included the weight of locomotives in their estimates.

[271] Vancouver Board of Trade, 1912-13, p. 34. See also Glazebrook, op. cit., pp. 313-319.

[272] Labour Gazette, Vol. 14, July, 1913, p. 37. See also those "Local Correspondents' Reports" for Vancouver and Calgary which were submitted to the Labour Gazette monthly after January 1913.

[273] Bury to Shaughnessy, April 21, 1913, PIC CPCA.

[274] See table 13.

[275] Bury to Shaughnessy, January 3, 1913, PIC CPCA. See also above, section (6.3).

[276] Canadian Railway And Marine World, August 1912, p. 416.

[277] Shaughnessy to Bury, March 18, 1912, "Letterbooks."

[278] Bury to Shaughnessy, July 19, 1912, PIC CPCA.

[279] "C.P.R. Co., Requisitions for Appropriations, Kamloops,

December 27th, 1912." The complete list of requisitions for the double-tracking project is available in File RG 2, "Rogers Pass Tunnel," No. 97850, CPCA.

[280] Bury to Shaughnessy, January 3, 1913. PIC CPCA.

[281] Sullivan to Bury, op. cit.

[282] Province, July 31, 1912, p. 1.

[283] Province, May 29, 1913, p. 14.

[284] Bury to Shaughnessy, July 19, 1912, op. cit.

[285] Ibid.

[286] Bury to Shaughnessy, March 26, 1913. PIC CPCA.

[287] "Statement of Costs of Double Tracking and Economics of Proposed Changes on Work Proposed to be Undertaken, Year 1913, North Bend to Revelstoke," enclosed in Bury to Shaughnessy, July 19, 1912.

[288] Province, September 7, 1912, p. 1; Canadian Railway And Marine World, October 1912, p. 505; May 1913, p. 203.

[289] Province, April 5, 1913, p. 1.

[290] See notes (183) and (184).

[291] C.P.R. Co., Annual Report, 1910, p. 8.

[292] Canadian Railway And Marine World, May 1913, p. 223.

[293] Grant Hall, tel. to Shaughnessy, January 30, 1913, PIC CPCA.

[294] Bury to Shaughnessy, April 21, 1913, op. cit.

[295] Cornell Civil Engineer, op. cit., p. 84.

CHAPTER 7

ALTERNATIVES AND THEIR EVALUATION

In 1912, the C.P.R. had identified a capacity problem in Rogers Pass. Unless a second main line into B.C. could be constructed within the next four years, the existing single-track facility would become too congested to meet the demand for increased traffic movement through the mountains. By 1912, therefore, there was a revival of interest in alternative routes across the Selkirk Divide. Once again, as in the early 1880's, the C.P.R. was compelled to address the question of determining an appropriate alignment through the mountains, and an appropriate level of investment in order to secure such an alignment. Once again, alternative solutions would have to be generated and evaluated before the investment decision could be taken. This chapter is concerned with the generation and evaluation of those alternatives.

7.1 Alternatives Beyond The Selkirk Mountains

In retrospect, Sir George Bury recalled that, when interest in alternative routes revived in 1912,

> There were three possibilities, via the Yellow Head, via Roger's Pass and possibly a route somewhere between Roger's Pass and the [U. S.] boundary.[1]

This initial range of alternatives was screened without detailed evaluation by the application of a "dominance" method to basic engineering criteria of distance and gradients.

a) Alternatives South Of Rogers Pass

> We first took the necessary steps to assure ourselves that there was no pass sufficiently low, across the Selkirk Mountains, between the Crows Nest line and Roger's Pass.[2]

Engineers surveyed the St. Mary's river valley, where a four-mile tunnel would be required to secure a 5,000-feet track summit, and Toby Creek, where a three-mile tunnel would be required to secure a summit of 4,700 feet. The summit of the existing facility was 4,342 feet. These amounts of tunnelling, without securing a reduction in the amount of rise and fall on the main line, were unacceptable to the C.P.R. During October 1912, an engineer was offered a bonus of $1,000 "if he could find any point at which we could get through at less than 4,000 feet with a tunnel of reasonable length."[3] By January, his search had failed: "His trip resulted only in confirming the figures we had as to the heights of the various passes."[4]

Without an alternative pass, the C.P.R. would have been compelled to follow the Crow's Nest Pass in any mountain crossing south of the existing main line. The Crow's Nest line had been built to develop mineral resources, and to pre-empt American rivalry in the Kootenays.[5] The C.P.R. had never intended it to form part of an alternative transcontinental system, and no direct link was available between the Crow's Nest line and the main line west of the mountains. Thus, although the maximum gradient on the Crow's Nest line was only 1% in either direction, this advantage in gradients was offset by the far greater distance entailed in crossing the mountains by any route involving the Crow's Nest railway.

The western terminus of the Crow's Nest line was at

Kootenay Landing. Beyond this point, several alternative routes were available, each of which would avoid the Selkirks. Most would rejoin the main line at Revelstoke, but one, the route proposed for the Kettle Valley Railway, would rejoin the main line at Hope. Each of these alternative routes was rejected, however, explicitly "on account of the excessive distances of all other lines by way of Robson or by way of the Kootenay Lake and Lardo [sic]."[6] The routes to Revelstoke may have been screened out quite simply because of their greater distance and their requirement, either for transhipments or for fresh construction around the lakes. As late as June 1913, however, Sullivan communicated a memorandum to the President explaining why the Crow's Nest and Kettle Valley route also afforded no improvement over the existing main line: in addition to increased distance, it required more rise and fall, and a far greater pusher mileage. Pusher locomotives would be required between Dunmore and Vancouver for 810 miles westbound and 975 miles eastbound on the Kettle Valley route, compared with 166 miles westbound and 406 miles eastbound on the existing main line. Total engine mileage would be 50% greater in either direction on the alternative route, and because of the additional rise and fall on the latter line, this would translate into an even greater disadvantage in fuel consumption.[7] This alternative, too, was therefore rejected.

b) <u>The Yellowhead Pass</u>

The C.P.R. may already have considered construction through the Yellowhead Pass prior to its decision to eliminate the Big Hill. Speculation was rife in 1906, and even after the driving of the Spiral Tunnels had begun in 1907, that the Company would complete this link from Edmonton to Kamloops because of its easier gradients, its potential for generating local traffic, and its competitiveness with the Grand Trunk Pacific.[8] Walter Moberly, in a memorandum prepared in October 1907, recorded

> The best and most convenient localities along the line of the proposed C.P.R. via the Yellow Head Pass, where good water powers for creating Electric energy can be obtained in the immediate vicinity of the line of railway...[9]

Later the same month, however, Shaughnessy scotched the rumours:

> The talked of extension from Edmonton through the Yellow Head Pass...had never seriously been considered by the C.P.R., and nothing was being done in this connection at the present time...[10]

The C.P.R.'s purchase of the Alberta Central Railway to Red Deer in 1909 briefly revived rumours of the C.P.R.'s ambitions upon the Yellowhead Pass,[11] but it was not until 1912, with the decision to seek a double track across the mountains, that the Company seriously re-examined the route. In March, engineers were dispatched into the Yellowhead,[12] and in April, the <u>Province</u> reported that the C.P.R. intended to link Red Deer, east of the Pass, with Kamloops, on the existing C.P.R. main line.[13] The alternative was rejected, however:

> The line through the Yellow Head would have to go via Edmonton. Starting out at Red Deer, in order to secure a low grade, it would have required a line of too great a distance.[14]

The reasons for which the C.P.R. had declined to build through the Yellowhead Pass in the 1880's were as compelling in 1912.

Thus, although the C.P.R. had been prepared seriously to consider alternative routes around the Selkirk Mountains, and although "engineers of eminence had advised in favor of the northern or southern passes rather than our present line,"[15] no suitable alternative had been found. The topography of the Kootenays and the piecemeal development of rail links complementary to the waterways militated against the adoption of an alternative south of Rogers Pass. To the north, the disadvantage of the greater distance via the Yellowhead Pass outweighed the advantage of its superior gradients, and the route was relinquished to the Grand Trunk Pacific and the Canadian Northern. The C.P.R. rejected these alternatives, and reaffirmed its confidence in the commercial supremacy of a route through the Selkirks.

7.2 Alternatives Within The Selkirk Mountains

By October 1912, "It therefore seem[ed] apparent that the only location from Golden west [was] via the present route."[16] Along the present route, there were three alternatives. The first alternative was to build around the "Big Bend" of the Columbia River, an alternative which, like the Yellowhead Pass, the C.P.R. had rejected when locating the original main line in the 1880's. The second alternative was to double-track the existing facility through Rogers Pass, and the third alternative was to tunnel beneath Rogers Pass and abandon the surface alignment altogether.

Walter Moberly had consistently canvassed the advantages of the Big Bend route in comparison with the existing main line. In May 1902, he sent a memorandum to the General Superintendent of the C.P.R.'s Pacific Division, recommending wholesale diversion of the existing main line between Revelstoke and Swift Current. Within this scheme, Moberly clearly believed that the first priority should be the abandonment of Rogers Pass, by means of a line constructed around the right bank of the Columbia River and through the Howse Pass to Red Deer, Alberta:

> At first the portion of the proposed line -- a distance of 330 miles -- from Revelstoke to Red Deer might be built, thus avoiding the Selkirk Mountains, and the section between Red Deer, by the Red Deer valley, subsequently constructed.[17]

Moberly envisaged the routeing of heavily loaded trains via Red Deer, with the existing line being reserved "for lighter traffic if not abandoned altogether."[18]

Moberly's scheme envisaged the operation of a short section on the west slope of Howse Pass by electricity. This would be "the only exceptionally heavy" gradient "from Vancouver to the East."[19] The realignment thus favoured westbound traffic. Moberly was optimistic about the prospects for westbound grain, citing orders placed in Seattle for grain shipments to Vladivostock.[20] He was also concerned about the strength of U.S. competition for transcontinental traffic.[21] In 1905, therefore, he petitioned the Royal Commission on Transportation for federal assistance to the realignment scheme:

> Taking all matter connected with the earlier days of the C.P.R. when under Government control and feeling convinced that it was during that period that the mistakes were made in not having the railway more advantageously located, I think it would only be fair that the Dominion Government should pay reasonably to get a better line for the C.P.R. through the mountains and thereby confer inestimable benefits upon the people

> of the Dominion by advancing both their home and foreign trade...[22]

The petition appears to have been unsuccessful: even the C.P.R. was unconvinced of the necessity for investment in the realignment. At this time, its principal traffic flows were eastbound. Moreover, it did not fear competition as much as Moberly believed it should. "If the G[rand] T[runk] P[acific] get possession of the Howse Pass any chance of light grades on the C.P.R. will be impossible," Moberly warned in 1904. He even offered his services to "take possession" of the Howse Pass for the C.P.R., in order to "head off the Grand Trunk Pacific and force them to build their railway through the Pine river Pass."[23] The C.P.R. must have resisted the offer, for six months later Moberly was writing to Charles M. Hays, President of the Grand Trunk Pacific, suggesting that the Grand Trunk Pacific might find a trial location through the Howse Pass more favourable than one through the Pine or Skeena River passes.[24] The Grand Trunk Pacific, however, would eventually locate its main line through the Yellowhead Pass.

Announcement of the C.P.R.'s intention to double track west of Winnipeg stimulated Moberly again to recommend diversion around the Big Bend and Howse Pass. Van Horne, however, informed Moberly that, "the shareholders would not stand the expense of the alterations in the line."[25] The C.P.R. did briefly consider construction around the Big Bend in 1907, during the quest for gradient revision which ultimately accorded priority to the elimination of the Big Hill. However, in order to offset the disadvantage of increased distance around the Big Bend, the diversion had to effect a gradient reduction as far west as

Clanwilliam. This would have entailed bypassing Revelstoke to the north. It would also have entailed the surrender of the local lumber traffic to water competition, for if the railway abandoned Revelstoke, the Columbia River, here flowing southwards into the United States, would provide a ready alternative outlet for the millowners at Arrowhead.[26]

A more serious investigation of the Big Bend route was undertaken in 1910. This investigation may have been prompted by the avalanche disaster of that year, and may have sought an alternative to the main line through Rogers Pass which offered greater safety rather than greater capacity. However, the survey may equally have been prompted by a C.P.R. policy initiative intended to head off the Grand Trunk Pacific at the Yellowhead Pass;[27] or it may have been prompted by the desire of the C.P.R. to increase its market share of lumber traffic to the prairies, by securing a route through the Columbia Valley which would "tap the vast areas of valuable timber in that district."[28] Whatever the motivation, the survey failed to locate an alternative transcontinental route superior to that through Rogers Pass:

> We could not figure any economics that would justify considering the line via the Columbia River on account of the extra distance, (one hundred miles more of mountain railway)...[29]

This alternative was therefore rejected on basic engineering criteria, perhaps as early as April 1912: it was "longer than the existing main line, and the grades [were] little better."[30] As in the Yellowhead Pass, so in the Big Bend, when the C.P.R. had the opportunity to rectify the "mistake" of locating its main line directly through the Selkirks, it reaffirmed its confidence in the original trade-off decision.

Decision among the remaining alternatives, whether to double-track the existing main line or to tunnel beneath Rogers Pass, was less clearcut, and the costs of the several alternatives were computed and compared in order to assist the decision-making process. The key feature of all of the cost comparisons was that they began with the assumption that double-tracking was necessary: the purpose of the analyses was simply to determine the least-cost alternative for achieving this end.

The results of the first cost comparison, conducted by Sullivan in October 1912, are reproduced in table 22. Given that the criterion of acceptance was least-cost, alternative (III) was preferred. The annual operating saving of $101,300 was based on the _a priori_ assumption that traffic would have doubled to 13,469,320 equivalent gross tons per year by the time the tunnel was opened. This saving, combined with the saving in snowshed maintenance, yielded an annual benefit of some $226,000 for the tunnelling project, when set against the cost of double-tracking the existing line.[31] Nevertheless, the results may not have been as convincing as they appeared from Sullivan's analysis. Bury was convinced, but in January 1913 he wrote that "hardly anyone shared" his belief that gradient reduction on the existing main line through Rogers Pass would make "the best transcontinental line." The American consultant, Virgil G. Bogue, was therefore dispatched in the winter of 1912 to conduct an independent analysis.[32] He reported on January 20, 1913, and his calculations decidedly favoured adoption of the tunnel alternative.[33]

TABLE 22

COST COMPARISON OF DOUBLE-TRACKING ALTERNATIVES THROUGH THE SELKIRK MOUNTAINS, OCTOBER 1912.

Alternative	Cost $
I. Double-Track Present Line, Wooden Snowsheds.	
23,760 ft. snowsheds, at $20 per foot	475,200
24 miles double track, at $30,000 per mile	720,000
1/2 mile steel bridges	750,000
Extra cost of operating, $101,300 annually, capitalised at 4%	2,532,500
Cost of maintaining snowsheds, $125,000 annually, capitalised at 4%	3,125,000
Total	7,602,700
II. Double-Track Present Line, Reinforced-Concrete Snowsheds	
23,760 ft. snowsheds, at $160 per foot	3,801,600
24 miles double track, at $30,000 per mile	720,000
1/2 mile steel bridges	750,000
Extra cost of operating, $101,300 annually, capitalised at 4%	2,532,500
Total	7,804,100
III. Tunnel Line.	
16 miles double track, at $75,000 per mile	1,200,000
Bear Creek Bridge	200,000
27,300 ft. double-track tunnel, at $150 per foot	4,095,000
Total	5,495,000
If electrification is required, add:-	
For construction	250,000
Extra cost of operating and maintenance, $60,000 annually, capitalised at 4%	1,500,000
Total	7,245,000

Source:- Sullivan to Bury, October 22, 1912. PIC CPCA.

Energy costs were a critical factor in influencing Bogue's recommendation. Sullivan's calculation of the operating saving had assumed coal consumption of 5 lbs. per horse-power hour, at a cost of $4 per ton, yielding an annual fuel saving on the tunnel line of $87,284.[34] Bogue, however, assumed coal consumption of 7 lbs. per horse-power hour, at a cost of $4.68 per ton, yielding an annual fuel saving of $142,974, which was 64% greater than Sullivan's estimate. Sullivan conceded that his own figures had been "very conservative," and that Bogue's assumed coal price was "more accurate." Furthermore, Bogue included other benefits of tunnelling which Sullivan had omitted. Inclusion of these benefits rendered fuel economies a lesser proportion of the total savings to be derived from tunnelling, but yielded a final estimate of the annual benefits of tunnelling of $370,000, compared with Sullivan's estimate of $226,300.[35] The effect of Bogue's calculations upon the cost comparison was to increase the cost of doubling the existing main line with wooden snowsheds to $11,195,200, and the cost of doubling the existing line with concrete snowsheds to at least $9,196,350.[36] This made the tunnel line, using Sullivan's estimate for its construction cost, appear even more strongly preferable.

The first round of bidding for the tunnel contract prompted a second cost comparison in April 1913. The bids proved disappointingly high, and the C.P.R. was compelled to revise upwards its estimate of the cost of the tunnel line. This cost was now projected at $8.5 million, based on the lowest contract price, excluding electrification,[37] and assuming that one-seventh of the tunnel would have to be lined with concrete. This represented an upward revision of 55% over the estimate of October 1912. However, the construction cost of double-tracking the existing main line with concrete snowsheds was also revised upwards, by 52% from $5,271,600 to $8 million.[38]

This reappraisal of construction costs still favoured adoption of the tunnel line. The C.P.R. would be investing $500,000 more on the tunnel line than on doubling the existing main line with concrete snowsheds. The gradient improvements which the Company would obtain from this investment of an additional $500,000 would yield annual operating savings of $226,000 according to Sullivan, and $370,000 according to Bogue: the additional investment required in the tunnel line would be repaid within less than three years.

When the final tender was accepted, a confirmatory cost comparison was undertaken. The contracted price for the tunnel line, excluding electrification, was actually $7,970,930,[39] 45% greater than Sullivan's initial estimate had been in October 1912. The length of double track had been reduced from 16 miles in Sullivan's evaluation to 13.2 miles, but the cost of the double track had almost tripled, from $75,000 per mile[40] to $218,640 per mile. The cost of tunnelling had also increased, from $150 per lineal foot to $189.65, the latter rate including provision for the lining of 8,400 feet of the tunnel, or approximately one-third.

The contracted price of the tunnel was thus actually greater than the initial estimates prepared by Sullivan in October 1912 for the respective costs of double-tracking the existing main line with either wooden or concrete snowsheds. However, the estimated costs of the latter alternatives had also escalated dramatically since October 1912. The construction cost of double-tracking the existing main line with wooden sheds was now estimated at $2,462,000, or $516,800 more than the construction cost projected by Sullivan in October 1912.[41] Moreover, the extra cost of operating over the gradients on the existing main line was now estimated at $180,000 per annum. Again, this was much greater than the $101,300 originally estimated by Sullivan, and may have been greater than Bogue's estimate, which, incorporating increased fuel costs, may only have been $156,990.[42] Finally, the cost of maintaining the double-track wooden snowsheds was now estimated at $150,000 per annum, compared with the $125,000 per annum estimated the previous October. The total additional cost of operations and maintenance over the existing line was thus $330,000 per annum, which was in fact $40,000 per annum less than Bogue's estimate for total savings of $370,000 per annum over the tunnel line.

The additional operations and maintenance costs, capitalised at 4% and added to the revised construction cost, increased the estimate for the cost of double-tracking the existing main line with wooden snowsheds to $10,712,000. Whilst this was almost $500,000 less than the cost derived from Bogue's estimates during the first cost comparison, it was almost $3 million more than the contracted cost of the tunnel line. Moreover, since the latter cost was contractual, it represented the maximum possible cost of the project, under conditions of certainty which were guaranteed by the weight of contractual law. The estimated cost of the double track with wooden snowsheds, however, which was already higher than the certain maximum cost of the tunnel line, would have to be inflated even further in order to incorporate a handsome risk premium. As Bury acknowledged, "...we have had snow slides break through the wooden sheds on the single track and the danger of breaking through would be much greater on a double track."[43]

The C.P.R. assumed that the cost of concrete snowsheds eliminated this risk premium, and all snowshed maintenance costs. In the third cost comparison, however, the cost of concrete snowshedding was estimated at $200 per lineal foot,[44] compared with the estimate of $160 per lineal foot in October 1912. This increased the estimated construction cost of the double track with concrete snowsheds by $1,190,400, from $5,271,600 to $6,462,000.[45] Moreover, with the extra cost of operating over the existing main line now estimated at $180,000 per annum, the total cost of double-tracking the existing main line with concrete snowsheds was increased to $10,962,000. The cost of this alternative was therefore greater than both the maximum cost of the tunnel line and the apparent cost, excluding the risk premium, of double-tracking the existing line with wooden showsheds.

TABLE 23

RESULTS OF COST ANALYSES OF ALTERNATIVE INVESTMENTS IN ROGERS PASS, 1912-13.

Date Of Analysis	Alternative		
	Double-Track Existing Main Line: Wooden Snowsheds	Double-Track Existing Main Line: Concrete Snowsheds	Tunnel Excluding Electrification
	$	$	$
Oct. 1912	7,602,000	7,804,100	5,495,000
Jan. 1913	11,195,200	> 9,196,350	5,495,000*
April 1913	11,195,200*	8,000,000	8,500,000
June 1913	10,712,000	10,962,000	7,970,930

* No specific forecast of cost, therefore assumed by author to have been unchanged since previous forecast.

Sources:- Oct. 1912: Sullivan to Bury, October 22, 1912.
Jan. 1913: Ibid., incorporating Bogue's estimates for fuel consumption, obtained from Sullivan to Bury, March 13, 1913.
April 1913: Bury to Shaughnessy, April 22, 1913.
June 1913: Bury to Shaughnessy, June 17, 1913.
All PIC CPCA.

The results of the several cost comparisons are summarised in table 23. The analyses sufficed to identify the tunnel line as the least-cost alternative for obtaining a double track through Rogers Pass. The tunnel line was expected to afford benefits over double-tracking the existing line in terms of operating savings and savings in snowshed construction. In comparison with double-tracking the existing main line and providing wooden snowsheds, the tunnel line would also eliminate snowshed maintenance costs and the risk premium of interruptions to traffic caused by snowshed failure. In 1913, therefore, the C.P.R. decided to construct a tunnel beneath the Selkirk Mountains, and to abandon the surface alignment through Rogers Pass.

A cost comparison, however, merely identifies the least-cost alternative for achieving a stipulated end. It does not indicate whether or not that alternative ought in practice to be adopted at all. That is, it does not indicate whether the benefits which are anticipated to accrue from a project will outweigh the costs incurred in undertaking the project. Only a detailed evaluation of those costs and benefits will determine this, and it is therefore appropriate that both the costs and the benefits which the C.P.R. anticipated from the abandonment of Rogers Pass should be examined in greater detail.

Moreover, even after the C.P.R.'s decision to abandon Rogers Pass and to construct a tunnel through the Selkirks, several alternative alignments remained to be considered. These alternatives involved tunnels of differing lengths, which would incur differing immediate capital costs. The alternatives also involved tunnel-approaches over gradients differing in length and severity, which would incur differing levels of variable costs throughout the period of subsequent operations through the tunnel. The decision to drive a tunnel beneath Rogers Pass therefore compelled the C.P.R. once again to trade off construction costs against operating costs, and immediate costs against delayed costs. Analysis of the costs and benefits which the C.P.R. anticipated from driving the tunnel reveals the manner in which the trade-offs were handled, and suggests criteria on which the decision was based.

7.3 Alternative Tunnels

This section analyses three alternative schemes for tunnelling beneath Rogers Pass. Each of these schemes was examined and evaluated in 1912, prior to the decision to abandon the surface alignment, and prior to the formulation of the proposal for which tenders were ultimately invited in April 1912.

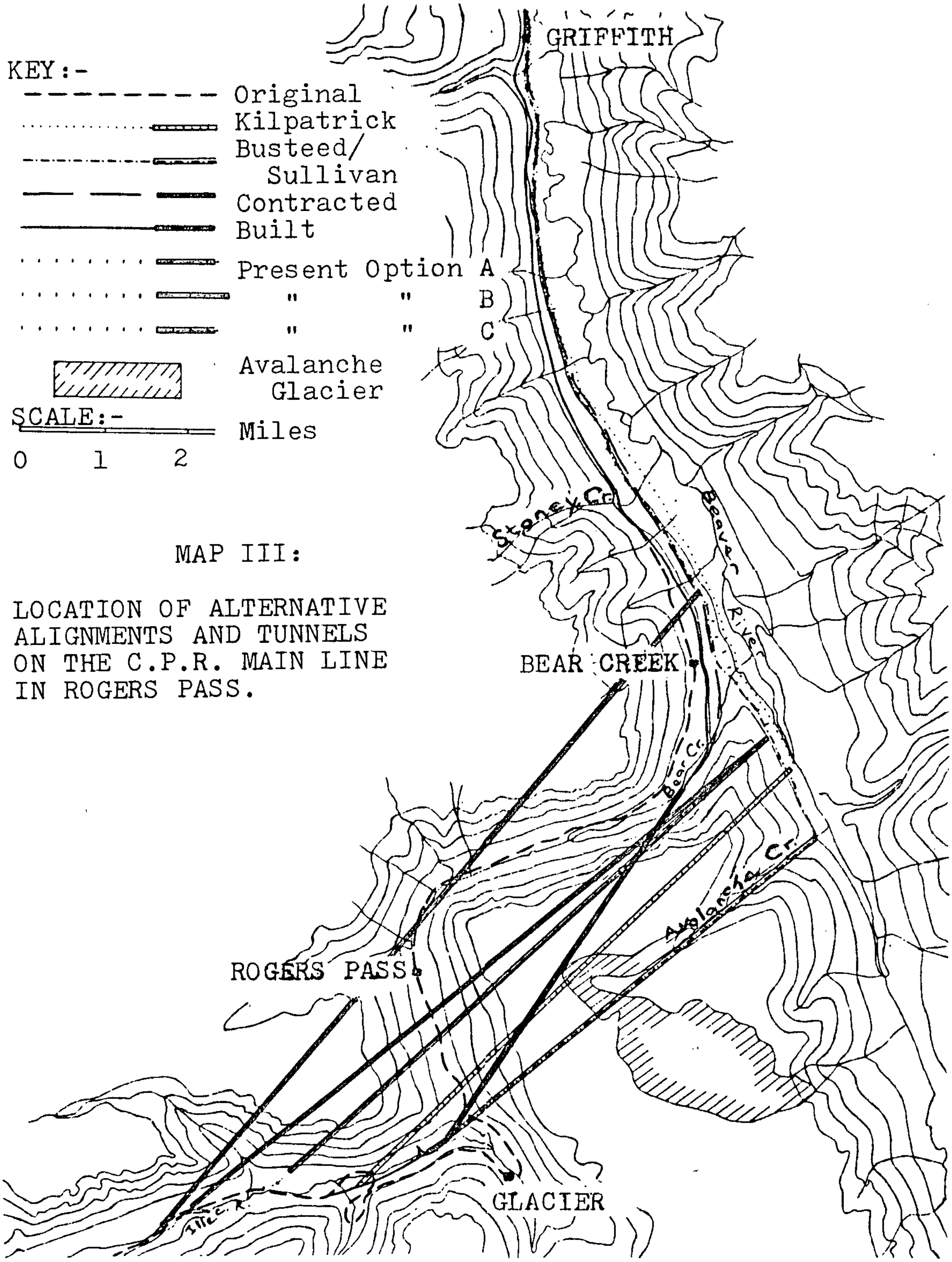
Before proceeding to the evaluations of these schemes, it is important to note several key data limitations, applicable to the alternatives described in this chapter and in the following chapter, which hamper critique of the C.P.R.'s financial assessments of the several tunnelling projects. First, as was noted in the previous chapter, the extant C.P.R. traffic forecasts were short-term in character. They envisaged only the eventuality that traffic would double. Doubling was expected to occur within four years of 1912, and nothing is known of C.P.R. expectations beyond this horizon. Furthermore, the extant data detail only the cost savings of handling traffic, whether the current volume or double that volume. There is no record of the C.P.R.'s having evaluated potential savings in congestion costs or potential savings in the opportunity costs of lost contribution from traffic which would be foregone if capacity were not to be expanded. Neither is there any evaluation of the additional contribution to be derived from traffic generated by the increase in capacity. Therefore, in each of the evaluations of the tunnelling schemes which follows, the only measures of the benefit of the schemes are those of "operating savings" and "snowshed savings." Clearly, these biases generate a lower-bound estimate of benefit, particularly if it is allowed that eventually the volume of traffic hauled through Rogers Pass might increase to more than double the 1912 level. Finally, whilst the benefits of the realignments, in the form of savings in operating and maintenance, were discounted as perpetuities by the C.P.R., it is not clear that the construction costs were discounted over the projected period of construction. In each of the following evaluations, it has been assumed that construction costs were not discounted, and appropriate schemes of discounting have accordingly been devised.

a) <u>The Kilpatrick Tunnel</u>

When the C.P.R. began its quest for a tunnel beneath Rogers Pass, this was the first realignment scheme to be proposed. It was championed by Thomas Kilpatrick, Superintendent of the Mountain Subdivision, who located the alignment in May 1912. The approximate location proposed by Kilpatrick may be followed on map (III), and the profile of the alignment is presented in figure 2. Kilpatrick described the alignment to F. F. Busteed, the Superintendent of Double-Tracking between Calgary and the West Coast, as follows:

> From Six Mile Creek on the proposed new line to connect with tunnel a .7 [per cent. gradient,] from there to a point about opposite Stony Creek Bridge and from there to the crossing of Bear Creek about two and a half miles would be one per cent. This grade would continue on for about one and a half or possibly a little more to the mouth of the proposed tunnel...
>
> ...I am assuming that the grade level of tunnel at west end will be 40 ft. below the present grade on the second crossing of the Illecillewaet Bridge near it.[46]

Kilpatrick's proposal would have replaced 16.1 miles of 2.2% gradient on the east slope of the Selkirks, between Six Mile Creek and Rogers Pass, with 8 1/2 miles at 0.7%, four miles at 1% and a tunnel, seven miles long, at an average gradient against westbound traffic of 1.6%, although Kilpatrick suggested that, "As this tunnel would no doubt be operated by electricity," 4 1/2 miles of the tunnel might be graded at 2.2% in order to ensure adequate drainage from both portals. Since gradient revision between Beavermouth and Six Mile Creek was expected to remove the need for pusher locomotives on that section, the westbound pusher gradient would have been reduced from 20.8 miles, the distance between Beavermouth and Rogers Pass, to 7 miles, the length of the tunnel. On the west slope of the Selkirks, the proposal would have reduced the length of the pusher gradient from 25.3 miles, the distance between Albert Canyon and Rogers Pass, to 18.4 miles, the distance between Albert Canyon and the second crossing of the Illecillewaet.

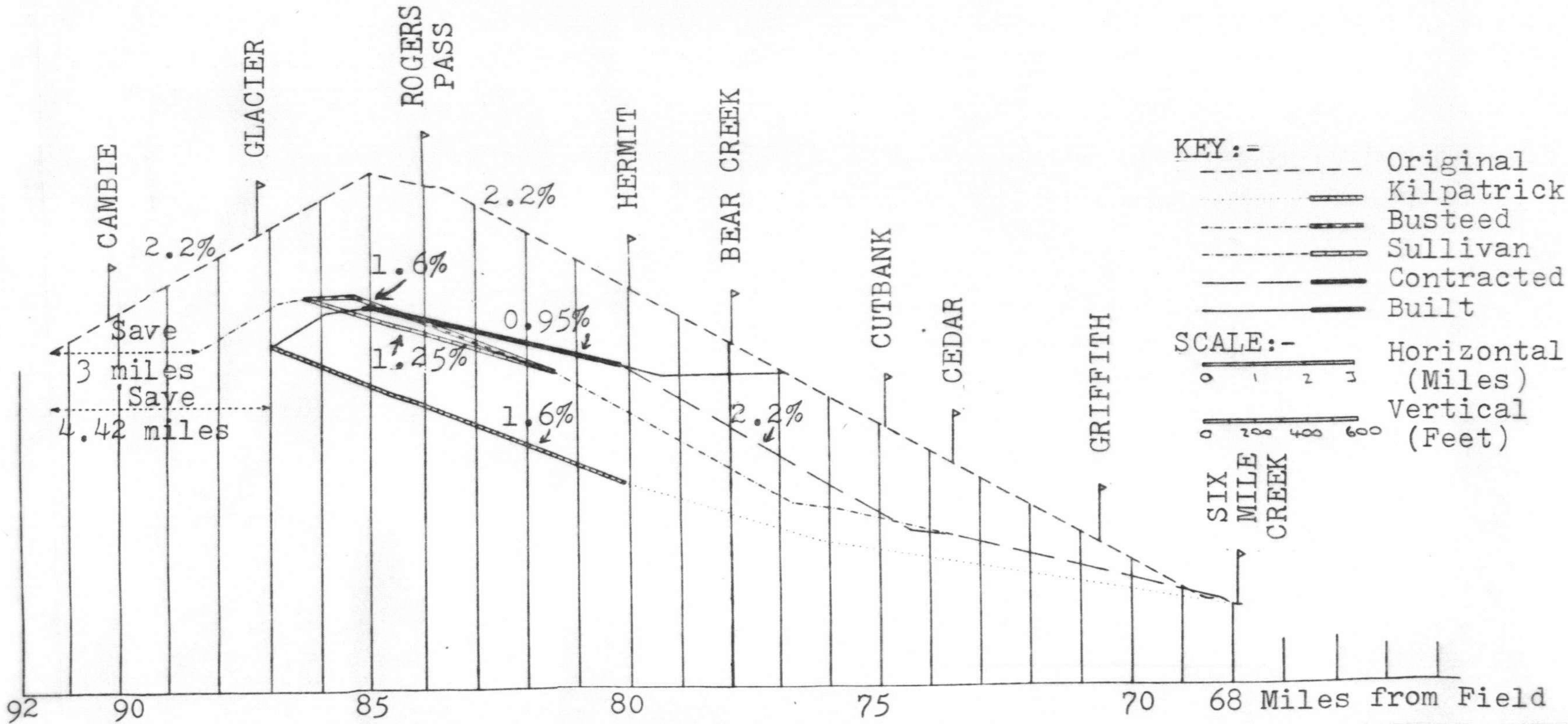


MAP III:

LOCATION OF ALTERNATIVE ALIGNMENTS AND TUNNELS ON THE C.P.R. MAIN LINE IN ROGERS PASS.

FIGURE 2: PROFILES OF ALTERNATIVE ALIGNMENTS AND TUNNELS ON THE C.P.R. MAIN LINE IN ROGERS PASS.

Sources:- "Rogers Pass Tunnel, Profile of Old and New Lines," enclosed in Bury, Memorandum for the President, July 23, 1915. PIC CPCA.
Kilpatrick to Busteed, May 8, 1912, Kilpatrick MSS, Vancouver.
Sullivan to Bury, October 22, 1912. PIC CPCA.



Kilpatrick's proposal, therefore, would have reduced the total length of the main line through Rogers Pass by about 4.4 miles. It would have saved 20.7 miles of pusher gradient in total, of which 13.8 miles would have been on the east slope and 6.9 miles on the west slope. The realignment thus strongly favoured westbound traffic, and, with associated revision at Leanchoil in the Rockies and Notch Hill in the Eagle range, it offered a maximum westbound gradient between the prairies and the West Coast of one per cent., except in the seven-mile tunnel through the Selkirks. The alignment would have eliminated "all high bridges on the East slope of the Selkirks," at Mountain Creek, Surprise Creek and Stoney Creek, and would have removed the Loops, with all their associated bridging, on the west slope. With piecemeal diversions west of Illecillewaet and west of Albert Canyon, the proposal would also "practically overcome all danger from slides," perhaps a key benefit according to the criteria of Thomas Kilpatrick, "The Snow King."

The proposal was rejected in 1912, but it has generated renewed interest in recent years as CP Rail, now confronting capacity problems on the east slope of Rogers Pass, has undertaken investigation of several alternative alignments through the Selkirks, intending to reduce the maximum gradient against westbound traffic to one per cent. Each alignment involves tunnelling of between eight and ten miles, and the alignment of the most preferred alternative may be compared in map (III) with Kilpatrick's alternative, and with the tunnel which was actually built.

No financial evaluation of Kilpatrick's proposal has survived. Indeed, it appears that the proposal was rejected without such an evaluation having taken place. The principal reason given for the rejection was that the alignment of the seven-mile tunnel

> ...would pass under the head waters of the Illecillewaet river. In the building of the Lotschberg tunnel in Switzerland, which was planned to be about 8.5 miles long and went underneath the valley of a river, after nearly two years work, when the tunnel was underneath the bed of the river, a break occurred and water and sand filled the tunnel for some half a mile or more. The line was abandoned, backed up at the end which was filled about 3/4 of a mile, a detour made in the tunnel, which lengthened the same some half a mile or more.[47]

Engineering constraints, the function of topography at the summit of the Selkirks, rendered the project high in risk. At seven miles, it would have been easily the longest railway tunnel in North America. Moreover, the degree of risk was exacerbated by the traffic situation which prevailed in 1912, and by the forecast for the near future. The capacity problem was sufficiently urgent that the C.P.R. could not afford the time required to bore a seven-mile tunnel. Neither could it tolerate the risk that the tunnel would not be completed on schedule. A further factor, implicit in the magnitude of the seven-mile alternative, was the scale of labour costs. Since it was expected that a seven-mile tunnel would require more time to bore than a five-mile tunnel, wage costs were expected to be proportionately higher. As Sullivan observed in March 1913,

> In the Lotchberg tunnel, which has recently been finished, the wages, with a bonus of about 75% or 80% of the daily wages, only amounted to 96c. to $2.60 per day for drill foremen, and $1.70 per day for drill runners, while we would probably have to pay from $3.50 to $5.00 per day.[48]

Sullivan would claim that the urgency for completion of gradient revision, and the discrepancy in labour costs between Europe and North America, together justified adoption of an unorthodox tunnelling technique, the "pioneer" method, in order to expedite construction. It does not appear that this technique was considered in May 1912 for the driving of the Kilpatrick tunnel.

In fact, however, the urgency of the capacity problem was alleviated after 1913 by economic forces. Indeed, no sooner had the C.P.R. begun double-tracking in Rogers Pass than the traffic volumes which had apparently made double-tracing essential began to decline. As has been noted above,[49] despite predictions of imminent recession during the first half of 1913, the C.P.R. was apparently confident that any downturn would be shortlived. Yet if the Company commenced its double-tracking programme in the Selkirks in the expectation of early economic recovery, it must have been grievously disappointed by the outbreak of world war in August 1914, for this postponed the expected increase in traffic volumes, not merely for the duration of the war, but for several years afterwards. The impact of both the recession and the war upon lumber and grain shipments through Rogers Pass is clearly illustrated in tables 15 and 16. By 1916, the fourth year after the forecast that traffic would double "within four years," lumber volumes had still not recovered to their 1912 peak, and grain volumes were less than one-quarter of their pre-war level.

The decline in traffic which began in 1913 must have eased congestion in Rogers Pass, and the outbreak of war provided the C.P.R. with further respite during which to construct a tunnel. Indeed, the C.P.R. could probably have waited at least five years after 1913 before commencing its second main line, with no adverse impact upon traffic receipts, as the effects of the recession and the war were worked out. For it appears probable that when the double track did open, in December 1916, and for several years thereafter, traffic volumes were sufficiently below their 1912 levels to render the second track superfluous, and to diminish considerably the operating savings which were anticipated from the gradient revision.

Had the C.P.R. been presented with the Kilpatrick alternative in 1913, it is possible that the proposal would have been accepted. The decline in traffic volumes, consequent upon recession and the outbreak of war, might have provided sufficient breathing-space to enable the original single line to meet the demand for traffic movements until the longer tunnel could have been completed. Indeed, had the C.P.R. employed the "pioneer" method on Kilpatrick's tunnel, the length of time required for completion, and the concomitant total labour cost, might have been considerably curtailed. Furthermore, the decline in traffic volumes would indirectly have reduced the risk of the project. Since the original single track would have been able to cope with demand, more time would have been available for engineering precautions which might avert a repetition of the Lotschberg cave-in. Moreover, even if such a cave-in had occurred, its impact upon the flow of traffic and upon revenues would have been markedly less under the conditions of traffic which actually prevailed than under the conditions of rapid growth which were forecast to prevail. Finally, as may be perceived from map (III), it is by no means clear that a seven-mile tunnel, commencing on the east slope at a point one and a half miles south of Bear Creek, with an elevation of 3,058 feet, and emerging on the west slope at a point between Cambie and Ross Peak, would have to pass under the headwaters of the Illecillewaet River at all.[50]

Did the C.P.R., therefore, commit a major blunder in its apparently cursory rejection of Kilpatrick's proposal during the summer of 1912? In fact, it appears that it did not. In table 24, a financial evaluation of the project has been pieced together from the sparse data available.

In construction, it has been assumed that the seven-mile tunnel could have been built for the same rate per lineal foot, $185.98, as was actually incurred in construction of the Connaught Tunnel. Likewise, it has been assumed that the rate for the approaches to the seven-mile tunnel would have been the same as the actual rate, $91,980 per mile of single main line.[51] From figure 1, it was estimated that 12 1/4 miles of double-track approach would have had to have been constructed. It was assumed that expenditures on the Bear Creek Bridge and the ventilation equipment would have been postponed until the final year. Since the C.P.R. sought completion of the Connaught Tunnel at the earliest possible date,[52] it was assumed that the expenditure streams actually incurred in the first two years of construction would have been emulated in Kilpatrick's alternative. It is known that the C.P.R. spent $8,798.26 on the Connaught Tunnel before June 30, 1913, and $1,091,108.12 between July 1, 1913 and June 30, 1914. These expenditures have been added to yield the "Year 1" construction cost. It is also known that between July 1, 1914 and June 30, 1915, in "Year 2," the C.P.R. invested a further $1,704,379.15 in the project.[53] However, the nature of the expenditure stream in the latter stages of the project is not known.[54] When construction commenced, the maximum rate of expenditure which the C.P.R. was prepared to sanction was $2,500,000 per year until completion.[55] It has therefore been assumed that this was the rate of expenditure after June 1915, at the height of construction in the Connaught Tunnel, and that this rate was required throughout the third and fourth years of the project, the balance of the work being completed in the fifth year.

In the calculation of operating savings, the reduction in rise and fall was estimated from figure 2: the summit of Kilpatrick's tunnel would have been 600 feet above the 3,058-foot contour, and this would have been 684 feet below the summit of the existing alignment. The savings in friction and curve resistance are assumed to have been the same as they would have been in Busteed's proposal. This latter formed the basis for the initial cost comparison presented in table 22, and it differed materially from Kilpatrick's proposal only in the location of the actual tunnel. The traffic estimates, the data on operating costs, the snowshed savings and the discount rate are all assumed to be the same as the C.P.R. calculated in its evaluation of the Connaught Tunnel which was released in December 1914.[56]

TABLE 24

COST-BENEFIT ANALYSIS OF KILPATRICK'S PROPOSED TUNNEL ALIGNMENT OF MAY, 1912.
(r = 4%)

Traffic Forecast	Tons
Actual Eastbound, 1912-13 Average:-	
1,342 1/2 passenger trains, at 443 tons	594,727.5
2,322 passenger locomotives, at 175 tons	406,350
1,738 1/2 freight trains, at 950 tons	1,651,575
3,477 freight locomotives, at 181 tons	629,237
Total	3,281,889.5
Actual Westbound, 1912-13 Average:-	
1,342 1/2 passenger trains, at 443 tons	594,727.5
2,322 passenger locomotives, at 175 tons	406,350
1,738 1/2 freight trains, at 898 tons	1,561,173
3,477 freight locomotives, at 181 tons	629,237
Total	3,191,487.5
Total traffic, 1912-13 average:-	6,473,377
Assuming doubling by 1917, forecast total:-	12,946,754

Undiscounted Cost Of Tunnel Alignment	$
Ventilation equipment	110,000
Bear Creek Bridge	200,000
Tunnel: 7 miles, at $185.98 per lin. ft.	6,873,821
Approaches: 24 1/2 miles, at $91,980 per mile	2,253,510
Total	9,473,331

Discounted Cost Of Tunnel Alignment

Year 5: Ventilation equipment 110,000 x .82193	90,412.30
Bear Creek Bridge 200,000 x .82193	164,386

Total remaining to be discounted:-
$9,473,331 - $310,000 = $9,163,331

Year 1:	1,099,906.38	x .96154	1,057,604
" 2:	1,704,379.15	x .92456	1,575,800.80
" 3:	2,500,000	x .889	2,222,500
" 4:	2,500,000	x .8548	2,137,000
" 5:	1,359,045.47	x .82193	1,117,040.30
	Total discounted cost:-		8,364,743.40

Benefits Of Tunnel Alignment

Saving in rise and fall (4,342 - 3,658 =)	684 feet
" " friction resistance	45 "
" " curve resistance	89 "
Total	818 feet

TABLE 24 (Cont.)

Fuel saving:-		$
6,473,377 tons x 818 ft. =		
5,295,222,400 ft. tons/1,000 =		
5,295,222 h.p. hrs. x 5lbs. coal per h.p. hr. =		
13,238.06 tons coal x $4.60 per ton =		60,895.06
Wage and maintenance saving:-		
Old line:		
6,162 trains for 23.1 miles =	142,342.2 train miles	
Kilpatrick's line:		
6,162 trains for 18.7 miles =	115,229.4 train miles	
Train miles saved	27,112.8	
27,112.8 train miles, at 22c. per train mile=		5,964.82
Old line:		
5,437 pushers for 23.1 miles =	125,594.7 pusher miles	
Kilpatrick's line:		
5,437 pushers for 7.5 miles =	40,777.5 pusher miles	
Pusher miles saved	84,817.2	
84,817.2 pusher miles, at 25c. per pusher mile=		21,204.30
Extra cost maintenance of way:		
4.4 miles, at $200 per mile +		
27,112.8 train miles, at 20c. per train mile =		6,302.56
Extra cost maintenance of way, on account of extra number of degrees of curvature, assuming that 400° of curvature per mile would increase rate of 20c. per train mile for maintenance by 30%:		
6,162 trains x 2,218° x 1/40c. =		3,416.83
Extra cost maintenance of equipment:		
27,112.8 train miles at 21c. per train mile =		5,693.69
Extra cost maintenance of equipment, on account of extra number of degrees of curvature, assuming that 400° of curvature per mile would increase rate of 21c. per train mile by 40%:		
6,162 trains x 2,218° x 21/1000c. =		2,870.14
Total annual operating saving (fuel, wage and maintenance)		106,347.40

Assuming traffic doubles, annual operating saving:
106,347.40 x 2 = $212,694.80
Annual operating saving realised after Year 5 for perpetuity
212,694.80/4% = $5,317,370
Discounted back to Year 0:
5,317,370 x .79031 = 4,202,370.70

TABLE 24 (Cont.)

Snowshed saving:-	
85,000 per year realised after Year 5 for perpetuity:	
85,000/4% = $2,125,000	
Discounted back to Year 0:	
2,125,000 x .79031 =	1,679,408.80
Total discounted benefit:-	5,881,779.50
Net present value of Kilpatrick's proposal:-	
5,881,779.50 - 8,364,743.40 =	-$2,482,963.90

Sources:- Cornell Civil Engineer, December 1914, pp. 80-81.
Bury, Memo for the President, August 10, 1915, PIC CPCA.
Kilpatrick to Busteed, May 8, 1912, Kilpatrick MSS, Vancouver.

Table 24 reveals that Kilpatrick's proposal had an extremely large negative net present value. This could only have been neutralised if traffic through Rogers Pass had been forecast to more than triple by the year of completion. The result of the evaluation is not sensitive to assumptions concerning fuel costs. It should be noted that although oil was the sole source of energy for trans-mountain haulage, and although it was intended to supersede this with electric traction over the Selkirk summit, the C.P.R. always calculated fuel savings in terms of coal consumption. Thus, Sullivan's cost comparison had assumed coal consumption of 5 lbs. per horse-power hour, at $4 per ton. Such a consumption rate would have decreased the magnitude of the annual operating savings to $98,404.56, and would have increased the negative net present value to -$2,796,829.20. Even under Bogue's assumption, that 7 lbs. of coal per horse-power hour would be consumed at $4.68 per ton, the net present value would still have been substantially negative (-$1,461,856.70).

Neither is the result sensitive to assumptions concerning snowshed savings. Although in its <u>ex post</u> release the C.P.R. assumed snowshed savings of $85,000 per annum, the Company estimated that the actual saving, for double-track wooden sheds, would be $125,000 per annum.[57] Even incorporating this saving, however, the net present value of Kilpatrick's proposal would still have been negative by $1,692,654.

The result of the evaluation may be sensitive to assumptions concerning the cost of capital. A fall in the discount rate from 4% to 3% would have yielded a net present value which was negative by only $312,776.30. However, since the C.P.R. consistently employed 4% as its discount rate in the evaluation of alternative alignments through the Selkirks prior to the outbreak of the First World War, it is unlikely that the selection of projects was influenced by interest-rate considerations.

Adoption of Kilpatrick's proposal would have secured annual benefits almost 20% greater than the benefits which accrued from the realignment which was actually constructed. (See table 31). It would have reduced the pusher gradient against westbound traffic to one-third of its existing length, and to one-half of the length of pusher gradient which remained after the Connaught Tunnel opened. By locating the line on the east slope up the centre of the Beaver Valley, where CP Rail is presently seeking a location, and by burying the line through the summit within a seven-mile tunnel, the proposal would also have virtually eliminated the risk of disruption from snowslides.

The C.P.R.'s rejection of the proposal may indicate its lack of conviction that the potential volume of westbound traffic would warrant such a drastic reduction in the gradient on the east slope of the Selkirks. The rejection may also indicate the C.P.R.'s belief that the marginal benefits of immunity from avalanches on the east slope were outweighed by the marginal costs of securing such immunity. The cost of continuing the existing system of avalanche defence, including the cost of actual disruption and the risk of disruption, may have been less than the cost of diverting the entire main line into the centre of the Beaver Valley. In any event, rejection of

Kilpatrick's proposal was consistent with the forecasts for future traffic volumes which were generated by the C.P.R. in 1912. From the foregoing financial analysis, it appears that rejection of the alternative was also a sound business decision.

b) The Busteed Tunnel

After the rejection of the tunnel proposed by Kilpatrick, F. F. Busteed submitted an alternative location, which is also shown in map (III) and figure 2.[58] The approach up the east slope was swung out into the centre of the Beaver Valley, as Kilpatrick had envisaged, and, like Kilpatrick, Busteed also proposed to cross Bear Creek and continue following the Beaver Valley southwards around the east side of Mount MacDonald before turning west and entering the tunnel. The eastern approach would be at 1% for the first seven miles, 0.5% for the next mile and 2.2% for the five miles before the tunnel entrance. Like Kilpatrick's scheme, this proposal

> keeps the line so low that no trouble is anticipated from snow slides, and Cedar Creek, Surprise Creek and Stoney Creek are crossed at such low grades that the bridging will be very inexpensive as compared with the present bridging on the present line.[59]

Busteed's proposal differed from that of Kilpatrick chiefly in the location of the tunnel. South of Bear Creek, Busteed intended to "turn west at the first large creek that comes from the west." This must have been Avalanche Creek, over half a mile south of the point at which Kilpatrick had proposed to commence tunnelling. Busteed's tunnel would have been 5.17 miles long, with the first four miles at a 1.6% compensated gradient against westbound traffic, and the remaining mile at 0.1% against eastbound traffic in order "to avoid trouble from water." The west portal of the tunnel would have been "in the valley of the Illecillewaet opposite Glacier," about two-thirds of a mile further east than Kilpatrick proposed, and at an elevation almost 200 feet higher. Thus, like Kilpatrick's proposal, it would still have eliminated the Loops and their associated operating problems.

Busteed's proposal would have reduced the length of the main line by three miles, and saved 2,218 degrees of curvature and 514 feet of rise and fall. It would have replaced the 16.1 miles of pusher gradient on the east slope between Six Mile Creek and Rogers Pass with approximately ten miles from the 0.5% gradient at Old Mileage 76 to the 0.6% gradient at the east portal. On the west slope, the pusher gradient would have been reduced from 25.3 miles to 19.1 miles.

With the expected elimination of the pusher gradient between Beavermouth and Six Mile Creek, Busteed's proposal would have saved a total of 17 miles of pusher gradients, of which 10.8 miles would have been on the east slope and 6.2 miles on the west. The realignment would thus have favoured westbound traffic, but less strongly than had Kilpatrick's scheme. Moreover, as Sullivan agreed, "the line for the entire distance is practically free from snow slides," and thus offered the same advantage in this attribute as Kilpatrick's had done. The key factor favouring Busteed's proposal over that of Kilpatrick was apparently its location of the west portal. Sullivan claimed to be "well satisfied that the west end of the proposed tunnel is correctly located, being at practically the end of the

Illecillewaet valley." From map (III), it is by no means clear that Busteed's line, closer to Avalanche Glacier and no further from the Illecillewaet headwaters, was potentially any less risky than Kilpatrick's line. Yet Busteed's location was largely accepted by Sullivan, and although the Chief Engineer would suggest certain modifications to the proposal, it was upon this alignment that the first cost comparison was based.

This analysis favoured the abandonment of Rogers Pass. In table 25, however, the construction costs of the proposal are set against the anticipated benefits. The costs were undiscounted in Sullivan's cost-effectiveness analysis, and an appropriate scheme of discounting has therefore been devised. In the realignment which was actually constructed, the known expenditures in the first and second years represented 18.20% and 28.21% respectively of the total expenditure. Assuming that the maximum rate of construction was achieved in the third year, and that the full appropriation of $2,500,000 was granted for that year's work, this would have represented 41.38% of the total expenditure, the balance, representing 12.21% of the construction cost, being incurred in the final year. These percentages have been applied to the construction cost of Busteed's proposal in order to obtain an approximate expenditure stream for the project. It is assumed that investment in the Bear Creek Bridge would have been delayed for as long as possible, that is, until the fourth year.

TABLE 25

COST-BENEFIT ANALYSIS OF BUSTEED'S PROPOSED TUNNEL ALIGNMENT OF OCTOBER, 1912.
(r = 4%)

Traffic Forecast		Tons
Eastbound Forecast For 1917:-		
Weight of passenger trains		1,368,750
4,380 passenger locomotives		788,400
Weight of freight trains		3,376,460
6,672 1/2 freight locomotives		1,201,050
	Total	6,734,660
Westbound Forecast For 1917:-		
Same as Eastbound		6,734,660
Forecast total for 1917 =		13,469,320

Undiscounted Cost Of Tunnel Alignment	$
Bear Creek Bridge	200,000
Tunnel: 27,300 ft., at $150 per ft.	4,095,000
Approaches: 16 miles, at $75,000 per mile	1,200,000
Total	5,495,000

Discounted Cost Of Tunnel Alignment

Year 4: Bear Creek Bridge 200,000 x .8548	170,960

Total remaining to be discounted:-
$5,495,000 - $200,000 = $5,295,000

Year 1: 18.20% x 5,295,000 x .96154	926,626.48
" 2: 28.21% x " x .92456	1,381,033.30
" 3: 41.38% x " x .889	1,947,862.10
" 4: 12.21% x " x .8548	552,644.87
Total discounted cost:-	4,979,126.75

Benefits Of Tunnel Alignment		
Saving in rise and fall	514	feet
" " Friction resistance	45	"
" " Curve resistance	89	"
Total	648	feet

Fuel saving:- $
13,469,320 tons x 648 ft. =
8,728,560,000 ft. tons/1,000 =
8,728,560 h.p. hrs. x 5lbs. coal per h.p. hr. =
21,821 tons coal x $4 per ton = 87,284

TABLE 25 (Cont.)

Wage and maintenance saving:-	
32 trains per day x 3 miles saved =	
96 miles per day x 365 =	
35,040 train miles saved per year x	
40c. per mile for wages and equipment repairs=	14,016
Total annual operating saving (fuel, wage and maintenance)	101,300
Annual operating saving realised after Year 4 for perpetuity	
101,300/4% = $2,532,500	
Discounted back to Year 0:	
2,532,500 x .82193 =	2,081,537.70
Snowshed saving:-	
125,000 per year realised after Year 4 for perpetuity:	
125,000/4% = $3,125,000	
Discounted back to Year 0:	
3,125,000 x .82193 =	2,568,531.30
Total discounted benefit:-	4,650,069
Net present value of Busteed's proposal:-	
4,650,069 - 4,979,126.75 =	-$329,057.75

Source:- Sullivan to Bury, October 22, 1912. PIC CPCA.

Even though Busteed's proposal represented the least-cost method of double-tracking through Rogers Pass, table 25 reveals that the magnitude of the anticipated benefits did not warrant investment in the project, which had a net present value of -$329,057.75. This result is, however, extremely sensitive to assumptions concerning fuel costs. Sullivan himself admitted that his assumptions were "very conservative," and that Bogue's may have been "more accurate." Had the latter's assumptions been employed, the annual benefit stream would have been inflated by $55,689.81, and the net present value would have been positive by $815,270.52. Had fuel consumption been calculated on the same basis as in the evaluation of the contracted tunnel, that is, at 5 lbs. per horse-power hour, costing $4.60 per ton, the net present value would still have been negative, but by only -$60,027.66.

The evaluation was also sensitive to assumptions concerning snowshed savings. Had the annual saving been only $85,000, as was assumed in the <u>ex post</u> release, instead of $125,000, the net present value would have been negative by -$1,150,987.80. Since the margin between positive and negative net present values was so narrow, the evaluation would also have been extremely sensitive to interest rate changes: a fall in the discount rate of one-half of one per cent. would have yielded a positive net present value for the project of $404,531.81.

The C.P.R. explicitly recognised only the significance of varying assumptions concerning energy costs upon the results of the evaluation. Sullivan was clearly concerned to ensure that any errors should be on the conservative side. Having acknowledged that his own estimates were "very conservative," he was nevertheless reluctant to base the evaluation upon the admittedly "more accurate" estimates of Bogue. Instead, Sullivan assumed, "for the sake of being conservative, that the average between the two estimates would be approximately correct."[60] Since Bogue had estimated an annual saving of some $370,000, and Sullivan had calculated savings of $226,000 per annum, the amount of annual saving which was assumed was therefore $300,000. This rate of saving, suitably discounted and set against the $4,979,126.75 discounted cost of the project, would have yielded a positive net present value of $1,185,348.25.

Even if the C.P.R. did not conduct a thoroughgoing cost-benefit analysis of the proposed tunnel alignment, and even if it did not employ a net-present-value approach, its own methods of evaluation clearly produced results consistent with those which would have been obtained from the application of these analytical techniques. In October 1912, when Sullivan had estimated annual savings of $226,000, the C.P.R. had apparently not been persuaded of the appropriateness of investment in a tunnel beneath Rogers Pass. Instead, the Company had commissioned an investigation, to be undertaken by Bogue. His report, in January 1913, that potential annual savings of $370,000 might be realised, clearly favoured the boring of a tunnel. Nevertheless, it appears that it was only after a conservative reappraisal of the potential benefits in March 1913 that the C.P.R. decided to proceed with the investigation of tunnel alignments.

c) <u>The Sullivan Tunnel</u>

Sullivan had already suggested certain modifications to Busteed's proposal in October 1912, and these modifications were incorporated into an alternative scheme, for which a detailed cost estimate was prepared in December 1912. The profile of Sullivan's location is traced in figure 2. The location of the tunnel approaches did not differ significantly from that proposed by Busteed, and Sullivan's proposal has therefore not been indicated separately on map (III). It differed from the proposal of Busteed only in the location of the tunnel. Sullivan did not share Busteed's view of the gravity of the water problems which might be experienced at the west portal:

> I think...that we will get into solid rock within 1,000 feet of where the tunnel starts and instead of using 1.6% grade in the tunnel, by moving the summit nearly a mile further west and lowering the grade some 10 or 12 feet, we can get a grade of 1.25% through the tunnel.[61]

Furthermore, at the west portal,

> By building a fill in the valley of the Illecillewaet, 40 or 50 feet high, we make room for the waste from the tunnel and put the line out in the valley where it will be free from snow troubles.

Thus, Sullivan's location preserved the benefit of eliminating the Loops, without incurring the penalty of increased vulnerability to snowslides on the western approach.

On the eastern approach, Sullivan had advised Busteed to turn west at Bear Creek in order to avoid bridging the Creek and continuing up the Beaver Valley. Sullivan had been prepared to accept more expensive bridging north of Bear Creek, an increase in the amount of 2.2% gradient and "some trouble from snow slides" in order to obtain such an alignment, apparently believing that the costs imposed by these latter features would be less than the costs of the former. However, it does not appear that such a location had been obtained by December 1912, for the detailed cost-estimate submitted in that month contained provision for a viaduct at Bear Creek costing $175,000, only $25,000 less than Sullivan had estimated the previous October.[62] The estimate also contained provision for a 28,000-feet, double-tracked tunnel, some 700 feet longer than that proposed by Busteed.

Sullivan's proposal would not have effected significantly greater operating economies than that of Busteed, for the savings in rise and fall and in the length of the pusher gradients would have been approximately the same. Moreover, the detailed estimate for Sullivan's proposal included the cost of work between Beavermouth and Six Mile Creek, and is not therefore directly comparable with the other cost estimates, which covered expenditures west of Six Mile Creek only. No cost-benefit analysis of Sullivan's proposal has therefore been conducted. The estimated cost of the entire revision between Beavermouth and Mile 89, at the west portal, was $7,466,121.62. Within this total, the cost of the tunnel which Sullivan proposed was $4,355,000, compared with the estimated cost of $4,095,000 for the tunnel which Busteed had proposed.

7.4 Criteria And Objectives

No clear statement has survived of the criteria according to which the available alternatives for double-tracking through the Selkirk Mountains were evaluated. Neither is there any explicit statement of the objectives which the C.P.R. sought to achieve from its investment. Nevertheless, objectives may be deduced from the attributes of each of the several alternative alignments, and from the major considerations which confronted the C.P.R. in weighing its decision between the alternatives. Moreover, criteria for the selection of the accepted proposal may be deduced from the manner in which these attributes of the alternative alignments were traded off against each other.

One major consideration appears to have been the obtaining of a one per cent. compensated gradient which would eliminate the pusher gradient through the Selkirks against westbound traffic. Insofar as gradient reductions in favour of westbound traffic were a priority, this may be regarded as an indication of the C.P.R.'s confidence that westbound flows, perhaps especially that of grain, would predominate in the future. Alternatively, it may be regarded as an indication of the C.P.R.'s determination to meet head-on the competitive threats posed by the Grand Trunk Pacific and the Canadian Northern, both of which would have ruling gradients not exceeding one per cent. against westbound traffic.

A second consideration may have been that the new alignment should eliminate the Loops on the west slope. Elimination of the Loops would save almost a mile of bridging -- all of which was built on ten-degree angles and at a gradient of 2.2% compensated -- and the maintenance costs of three miles of track. It would also increase line speeds, and hence main-line capacity on the western ascent. Insofar as elimination of the Loops was a consideration, this may be regarded as an indication of the C.P.R.'s continuing concern to facilitate the passage of eastbound shipments through the mountains, concern which had already found expression in the investment in the Spiral Tunnels through the Rockies four years previously.

A third consideration was that the selected gradient-reduction project had to be completed within four years of 1912, for it was forecasted that by this time traffic would have doubled. Insofar as rapid construction was a priority, this may be regarded as an indication of the severity and the imminence of the capacity problem which the C.P.R. was facing in the Selkirks. The gestation period of the project could be no longer than four years, for if it were, the existing facility would be unable to handle the traffic, and both the C.P.R. and Western Canada would bear the cost of the inadequacy.

A fourth consideration, closely related to the third, was that the estimate for the completion time of the project had to be low in risk, for according to its own traffic forecasts, the C.P.R. had no margin for delays in completion. Insofar as low risk was a priority, this may be regarded as an indication of the gravity of the capacity problem which the C.P.R. was facing in Rogers Pass. It was also, however, an indication of the high-risk character of contemporary railway tunnelling, and an indication of the uncertainty which surrounded railway tunnelling in North America. The high risk had been demonstrated by the Lotschberg collapse in 1908, which had delayed completion by over a year. The uncertainty was demonstrated by the fact that in 1900, two years after the commencement of the 12.4-mile Simplon Tunnel in Europe, the largest tunnel on the C.P.R. in the Rockies was 800 feet long, and prior to construction of the

Connaught Tunnel, the longest tunnel in North America was the Hoosac, 4 3/4 miles in length. Whilst the C.P.R. attempted to remedy this uncertainty by dispatching Bury to England in April 1913 to consult with the Great Western Railway Company, which was at that time driving a tunnel beneath the River Severn, the construction of long tunnels at high altitudes would continue to be a high-risk, uncertain venture long after completion of the Connaught Tunnel.

A fifth consideration may have been that the new line had to be at least as safe from snowslides as the existing alignment was. Even if this was a consideration, however, this does not imply that the C.P.R. was actually seeking a <u>greater</u> degree of protection from snowslides than it already enjoyed. Evidence suggests that reduction of the cost of securing the existing degree of protection was not a consideration in the evaluation, although reduction of the cost of securing protection for double the existing volume of traffic may have been a consideration. If it was a consideration, however, it was of secondary importance in the project evaluations. Certainly Kilpatrick, Busteed and Sullivan all noted that their respective proposals afforded safety from snowslides. Nevertheless, this benefit was in each case an incidental characteristic of the respective proposals. The precise alignments of the alternative schemes were each determined primarily by the necessity to obtain gradient improvements. Nowhere were diversions undertaken, or gradients inserted, merely for the purpose of avoiding snowslides. Moreover, when the C.P.R. weighed these five considerations in the evaluation procedure, there is explicit evidence that the

Company was prepared to sacrifice freedom from snowslides in order to secure low-risk, rapid implementation of gradient revision.

In the evaluation of the alternative proposals before the C.P.R. in 1912, it was not possible to give equal weight to these five considerations. Trade-offs had to be made, and from the manner in which these trade-offs were handled, it is possible to discern an ordering of the C.P.R.'s objectives in investing in Rogers Pass.

Elimination of the Loops appears to have been a principal objective, for it was incorporated into each of the alternative realignment schemes. It may be deduced that the expense of elimination was expected to be justified by the subsequent cost-savings under each proposal. Busteed's scheme may have eliminated the Loops only at the expense of increased vulnerability to snowslides, but the C.P.R. was relieved from the necessity of trading off safety from snowslides against the Loop elimination by Sullivan's proposal to provide a fill in the Illecillewaet Valley which threw the new line clear of the slide-paths. These two considerations were therefore reconciled, and in both the realignment which was contracted and the realignment which was constructed, the Loops were eliminated and the Illecillewaet Valley at the west portal filled. The fill in the Valley appears to have been the only concession made to the consideration of safety from snowslides on any of the proposed alternative routes.

The objective of eliminating the westbound pusher gradient as far as possible clearly favoured the Kilpatrick alternative, which secured the greatest reduction in the length of the 2.2% ascent. Nevertheless, the desire for rapid completion and low risk militated against the Kilpatrick scheme, and favoured the proposals of Busteed and Sullivan. Kilpatrick's project was expected to have the longest gestation period, because it entailed the longest tunnel, and it was perceived to involve the highest degree of risk, because of the length and the physical location of the tunnel within the mountains. In turn, however, adoption of the Sullivan and Busteed proposals compelled the C.P.R. to accept a lesser reduction in the length of the westbound pusher gradient.

The C.P.R. had therefore to make a trade-off decision, and this decision involved the familiar trade-off between construction costs and operating costs. The construction costs of the Busteed and Sullivan proposals would be less than the construction costs of the Kilpatrick proposal, first because the length of tunnelling was less in the former proposals than in the latter proposal, and tunnelling was by far the most expensive component of the realignment schemes; and second because the risk of protracted gestation was less in the former proposals than in the latter proposal. Protracted gestation would not only cause escalation of construction costs, but also, in the short run, of operating costs, given that the C.P.R. expected the existing single line to have become inadequate for economical operation within four years. Once the realignment was operational, however, the level of subsequent operating costs over the alignments of Busteed and Sullivan would be higher than the level of operating costs over

Kilpatrick's alignment, for the length of pusher gradient would be greater by 3.7 miles over the former alternatives than over the latter.

The fact that the C.P.R. preferred the proposals of Busteed and Sullivan to that of Kilpatrick suggests that the Company believed the cost of obtaining the 3.7-mile reduction in the pusher gradient to be greater than the cost of subsequently operating over it. At the margin, therefore, the Company attached a higher priority to rapid construction and low risk than it did to the reduction by 3.7 miles of the pusher gradient against westbound traffic.

When these five considerations were weighed against each other, the Busteed and Sullivan proposals dominated that of Kilpatrick, which was accordingly rejected. It does not appear, however, that these five considerations influenced the decision between the two remaining alternatives, however. Both alignments eliminated the Loops and offered comparable freedom from snowslides and comparable reductions in the length of pusher gradients. Reduction of the gradient within the tunnel from 1.6% to 1.25% would not affect the rapidity of construction nor the risk of timely completion. Pusher service would still be required through the tunnel, for the 1.25% gradient would still exceed the 1% ruling gradient which was being sought elsewhere in the mountains. However, a 1.25% gradient, if obtainable, would permit greater line speeds through the tunnel, and hence increase line capacity. It would also reduce the risk of stalling: Busteed's 1.6% uncompensated gradient within the tunnel was equivalent in steepness to the 2.2% compensated gradient on the eastern approach, and left no margin for error should rail conditions within the tunnel be exceptionally greasy.

Sullivan was still anxious to obtain a location within Bear Creek, rather than crossing the Creek and continuing up the Beaver Valley. This anxiety may have once again reflected concern for rapidity of construction and low risk. The C.P.R.'s existing main line already followed Bear Creek, although at a much higher elevation than the C.P.R. was seeking for its double track, whilst the nature of construction work south of Bear Creek, and as far as "the first large creek that comes from the west" may have been less well known. Alternatively, perhaps because an alignment up Bear Creek entailed less risk in construction than an alignment up Beaver Creek, or because it entailed more bridging, which, at least during the period of construction of the original line, had represented a rapid solution to the problem of mountain railway location, a route within Bear Creek may have offered a shorter gestation period than Sullivan's initial proposal. Location within Bear Creek would not affect the elimination of the Loops. It might, however, entail subordination of both pusher-gradient-reduction and safety from snowslides, as Sullivan explicitly recognised:

> This line may make the bridging more expensive and would increase the amount of 2.2% grade and might get us into some trouble from snow slides, but these, however, are details that we can decide on later.[63]

Sullivan was clearly prepared to trade off these attributes in return for a location up Bear Creek, and when such a location was discovered, the search for alternatives ended. The C.P.R. could now make the trade-off decision which it most preferred.

From this analysis, it may be deduced that the ordering of the considerations which the C.P.R. weighed in its evaluation of alternative tunnelling schemes through Rogers Pass was thus: rapidity of construction and low risk -- two considerations which were not mutually exclusive; elimination of the Loops; reduction of the pusher gradient against westbound traffic; and safety from snowslides. Moreover, this ordering of the considerations may be interpreted as a reflection of the ordering of objectives which the C.P.R. was seeking in its gradient-revision programme through the Selkirks. After the rejection of Kilpatrick's proposal, the generation of alternative schemes for gradient improvement in Rogers Pass was a process of adaptation, drawing upon preceding schemes and incorporating modifications to the details of the several projects. The extent to which these modifications were guided by the application of the foregoing considerations, and the extent to which those considerations assisted the C.P.R. in fulfilling the objectives which it sought from gradient revision through Rogers Pass, are revealed by analysis of the realignment proposal for which the C.P.R. let contracts in 1913, and by analysis of the realignment which was actually implemented in December 1916.

FOOTNOTES

[1] Bury, Memorandum for the President, July 23, 1915. PIC CPCA.

[2] Ibid.

[3] Sullivan to Bury, October 22, 1912, op. cit.

[4] Bury to Shaughnessy, January 3, 1913, op. cit.

[5] C.P.R. Co., Annual Report, 1897, pp. 5-6.

[6] Sullivan to Bury, October 22, 1912, op. cit.

[7] Sullivan, Memorandum for the President, June 17, 1913. PIC CPCA.

[8] Canadian Railway And Marine World, July 1906, p. 393; Province, August 26, 1907, p. 1; August 28, 1907, p. 17; September 30, 1907, p. 15; Victoria Daily Times, January 22, 1907, p. 1.

[9] Moberly MSS, p. D1037.

[10] Canadian Railway And Marine World, December 1907, p. 887.

[11] Province, July 9, 1909, p. 14.

[12] Vancouver Sun, March 7, 1912, p. 1.

[13] Province, April 2, 1912, p. 1.

[14] Bury, Memorandum for the President, July 23, 1915, op. cit.

[15] Bury to Shaughnessy, January 3, 1913, op. cit.

[16] Sullivan to Bury, October 22, 1912, op. cit.

[17] "Copy of Memoranda sent to R. Marpole, etc.," May 1902. Moberly MSS, pp. D966-7.

[18] Ibid., p. D968. The current Beaver Tunnel Project envisages the routeing of heavily loaded trains via the new single-track tunnel, with the existing line through the Connaught Tunnel being reserved for lighter trains.

[19] Ibid.

[20] Moberly to the Royal Commission on Transportation, September 27, 1905. Ibid., p. D1004.

[21] Ibid., p. D968.

[22] Ibid., pp. D1003-1004.

[23] Moberly to George Webster, March 23, 1904. Ibid., p. E1126.

[24] Moberly to Charles M. Hays, August 25, 1904. Ibid., pp. E1130-33.

[25] Ibid., p. D946.

[26] Anonymous letter to Schwitzer, op. cit.

[27] See chapter 5, note (44).

[28] Revelstoke Mail-Herald, June 11, 1910, p. 1.

[29] Bury, Memorandum for the President, July 23, 1915, op. cit.

[30] Province, April 2, 1912, p. 1.

[31] Sullivan to Bury, March 13, 1913, PIC CPCA.

[32] Bury to Shaughnessy, January 3, 1913, op. cit.

[33] Bury to Shaughnessy, June 16, 1913, PIC CPCA.

[34] Sullivan to Bury, October 22, 1912, op. cit.

[35] Sullivan to Bury, March 13, 1913, op. cit.

[36] Bogue estimated a total annual saving by tunnelling of $370,000. The precise composition of this estimate is not known. If Bogue's estimate for fuel savings ($142,974) is added to Sullivan's estimate for traincrew wages and repairs to equipment ($14,016), $156,990 of the $370,000 is accounted for, leaving an unknown allocation for snowshed maintenance and other operating costs.

[37] For more detailed treatment of the electrification proposals which were associated with the tunnelling projects, see chapter 8.

[38] Bury to Shaughnessy, April 22, 1913, PIC CPCA.

[39] Bury, Memo for the President, August 10, 1915, PIC CPCA.

[40] $87,500 per mile if the cost of double-tracking the bridges is included in the calculation. The contract price of $109,320 per mile of single track included the cost of double-tracking the bridges.

[41] Bury to Shaughnessy, June 17, 1913, PIC CPCA.

[42] See note (36).

[43] Bury to Shaughnessy, June 17, 1913, op. cit.

[44] Bury to Shaughnessy, June 16, 1913, PIC CPCA.

[45] Bury to Shaughnessy, June 17, 1913, PIC CPCA.

[46] Kilpatrick to Busteed, May 8, 1912, Kilpatrick MSS, Vancouver.

[47] Sullivan to Bury, October 22, 1912, op. cit.

[48] Sullivan to Bury, March 13, 1913, op. cit.

[49] See chapter 6, note (273).

[50] Kilpatrick to Busteed, May 8, 1912, op. cit. It does seem possible that the C.P.R. misunderstood Kilpatrick's proposal. A 1915 map contrasting alternative alignments through Rogers Pass marks four routes boldly. These are the existing route, the route for which contracts were let, the route which was actually constructed, and an alignment giving a steady 1.6% gradient from Six-Mile Creek to the mouth of the Connaught Tunnel. Two other alternatives are sketched feintly on the map. The first crosses Bear Creek, continues south down the east side of Mount Macdonald, and turns west at the first large creek flowing from the west, Avalanche Creek. This must have been Busteed's original proposal. See below, pp. 317-323. The second continues for almost another two miles south of Avalanche Creek before turning west through Mount Macdonald, and is shown rejoining the main line at the opposite side of the mountain near Cambie. This line quite clearly passes beneath Glacier Creek, which was fed directly from the Illecillewaet Glacier. It is possible, therefore, that this line is intended to represent the route of Kilpatrick's proposal, as interpreted by Sullivan. Kilpatrick, however, stated quite clearly that his alignment should continue beyond Bear Creek only "for about one and a half [miles] or possibly a little more to the mouth of the proposed tunnel." It does not appear that he intended to proceed even as far as "the first large creek that comes from the west," let alone continue for another two miles beyond. C.P.R. Co., "Rogers Pass Tunnel Map Shewing Old and New Lines, Winnipeg, September 8th, 1915." CP Rail, Engineering Department Maps, No. 8498-14.

[51] Bury, Memo for the President, August 10, 1915, op. cit.

[52] See the C.P.R. tender to contractors, April 8, 1913, quoted in Engineering News, Vol. 75, No. 8, February 24, 1916, p. 382.

[53] Bury, Memo for the President, August 10, 1915, op. cit.

[54] The Company's Annual Reports record expenditures on the Connaught Tunnel of $1,251,732.47 in 1915-16; $64,205.08 for the half-year to December 31, 1916, during which month the new alignment opened; and $128,923.83 in 1917. These expenditures, however, may exclude the cost of other work related to the Rogers Pass realignment, for, added to those which are known to have been made between 1913 and 1915, they yield a total cost for the project of only $4,249,146.91. This total seems too low, for in August 1915, with completion barely sixteen months away, and with the savings of the major modifications to the project

incorporated in the estimate, Bury predicted that the total cost would be $6,041,719. Bury, Memo for the President, August 10, 1915, op. cit. The estimated expenditure for the calendar year 1915 was $2,135,000. J. M. R. Fairbairn, Memorandum for Mr. Bury, November 10, 1915, CPCA, File 97850. Therefore, the estimate of $2,500,000 for the expenditure in the fiscal year 1915-16 may not be inaccurate.

[55] Bury, Memo for the President, August 10, 1915, op. cit.

[56] Cornell Civil Engineer, op. cit., pp. 80-81.

[57] Ibid., p. 84. See also table 24.

[58] This location has been traced from, "C.P.R. Co., Condensed Profile Shewing Proposed Grade Change for Double Track Between Mile 69 & Mile 91.6 Mountain Subdivision," CP Rail, Engineering Department Maps, No. 8498-13.

[59] Sullivan to Bury, October 22, 1912, op. cit.

[60] Sullivan to Bury, March 13, 1913, op. cit.

[61] Sullivan to Bury, October 22, 1912, op. cit.

[62] C.P.R. Co., "Requisition for Appropriation, Mile 63 to Mile 89, Mountain Sub-Division, Kamloops, December 27th, 1912," op. cit.

[63] Sullivan to Bury, October 22, 1912, op. cit.

CHAPTER 8

THE CONNAUGHT TUNNEL

The C.P.R. had generated and evaluated alternative routes for a second main line across the Selkirks. The Company had decided to abandon its existing route over the summit of the range, and to breach the mountains at a lower elevation, by means of a tunnel beneath Rogers Pass. In the summer of 1913, contracts were let, and construction commenced. The project for which contracts were let embodied the trade-off which the C.P.R. most preferred to make between construction costs and operating costs in constructing a new main line through the Selkirks. The first section of this chapter analyses the C.P.R.'s own evaluation of the project. The analysis reveals the outcome which the C.P.R. desired from the trade-off decision, and the criteria upon which the trade-off decision was based.

The C.P.R.'s evaluation, however, considered only the cost savings of the project. An alternative technique of evaluation, that of social cost-benefit analysis, is therefore applied in the second section of the chapter, and the results of the application of this technique are contrasted with the results which the C.P.R. obtained from the cost-savings approach. The introduction of this technique into the analysis is not in any way intended as an indictment of the C.P.R.'s own evaluation. It is intended merely to highlight aspects of the decision which might be obscured if the emphasis were to be placed solely upon the cost savings of the project. Moreover, the application of cost-benefit techniques will permit integration into the analysis of data which, although available and relevant to the appraisal, would otherwise remain outside the evaluation.

The realignment project was modified during implementation. In the third section of this chapter, the circumstances impelling modification, the nature of the specific modifications and the impact of these modifications upon the economics of the revised alignment are analysed. Evaluation of the modified project reveals the actual outcome of the trade-off decision which the C.P.R. made in Rogers Pass, and reveals the legacy which the realignment bequeathed to future generations in Rogers Pass.

8.1 The Alignment As Contracted

The proposal for which contracts were let is traced on map (III), and its profile is shown in figure 2. From Six Mile Creek, the main line was to be swung into the centre of the Beaver Valley, as both Kilpatrick and Busteed had recommended. Instead of crossing Bear Creek, however, the line turned westwards out of the Beaver Valley, as Sullivan had recommended, and followed the valley of Bear Creek for two miles to the east portal of the tunnel. At the opposite side of the mountain, the effect of this change was to move the west portal about a mile further east. This in turn involved diversion of the Illecillewaet River for about a mile in order that the line could still be located in the centre of the valley, as Sullivan had proposed, "to avoid danger from snow slides and the necessity for protection therefrom."[1]

The contracted alignment followed Busteed's 1% approach for

5 1/2 miles up the eastern slope. After a mile of easement to 0.75%, upon which pusher locomotives would be attached, the ascent would continue at 2.2% for 5 1/2 miles to the east portal. The tunnel would be 5.2 miles long,[2] with a gradient against westbound traffic of 0.95% for its entire length, except for a short section at the west portal which was graded against eastbound traffic in order to facilitate drainage. Outside the west portal, 3/4 miles of 0.5% gradient against eastbound traffic would permit the detachment of pusher locomotives in preparation for their return.

Located at a lower elevation than the existing main line, the contracted alignment would permit elimination of the massive steel bridges at Mountain Creek, 586 feet long; Surprise Creek, 290 feet long; and Stoney Creek, 336 feet long. All the bridges between Six Mile Creek and the second crossing of the Illecillewaet -- there had been 119 in 1893 -- would be replaced with structures no larger than "culverts," except for "two 70-ft. and one 60-ft. deck girder spans, and one steel viaduct 500 ft. long and 125 ft. high."[3] the alignment would lower the Selkirk summit from 4,342 feet to 3,794 feet, a saving in rise and fall of 548 feet.[4] It would save 1,222 degrees of curvature in the eastbound direction, and 1,225 degrees in the westbound direction. While the maximum angle of curvature would still be ten degrees, the number of such curves would be reduced from "a large number" to three,[5] and the ten-degree reverse-curves on the Loops would all be eliminated. The length of the westbound ascent would actually be increased by 0.12 miles, but the length of the eastbound approach would be reduced by 4.54 miles, saving a total of 4.42 miles in the length of the main line.[6]

The proposal would have concentrated the pusher gradients into a short section on either side of the tunnel, over which it was anticipated that trains would be operated by electric traction. The length of 2.2% gradient on the west slope would be reduced from 25.3 miles to 19.4 miles. On the east slope, the length of 2.2% gradient would be reduced far more drastically, from 20.8 miles to 5.5 miles, although, since it was intended that westbound trains would be pushed through the tunnel, the actual reduction in pusher mileage was less pronounced, the length of pusher gradient being reduced from 20.8 miles to 11.2 miles.

The contractual alignment was thus far less favourable to westbound traffic than any of the proposals which the C.P.R. had previously rejected. It saved 15.5 miles of pusher gradient, of which 9.6 miles were on the east slope and 5.9 miles on the west slope. The reduction in train resistance which was effected by the proposal was actually greater for eastbound traffic than for westbound, 664.8 feet being saved on the west slope against only 595 feet on the east slope.

The associated criteria of rapid construction and low risk, which may have dictated the decision to seek a location through Bear Creek rather than around the east side of Mount MacDonald, certainly influenced both the selection of a tunnelling technique and the letting of a tunnelling contract. As early as October 1912, Sullivan had recommended

> ...that the contractor who will guarantee to complete the work in the shortest period be given the contract, providing his figures be at all reasonable...[7]

Sullivan, therefore, was prepared to accept a premium on the cost of the project in order to ensure both speedy construction and low risk of the project's being incomplete by the time that the tunnel was required. He himself admired the speed of the European tunnelling techniques. The monthly record for progress in a single heading had been set in the Simplon in 1904, at 685 feet. In contrast, the greatest American progress, achieved in June 1908, was only 333 feet for a single heading. Sullivan suggested that, "If we advertise at once it would give European contractors an opportunity of visiting the work and putting in tenders." However, as he subsequently realised,

> ...the European method of driving a small lower heading and stoping out the remainder of the tunnel, is too expensive on this side [of the Atlantic] on account of the difference in the cost of labor.[8]

Clearly, Sullivan did not believe that the benefits of rapid construction and low risk of untimely completion justified the premium costs implicit in the adoption of the European technique.

Lord Shaughnessy "was of the opinion...that we would possibly have to adhere to the American practice, namely, doing what mucking can possibly be done with steam shovels,"[9] thus minimising manpower requirements. Sullivan, however, with his assistant, A. C. Dennis, contrived to devise a method which combined the advantages in speed of the European technique with the advantages in manpower requirements of the American technique. The resulting tunnelling method involved construction of a small "pioneer" heading, driven parallel to but some 50 feet apart from the main bore, from which cross-cuts were driven at intervals to the centre-line of the main tunnel, thus permitting work upon the main bore to be pursued simultaneously from several faces.

This tunnelling technique was hitherto untried on the North American continent. Its adoption, therefore, appears to represent a risk-seeking decision on the part of C.P.R. management. Nevertheless, as Sullivan observed, "When all is said and done it is only a modification of the European practice, only that they drive the pioneer tunnel within the section of the main tunnel."[10] Moreover, the C.P.R.'s conduct of the bidding for the project demonstrated preparedness to pay a considerable premium in order to reduce the risk and to ensure rapid completion.

Tenders were invited in the following terms:

> The necessity for this tunnel is so great and the expenditure so large that it would be worth considerable money to this company to have the tunnel completed as soon as possible. Therefore, everything else being equal, the party who will guarantee completion in the shortest time will be the party who will receive the work.[11]

The C.P.R. valued the advantage of rapid completion at $750 per day, which was

> ...the amount per day...to be paid as a bonus for time saved over the agreed time, the same amount to be exacted as a penalty for the time lost, being the time between the fixed day of completion and the actual date of completion.[12]

In the first round of bidding, conducted between April 8 and April 22, 1913, Foley Bros., Welch & Stewart offered completion within 42 months, based upon the tunnelling technique recommended by Sullivan and Dennis, for a cost of $5,581,674.50.[13] The nearest bids which were competitive in cost were those of Grant Smith & Co., & McDonnell ($5,819,974.90) and

McArthur Bros. ($5,922,041.10). However, these contractors, employing conventional techniques, required 58 months and 78 months respectively for completion -- gestation periods of unacceptable length to the C.P.R. The nearest bid which was competitive in time was that of M. P. & J. T. Davis, who offered completion within 46 months, but only at a cost of $9,242,736.50.

All of these bids proved disappointingly high to the C.P.R., principally because the contractors perceived the project to be high in risk, and "made their prices unduly high to provide against unexpected contingencies."[14] Sullivan had estimated the cost of boring the tunnel at $150 per lineal foot, and the lowest bid, that of Foley Bros., had stipulated $152.50, making the total cost of the realignment project $8,500,000, against an estimated cost of $8,000,000 for double-tracking the existing line with concrete snowsheds. The C.P.R. was still prepared to proceed with realignment, calculating that "we will be able to reduce the grades and save three miles of line, besides avoiding the snow slides on the East and West slopes, for $500,000 more."[15] Nevertheless, a second round of bidding was called.

In the second round, the C.P.R. sought to lower the cost to itself of tunnelling, without removing the incentive to the contractors for rapid completion. These dual objectives could only be reconciled by the C.P.R.'s agreeing to assume an increased share of the total risk associated with the project, and reducing the share of the risk borne by the contractors.[16] This was achieved by inviting bids based on "cost-plus" a certain percentage, "with penalty and bonus clauses," in which the contractors would receive or forfeit a certain proportion of their percentage, according to their actual performance against the contracted time and cost.[17] The second round of bidding was completed by April 29, 1913, and the bids are summarised in table 26.

As a result of this bidding, Foley Bros., Welch & Stewart were awarded the contract, for the following reasons:

> ...first, that they are the lowest bidder; second, that they have a considerable amount of their heavy plant now in Canada and will save us considerable in freight and duty; third, they have had vast experience in the West and I think are better qualified to handle the Western labor than Messrs. Rhinehart & Dennis, who have had most of their experience in the south-east.[18]

Foley Bros. agreed to reduce their percentage from 12 1/2 to 10, and the contract was approved on May 5[19] and finalised by July 1, 1913.[20]

TABLE 26

COMPARISON OF PERCENTAGE TENDERS OF COST PER FOOT OF ROCK SECTION, ROGERS PASS TUNNEL.

Contractor	Estimated Cost ($), at 30 ft. per day			Estimated Cost ($), at 20 ft. per day		
	Estimate per foot	Contractor's %	Total cost per foot	Estimate per foot	Contractor's %	Total cost per foot
Rhinehart & Denis	139.40	15	160.31	118.00	15	135.70
Grant Smith & Co. and McDonnell	153.66	15	176.71	126.70	15	145.70
Foley Bros. Welch & Stewart	131.55	12.5	148.00	--	--	--

Source:- Bury to Shaughnessy, April 29, 1913, PIC CPCA.

The bidding procedure itself had been conducted under fierce time pressure. After the second round, Bury had urged Shaughnessy,

> ...you of course understand that this work must be started by June first, or we will be apt to lose another year in the time of completing the tunnel, which, as you know, is required so badly.[21]

Although construction did not actually commence until July,[22] the C.P.R. had secured the contract which promised the most rapid completion, within forty-two months of June 1913. It had paid the lowest obtainable premium in order to secure rapid completion, amounting to 8% over the Rhinehart bid, in return for a saving of eighteen months. It was now assumed that one-third of the tunnel, or 8,400 feet, would require concrete lining, instead of the one-seventh which had been assumed in April. The total contracted cost of the project, including lining but excluding electrification, was $7,970,930.[23]

Table 27 presents an evaluation of the tunnel for which the contracts had been let. It has been assumed that the costs would have been the same as they actually were until the summer of 1915, after which time the project was modified. It has been further assumed that in the third year, the C.P.R. spent the maximum amount which it was prepared to sanction for a single year, $2,500,000, and that the balance of the cost estimate was expended in the final year. Although this final year expenditure exceeds the C.P.R.'s stipulated maximum annual appropriation, the excess is conceptually permissible if it is interpreted as the premium which it was necessary for the C.P.R. to pay in order to ensure completion of the tunnel within the fourth year.

TABLE 27

COST-BENEFIT ANALYSIS OF CONNAUGHT TUNNEL ALIGNMENT, AS CONTRACTED FOR, JUNE 1913. (r = 4%)

Traffic Forecast	Tons
Actual Eastbound, 1912-13 Average:-	
1,342 1/2 passenger trains, at 443 tons	594,727.5
2,322 passenger locomotives, at 175 tons	406,350
1,738 1/2 freight trains, at 950 tons	1,651,575
3,477 freight locomotives, at 181 tons	629,237
Total	3,281,889.5
Actual Westbound, 1912-13 Average:-	
1,342 1/2 passenger trains, at 443 tons	594,727.5
2,322 passenger locomotives, at 175 tons	406,350
1,738 1/2 freight trains, at 898 tons	1,561,173
3,477 freight locomotives, at 181 tons	629,237
Total	3,191,487.5
Total traffic, 1912-13 average:-	6,473,377
Assuming doubling by 1917, forecast total =	12,946,754

Undiscounted Cost Of Tunnel Alignment	$
Tunnel: 25,900 ft., at $189.65 per ft.	4,919,877
Tunnel trackwork	165,000
Approaches: 26.4 miles, at $109,320 per mile	2,886,053
Total	7,970,930

Discounted Cost Of Tunnel Alignment			
Year 1:	1,099,906.38	x .96154	1,057,604
" 2:	1,704,379.15	x .92456	1,575,800.80
" 3:	2,500,000	x .889	2,222,500
" 4:	2,666,645	x .8548	2,279,448.10
Total discounted cost:-			7,135,352.90

Benefits Of Tunnel Alignment	Eastbound	Westbound
Saving in rise and fall	547.8 ft.	547.8 ft.
" " friction resistance	68.1 "	-1.8 "
" " curve resistance	48.9 "	49.0 "
Total	664.8 ft.	595.0 ft.

Fuel saving:-	
Eastbound: 3,281,890 x 664.8 =	2,181,800,472 ft. tons
Westbound: 3,191,488 x 595.0 =	1,898,935,360 ft. tons
Total	4,080,735,832 ft. tons

TABLE 27 (Cont.)

		$
4,080,735,832 ft. tons/1,000 =		
4,080,736 h.p. hrs. x 5lbs. coal per h.p. hr. =		
10,202 tons coal x $4.60 per ton =		46,928.46
Wage and maintenance saving:-		
Old line:		
6,162 trains for 23.10 miles =	142,342.2 train miles	
Contracted line:		
6,162 trains for 18.68 miles =	115,106.2 train miles	
Train miles saved	27,236	
27,236 train miles, at 22c. per train mile =		5,991.92
Old line:		
5,437 pushers for 23.1 miles =	125,594.7 pusher miles	
Contracted line:		
5,437 pushers for 13.0 miles =	70,681.0 pusher miles	
Pusher miles saved	54,913.7	
54,913.7 pusher miles, at 25c. per pusher mile =		13,728.40
Extra cost maintenance of way:		
4.42 miles, at $200 per mile +		
27,236 train miles, at 20c. per train mile =		6,331.20
Extra cost maintenance of way, on account of extra number of degrees of curvature, assuming that 400° of curvature per mile would increase rate of 20c. per train mile for maintenance of way by 30%:		
6,162 trains x 2,447° x 1/40c. =		3,769.60
Extra cost maintenance of equipment:		
27,236 train miles at 21c. per train mile =		5,719.56
Extra cost maintenance of equipment, on account of extra number of degrees of curvature, assuming that 400° of curvature per mile would increase rate of 21c. per train mile by 40%:		
6,162 trains x 2,447° x 21/1000c. =		3,166.47
Total annual operating saving (fuel, wage and maintenance)		85,635.61
Assuming traffic doubles, annual operating saving:		
85,635.61 x 2 = $171,271.22		
Annual operating saving realised after Year 4 for perpetuity		
171,271.22/4% = $4,281,780.50		
Discounted back to Year 0:		
4,281,780.50 x .82193 =		3,519,323.80
Snowshed saving:-		
85,000 per year realised after Year 4 for perpetuity:		
85,000/4% = $2,125,000		
Discounted back to Year 0:		
2,125,000 x .82193 =		1,746,601.30
Total discounted benefit:-		5,265,925.10

TABLE 27 (Cont.)

Net present value of contracted alignment:- 5,265,925.10 - 7,135,352.90 =	-$1,869,427.80

Sources:- <u>Cornell Civil Engineer,</u> December 1914, pp. 80-81. Bury, Memo for the President, August 10, 1915, PIC CPCA.

Data for the benefits of the project are those which the C.P.R. released to the public in 1914 as vindication for the project.[24] These data address only the direct operating cost savings which were anticipated from the project, and ignore the benefits of saved congestion costs and opportunity costs, and of contribution from generated traffic. The magnitude of the cost savings is alone cited as justification for undertaking the project, without reference to the costs which had to be incurred in order to obtain those savings. Furthermore, the C.P.R.'s evaluation assumes that if the volume of traffic doubles, the operating savings derived from the tunnel line will exactly double also. Thus:

> In arriving at the above figures no account is taken of whether line is single or double track and for comparative figures it was assumed that methods of operation would be the same.[25]

this was intended to be a simplifying assumption, but its effect was in fact to distort rather than to clarify the analysis.

The guiding principle of the cost-savings approach, the purpose to which it was directed and the conclusion to which it led, are neatly summarised in the Chief Engineer's ex post evaluation:

> ...the problem was to find out if the cost of operating and maintaining the tunnel line, taking into account the extra costs of operating on account of having a short section of electric operation and extra cost of maintaining tracks in the tunnel, plus the interest on the cost of building the new double track line including the cost of electrifying the tunnel would be less than the cost of operating and maintaining a double track on the present location plus the interest on the cost of building the second track. The figures would not have been very decisive one way or the other were it not for the fact that there is now 4 1/2 miles of wooden snow sheds on the present location which will all be done away with on the new location...(W)ith a saving of about $125,000 per year in maintenance and renewals of snow

> sheds and a calculated saving in operation and maintenance of $171,271.22 on a traffic that surely will be reached in the near future, there was no doubt as to the proper course to pursue.[26]

It was probably this statement which led Lavallee to the conclusion, "that the savings in snowshed maintenance alone would tip the scales in favour of a five-mile, double-tracked tunnel."[27] However, if the snowshed savings were estimated at $85,000 per annum, they would comprise only one-third of the total annual benefits of the project, which were estimated at $256,271.22. Even if snowshed savings were estimated at $125,000 per annum, increasing the estimate of total annual benefits to $296,271.22, they would still comprise barely four-tenths of the total annual savings. Moreover, table 27 shows that the snowshed savings were not alone decisive: when the total savings which the C.P.R. anticipated, in both snowshed and operating costs, are set against the costs which the C.P.R. had contracted, the net present value of the project is -$1,869,427.80. Even if traffic had been forecast to triple, at these rates of cost savings the net present value of the project would still have been negative, by $109,765.88. The result was not sensitive to assumptions concerning fuel costs. With coal consumption of 5 lbs. per horse-power hour at $4 per ton, the net present value would have been -$2,120,957.50, and even with consumption of 7 lbs. per horse-power hour at $4.68 per ton, the net present value would still have been -$1,051,032.30. Neither was the result sensitive to assumptions concerning the magnitude of snowshed savings: even if these had reached $125,000 per annum, the net present value would still have been -$1,047,497.80. The result may have been somewhat sensitive to interest-rate changes, although the cost of capital would have had to have been an entire percentage point lower before the project could have generated a positive net present value, and this by a margin of only $37,186.04.

When Sullivan had forecast operating savings of $226,000 per annum on a project with an estimated undiscounted cost of $5,495,000, the C.P.R. had equivocated and commissioned an investigation by Bogue. Eight months later, the Company signed a contract for a tunnel costing $7,970,930, and claimed that the investment was justified by annual cost savings of $256,271.22. The analysis in this section reveals that these latter cost savings were not alone sufficient to warrant the undertaking of the project. Even though the C.P.R. did not itself employ a net present value approach in its evaluation, the fact that the project was still undertaken despite its bearing a demonstrably negative net present value should trigger an awareness of serious omissions from the ex post release. The following section will seek to rectify these omissions, and to explain why the C.P.R. decided to construct the Connaught Tunnel even though the magnitude of the cost savings which it anticipated did not alone justify the project.

8.2 A "Social Cost-Benefit Analysis" Of The Contracted Alignment

Although the C.P.R. claimed in December 1914 that the benefits of the project would be $256,271.22 annually, and that these benefits were sufficient to justify the project, it appears that the Company had in fact based the decision to proceed with the tunnel upon alternative, and much more favourable, estimates of savings in operating costs. The actual magnitude of the estimates is known, and in this section it will be analysed in order to determine whether or not it did indeed justify the investment. The precise composition of the estimate is not known, however, and later in this section an attempt will be made to reconstruct the estimate by suggesting and quantifying several plausible components.

In March 1913, Sullivan reported that Bogue's estimate of the potential savings was $370,000 per annum.[28] Benefits of this magnitude, received in perpetuity once the tunnel had opened in the fifth year, and discounted accordingly, would have warranted the investment of $7,602,852.50. Since the alignment for which the C.P.R. let contracts required a discounted investment of $7,135,352.90, the project would have boasted a positive net present value of $467,499.50. On the basis of this estimate of benefits, therefore, the investment was justified.

In June 1913, however, Bury recorded that Bogue's report contained an estimate for the benefits of the revised alignment of $462,821 per annum.[29] Capitalising these benefits at 4%, the C.P.R. would have been justified in investing $11,570,525 in the realignment. It must have been this estimate of the potential benefits, rather than Sullivan's more conservative estimate, to which Bury was referring when he explained in retrospect the decision to drive the tunnel. In 1926, he recalled that

> ...we could afford to spend $12,000,000 and some hundreds of thousands of dollars on the project, leaving out the question of safety which, of course, could not be calculated.[30]

Benefits of $462,821 per annum would, after discounting, yield a positive net present value of $2,374,808.70, and again would clearly vindicate the decision to tunnel.

Bogue's report, which investigated in detail the economics of double-tracking along the entire main line through the mountains, has unfortunately not survived. However, the discrepancy between Bogue's estimate of the savings and the estimate released by the C.P.R. _ex post_ the decision to tunnel is clearly large and crucial, for Bogue's estimate justified the decision, while the C.P.R.'s _ex post_ estimate did not.

The C.P.R.'s _ex post_ estimate of benefits did not justify investment in the tunnel, and yet the investment was undertaken. There are two possible explanations. First, the economics of the project may not have favoured adoption, and yet the C.P.R. may nevertheless have felt obligated to undertake the investment. That is, the C.P.R. may have believed that, although it did not offer an acceptable rate of return from quantifiable benefits, the investment was still "necessary," and offered non-quantifiable benefits which were decisive in the evaluation. It is possible to argue that the "necessity" for this investment arose from the avalanche danger through Rogers Pass, and that the non-quantifiable benefit which was decisive was the benefit which was expected to accrue from savings in human life.

According to Bury's recollection in _Maclean's,_ however, the C.P.R. would have been justified in building the tunnel regardless of the non-quantifiable benefits to be derived from the savings in human life. A second explanation for the investment decision is therefore more probable. This is that the C.P.R.'s _ex post_ estimate of the savings to be obtained from the project omitted consideration of certain key benefits which could be quantified -- which indeed may have been quantified by Bogue -- and which were in themselves decisive in the tunnel evaluation. The following analysis will identify the categories of quantifiable benefits, and where possible will attempt quantification corresponding to that which may have been undertaken by Bogue.

The present analysis assumes that Bogue's estimates of potential benefits were based on the premise that the volume of traffic would have doubled <u>and</u> <u>no</u> <u>more</u> by the time that the tunnel could be opened. This assumption, whilst crediting Bogue's estimates with a downside bias which the C.P.R. clearly did not acknowledge, implies that the entire $462,821 of annual savings accrued from a traffic volume which was twice as great as that of 1913. That is, none of the $462,821 may be attributed to benefits from incremental traffic beyond a level which was double the existing volume.

It has already been noted that Bogue assumed fuel consumption at a rate of 7 lbs. per horse-power hour, and fuel costs of $4.68 per ton of coal. With double the existing traffic volume, these assumptions implied savings in energy costs by the tunnel alignment of $142,973.81 per annum, compared with Sullivan's estimate of $93,856.92.

Sullivan calculated that savings in the costs of traincrews and maintenance of way and equipment would be $38,707.15 for the existing volume of traffic, and therefore $77,414.30 for double the volume.[31] This estimate, although included in the C.P.R.'s <u>ex</u> <u>post</u> release, which was itself conservative,[32] has nevertheless been attributed to Bogue also. The total annual operating savings which Bogue estimated may therefore have been $220,388.11, in comparison with Sullivan's estimate of $171,271.22.

Bogue's estimate may have included the savings obtained from removal of the obligation to maintain and renew double-track wooden snowsheds. The C.P.R., again in its conservative release, had valued these savings at $125,000 per year. Assuming that Bogue's estimate was the same, this would have taken his estimate of annual savings to a minimum of $345,388.11.

Thus far, this analysis has considered only those categories of benefits which the C.P.R. had itself identified, and has merely re-evaluated some of the benefits according to less conservative assumptions. Other categories of quantifiable benefits remain, categories which were certainly omitted from the C.P.R.'s ex post release, and which may have been omitted from Bogue's evaluation also.

One such category is that of contribution which the C.P.R. could expect to derive from the incremental traffic between the existing volume and double that volume. The C.P.R. had been prepared to pay a premium of $750 per day in order to ensure rapid completion of the tunnel. It is assumed that this sum represented the amount per day which the C.P.R. was prepared to pay at the margin in order not to forego the benefits which it expected to accrue from operating through the tunnel. This sum is therefore multiplied by 365 in order to obtain an estimate of the annual benefits which would have been required in order to offset the payment of this premium. This amount, however, ($273,750), exceeded the annual benefits which the C.P.R. claimed in its ex post release to be anticipating ($256,271.22). Since the latter amount included only operating savings and snowshed savings, it is assumed that the discrepancy between the amount which the C.P.R. was prepared to pay, $273,750, and the amount which it should have been prepared to pay according to its own calculations of savings, $256,271.22, represented the annual contribution which the C.P.R. expected to accrue from the incremental traffic between the existing volume and double that volume. This discrepant amount was $17,478.78, and its inclusion would have taken Bogue's estimate of the annual benefits to $362,866.89. As has been noted, the amount which Bogue actually estimated that the C.P.R. would save from the tunnel was $462,821. This was $99,954.11 greater than the estimate reconstructed above. The balance may be composed of two other categories of benefit.

The first is that of incremental contribution from traffic beyond a level of double the existing volume. Quantification of this benefit, however, depends upon the assumption of a ceiling volume of traffic which, whilst not exceeding the capacity of the double track, must necessarily be imposed somewhat arbitrarily.

The second is that of savings in congestion costs. Even if it is accepted that the existing single line could physically support double the current volume of traffic, the increase in traffic would not incur uniformly increasing costs. Instead, as the line became more congested, the increment in traffic would not only incur its own operating cost, but, by delaying other traffic, it would impose a "congestion cost" upon all other traffic to be moved over the Pass. This congestion cost is difficult to quantify, and this analysis does not attempt quantification. Nevertheless, it is clear that this congestion cost was a function both of the level at which traffic could flow through the Pass without congestion, and of the rate at which the traffic flow would increase beyond this level. From the analysis of the capacity of the existing facility, which was conducted in Chapter 6, it seems probable that congestion costs were already being incurred in the movement of the 1912-level of traffic over the single line. Doubling that volume would increase the burden of the congestion costs, and construction of a double track with an easier alignment which would alleviate the congestion would save these congestion costs as well as saving some of the original operating costs.

The C.P.R.'s ex post release, which purported to justify the investment decision, certainly omitted consideration of these three categories of benefit. Bogue's calculation of total savings, in which almost $100,000 remains unaccounted for, may have included an estimate of benefits from each of these categories. However, even Bogue's estimate may have been conservatively biased by his omission of the valuation of human lives which would be saved by the project. The C.P.R. recognised the principle of attaching a value to human life, in order the more accurately to assess the benefits of the project. It also recognised the need to trade off construction and operating costs against human life in the Rogers Pass realignment, and it was prepared to make such a trade-off if necessary -- it has already been noted that Sullivan envisaged "some trouble from snow slides" as part of the price of a location up Bear Creek.[33] When seeking to justify investment in the Connaught Tunnel, however, the Company shied away from the practice of attaching a dollar-value to human life. This evasion may have reflected the inherent difficulty of the practice, or it may have reflected a very sincere lack of belief on the part of the C.P.R. that the benefits to be derived from savings in human life were in fact crucial to the evaluation, given that the directly quantifiable benefits of the project, estimated at $462,821 per annum, already ensured a positive net present value.

Certainly, it was only at the very end of a fourteen-page letter rationalising construction of a tunnel on the grounds of potential operating savings that Sullivan added:

> Another feature that is hard to measure in dollars and cents which has not been dwelt upon is the toll of life. I presume the average loss of life since the road was built, on account of snow slides on this section, will average between 5 and 10 per year.[34]

The lives which the C.P.R. was here considering were those of railway servants. Between 1883 and 1916 the total death toll was estimated at 236,[35] or an average of seven per year. "No passenger ever lost his life."[36] In the aftermath of the 1910 avalanche disaster, the C.P.R. is known to have paid $500 in compensation to the brother of one of the victims:

> It is distinctly understood, however, that the Company does not admit but disputes legal liability for the said accident, the amount being given as a gratuity and for the sake of peace.[37]

Many of the snow-clearing gangs who were most prone to death in avalanches were seasonal labourers, often Asian immigrants.[38] It is unlikely that compensation was paid to the relatives of all of these who might be killed. It is also unlikely that recruitment and training costs for their replacements were very high. Therefore, $500 may be taken as a reasonable measure of the value of life among mountain railway employees. If it is assumed that seven lives per year would be saved for perpetuity by the tunnel, the total benefit may be estimated at $87,500, or less than one per cent. of the directly quantifiable benefits of the tunnel when discounted as perpetuities ($11,570,525).[39]

It may be argued that it was not the actual death toll among railway servants with which the C.P.R. was concerned in Rogers Pass, but the potential death toll among the public, and the risk that such a death toll might be incurred in "catastrophic" circumstances. That is, passenger deaths might occur extremely rarely, but, when they did occur, might be extremely large in number if, for example, a passenger train were to be struck by an avalanche. No such incidents in fact occurred upon the C.P.R. during the thirty years of surface operations through Rogers Pass. However, even if it is assumed that one such incident would occur once every ten years on the main line, that 200 passengers would be killed in each incident -- more than twice as many as were killed when an avalanche struck the Great Northern's Spokane Express at Wellington on March 1, 1910[40] -- and that passengers' lives were valued at twice as much as those of railway servants, or $1,000 each, then the total value of the lives saved, discounted as a perpetuity, would have been $500,000. This was still less than 5% of the directly quantifiable benefits of the tunnelling project.

This analysis of the categories of benefits arising from construction of the tunnel leads to a revised estimate of the total benefits of the project. This revised estimate is presented in table 28. The estimate confirms the impression that it was the operating-cost savings anticipated from the tunnel alignment which were the chief benefit sought from the project, and that it was the savings in snow-related costs which were the incidental benefit, rather than vice-versa. The savings in direct operating costs accounted for 45.3% of the total benefits of the project, whilst the savings in snow-related expenses, including the value of human lives, accounted for 30.5% of the total benefits.

TABLE 28

REVISED ESTIMATE OF BENEFITS OF CONTRACTED TUNNEL ALIGNMENT.
(Assuming double the 1912-13 traffic volume; r = 4%)

Source Of Benefit	Annual Value Of Benefit	% Total
Operating savings (fuel, wage and maintenance)	220,388.11	45.3
Snowshed savings	125,000	25.7
Contribution from generated traffic	17,478.78	3.6
Unaccounted balance of Bogue's estimate of total annual benefits*	99,954.11	20.6
Workmen's lives saved	3,500	0.7
Passengers' lives saved**	20,000	4.1
Total annual benefits	486,321	100.0

Discounted value of benefits:-
Annual benefits realised after Year 4 for perpetuity:
486,321/4% = $12,158,025
Discounted back to Year 0:
12,158,025 x .82193 = $9,993,045.50

Discounted cost of contracted alignment: $7,135,352.90

Net present value of contracted alignment:-
9,993,045.50 - 7,135,352.90 = +$2,857,692.60

* The difference between Bogue's estimate of benefits and the estimates reconstructed in section (8.2) may include estimates of contribution from incremental traffic above double the present volume, and savings in congestion costs.

** Value of expected number of deaths per year, assuming 200 deaths once every ten years.

Source:- See text.

Moreover, the fact that this magnitude of total benefits could be obtained for a discounted outlay of just over $7 million reinforces the impression that the Connaught Tunnel was not simply a <u>necessary</u> investment, dictated by concern to save lives or to avoid probabilistic opportunity costs consequent upon line blockage by avalanches. Rather, it was a <u>sound</u> investment, offering a substantial positive return in directly quantifiable operating savings and in contributions to be derived from generated traffic, even without the savings in snow-related expenses. This, at least, may have been the manner in which the investment was perceived in 1913, when the decision to undertake the project was reached. It remains to determine whether the project as constructed, modified during the war years, was still a sound investment.

8.3 The Alignment As Constructed

The contracted realignment, upon which construction commenced in the summer of 1913, was never completed. The western approach, including the provision of a 300,000-cubic-yard embankment in order to divert the Illecillewaet River away from the tunnel entrance,[41] was built as planned. Construction of the tunnel also proceeded satisfactorily. After a slow start, occasioned by the unexpected length of soft-earth tunnelling required at both portals, recovery was swift as soon as solid rock was reached. The world tunnelling record was broken in successive months between November 1914 and January 1915,[42] the pioneer headings met at the centre of the tunnel on December 19, 1915, and the main headings met on July 7, 1916. Although the contract had set back the date for completion to June 1, 1917, on account of the amount of soft ground which was encountered,[43] the Order opening the tunnel to traffic was approved on December 13, 1916,[44] which was within the original deadline. The tunnel itself was 26,512 feet long,[45] some 612 feet longer than had initially been anticipated, but it was completed at an average rate of $3.67 per lineal foot less than the contracted rate, and for a total cost of $5,071,702, which was $13,175 less than the contracted price.[46] Whilst it had been expected that 8,400 lineal feet of the tunnel would have to be lined with concrete, only 7,837 feet were actually lined.[47] This permitted the saving of $70,720, or nearly 10%, over the contracted lining cost of $680,000.[48]

It was on the eastern approach to the tunnel that the alignment which was constructed diverged markedly from that for which contracts had been let in 1913. This eastern approach was not double-tracked. Neither was the length of 2.2% gradient against westbound traffic reduced from 20.8 miles to 5.5 miles. Neither was the westbound pusher gradient electrified.

The main reason for the change in the contracted alignment was the escalation of the estimated cost of electrifying the pusher gradient. Ever since the possibility of driving a tunnel beneath Rogers Pass had been conceived, electrification had been regarded as an integral part of the project. Shaughnessy, Bury and Herbert S. Holt, eminent among the C.P.R. Directors, had all been convinced of the necessity to electrify the tunnel. The only question concerned the extent to which electrification should be undertaken on either side of the approaches. In March

1913, Holt had proposed to Shaughnessy that,

> As you will no doubt operate the heavy grade sections through the mountains by electricity, I think it would be advisable for you to have a thorough survey of prospective hydro-electric powers on the Beaver and Columbia rivers both above and below Beavermouth.[49]

In June, Bury had arrayed the following alternatives:

> ...to simply electrify the tunnel; to electrify the tunnel from Albert Canyon to the foot of the 2.2% grade east of the tunnel and use electrical helpers altogether; or electrify the line from Revelstoke to Field...As I see it, as a beginning it will be advisable simply to electrify the tunnel.[50]

Shaughnessy's ultimate ambitions appear at this stage to have been much more far-reaching, although he agreed with his Vice-President in the short term:

> My own feeling is that we should look to the operation of the line between Laggan and Revelstoke by electricity, although in the beginning the electric traction may be confined to the tunnel only.[51]

By October 1913, however, Shaughnessy's visions had come to resemble more closely those of Bury, and the President strenuously denied plans for the wholesale electrification of the western divisions. "What I did say," he pointed out to the editor of the Canadian Railway And Marine World, "was that the tunnel...would be operated by electricity, and that that would probably make it desirable to use electricity over that section, from Field to Revelstoke."[52]

Plans for electrification were still active in the spring of 1914. In February, Bury travelled to New York to examine electrification systems on the New York, New Haven and Hartford and Pennsylvania Railroads, and was pleased to report thus:

> The main thing we had to determine was what size of tunnel we would require, depending on the type of electrification adopted, but as a result of going into the matter most thoroughly we have found that the size

> of tunnel it would be necessary to build anyway for clearance and ventilation would be more than ample to take care of any type of electrification that may be determined upon.[53]

At the end of April, the C.P.R. informed the Board of Railway Commissioners that,

> The type of electrification to be used has not yet been definitely decided upon. We are, therefore, making our clearances high enough to permit of the use of any type.[54]

The chief objective of the C.P.R. in seeking to electrify the tunnel was to facilitate ventilation. Sullivan had ventured in October 1912 that,

> Our proposed tunnel...I really believe can be operated by steam without any great risks, but when traffic gets very dense it would, of course, be necessary to either put in very extensive fans or an electric system.[55]

The provision of electric traction would also permit the multiple-heading of motive power on the assisted trains over the summit. This, however, was perceived as an incidental implication, and Sullivan in fact forecast that the cost of operating through the tunnel by electricity would be greater by some $60,000 per annum than the cost of operating by steam.[56] Nevertheless, there is no doubt that the alignment for which the C.P.R. let contracts was markedly influenced by the expectation that the main line at the summit would be electrified. As the C.P.R. explained in retrospect,

> When the application was made...the Company contemplated operating the tunnel by electricity and a steep gradient of 2.2 per cent. was placed adjacent to the tunnel so that the electric locomotives which would haul the trains through the tunnel could act as pushers on the steep grade.[57]

From this statement, it appears that the scope of electrification which was envisaged when the contract was let may have spanned those 11.2 miles of the main line between the west portal and the base of the 2.2% gradient on the east slope. In October 1912, Sullivan had estimated the capital cost of electrification at $250,000. By June 1913, this estimate had increased to $500,000.[58] Nevertheless, the C.P.R. proceeded to let the contract for the alignment, intending to concentrate the pusher gradients on either side of the tunnel, and the Company did not apparently undertake a detailed investigation of the economics of electrification until over a year after construction of the tunnel had commenced.

In the summer of 1914, the Westinghouse Church Kerr Company was commissioned to study electrification throughout the B.C. mountains. The principal conclusions of its preliminary report were thus:

> ...it would not be economical to electrify the line from Revelstoke to Lake Louise until the traffic has increased 60%. As the traffic increases from 60% to 100% the economics show savings in electric traction over steam.
>
> . . . .
>
> We would not under any conditions be justified in electrifying the line between Revelstoke and the toe of the east slope of the Selkirks.
>
> As the tunnel should be operated by electricity in any event the economics are in favor of electrifying the line from the west portal of the tunnel to the foot of the 2.2 grade on the east slope, a total distance of 12 miles.[59]

It appears from this report that by the summer of 1914, the extent of electrification which was deemed appropriate was confined to the tunnel and the summit on the east slope, and that electrification was not deemed appropriate for any portion of the west slope. This may seem surprising, for at the time when the realignment had been conceived, the eastbound tonnage had outweighed the westbound, and the two flows were forecast merely to balance by 1916. Moreover, it was expected that when the project was completed, the length of 2.2% gradient against eastbound traffic would be 19.4 miles, in comparison with only 5.5 miles against westbound traffic. It appears, therefore, that this ordering of electrification priorities, commencing at the summit on the east slope, was intended, like the configuration of the gradient revision scheme itself, primarily to expedite the future flow of traffic westbound. This impression is reinforced by the fact that Westinghouse Church Kerr, in its final report upon the economics of electrification, envisaged that the C.P.R. would be able, as a result of electrifying the eastern approach, to double the weight of its westbound freight trains over the summit to 2,000 tons.[60]

The potential impact upon main-line capacity of the combined investment in double-tracking and electrification is readily calculable. If it is assumed, simplistically, that double-tracking would have doubled the number of train paths available to westbound trains on the east slope, and if it is assumed that, as a result of multiple-heading, 2,000-ton trains could ascend as rapidly with electric traction as 1,016-ton trains ascended with steam, then westbound capacity over the summit would have increased to 13,908,000 equivalent gross tons per year.[61] The revised, electrified main line could therefore have supplied 333% more capacity, in tonnage terms, than was actually required in 1912-13, the year during which capacity pressures persuaded the C.P.R. that realignment was necessary.

The precise estimates for the cost of electrification which Westinghouse Church Kerr presented to the C.P.R. in its two reports are not known. It seems, however, that the estimates were disappointingly high. Certainly, A. N. Vaughan, who analysed the reports for the C.P.R., contrived to scale down the potential costs by substituting a lower forecast for traffic growth. A 25% increase was assumed, and Vaughan recommended that the C.P.R. should continue operating 1,000-ton trains over the summit, resorting to steam operation in emergencies, in order to reduce the requirement for electric locomotives from seven, as envisaged by Westinghouse Church Kerr, to four. Even under these assumptions, however, the fixed investment in electrification was still estimated at $825,000 for the tunnel, and $953,000 if electrification were to be extended to the foot of the 2.2% gradient on the east slope. In addition, the direct operating costs associated with the two alternative electrification schemes were now respectively estimated to be $72,000 and $66,000 per annum greater than the cost of steam operations.[62]

It was not until Vaughan's analysis of Westinghouse Church Kerr's final report was submitted to Shaughnessy in November 1914 that the expense of electrification appears to have been fully appreciated by the C.P.R. On receipt of the analysis, Shaughnessy observed to Bury that,

> If Mr. Vaughan's figures, concerning the increased cost of operation by electricity of the tunnel and East approach, be correct, we have got rather an expensive proposition on our hands.[63]

Even upon the basis of these cost estimates, however, Bury was prepared to proceed with electrification:

> We were aware that with partial electrification of the Mountain Section there would be some extra expense, but are satisfied that extra expense will not be as great as has been estimated by the Westinghouse Church Kerr people.[64]

He still did not question that electrification should be carried out. At this time his chief concern was with the type of electrification which should be adopted, and even upon this, he observed that, "We have until next year to decide..."[65]

By the time that the decision had to be made, however, in 1915, the C.P.R. had been compelled once again to revise upwards its estimates of the cost of electrification. It is not clear whether the new estimates were the Company's own, or whether the C.P.R. had simply been forced to accept that the estimates provided by Westinghouse Church Kerr, which it had rejected the previous year as being too high, were accurate after all. Irrespective of source, the estimates were virtually twice as high as those of the previous year: the capital cost of electrification was now projected at $1,500,000, and the operating cost at $150,000 per annum.[66]

These estimates were unacceptably high to the C.P.R. As Bury recalled,

> Rather than face this charge, as soon as our engineers found out what the cost of electrification and the extra cost of operation would be, due to electrifying this small section of the line, studies were made seeking a means to save this...[67]

Since electrification had been intended primarily to facilitate ventilation, the search for cost savings began in this area. Following European and American practice, a mechanical system was adopted, comprising twin fans located at the western portal in order to suck in fresh air from the prevailing westerly airstream. The installation cost of this mechanical ventilation system was estimated at between $100,000 and $125,000, and its operating cost was estimated at less than $40,000 per annum.[68]

The decision to ventilate the tunnel mechanically enabled the C.P.R. to abandon its plans for electrification, and to "continue to operate by steam for some years to come." Main-line electrification had been renounced by July 1915.[69] It is tempting, because electrification had been included as an integral part of the realignment project as conceived in 1912, and had then been abandoned in 1915, to conclude that it was the First World War which put an end to the proposals, and which therefore irretrievably delayed the course of main-line electrification in Western Canada. Such a conclusion would be misleading, however. Investment in electrification had been perceived by the C.P.R. as a necessary additional cost associated with building and operating through the five-mile tunnel. From the outset, the economics of electrification were perceived to be unfavourable, even under the most optimistic conditions of traffic growth. In October 1912, Sullivan had estimated that it would add $1,750,000 to the discounted cost of the tunnel route. By July 1915, the estimated additional discounted cost had exactly tripled, to $5,250,000. According to this calculation, upon which the decision to cancel electrification was based, the total cost of the realignment project would have been increased by some two-thirds, from $7,970,930 to $13,220,930. Moreover, the annual benefits accruing from the realignment, which would have been reduced by $150,000 under electric operation, would, according to the C.P.R.'s calculations, would have been sufficient to cover only half the cost of electrification, without offering any contribution towards the cost of the gradient revision itself.[70]

In contrast, the tunnel could be ventilated mechanically for a total discounted cost of $1,062,500, or one-fifth of the cost of electrification. Confronted by these alternatives, it is extremely likely that the C.P.R. would have shelved its electrification proposals whether or not war conditions had prevailed in 1915.

The realignment project through Rogers Pass was, however, further scaled down during 1915, and most of the revision which had been proposed for the east slope was never undertaken. The prevalence of war conditions was certainly one factor in the decision to modify the proposal, but the abandonment of electrification had already paved the way for more retrenchment.

The proposal for which contracts had been let had envisaged concentrating the pusher gradient on the east slope of the Selkirks immediately at the eastern portal of the tunnel. This alignment had been intended to foster more effective utilisation of the pusher locomotive fleet which was planned for summit operations: in addition to hauling trains over the less-than-one-per-cent. gradient through the tunnel, the fleet could take over from the existing motive power all pusher duties for westbound traffic across the Selkirks.

When electrification was abandoned, therefore, the operating advantage of constructing this new 2.2% gradient was nullified: since pushers would not be required through the tunnel, it was no longer necessary to concentrate the pusher gradient at the eastern portal. This elimination of the requirement to relocate the pusher gradient, however, did not of itself imply that no realignment at all should be undertaken on the east slope. Had the C.P.R. still deemed double-tracking of the main line expedient, it might still have proceeded to replace the 8.8 miles of single-tracked 2.2% gradient between Six Mile Creek and Stoney Creek with 5.5 miles of double-tracked 2.2% gradient at the tunnel mouth. It might have anticipated that the savings in congestion costs and in the cost of haulage over 3.3 miles of 2.2% gradient would have offset the investment in relocating the pusher ascent prior to doubling.

By 1915, however, traffic conditions had altered: both actual volumes and forecasts had decreased, to such an extent that the C.P.R. could no longer justify double-tracking the eastern approach. As has been noted,[71] the decline in traffic volumes began in 1913, over a year before the outbreak of the First World War. The C.P.R. had believed that the decline would be temporary, and, continuing to forecast the doubling of traffic within the next four years, had refused to modify its investment policy in the mountains. The outbreak of war, however, prolonged and exacerbated the decline. Tables 15 and 16 are illustrative: by the end of 1914, volumes of lumber and grain had each fallen by 40% over the previous two years, and were lower than at any time since 1909. Moreover, the optimism of the C.P.R. forecasts, which had outlived the 1913 recession, was subdued by the first autumn of the war. In November 1914, when the C.P.R. evaluated the Westinghouse Church Kerr electrification report, it determined to provide sufficient electrified capacity to handle an increase in traffic of only 25%.[72]

The effect of the reduction in actual and forecasted traffic volumes was to decrease the magnitude of the benefits which could be anticipated from the project. Given this reduction in potential benefits, the C.P.R. could either extend the payback period which it allowed for the project, or it could seek to scale down the magnitude of the investment which had to be recovered. In view of wartime uncertainty, the Company may have been reluctant to adopt the former alternative. Instead, it sought to reduce its initial investment. That the retrenchment decision was a product both of the Company's prior decision to abandon electrification and of unforeseen changes in traffic levels is evidenced by Bury's retrospective explanation, which accords equal weight to both factors:

> In view of traffic conditions and the change in operating features from the use of electrical pushers to steam pushers, we were warranted, under the present extraordinary world wide conditions, to seek a means by which we could reduce the cost of this work...[73]

The burden of cost reduction fell upon the east slope of the Selkirk Mountains, as Bury went on to explain:

> ...we therefore determined...instead of building a double track line from Six Mile Creek to the east portal of the tunnel, to simply leave the main line just west of Stony Creek Bridge and build a single track from there to where the material from the tunnel and approach cut would make fill about two miles east of east portal...[74]

This new spur was level, and 2.8 miles long. Beyond it, eastwards as far as Beavermouth, the C.P.R. would continue to operate its trains over the same single-track 2.2% gradient that it had worked since the 1880's.

There were perhaps four reasons why the burden of cost reduction fell upon the east slope. The first and most obvious reason was that by 1915, no work had as yet been commenced on the east slope, except at the very mouth of the tunnel. The gestation period of the entire realignment was dependent solely upon the time required for the boring of the tunnel. Construction on the east slope, like the decision on the type of electrification, was postponed for as long as possible. This postponement secured for the C.P.R. sufficient flexibility that, when circumstances dictated, both of these decisions could be reversed at no sunk cost.

A second reason may have been that the potential for reducing the level of variable costs was less on the east slope than elsewhere over the proposed realignment. Therefore, the opportunity cost of not reducing that level would also have been less on the east slope than elsewhere. The value of the entire realignment scheme would have been far more seriously jeopardised, for example, had the C.P.R. been compelled by retrenchment to retain the Loops, or to abandon the tunnel itself. As it was, the modification which the C.P.R. in fact incorporated into the main-line configuration on the east slope did not add more than one-tenth of a mile to the length of line envisaged in the original proposal, and entailed no lesser reduction than the original proposal in rise and fall. Admittedly, the length of 2.2% gradient was increased from 5.5 miles in the contracted proposal to 8.8 miles in the alignment as built. However, the distance over which westbound trains had to be pushed was increased by only 2.4 miles, from the 11.2 miles which were intended to be electrified to the 13.6 miles between Beavermouth and Stoney Creek. Even this disadvantage may not have been perceived to be acute, given the third possible reason for the curtailment of the east-slope revision.

This third reason may have been that the decline in traffic volumes and forecasts was probably more severe in the westbound direction than in the eastbound direction. Again, tables 15 and 16 are illustrative. Between 1912 and 1914, the decline in lumber traffic far outweighed that in grain, in terms of absolute volume. The decline in lumber traffic was reversed after 1914, however, and by 1916, volumes had reached their pre-war heights again. In contrast, the decline in westbound grain traffic was unrelenting, and in 1916, volumes were less than one-quarter of their 1912 peak. Moreover, it is likely that longer-term forecasts were revised downwards more drastically for westbound than for eastbound traffic. Table 29, which details westbound grain exports from Vancouver between 1910 and 1935, provides some index of the probable expectations for future westbound grain traffic. Not only did actual volumes decline during the war years, but the war itself interrupted merchant shipping and forced ocean freight rates upwards. It was not until the autumn of 1917 that the first bulk shipment of grain, 100,000 bushels, was exported from Vancouver to London,[75] and grain exports via this route did not "take off" until at least the early 1920's. The C.P.R. may therefore have calculated that the increase in westbound grain traffic through the mountains would be delayed for several years after the cessation of war, and that, since the east-slope revision was expected to take less than two years to complete, there would be ample time to undertake this final stage of the project, should it become necessary, under peace-time conditions.

TABLE 29

GRAIN EXPORTS FROM VANCOUVER, 1910-1935.

Year	Bushels
1910*	987,594
1911	14,209
1912	233,916
1913	765,156
1914	226,346
1915	138,999
1916	82,237
1917	369,633
1918-20	not available
1921**	1,251,071
1922	14,463,833
1923	24,663,017
1924	53,240,516
1925	34,868,192
1926	45,229,906
1927	43,552,210
1928	97,561,716
1929	73,984,114
1930	63,437,312
1931	70,841,445
1932	105,006,925
1933	68,828,024
1934	51,757,614
1935	46,265,612

* Crop Years, 1910-17.

** Calendar Years, 1921-35.

Sources:- 1910-17: _Annual Reports of the Board of Grain Commissioners for Canada,_ DSP.
1921-35: _Annual Reports of the Vancouver Harbour Commissioners,_ Vancouver, B.C.

A fourth and final reason may have been a lingering fear haunting President Shaughnessy that the cost of the realignment project would exceed its estimates. Shaughnessy must have known that by August 1914 the contractors had fallen "some $300,000 behind their estimated tender for this work" on account of the difficulty of boring the approach cuts through soft earth. Sullivan expressed the opinion that, "The contractors' estimate for the allowance of time for earth tunnelling was not one half as large as it should have been to cover the time required to go through this."[76] The shovels which were to enlarge the tunnel to its full width did not encounter hard rock until January 1915 at the east end, and February 1915 at the west end.[77] By the summer of 1915, it appears that Shaughnessy was extremely concerned about the costs of the project, for Bury drafted a memorandum to the President detailing the savings which had been made in actual costs over the estimates which Busteed had submitted in 1913. Bury ended the memorandum thus:

> I sincerely trust that the above information will relieve your mind of the feeling that the cost of this work will exceed the estimate...but if you wish for anything further I can arrange for Mr. Sullivan to come East with full data, so that any further details you may require will be available.[78]

In fact, however, there were neither time- nor cost-overruns. In January 1917, A. C. Dennis, who had collaborated with Sullivan to devise the "pioneer" method adopted in the construction of the tunnel, would report that, "The tunnel has been finished 11 months ahead of the contract time, and for a substantial sum less than the price bid."[79]

Irrespective of the reasons, the decision to freeze the revision on the east slope was certainly successful in both reducing the immediate cost of the project and in preserving the C.P.R.'s flexibility to undertake further improvements at low capital cost should a future escalation of operating expenses so dictate. The single-track spur from Stoney Creek to the east portal of the tunnel cost $80,000,[80] and the total cost of the tunnel approaches was $860,017, in comparison with the $2,886,053 which had been projected in 1913.[81] In return for this saving, the C.P.R. incurred the expense of operating all trains over an additional one-tenth of a mile, and of operating pusher service over an additional 2.4 miles. The Company also forfeited 9.4 miles of double track, with their associated saving in congestion costs.[82]

In table 30, the costs and benefits of this modification are computed. It is assumed that the savings in rise and fall, curvature and friction resistance were the same on the completed alignment as on the contracted alignment. Moreover, the assumption is maintained that traffic volumes would be double their average 1912-13 level, even though volumes in 1915 had actually fallen below their 1912-13 average. It appears from the table that the benefits of cancelling the east slope revision easily outweighed the additional costs. The discounted congestion cost entailed by the foregoing of the 9.4 miles of double track would have had to have exceeded $1,843,015.80 in order to have rendered the modification uneconomical. This congestion cost, annualised at 4%, would have been $73,720.63 per annum: almost as much as the annual amount which the C.P.R. had expected to save upon existing traffic by the original realignment proposal.[83]

TABLE 30

COSTS AND BENEFITS OF THE CANCELLATION OF THE EAST-SLOPE REVISION.
(Assuming double the 1912-13 traffic volume; r = 4%)

Benefits Of Cancellation	$
Cost of tunnel approaches, as contracted for	2,886,053
" " " " , as built	860,017
Total capital saving	2,026,036

Costs Of Cancellation	$
Additional wage and maintenance costs, contracted line:-	
Additional train miles:	
6,162 trains x 2 x 1/10 mile = 1,232.4 train miles	
1,232.4 train miles, at 22c. per train mile =	271.13
Additional pusher miles:	
5,437 pushers x 2 x 2.4 miles = 26,097.6 pusher miles	
26,097.6 pusher miles, at 25c. per pusher mile=	6,524.40
Extra cost maintenance of way:	
1/10 mile, at $200 per mile +	
1,232.4 train miles, at 20c. per train mile =	266.48
Extra cost maintenance of equipment:	
1,232.4 train miles, at 21c. per train mile =	258.80
Total additional annual operating cost	7,320.81
Additional operating cost, incurred for perpetuity:	
7,320.81/4% =	183,020.25
Net benefit of cancellation of east-slope revision:-	
2,026,036 - 183,020.25 =	+$1,843,015.80
Annual net benefit of cancellation:-	
1,843,015.80 x 4% =	+$73,720.63 per year.

Sources:- Cornell Civil Engineer, December 1914, pp. 80-81.
Bury, Memoranda for the President, July 23, 1915; August 10, 1915. PIC CPCA.

Moreover, as Bury pointed out, the modification could be undertaken without the C.P.R.'s having to foreclose future realignment alternatives:

> If in the future it should be determined to electrify the mountain section, we have before us a number of alternatives, either to double track the present line, or to abandon the connection from Stoney Creek to the permanent location and build the line originally located, or any improvements which could be found in it.[84]

Since the modification had been so cheap to implement, the sunk cost of its abandonment would not be a barrier against future revision: "To abandon this connection from the west end of Stoney Creek Bridge would mean simply throwing away between $60,000 and $70,000."[85]

The location of the realignment which was actually constructed may be traced on map (III), and the profile of the realignment is presented in figure 2. The new alignment reduced the length of 2.2% gradient on the east slope of the Selkirks from 16.1 miles to 8.9 miles, and the length of 2.2% gradient on the west slope from 25.3 miles to 19.4 miles. Thus, out of a total reduction of 13.1 miles in the length of 2.2% gradient, 7.2 miles were saved on the east slope, and 5.9 miles on the west slope. 13.6 miles of pusher gradient remained on the east slope between Beavermouth and Stoney Creek, compared with 19.4 miles on the west slope between Albert Canyon and Glacier. Moreover, none of this pusher mileage in either direction was double tracked. Indeed, only 5.8 miles of double-track, including five miles within the tunnel, were provided by the project, instead of the 24 miles between Beavermouth and Glacier which had originally been envisaged.[86]

TABLE 31

COST-BENEFIT ANALYSIS OF CONNAUGHT TUNNEL ALIGNMENT, AS COMPLETED, DECEMBER 1916.
(r = 4%)

Traffic Forecast	Tons
Actual Eastbound, 1912-13 Average:-	
1,342 1/2 passenger trains, at 443 tons	594,727.5
2,322 passenger locomotives, at 175 tons	406,350
1,738 1/2 freight trains, at 950 tons	1,651,575
3,477 freight locomotives, at 181 tons	629,237
Total	3,281,889.5
Actual Westbound, 1912-13 Average:-	
1,342 1/2 passenger trains, at 443 tons	594,727.5
2,322 passenger locomotives, at 175 tons	406,350
1,738 1/2 freight trains, at 898 tons	1,561,173
3,477 freight locomotives, at 181 tons	629,237
Total	3,191,487.5
Total traffic, 1912-13 average:-	6,473,377
Assuming doubling by 1917, forecast total =	12,946,754

Undiscounted Cost Of Tunnel Alignment	$
Tunnel: 26,400 ft., at $185.98 per ft.	4,910,050
Tunnel trackwork:	161,652
Approaches: 7.6 miles, at $91,980 per mile	860,017
Ventilation equipment	110,000
Total	6,041,719

Discounted Cost Of Tunnel Alignment	
Year 1: 1,099,906.38 x .96154	1,057,604
" 2: 1,704,379.15 x .92456	1,575,800.80
" 3: 2,500,000 x .889	2,222,500
" 4: 737,433.47 x .8548	630,358.13
Extra cost of operating ventilation equipment:-	
37,500 per annum incurred after Year 4 for perpetuity:	
37,500/4% = $937,500	
Discounted back to Year 0:	
937,500 x .82193 =	770,559.38
Total discounted cost:-	6,256,822.31

Benefits Of Tunnel Alignment	Eastbound	Westbound
Saving in rise and fall	547.8 ft.	547.8 ft.
" " friction resistance	68.1 "	-1.8 "
" " curve resistance	48.9 "	49.0 "
Total	664.8 ft.	595.0 ft.

TABLE 31 (Cont.)

Fuel saving:-

Eastbound: 3,281,890 x 664.8 =	2,181,800,472 ft. tons	
Westbound: 3,191,488 x 595.0 =	1,898,935,360 ft. tons	
Total	4,080,735,832 ft. tons	
		$
4,080,735,832 ft. tons/1,000 =		
4,080,736 h.p. hrs. x 5lbs. coal per h.p. hr. =		
10,202 tons coal x $4.60 per ton =		46,928.46
Wage and maintenance saving:-		
Old line:		
6,162 trains for 23.10 miles =	142,342.2 train miles	
Completed line:		
6,162 trains for 18.78 miles =	115,722.4 train miles	
Train miles saved	26,619.8	
26,620 train miles, at 22c. per train mile =		5,856.40
Old line:		
5,437 pushers for 23.1 miles =	125,594.7 pusher miles	
Completed line:		
5,437 pushers for 15.4 miles =	83,729.8 pusher miles	
Pusher miles saved	41,864.9 pusher miles	
41,865 pusher miles, at 25c. per pusher mile=		10,466.23
Extra cost maintenance of way:		
4.32 miles, at $200 per mile +		
26,620 train miles, at 20c. per train mile =		6,188.00
Extra cost maintenance of way, on account of extra number of degrees of curvature, assuming that 400° of curvature per mile would increase rate of 20c. per train mile for maintenance by 30%:		
6,162 trains x 2,447° x 1/40c. =		3,769.60
Extra cost maintenance of equipment:		
26,620 train miles, at 21c. per train mile =		5,590.20
Extra cost maintenance of equipment, on account of extra number of degrees of curvature, assuming that 400° per mile of curvature would increase rate of 21c. per train mile by 40%:		
6,162 trains x 2,447° x 21/1000c. =		3,166.47
Total annual operating saving (fuel, wage and maintenance)		81,965.36
Assuming traffic doubles, annual operating saving:		
81,965.36 x 2 = $163,930.72		
Annual operating saving realised after Year 4 for perpetuity		
163,930.72/4% = $4,098,267.80		
Discounted back to Year 0:		
4,098,267.80 x .82193 =		3,368,489.20

TABLE 31 (Cont.)

Snowshed saving:-	
85,000 per year realised after Year 4 for perpetuity:	
85,000/4% = $2,125,000	
Discounted back to Year 0:	
2,125,000 x .82193 =	1,746,601.30
Salvage value of abandoned line:	
1,665,000 realised in Year 5	
Discounted back to Year 0:	
1,665,000 x .82193 =	1,368,513.50
Total discounted benefit:-	6,483,604.00
Net present value of completed alignment:-	
6,483,604 - 6,256,822.31 =	+$266,781.69

Sources:- Cornell Civil Engineer, December 1914, pp. 80-81.
Bury, Memoranda for the President, July 23, 1915; August 10, 1915. PIC CPCA.
C.P.R. Co., Annual Report, 1916, p. 9.

Table 31 contains the final analysis of the Rogers Pass realignment which opened to traffic in December 1916. This table incorporates the saving in construction costs realised upon the east slope by retention of the existing line; the capital and operating costs of ventilating the tunnel mechanically; the reduction in benefits entailed by the addition of one-tenth of a mile to the distance travelled by each train, and by the addition of 2.4 miles to the distance travelled by each pusher locomotive, in comparison with the contracted scheme; and the terminal value of the 15 miles of main line over the surface of Rogers Pass which were salvaged in the autumn of 1917.

The calculation of construction costs is based upon Sullivan's estimate, submitted to Bury in June 1915 and itself drawn from data concerning actual costs up to that date. The calculation of operating benefits is founded upon the assumptions employed by the C.P.R. in its assessment of the benefits of the contracted scheme. This calculation incorporates the benefits in train miles, pusher miles, maintenance and equipment which were foregone by modification of the scheme, but excludes benefits which may have been foregone in fuel savings and savings in curvature and friction resistance. The categories of benefits are those which the C.P.R. identified in its own ex post evaluation of the contracted project, with the exception of that category comprising the salvage value of the abandoned track and equipment upon the surface route. The omission of this category from the C.P.R.'s own estimates may have reflected a belief, when the project commenced, that the value of the abandoned track and equipment would not justify the expense of salvage. However, war conditions increased the marginal value of the equipment sufficiently to warrant reclamation, and in July 1917 the C.P.R. decided "to salvage everything that would justify the expense of recovery."[87] By October, 18 miles of track and 25,000 feet of snowsheds had been dismantled, for a net benefit valued by the C.P.R. at $1,665,000.[88]

When this benefit is added in to the calculation, it may be seen from table 31 that the project as constructed boasted a positive net present value of $226,781.69. The positivity of this result, however, is quite sensitive to changing assumptions concerning energy costs and interest rates. Substitution of Sullivan's estimate for fuel consumption renders the net present value negative by $24,747.79, while substitution of the estimate of Bogue increases the positive net present value to $1,045,177.21. Substitution of an estimate for snowshed savings of $125,000 per annum increases the net present value to $1,048,711.69, while an increase in the discount rate of one half of one per cent. renders the net present value negative by $316,068.93.

It was noted in section (8.2) above, however, that the framework according to which the C.P.R. computed the potential benefits of the project generated conservative estimates of those benefits. The benefits may be recalculated according to the alternative framework suggested in table 28. Substitution of Bogue's assumptions concerning fuel consumption increases the estimate of operating savings upon double the existing traffic volume to $203,758.71. If it is assumed that the savings in snowshed maintenance costs and human lives, the contribution from generated traffic, and the savings in congestion costs would have been identical in amount to those detailed in table 28, then the annual benefits of the realignment would have totalled \$469,691.60. Capitalised at 4% for perpetuity, and discounted back to 1913, the aggregate net benefit would have been \$9,651,340.40, and this would have inflated the net present value of the project to +\$3,394,518.11.

The analysis in this chapter reveals that, according to the C.P.R.'s own calculations, the Rogers Pass realignment was at best a marginal project when the Company so eagerly espoused it in the spring of 1913. By the C.P.R.'s own reckoning, the justification for the investment depended crucially upon assumptions in the key areas of future traffic volumes, snowshed savings and energy costs. However, this analysis also reveals that the structure of the C.P.R.'s categorisation of costs and benefits was conducive to downside bias in the computation of savings accruing from the project. When this downside bias is compensated by alternative assumptions, the project is revealed to boast a positive net present value of substantial magnitude, a net present value which even the unforeseen modifications which were perforce undertaken in 1915 could not erode.

Indeed, the sacrifice of benefits which the modifications entailed was relatively minor. Comparison of the operating savings calculated by the C.P.R. in table 27 (\$171,271.22) with those calculated in table 31 (\$163,930.72) reveals that the sacrifice may have amounted to only \$7,340.50 per year on a traffic volume double that of 1913. This represented less than 9% of the operating savings, and less than 3% of the total annual savings, which the C.P.R. had anticipated when it had accepted the proposal in 1913. On the other hand, the cost savings effected by the modifications were considerable. The project was completed for approximately $1,929,211 less than the cost which the C.P.R. had been prepared to sanction in 1913.[89] This represented a reduction in capital costs of some 24% compared with the estimate based upon contract prices.

The modifications had not been foreseen by the C.P.R. in 1913. Instead, they had been thrust upon the Company as economy measures, the product of escalating estimates for electrification, and of the exigencies of war. Yet the modifications did not negate the value of the realignment. Indeed, they may even have enhanced it, for they enabled the postponement of costly gradient revision and double-tracking on the east slope of the Selkirks: improvement measures which, in the traffic conditions created by the First World War, would not have offered a positive return on the marginal investment which they required. It remains in the concluding chapter to consider the extent to which the opening of the Connaught Tunnel represented the re-establishment of an alignment appropriate to the demands for traffic movement through the Selkirks, and to speculate upon the length of time for which that appropriateness would once again endure.

FOOTNOTES

[1] Railway Age Gazette, December 11, 1914, op. cit., p. 1082.

[2] Bury to Shaughnessy, April 22, 1912, op. cit.

[3] Railway Age Gazette, December 11, 1914, op. cit., p. 1082.

[4] CP Rail Map 8498-16 shows the existing summit at 4,342 feet. The expected saving in rise and fall was 547.8 feet in December 1914. Cornell Civil Engineer, op. cit., p. 80.

[5] Railway Age Gazette, December 11, 1914, op. cit., p. 1082.

[6] Cornell Civil Engineer, op. cit., p. 80.

[7] Sullivan to Bury, October 22, 1912, op. cit.

[8] Sullivan to Bury, March 13, 1913, op. cit.

[9] Ibid.

[10] Ibid.

[11] C.P.R. Co., circular letter to contractors, reprinted in Engineering News, February 24, 1916, op. cit., p. 382.

[12] Ibid.

[13] Bury to Shaughnessy, April 22, 1913, op. cit.

[14] Ibid.

[15] Ibid.

[16] This did not, of course, imply any change in the overall level of risk of the project, but merely a change in the proportion of the total risk which the C.P.R. would assume.

[17] Bury to Shaughnessy, April 22, 1913, op. cit.

[18] Bury to Shaughnessy, April 29, 1913, op. cit.

[19] Bury, tel. to Shaughnessy, May 5, 1913, PIC CPCA.

[20] Railway Age Gazette, Vol. 62, No. 7, February 16, 1917, p. 276.

[21] Bury to Shaughnessy, April 29, 1913, op. cit.

[22] Labour Gazette, Vol. 14, August 1913, p. 113.

[23] Bury, Memo for the President, August 10, 1915, op. cit.

[24] *Cornell Civil Engineer,* op. cit., pp. 79-85.

[25] Ibid., p. 84.

[26] Ibid.

[27] Lavallee, *Rogers Pass: Railway To Roadway,* op. cit., p. 155.

[28] Sullivan to Bury, March 13, 1913, op. cit.

[29] Bury to Shaughnessy, June 17, 1913, op. cit.

[30] Sir George Bury, "The Making of a Railwayman, Part III: The Vice-Presidency," *Maclean's,* Vol. XXXIX, No. 3, February 1, 1926, p. 22.

[31] *Cornell Civil Engineer,* op. cit., p. 81.

[32] Ibid., p. 85.

[33] Sullivan to Bury, October 22, 1912, op. cit.

[34] Ibid.

[35] D. Layzell, "Rogers Pass -- Where Avalanches Brought Death," *British Columbia Digest,* Vol. 19, No. 1, Jan.-Feb., 1963, p. 16.

[36] *Province,* March 5, 1910, p. 1.

[37] C.P.R. Co. to Fredrick Vilhelm Carlsson, op. cit.

[38] See for example, *Toronto Globe,* March 7, 1910, p. 1; *Golden Star,* March 12, 1910, p. 1.

[39] Bury to Shaughnessy, June 17, 1913, op. cit.

[40] *Toronto Globe,* March 4, 1910, p. 1.

[41] *Railway Age Gazette,* December 11, 1914, op. cit., pp. 1082-3.

[42] *Province,* December 2, 1914, p. 1; January 2, 1915, p. 11; *Railway Age Gazette,* February 16, 1917, op. cit., p. 276.

[43] *Railway Age Gazette,* ibid.

[44] *Orders of the Board of Railway Commissioners,* Ottawa, No. 25717, December 13, 1916.

[45] *Railway Age Gazette,* February 16, 1917, op. cit., p. 274.

[46] Bury, Memo for the President, August 10, 1915, op. cit.

[47] *Railway Age Gazette,* February 16, 1917, op. cit., p. 276.

[48] Bury, Memo for the President, August 10, 1915, op. cit.

[49] H. S. Holt to Shaughnessy, March 22, 1913, CPCA File 97850.

[50] Bury to Shaughnessy, June 7, 1913, op. cit.

[51] Shaughnessy to Bury, June 10, 1913, op. cit.

[52] Shaughnessy to Burrows, October 25, 1913, CPCA File 97850.

[53] Bury to Shaughnessy, February 25, 1914, CPCA File 97850.

[54] Beatty to Cartwright, April 29, 1914. CTC, Ottawa, Official File No. 21029.3.

[55] Sullivan to Bury, October 22, 1912, op. cit.

[56] Ibid.

[57] C.P.R. Co., "Application to the Board of Railway Commissioners," August 30, 1915. CTC File No. 21029.4.

[58] Bury to Shaughnessy, June 16, 1913, op. cit.

[59] Bury to Shaughnessy, August 18, 1914, PIC CPCA.

[60] A. N. Vaughan, Memorandum for the President, November 19, 1914, PIC CPCA.

[61] 3,477 x 2 x 2,000.

[62] Vaughan, Memorandum for the President, op. cit.

[63] Shaughnessy to Bury, November 19, 1914, "Letterbooks," op. cit.

[64] Bury to Shaughnessy, November 26, 1914, CPCA File 97850.

[65] Ibid.

[66] Bury, Memorandum for the President, July 23, 1915, op. cit.

[67] Ibid.

[68] Ibid.

[69] Ibid.

[70] According to the C.P.R.'s own estimates, (see table 28), the annual benefits would have been ($256,271.22 - $150,000 =) $106,271.22, which, discounted at 4%, would have aggregated $2,656,780.50. Even with the most sanguine estimates, (see table 29), discounted net benefits would have aggregated only $8,409,172.30: enough to recover the cost of electrification, or the cost of the tunnel, but not both.

[71] See above, pp. 261-2.

[72] "To properly protect the electric operation of the tunnel, three electric locomotives are required, which would be sufficient for an increase in traffic and number of trains of 25%." Vaughan, Memorandum for the President, op. cit. It is not clear whether the base year for the forecast was 1912 or 1914, but if the 1914 levels increased by 25%, it is unlikely that they would have matched the levels of 1912.

[73] Bury, Memorandum for the President, July 23, 1915, op. cit.

[74] Ibid.

[75] MacGibbon, op. cit., pp. 267-9.

[76] Sullivan to Bury, August 7, 1914, CPCA File 97850.

[77] Engineering News, February 24, 1916, op. cit., p. 383.

[78] Bury, Memo for the President, August 10, 1915, op. cit.

[79] A. C. Dennis, "Construction Methods for Rogers Pass Tunnel," in, Proceedings of the American Society of Civil Engineers, Vol. XLIII, No. 1, January 1917, p. 25.

[80] Bury, Memorandum for the President, July 23, 1915, op. cit.

[81] Bury, Memo for the President, August 10, 1915, op. cit.

[82] Ibid.

[83] This was $85,635.61. See table 28.

[84] Bury, Memorandum for the President, July 23, 1915, op. cit.

[85] Ibid.

[86] C.P.R. Co., B. C. District, Supplement No. 2 to Timetable 31, December 10, 1916. Sullivan's estimates for the capital savings accruing from the modified proposal, upon which Bury reported in August 1915, had assumed that 3.8 miles of approaches would be double-tracked, in addition to the tunnel. This 3.8 miles may have embraced the spur west of Stoney Creek, for the distance from here to Glacier was exactly 8.8 miles. Bury, Memo for the President, August 10, 1915, op. cit. Bury, however, clearly intended that the new spur be single-tracked at the outset. Bury, Memorandum for the President, July 23, 1915, op. cit.

[87] Canadian Railway And Marine World, December 1917, p. 457.

[88] C.P.R. Co., Annual Report, 1916, p. 9.

[89] Construction costs only, in undiscounted dollars: $7,970,930 - $6,041,719. Bury, Memo for the President, August 10, 1915, op. cit. This reduction in capital costs excludes the additional costs of operating the mechanical ventilation equipment in the completed tunnel.

CHAPTER 9

CONCLUSIONS

The objectives of this thesis were, first, to establish what forces created a decision situation at the summit of the Selkirks in 1913; second, to weight the factors which influenced the decision to build the Connaught Tunnel; and third, to assess the criteria against which the investment decision was evaluated. In pursuit of these objectives, the analysis investigated the initial trade-off decision between construction and operating costs in the Selkirks; the operating conditions and traffic developments which prevailed on the surface crossing, which ultimately rendered it an inappropriate route for the transcontinental rail link; and the generation and evaluation of alternative alignments through Rogers Pass. The conclusions of the analysis are now presented.

What forces created a decision situation in Rogers Pass in 1912? There were two forces, those of avalanche problems and those of traffic developments. The C.P.R. had had to cope with avalanche problems ever since the line had opened in 1885. The avalanches imposed a fixed cost upon the C.P.R., that of maintaining an avalanche defence system, the expense of which was reasonably constant and predictable from year to year. They also imposed a "variable" cost, that of interruption to traffic, comprising the direct cost of clearing the line and the opportunity cost of the line blockage. This variable cost was unpredictable in both frequency and magnitude.

The force of traffic developments was much more complex in character. Due to the severity of the original alignment, the variable cost of traffic movement through the Selkirks had always been high. The total cost of traffic movement had been low in the early years of operation, however, as the total volume of business was low. The total volume of business, and the concomitant total cost of the operation, increased after the turn of the century. The increases were most pronounced in bulk commodities, resource flows from which Canadian national interests as well as provincial B.C. interests would reap benefit. B.C. lumber moved eastwards, building permanent settlement on the prairies. Export grain was expected to move westwards, opening up the European market via an alternative route and relieving congestion on the "funnel" through eastern Canada.[1] The increases also occurred over a very short period, and were very dramatic in extent, as were those through the Selkirks in the 1970's. Finally, as in the 1970's, it was forecasts of future traffic increases, as much as existing business levels, which injected urgency into the decision situation, for the forecasts indicated escalating variable costs, a shortage of main-line capacity, and very little time available in which to undertake remedial action.

The C.P.R. was also confronted with unprecedented competitive pressures in 1913, with the imminent opening of two rival transcontinental railways and the Panama Canal. It appears that the C.P.R. was particularly sensitive to competition for westbound grain, as it sought westbound gradients comparable with those of its rivals, even though its principal flows were eastbound. The possibilities for divisible investments in order to head off these competitive threats had been exhausted by 1913. There was now a necessity for a "lumpy" investment, in order to secure a long-term solution to the operating problems through Rogers Pass, and a long-term competitive advantage. In 1913, the C.P.R. commanded the resources required for such an investment.

What is the appropriate weighting to accord to these factors? The belief is widely held that it was avalanche problems which impelled the decision. The prevalence of this belief is hardly surprising. Rogers Pass does present a formidable snowslide hazard, which even the driving of the Connaught Tunnel has not eliminated. Moreover, the 1910 disaster serves as a very convenient proximate cause for the abandonment of the surface route. Finally, it must be conceded that a reduction in the avalanche hazard was one achievement of the realignment which was largely unaffected by the intermediate modification of the project. The scheme failed to provide electrification and failed to provide double-tracked approaches to the summit of the Selkirks, but all of the snowsheds which it had been intended to abandon in 1913 were abandoned in 1916.

Nevertheless, this thesis presents extensive evidence to refute the view that snowslide problems were the primary factor in motivating construction of the tunnel. The anticipated savings in avalanche defence were not sufficient to justify investment in the tunnel, nor even to match the benefits which were expected to accrue from direct operating savings. The analysis in chapter 8 reveals that the savings in snow-related expenses, including the value of human lives saved, accounted for only 30% of the annual benefits anticipated from the project, in comparison with 45% anticipated in direct operating savings. The C.P.R. had met the expense of providing avalanche protection for its single line for the previous thirty years. It might baulk at the cost of providing protection for a double track, but the double track was necessary only because of the dramatic increase in traffic which occurred after 1908, and because of the gravity of the capacity problem which emerged in 1912.

It was the capacity problem which was at the core of the decision to abandon the surface route over the Selkirks. Had it not been, a single-tracked tunnel would have sufficed. As it was, double-tracking through Rogers Pass was conceived as merely one project in a massive scheme for double-tracking and gradient improvement from Calgary to the West Coast. It was not an impulsive reaction to the incidence of avalanches. It was part of a much wider "system" decision, that is, a decision to provide a rail system which would be appropriate for long-term traffic requirements throughout the West. The decision which CP Rail must make in Rogers Pass today is a similar decision. It is a "system" decision, which will determine the level of main-line capacity which will be appropriate in Western Canada beyond the 1980's. As in 1913, certain constituent projects within the system programme have already been implemented. Early in the present century, it was the Vancouver - Ruby Creek, Pritchard - Kamloops - Tranquille, and Revelstoke - Taft sections which could be quickly put in place. In the 1970's, it was the Lake Louise - Stephen, Revelstoke - Clanwilliam, and Notch Hill -

Tappen sections which were upgraded first. The decision concerning Rogers Pass remains to be taken.

Finally, what were the criteria against which the decision to drive the Connaught Tunnel was evaluated, and what were the techniques of appraisal employed by the C.P.R.? No evidence is available concerning a stipulated rate of return on capital beneath which the C.P.R. would refuse to invest. Nevertheless, it is clear that the C.P.R., in evaluating the alternative schemes, had a very firm grasp, both upon the extent of operating-cost savings which it expected to derive from the project, and upon the amount of capital which it should be prepared to invest in order to secure these savings. The Company's own estimates of variable-cost savings were deliberately conservative, but were nevertheless believed by the C.P.R. to justify the investment. When the calculations of the consultant Bogue indicated that $11,570,525 could be saved in variable costs by an expenditure estimated at $8 million,[2] the investment appeared not merely necessary but sound, a healthy provision for the future. The application of net-present-value techniques throughout this thesis is not in any way intended as an indictment of the C.P.R.'s own evaluations. Rather, it is intended simply to facilitate comparison between the alternative schemes which were considered by the C.P.R., and to highlight the impact of changing assumptions upon the several categories of costs and benefits anticipated from the project. Indeed, this thesis demonstrates that, with the available data, the explicit application of net-present-value techniques would have generated results exactly consistent with those which the C.P.R. derived from its own evaluations in 1913.

What did the Connaught Tunnel achieve? It did not reduce the ruling gradient across the Selkirks below the 2.2% which had prevailed since 1885, and thus it did not make possible any increase in train weights through Rogers Pass. It did not eliminate the pusher gradients on either side of the Selkirk summit, and it did not provide double track upon these severe ascents, where capacity, as a result of gradients and train speeds, would be at its most restricted.

Nevertheless, from the 46.1 miles of pusher gradient between Albert Canyon and Beavermouth, the Connaught Tunnel realignment reduced the total length of main line by 4.32 miles. It shaved off over seven miles of the 2.2% gradient on the east slope, and nearly six miles on the west slope. At the summit of the Selkirks, it reduced the gradient to less than one per cent for 8.8 miles, of which 5.8 miles were double-tracked.

The tunnel itself was perceived by contemporaries as the most long-term achievement of the realignment project. Had it been envisaged in 1913 that there would be a need in the foreseeable future for a further discrete increment in main-line capacity through Rogers Pass -- the provision of a third main line -- it is possible that the pioneer tunnels which were driven on either side of the main bore might have been driven on the same side of the main bore, and been linked with each other at construction time. The Simplon Tunnel in Europe had been designed in this way. A continuous pioneer tunnel had been driven adjacent to the path of the main bore, and the main bore had then been constructed to single-track dimensions. A further increment in capacity was subsequently obtained by enlarging the pioneer tunnelitself to single-track dimensions, thus providing two parallel, single-track, main-line tunnels through the Alps. The Connaught Tunnel was conceived as a double-track tunnel from the outset. The driving of the pioneer heading to the south of the main bore at the west end and to the north of the main bore at the east end would effectively preclude the C.P.R. from incrementing main-line capacity through the tunnel in a manner similar to that adopted in the Simplon.

Nevertheless, the C.P.R. had not foreclosed upon alternative means of incrementing main-line capacity when it opened the Connaught Tunnel. As has been noted,[3] the tunnel was built with a clearance which was believed by contemporaries to be sufficient to permit of any kind of electrification. Moreover, the tunnel approaches could still be double-tracked, and these double tracks could then be electrified in accordance with the initial scheme, if capacity requirements so dictated.

In fact, however, ancillary developments in operating methods over the Selkirks would provide sufficient capacity to obviate the necessity for the implementation of these alternatives. Automatic block signals were installed in the early 1920's,[4] just in time for the great grain rush which began in mid-decade. The volume of traffic which the grain rush presaged induced the C.P.R. to commission intensive studies of both dieselisation and electrification between Revelstoke and Lake Louise in 1926,[5] but in 1929 the introduction of the massive "Selkirk" steam locomotives, which reigned until the 1950's, further postponed the provision of double track and catenary. After the Depression and the Second World War, multiple-aspect signalling was installed through Rogers Pass in 1950,[6] and the route was dieselised in 1954.[7]

These developments served to prolong the life of the Connaught Tunnel, and to assure that the configuration of the main line across the Selkirks continued to be appropriate to traffic demand. The chief threat to the life of the tunnel was imposed, not by line-capacity constraints, which henceforth were experienced most acutely on the steeply-graded, single-track approaches to the tunnel, but by loading-gauge constraints consequent upon the limited vertical clearance of the tunnel.

When first proposing the tunnel in October 1912, Sullivan had envisaged that its cross-section would be "about 30 ft. wide, 24 ft. high."[8] In March 1913, he informally asked, and obtained, the permission of the Chief Engineer of the Board of Railway Commissioners, for

> a clearance of 17' or 18' above the base of rail in this tunnel, on the understanding that no men would ride on top of cars through the tunnel.[9]

This would have provided an extremely limited clearance through the tunnel, and the low-clearance option was not in fact exercised. As construction of the tunnel commenced prior to the taking of any decision concerning the type of electrification which would be installed, the bore was provided with a vertical clearance which was believed capable of accommodating any type of electrification equipment. The interior dimensions were much as Sullivan had initially recommended: a width of 29 feet and an overall height of 24 feet.[10] After ballasting, the height at the centre of the tunnel was 21 feet 6 1/2 inches,[11] and the vertical height above the centre of each track was 20 feet.[12] The height-at-centre was greater than that initially stipulated for the snowsheds: in 1888, this had been 21 feet.[13] The vertical clearance above rail level, however, may not have been as great as that provided through all of the other railway tunnels on the main line between Donald and Kamloops. A list of "Tunnels on the Pacific Division," undated but certainly compiled around the turn of the century, records vertical clearances of 20 feet 7 1/2 inches through every main-line tunnel as far west as Ashcroft.[14] Moreover, the height above the centre of track was certainly less through the Connaught Tunnel than through the Spiral Tunnels which had been built five years previously: in the latter, the vertical height above "grade line" was 24 feet 6 inches.[15]

Despite the cancellation of electrification, which would have further reduced the available headroom, the clearance constraint through the Connaught Tunnel was soon felt. The tunnel had been open to traffic for barely four months when a train loaded with cedar, presumably having travelled eastbound through tunnels of greater clearance, struck the roof of the Connaught Tunnel.[16] The C.P.R. refused to revise the through clearance for the Mountain Subdivision as a result of this incident, but a further loss in clearance may have been experienced in the years immediately following. As a result of persistent problems with crumbling rock in the roof, it became necessary to extend the concrete lining from the initial 7,837 feet throughout the entire length of the 26,512-feet tunnel, at an undiscounted cost, spread over the years 1919 to 1925, of

$2,595,135.31.[17] This was over one-third as much again as the tunnel itself had cost.

When the "Selkirk" locomotives were introduced after 1929, they had to be switched to the left-hand track before negotiating the tunnel, in order to provide the locomotive engineers with adequate visibility.[18] Finally, when the C.P.R.'s automobile traffic increased in the 1950's, and it wished to deploy tri-deck automobile-carriers through the tunnel, the available vertical clearance was insufficient. In December 1958, the C.P.R. obtained authorisation to remove one of the tracks through the tunnel, and to relocate the remaining track down the centre of the bore.[19] The capacity increments obtained from dieselisation and resignalling had rendered the second main line dispensable and inappropriate, and the double-tracking through Rogers Pass, which had been achieved in 1916, was undone.

Today, it appears that CP Rail's facilities through the Selkirks are once again becoming inappropriate for traffic demand. In contrast to the situation in 1913, the pressures which are being experienced upon those facilities are being exerted peculiarly in the westbound direction only. Once again, the major growth areas are in bulk commodities, and in particular in the coal, sulphur and potash markets. Again, as in 1913, there is fierce competition for the business, and this competition is being waged at both company- and national levels. At company level, CP Rail is already competing directly with Canadian National for the sulphur and potash traffic. If the coalfields of northern B.C. are developed, CP Rail's service into Sparwood will compete directly with the CN and B.C. Rail services to Fort Nelson for coal markets; and if Hat Creek is developed and coal exported from there, B.C. Rail will become engaged in the competition directly. At national level, Canada is competing with Australia for the commercial right to supply Japan with its bulk materials. Insofar as coal, sulphur and potash are all destined primarily for export, it is national as well as provincial and company interests which are at stake. Finally, as in 1913, it is the forecasts for future business, at least as much as existing traffic volumes, which are providing the impetus for investment decisions. If CP Rail's forecasts are correct, and if they are not on this occasion confounded by the outbreak of war, then the existing rail facility through the Selkirks will become inappropriate for demand within a few years. If the necessary increment in rail capacity is to be available when it is required, then the decision to provide that capacity will have to be taken very soon.

This decision will be of a nature that by now should be familiar to the reader. It will entail a trade-off between capital costs and operating costs. There is, however, perhaps one crucial difference between the decision faced by CP Rail now, and that faced by the C.P.R. in 1913. This difference is one of magnitude, both relative and absolute. In 1913, the Connaught Tunnel was budgeted to account for $8 million of a double-tracking programme expected to cost $60 million. In that same year, the C.P.R.'s gross receipts were $139 million, or seventeen times the total cost of the tunnel. In 1980, the cost of the tunnel which CP Rail proposes to build through the Selkirks in order to provide the necessary increment in main-line capacity is estimated at $300 million. In 1979, the gross receipts of CP Rail were $1,619 million, scarcely five times the estimated cost of the projected tunnel.

The chief reason why the capital burden is so severe in the present decision situation is that in order to meet the estimated future demand for rail capacity, and in order to eliminate the Selkirks as a bottleneck against westbound traffic, CP Rail believes that it must construct a tunnel 8.9 miles long, at an elevation some 300 feet beneath the Connaught Tunnel. The Company is prepared to proceed with the investment only if it is assured of obtaining a cash flow from its export grain traffic. At present, that traffic is carried at statutory rates which do not cover the variable cost of the movement. Until the statutory rates are revised, CP Rail asserts that it will not make another trade-off between construction and operating costs at the summit of the Selkirks. The federal government must decide whether or not such a trade-off can be rendered economical, and whether or not the trade-off is necessary for Canada. The federal government must decide whether it is prepared to revise the unremunerative Crow's Nest rates on export grain, or whether it is prepared to grant some form of construction subsidy instead.

This thesis has considered the appropriateness of rail facilities through the Selkirks from the time that the first railway link penetrated the mountains until 1916. When the original main line was built, it was appropriate that it should cut directly through those mountains. The short route with its steep gradients was appropriate for the light traffic of the first Canadian transcontinental railway. When traffic increases rendered the single line inappropriate, revision was undertaken. It was not appropriate that a long, low-elevation tunnel should be provided, nor that the line should be electrified, nor that it should be doubled throughout its entire mountain crossing. The operating savings which would be derived from such investments would not justify the necessary capital expenditure. Instead, a revision was undertaken which required a lesser capital expenditure, but from which the operating savings to be derived from the traffic volumes which had been forecast were nevertheless sufficient to offer an acceptable rate of return. This revision provided rail facilities through the Selkirks which would be appropriate to traffic demand for the next sixty years.

Now, those rail facilities have become inappropriate once again. Moreover, the cost of rendering them appropriate appears to be too great for CP Rail to accept. Now, perhaps, it is incumbent both upon CP Rail and upon Canada to determine whether or not alternative and more appropriate facilities should be provided for the transportation of Canadian resources through the mountains to the West Coast. Alternative routes may have to be developed, and an alternative technology, perhaps that of the slurry pipeline, may be brought forward to serve the new markets, or to link them with existing railheads.

For the past one hundred years, the C.P.R. has provided Canada with appropriate transportation facilities through the mountains of British Columbia to tidewater in Vancouver. Now, those facilities are inappropriate. The search for more appropriate facilities will not be confined to existing carriers. It will not be confined to exising routes. It may not even be confined to Canada. And it may not be confined to existing modes, nor to the existing technology.

Suggestions For Further Research

Suggestions for further research fall naturally into two categories. There is scope for further research within the horizons of the present thesis, and there is also scope for expanding those horizons, both temporally and geographically, and for undertaking further research within the new horizons.

Within the framework of the present thesis, there are at least four areas where much fruitful analysis remains to be carried out. The first such area concerns traffic flows through the mountains during the period spanned by this thesis. Data for flows by commodity, volume, direction and frequency are diffuse, but are likely to be retrievable from a variety of contemporary sources. For the principal flows, records of the early lumber mills and salmon canneries, for example, might give some insight into freight-car orderings and forwardings, and into expected future flows. The extensive transcripts of hearings before the Board of Railway Commissioners, particularly upon rate-discrimination cases, deserve far more thorough investigation than it was possible to accord them in the preparation of this thesis.

The second area, which receives very cursory treatment in this thesis, but which may yet prove crucial to a proper understanding of the economics of the C.P.R.'s investment decisions in Rogers Pass, concerns the matter of rates on rail traffic through the Selkirks. Fascinating economic and historical questions arise. In the economic aspect, it would be helpful to discover the principles and the practice of C.P.R. rate policy in the mountains, for both freight and passenger traffic, before and immediately after construction of the Connaught Tunnel. It would be valuable to know whether the rates were intended merely to cover the variable costs of operating through the mountains; whether they were aggressively competitive with rates on the U.S. railroads; or whether they were "promotional," and internally subsidised from revenues derived elsewhere upon the C.P.R. system. Finally, it would be interesting to determine whether or not the opening of the Connaught Tunnel, with its concomitant variable-cost savings, prompted any change in either the principles or the practice of C.P.R. rate policy towards trans-mountain traffic, and whether or not any change in rate policy was envisaged when the C.P.R. was contemplating construction of the tunnel.

There are two intriguing historical questions upon which further research may shed light. The first concerns Western Canadian agitation against "unjust" rate discrimination, particularly through the mountains. Since 1903, the Freight Rates Committee of the Vancouver Board of Trade had campaigned for redress,[20] but after obtaining certain concessions in 1907,[21] the Committee had been compelled in February 1912 to accept that its case was "closed and argued."[22] Barely had the C.P.R. commenced construction on the Connaught Tunnel than the agitation revived, precipitating the "Western Freight Rates

Case" of 1914. Analysis of the transcripts of the case may reveal whether the Vancouver Board of Trade's renewed agitation was motivated by awareness that the rail improvements in the Selkirks would reduce the marginal cost of freight transport through the mountains; or whether the rail improvements were motivated by a C.P.R. desire to pre-empt the agitation in B.C.

The other historical question concerns the C.P.R.'s posture towards the Crow's Nest Pass rates on export grain. In 1913, these rates applied only to grain exported through eastern Canada. The rates were remunerative. It is possible, however, that the C.P.R.'s cool reception towards the prospects of exporting grain via the West Coast was prompted by a fear that, given the gradient system over which it was obliged to operate between the prairies and Vancouver, it could not hope to continue to carry westbound grain profitably at the agreed rates. The investment in the Connaught Tunnel may have been undertaken in an attempt to ensure that, if the C.P.R. were to compete for the grain traffic with the Canadian Northern and Grand Trunk Pacific Railways, its variable costs for conducting the operation would at least be reduced. Alternatively, the investment may have been undertaken in the hope, or expectation, that the federal government would not extend the Crow rates to westbound export grain. If the rates were not extended, the C.P.R. might hope to circumvent the rates on eastbound grain by diverting grain westbound; and in order to divert grain westbound, it would require an increment in main-line capacity through the mountains, and a gradient improvement which would reduce the variable cost of the movement.

This is mere supposition at present, and the evidence supporting the postulates is extremely circumstantial. If the hypothesis were to be substantiated, however, it would suggest that the C.P.R. was grievously disappointed in 1925 by the extension of the Crow rates to westbound export grain. This would prevent the C.P.R., "for perpetuity," from transporting grain to tidewater at any point in Canada for a rate higher than that prevailing in 1897.

The third area wherein fruitful research might be pursued, an area which again receives cursory treatment in the present thesis, concerns the influence of competitive factors on the conduct of the C.P.R.'s operations through the mountains, and on the investment decisions which the Company accordingly made. This thesis suggests that both the timing and the objectives of the C.P.R.'s decision to construct the Connaught Tunnel were influenced by the imminence of competition for Canadian trans-mountain rail traffic from the Canadian Northern and Grand Trunk Pacific Railways. Further research into the manner in which each of these rival enterprises viewed its competitors might reveal the impact which the presence of competition was expected to have upon C.P.R. traffic receipts in the West, and hence upon the economics of investment decisions along the C.P.R. main line. Moreover, the competition which the C.P.R. faced through the mountains was not confined to Canada: it would be appropriate for a review of investments in main-line capacity in Canada to incorporate analysis of similar contemporaneous investments along the transcontinental routes in the United States.

The final area in which further research is suggested concerns previous comparable investment decisions taken by the C.P.R. on its main line through the mountains. Obvious candidates for more intensive study, within a framework similar to that employed in the present analysis of the decision to build the Connaught Tunnel, are the Palliser tunnel and the Spiral Tunnels. The economics of the several electrification projects proposed for the mountains would form a study in themselves.

Beyond the confines of the present thesis, the next logical step is to bring the analysis forwards in time. The examination should be extended to consider the nature of capacity constraints experienced by the C.P.R. on its main line through the mountains after 1916, and to investigate the appropriateness of the investment responses triggered by these constraints. Finally, the analysis should be extended geographically, in order to consider capacity constraints and the economics of their elimination on other routes served by other carriers through the mountains in both Canada and the United States.

FOOTNOTES

[1] In 1913, there was also a large and lucrative passenger market in both directions through the mountains. This has no counterpart today.

[2] Bury to Shaughnessy, June 17, 1913, op. cit.

[3] See chapter 8.

[4] N. B. McCallway to A. LeSage, Assistant Director of Operations, Board of Railway Commissioners, February 28, 1958. CTC File 21029.7.

[5] The Junkins (Sidney E.) Co. Ltd., "Report on the diesel-electric locomotive in comparison with steam and straight electric locomotives for operating the main line of the Canadian Pacific Railway between Revelstoke and Lake Louise." Vancouver, 1926. Mimeo., Glenbow Alberta Institute.

[6] Beatty, CP Rail's Connaught Tunnel, op. cit., p. 229.

[7] McCallway to LeSage, op. cit.

[8] Sullivan to Bury, October 22, 1912, op. cit.

[9] Sullivan to Bury, March 13, 1913, op. cit.

[10] Engineering News, Vol. 71, No. 14, April 2, 1914, p. 718.

[11] Transactions of the Canadian Society of Civil Engineers, Vol. XXX, 1916, Plate 5, following p. 133.

[12] Railway Age Gazette, December 11, 1914, op. cit., p. 1084.

[13] Keefer, op. cit., p. 70.

[14] "Tunnels on Pacific Division," op. cit.

[15] Engineering News, November 10, 1910, op. cit., p. 513.

[16] Frank Lee, Principal Assistant Engineer, Winnipeg, to F. W. Peters, General Superintendent, Vancouver, April 16, 1917. RCM 76.15.249-018693.

[17] C.P.R. Co., Annual Reports, "Expenditures on Additions and Improvements," 1919-1925.

[18] "It also eliminated any possibility of decapitation should he have put his head out the cab window." "Ken Liddell's Corner," Calgary Daily Herald, February 22, 1963.

[19] CTC Order No. 96567, December 12, 1958.

[20] Vancouver Board of Trade, Annual Report, 1903-04, p. 19.

[21] Vancouver Board of Trade, Annual Report, 1907-08, p. 12.

[22] Vancouver Board of Trade, Annual Report, 1911-12, pp. 28-29.

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