HIGHWAY INVESTMENT IN BRITISH COLUMBIA 1946-71:
A STUDY
OF THE SPATIAL DISTRIBUTION OF INVESTMENT
AND AN ASSESSMENT
OF ITS IMPACT ON THE HIGHWAY NETWORK
by
DON FRANK TOWNSEND
B.A., University of Sydney, 1963
A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS
in the Department
of
Geography
We accept this thesis as conforming to the
required standard

THE UNIVERSITY OF BRITISH COLUMBIA
April, 1973
In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the Head of my Department or by his representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

DON FRANK TOWNSEND

Department of Geography

The University of British Columbia
Vancouver 8, Canada

Date April, 1973
ABSTRACT

The subject of this study is road investment in B.C. made through the Provincial Department of Highways in the years 1946-71. The pattern of investment is described and is used to indicate policies and objectives being evolved over the period. An effort is also made to evaluate the impact of the investment in terms of the benefit to certain classes of road users.

Data on investment were gathered from the Annual Reports of the Minister, and assembled according to area, item, time period and class of road. The nature of investment has been given close attention because it is felt that its role has been somewhat overlooked in the previous studies of the relationship between transport infrastructure and economic activity. That relationship has usually been treated in summary form, with highly generalized indices. There is an attempt in this study to find a rationale of spending to explain the variations between areas, and from which to draw inferences about policies. This leads on to closer examination of the trunk network.

Some structural measures of improvement in the network were calculated, but were not very helpful. This study argues that the improvement has to be valued by some user before it is translated into increased accessibility and responses
amongst economic activities. Because improvements mean different things to different users and non-users, different approaches to evaluation have to be taken. A large truck is chosen for the case of B.C., and operating costs are simulated for the roads existing in 1952, 1962 and 1971. The changes in truck operating costs are used to explore the meanings of 'improvement' and the 'justification' of certain investments. An estimate of annual savings to trucks from road improvements is derived from the simulated costs.

The approach through investment is found to aid understanding of route and network development. It provides criteria by which to evaluate other aspects of road development, such as the road needs of certain populations, and the effects of external connections and through paths. It reveals the highly variable per mile cost of links, and emphasizes the interdependence of different types of spending. It suggests a relationship between inter-urban and local spending and traffic, which should be worth following up in other situations.

Among other things, it is discovered that there has been a tendency to spend an increasing proportion on the branch or feeder roads. In the last few years, there has been an increasing concentration on urban or near-urban roads for the relief of congestion. The purposes of roads and routes are seen to change over time. The pattern of spending has been much affected by the difficulty of road construction in B.C. Increases in election years have stood out markedly. These have 'cost' the Province a significant amount through inflated contract prices.
Some suggestions are made on how over-the-road savings could make their way through to freight rates, schedules and services, and thus affect the client economic activities. The estimate of annual savings of $15-20 million to large trucks is a conservative and partial measure of benefit.

The aim was not a definitive measure of improvement and partial benefit, but to use the measure in different contexts and reveal the different meanings and quantities of improvement. Different 'justifications' for link investment were provided from different perspectives. The interdependence of links and of investment allocations in the total system was emphasized. It is the main strength of this modified network perspective that it allows the simultaneous consideration of flows, structure, link importance and nodal accessibility.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Abstract</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ii</td>
</tr>
<tr>
<td>List of Tables</td>
<td>viii</td>
</tr>
<tr>
<td>List of Figures</td>
<td>x</td>
</tr>
<tr>
<td>Acknowledgement</td>
<td>xii</td>
</tr>
</tbody>
</table>

**Chapter 1 - SCOPE OF THE STUDY**

1. Introduction ............................................ 1
2. Definitions ............................................. 2
3. Resume of Spending: Actual Amounts, Possible Objectives ................. 3
4. Investment by Direction and By Item: A Hypothetical Generalized Programme ........................................... 8
5. The Potential of a Changed Road Network ........................................... 10
6. Summary of the Argument ........................................... 13
7. Organization of the Study ........................................... 14

**Chapter 2 - ANTECEDENTS OF THE STUDY**

1. Transportation Studies in Geography.. 18
2. Description of Transport Networks ... 20
3. Investment in highway facilities .... 21
5. Investment, Accessibility and Economic Response ....................... 25
6. Synthesis of Themes and Interests in the Literature .................... 28

**Chapter 3 - TOTAL SPENDING ON HIGHWAYS IN B.C.**

1. Introduction - Aims and Sources ..... 31
2. A Conceptual Framework of Spending .. 35
3. A Formula for Amounts of Spending? .. 38
4. Actual Distribution of Investment ... 40
<table>
<thead>
<tr>
<th>Chapter 3 - 5. Possible Validity of the Postulated Pattern</th>
<th>47</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Breakdown of the Whole Period - Construction Price Changes</td>
<td>48</td>
</tr>
<tr>
<td>7. The Allocations over Time</td>
<td>52</td>
</tr>
<tr>
<td>8. The Districts' Allocation over Time</td>
<td>57</td>
</tr>
<tr>
<td>9. Emphasis within Sub-periods</td>
<td>62</td>
</tr>
<tr>
<td>10. The Total Allocation Reviewed</td>
<td>67</td>
</tr>
</tbody>
</table>

| Chapter 4 - SPENDING ON B.C. HIGHWAYS, ACCORDING TO CATEGORIES |
|---------------------------------------------------------------|----|
| 1. Purpose of the Chapter | 71 |
| 2. Relationship between Trunk Development and Branch Development | 72 |
| 3. Spending in B.C., by Road System | 77 |
| 4. Changes in the Trunk/Branch Ratio Over Time | 82 |
| 5. Meaning of the T/B Division of Spending | 87 |
| 6. Relationship between Maintenance and Construction Costs | 90 |
| 7. Maintenance Costs over Area | 95 |
| 8. Meaning of Maintenance Cost Patterns | 97 |

| Chapter 5 - INVESTMENT IN THE TRUNK NETWORK |
|--------------------------------------------|----|
| 1. Introduction | 100 |
| 2. Importance of the Trunk System | 101 |
| 3. Build-up of the Trunk System, 1946-71 | 105 |
| 4. Link Investment and Node Activity | 112 |
| 5. Network Improvement from the Allocations | 117 |
| 6. Measurement of Network Change | 121 |

<p>| Chapter 6 - EVALUATING IMPROVEMENTS IN THE TRUNK SYSTEM |
|---------------------------------------------------------|----|
| 1. Introduction | 124 |
| 2. Choice of a Large Truck in Evaluating Link Changes | 125 |</p>
<table>
<thead>
<tr>
<th>Chapter 6 -</th>
<th>3. Trucks in the Total Traffic</th>
<th>131</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Method of Simulation of Truck Operating Costs</td>
<td>139</td>
<td></td>
</tr>
<tr>
<td>5. Output from the Simulation</td>
<td>146</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 7 -</th>
<th>CHANGE IN THE NETWORK INDICATED BY TRUCK COSTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction</td>
<td>154</td>
</tr>
<tr>
<td>2. Investment Allocations and Truck Cost Savings</td>
<td>154</td>
</tr>
<tr>
<td>3. Link Characteristics of Truck Cost Savings</td>
<td>164</td>
</tr>
<tr>
<td>4. Link Changes in a Network Context</td>
<td>170</td>
</tr>
<tr>
<td>5. Minimum Paths in the Network</td>
<td>173</td>
</tr>
<tr>
<td>6. The Chapter Reviewed</td>
<td>179</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 8 -</th>
<th>THE VITAL CONCERN - USE OF TIME AND COST SAVINGS</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Chapter 9 -</th>
<th>CONCLUSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The Approach</td>
<td>191</td>
</tr>
<tr>
<td>2. The Pattern Observed</td>
<td>194</td>
</tr>
<tr>
<td>3. Measurement of Improvement</td>
<td>199</td>
</tr>
</tbody>
</table>

BIBLIOGRAPHY | 205 |

APPENDIX I | Changes in Electoral Districts Since 1946 | 219 |

APPENDIX II | The Trunk Roads, as Used in This Thesis | 220 |

APPENDIX III | Content and Methods of the Simulation of Heavy Truck Costs | 221 |
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td>Influence on Cost per Mile of the Trunk Mileage</td>
<td>46</td>
</tr>
<tr>
<td>II.</td>
<td>Breakdown of Spending, by Period</td>
<td>53</td>
</tr>
<tr>
<td>III.</td>
<td>Indicators of Road-user Activity, 1950-72</td>
<td>54</td>
</tr>
<tr>
<td>IV.</td>
<td>Grouping of Districts According to the Sub-period of their Largest Share of Total Spending</td>
<td>58</td>
</tr>
<tr>
<td>V.</td>
<td>Grouping of Districts According to the Sub-period of their Most Intensive Activity</td>
<td>63</td>
</tr>
<tr>
<td>VI.</td>
<td>% Reduction from 1946-71 Total after Adjustment for Inflation</td>
<td>64</td>
</tr>
<tr>
<td>VII.</td>
<td>Total Spending in the Districts, According to Item and To Road System, 1946-71</td>
<td>78</td>
</tr>
<tr>
<td>VIII.</td>
<td>Percentage of Total Spent on Branch System, by District</td>
<td>79</td>
</tr>
<tr>
<td>IX.</td>
<td>Relationship of Dollar Allocations and Flows, on Selected Links</td>
<td>117</td>
</tr>
<tr>
<td>X.</td>
<td>Structural Changes Resulting from Link Addition</td>
<td>120</td>
</tr>
<tr>
<td>XI.</td>
<td>Percentage of Free Speeds, Under Width Restrictions</td>
<td>143</td>
</tr>
<tr>
<td>XII.</td>
<td>Indices of Free Speed and Normal Consumption, Due to Increasing Rise and Fall</td>
<td>144</td>
</tr>
<tr>
<td>XIII.</td>
<td>Percentage of Free Speeds, Under Average Daily Flows</td>
<td>145</td>
</tr>
<tr>
<td>XIV.</td>
<td>Indicative Fuel Consumption at Average Running Speeds</td>
<td>145</td>
</tr>
<tr>
<td>XV.</td>
<td>Truck Operating Costs on Selected Links</td>
<td>147</td>
</tr>
<tr>
<td>XVI.</td>
<td>Reliability of Calculated Costs</td>
<td>147</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>XVII.</td>
<td>Reliability of Calculated Speeds</td>
<td>148</td>
</tr>
<tr>
<td>XVIII.</td>
<td>Relationship of Investment, Traffic Flows and Truck Operating Costs</td>
<td>161</td>
</tr>
<tr>
<td>XIX.</td>
<td>Improvements in Truck Operating Costs</td>
<td>164</td>
</tr>
<tr>
<td>XX.</td>
<td>Shimbel Accessibility Scores, 1971 Truck Costs</td>
<td>172</td>
</tr>
<tr>
<td>XXI.</td>
<td>Shimbel Index Scores, 1952 and 1971, Selected Nodes</td>
<td>175</td>
</tr>
<tr>
<td>XXII.</td>
<td>Link Occurrence In All Paths, 1952 and 1971</td>
<td>176</td>
</tr>
<tr>
<td>XXIII.</td>
<td>Diversion of Traffic from Kootenay Lake ferry, 1962-5</td>
<td>178</td>
</tr>
<tr>
<td>XXIV.</td>
<td>Relationship Between Link Occurrence and Actual Traffic, in 1971, Selected Links</td>
<td>179</td>
</tr>
<tr>
<td>XXV.</td>
<td>For-hire Trucks, Freight Movements, B.C. 1970</td>
<td>189</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Spending on Highways as % of Total Government Spending</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>Total Spending by Electoral Districts, 1946-71</td>
<td>41</td>
</tr>
<tr>
<td>3.</td>
<td>Total Spending per Mile of Road Open, 1946-71</td>
<td>43</td>
</tr>
<tr>
<td>4.</td>
<td>Total Spending per Mile of Road Improved, 1946-71</td>
<td>45</td>
</tr>
<tr>
<td>5.</td>
<td>Highway Construction Price Index, 1956-71</td>
<td>50</td>
</tr>
<tr>
<td>6.</td>
<td>Relationship of Spending on Roads to Indicators of Road User Activity</td>
<td>55</td>
</tr>
<tr>
<td>7.</td>
<td>Share of Total Spending, According to Sub-periods</td>
<td>61</td>
</tr>
<tr>
<td>8.</td>
<td>Distribution of a District's Total, According to Sub-periods</td>
<td>66</td>
</tr>
<tr>
<td>9.</td>
<td>Hypothetical Presentation of Trunk/Branch Ratio of Spending</td>
<td>73</td>
</tr>
<tr>
<td>10.</td>
<td>Generalized Diagrams of the Relation of Increasing Traffic Flow to the Accumulating Capital and Maintenance Cost of Facilities</td>
<td>75</td>
</tr>
<tr>
<td>11.</td>
<td>Diagrams of Trunk Mileage Within Electoral Districts</td>
<td>81</td>
</tr>
<tr>
<td>12.</td>
<td>Trunk/Branch Spending for Selected Districts, 3-year Averages</td>
<td>83</td>
</tr>
<tr>
<td>13.</td>
<td>Trunk/Branch Spending for Selected Districts, Annually</td>
<td>86</td>
</tr>
<tr>
<td>14.</td>
<td>Diagrams of the Relationship of Trunk and Branch Systems</td>
<td>88</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>15.</td>
<td>Relationship of Construction, Maintenance and Traffic Flows</td>
<td>93</td>
</tr>
<tr>
<td>16.</td>
<td>Development of the Trunk System, by Period</td>
<td>106</td>
</tr>
<tr>
<td>17.</td>
<td>Total Cost of Links in the Trunk System, 1946-71</td>
<td>107</td>
</tr>
<tr>
<td>18.</td>
<td>Cost per Mile of Trunk Links, 1946-71</td>
<td>108</td>
</tr>
<tr>
<td>19.</td>
<td>Simulated Heavy-Truck Costs, 1952 Links</td>
<td>156</td>
</tr>
<tr>
<td>20.</td>
<td>Simulated Heavy-Truck Costs, 1962 Links</td>
<td>157</td>
</tr>
<tr>
<td>21.</td>
<td>Simulated Heavy-Truck Costs, 1971 Links</td>
<td>158</td>
</tr>
<tr>
<td>22.</td>
<td>1971 Costs Related to 1952 Costs</td>
<td>159</td>
</tr>
<tr>
<td>23.</td>
<td>Spending per Mile Related to Unit Savings in Truck Costs</td>
<td>160</td>
</tr>
<tr>
<td>24.</td>
<td>Average Truck Costs per Mile, 1971 Links</td>
<td>167</td>
</tr>
<tr>
<td>25.</td>
<td>Running Costs for Heavy Trucks At Increasing Speed</td>
<td>168</td>
</tr>
<tr>
<td>26.</td>
<td>Imbalance in Freight Movements in B.C., 1970</td>
<td>186</td>
</tr>
</tbody>
</table>
ACKNOWLEDGEMENTS

Gabrielle was the severest critic and most willing helper. Special thanks are due to Roger Leigh, for his guidance and encouragement throughout, and to Bob North and Ken Denike for their criticisms and suggestions. Larry Meyer's help with the computer operations was indispensable. The Transport Development Agency made survival possible, by means of a fellowship award. My fellow graduate students helped to make the days interesting and the winters tolerable.

A special note of appreciation is due to Isabell and Alexandra, for the typing and illustrations respectively.
CHAPTER 1

SCOPE OF THE STUDY

1.1 INTRODUCTION

The intention of this thesis is to describe and analyze road development in British Columbia since World War II, trying especially to discern patterns in the allocations of provincial government spending that will provide some clues to the policy objectives existing for various times and for various areas. The description concentrates on the main trunk network, which is separated out for a special inspection of changes in structure and quality, as related to dollars spent on improvements.

It must be emphasized that highways comprise only part of the total system of transportation in British Columbia, and also that investment in transportation is only one of a number of means by which society can hope to achieve desired objectives. Governments can adjust the priority of transportation amongst the social services they provide. Businesses can adjust the transport component of their factors of production. To consumers, transportation is an adjustable element of demand. However, there is probably little need to argue the case that in B.C. over the last 25 years highway investment
has been a major tool of government, and is a fit topic for geographic analysis.

1.2 DEFINITIONS

The term "highways" does not cover a homogeneous entity. On the contrary, highways vary greatly in their purposes of service, their design, their capacity, their traffic composition, and their importance to the whole network. Within one region, it is possible to identify routes serving mainly commuters or tourists or local recreational activity, truck traffic, and less tangible purposes such as pioneering or integration. It is likely that the purposes will change over time and area as structural and spatial shifts occur in the economy, and that these will be reflected in the allocations of spending.

The highway system, in this study, includes all highways, roads, trails, bridges and ferries which are administered, constructed, maintained, patrolled or subsidized by, or through, the provincial Department of Highways. All shared projects, where they have been detailed in the accounts of the Annual Report of the Minister of Highways, are included in the general term, "highway system", - for example, the access to hydro-electric development on the Columbia River, or the main highways through national parks. The highway system also includes the B.C. Ferries Division, though its allocation will be kept out of most of the analysis.

The reason for this separate treatment is in the
range and influence of the operations of the Division. Ferries, whether across rivers or across gulfs, connect-up subsystems of the whole network. With a mainland ferry, such as at Castlegar, or at Kelowna, the range of influence is relatively local. Therefore, one is on safer ground in attributing costs and gains from those ferries to the local or surrounding subsystems. One of the requirements of network analysis applied to geography is a close relationship between investment in links of a subsystem and some observable response at the same scale. Not so with the Gulf ferries, since the subsystems connected are more numerous, more complex, and of greater extent.

The highways system also includes roads and trails constructed or maintained under the scheme of grants-in-aid of mining development, and roads which are within municipal limits but which have been designated as arterials.

The system excludes the labyrinth of logging trails. It also excludes the enormous mileage of roadway constructed and maintained by the municipalities. This is a significant exclusion, since in an increasingly urban society, a greater burden of the overall road construction and maintenance will shift to the local authorities, and more provincial funds will be channelled through the municipalities and not through the Department of Highways.²

1.3 RESUME OF SPENDING: PROVINCIAL TOTALS, POSSIBLE OBJECTIVES

In British Columbia since 1946, the budget allocations
to the highway system suggest two distinct periods, described simply as "increasing priority" and "decreasing priority". The first fifteen years peaked in 1960-61, when the allocation reached 25 per cent of the total expenditure (see Figure 1), up from about 16 per cent in 1947-48. In recent years, greater priority has been given to education, health and social services, so that the allocation to highways has decreased to around 11 per cent.

Fig. 1 - Spending on Highways as a Percentage of Total Government Spending
B.C. 1946-1972*

*plotted as 4- or 5-year averages, to illuminate the trends.
...dotted line represents provincial spending, net of credits from Federal Government and B.C. Hydro.

B.C. Financial and Economic Review, years 1961 to 1972, Department of Finance, Victoria, B. C.
Actual spending on highways has maintained an impressive rate of increase - from $91 million in the three years 1949 to 1952 (including $3 million Federal payments), to $251 million in 1959 to 1962 (including $42 million Federal), and to $430 million in 1969 to 1972. The budget for 1973 to 1974 allows for $230 million - so the period 1971 to 1974 will total about $650 million. Total spending maintained something of a gently sloping plateau from 1957 through to 1969, as the main external connections and through-routes were put in (see Fig. 5, Ch. 3). Spending in 1969 to 1970, and 1971 to 1972, has been extraordinarily high, suggesting that the province is entering onto a new level of annual spending on highways. This will probably not be for another "development" phase, rather a "relief-of-congestion" phase that will be expressed in the widening of bottlenecks, adding of freeways or alternates, constructing by-passes, and reorganizing the operations of the ferries. It is in this phase that parochial-provincial tensions become more pronounced - the jurisdiction is local; the disruption of communities is local; the need for relief appears local though may, in fact, be regional; the repercussions of relief in one link or in one community are practically immediate on the adjacent link or community; but the decisions on funding and priority are still provincial.

The preceding paragraphs open up a consideration of some of the objectives of highway development. For a region, starting from a poor base of transport infrastructure, there is a tendency to go through the following arrangement of priority of objectives:
a) access to known or possible resources;

b) political-social intangibles, i.e., "connecting up the region", for both internal integration and external contact, or for spreading more evenly cultural and economic opportunities;

c) reducing costs of production and distribution through lower running and operating costs and travel time. The intention is to stimulate or attract activity, often directed to attracting investment from outside the region;

d) increasing the reliability of travel and supply;

e) access to specific sites of development, such as dams, installations, and pipelines;

f) encouraging and facilitating recreational travel to existing and new areas;

g) favouring some industries and sub-regions over others, through the quality of transportation;

h) reduction of the elements of movement for which cost assessment is impossible or extremely controversial - congestion, accidents, discomfort, inconvenience;

i) reduction of freight and travel costs indirectly, through inter-nodal competition;

j) influence on "liveable" areas and on the supply of land for specific uses, through new access, ferries, bypasses, limited-access freeways, toll facilities;

k) short-term unemployment relief and stimulus to a local economy;

l) capital investment in the present to reduce future operating and maintenance costs of the authorities.

Because of the range of responses to any investment in transport infrastructure, it is very unlikely that one objective will be pursued for itself alone. For instance, (h) above has a strong bearing on (f), and (d) could perhaps be considered as part of (c). Given this interdependence of objectives,
there are, however, examples in the B.C. experience of the obvious predominance of one objective over others.

Reading in the government reports of the mid-1940s, particularly those of the Rehabilitation Commission, suggests that the demands on the highway authorities were probably quite clearly and narrowly perceived. The war would have reminded people of the economic and psychological concern for national security and communal integration. The war had convincingly demonstrated the importance of mobility and motor power. It now left problems of social and economic rehabilitation and absorption of labour. The first major highways projects after 1945 were basically attempts at integration - John Hart Highway into the Peace River district, and the Southern Transprovincial from Hope to Keremeos and Penticton, and again from Nelson to Creston. For these projects, a high rate of spending was maintained from 1946 to 1952.

As the economy has developed, and as the highway network has been built up by the completion and improvement of "obviously" urgent links, the authorities are faced with a growing number of demands with finer margins of urgency. In purely economic terms, the disparities (in freight and travel costs) between various links in the system have been greatly reduced. The urgent tasks are now less "obvious"; choices now involve more social issues which are increasingly controversial and less quantifiable. Strict economic analysis of investment proposals, nevertheless, becomes more important in the sense of identifying and measuring what is quantifiable. In a less
than perfect political system, it is economically and socially unsound to wait for local protest as an indicator of road needs.

The main data input to decisions on the allocation of road investment in B.C. has been undifferentiated traffic counts, usually taken in the peak months of July and August. To use such a criterion exclusively over a long period would result in a uniform pattern, centered around the major producing and the major populated areas, extending along the inter-urban trunks, and shading off into the remote "economic wilderness". If the authorities were bound to this criterion, then highway investment would always follow structural and spatial shifts in the economy to the extent that they influence traffic flows. Highways would then reinforce economic-population patterns, and not help to mould them. As we shall see, the actual pattern of investment over the past 25 years shows a severe distortion away from such a simple pattern: the strongest factors in that distortion appear to be physiography, external connection, and official government policy pursuing specific objectives.

1.4 INVESTMENT BY DIRECTION AND BY ITEM: A HYPOTHETICAL, GENERALIZED PROGRAMME

A regional highway system is made up of inter-urban long distance arteries (trunks), and local lower-volume feeders (branches). A very primitive network, serving unplanned settlements, will usually have a greater proportion of branch
mileage, in the form of sub-systems of crude roads and trails to farms, forests, mines and so on, the sub-systems being connected by low quality trunks, by rail, or river transport. But with a central government programme of development, and an economy tending towards centralization, attention is usually directed towards the trunks to improve the quality, rather than to increase the mileage. At this stage, the choice of projects is relatively limited, especially where settlement has preceded the "Motor Age" - settlement appears to dictate the priorities.

After the major trunks are completed, more attention can be given to the branches until such time as the increase in traffic or deterioration of the facility forces improvement, relocation or replacement of a trunk link. A link requiring such an adjustment can occur within a sub-region where the feeders are being developed, or elsewhere in the path to major populated areas. Over a long period, once can expect some shift in the trunk/branch ratio of spending. This ratio will vary amongst sub-systems of the whole, will vary for the whole system over time, and for particular sub-systems over time. Observing this ratio for B.C. roads since 1946 should indicate particular policies of development prevailing from time to time.

As roadways are improved, maintenance costs will decrease, at least for a short time after the improvement. Tarmac surfacing abolishes the need for grading; good design and wide shoulders reduce the damage caused by spring runoff and washouts; good design also reduces accidents and congestion,
depending of course on the rate of traffic generation. Rising maintenance and operating costs indicate the need for a major capital investment - bridge replacing ferries is the most obvious example of the substitution of facilities. Re-routing of traffic flows is another way of reducing maintenance costs in a district: the alternate route may occur in another part of the system and not be revealed by the accounts of one particular district.

In an early stage of road development, maintenance costs \(M\) will be high in relation to construction and improvement costs \(C\). With a deliberate programme of connection and improvement, \(C\) will rise rapidly, and \(M\) will tend to decrease, on a per mile basis. In a fully developed sub-system, with very low \(C\), \(M\) will rise as traffic flow \(F\) increases. Increases in \(M\) tied to increases in \(F\) indicate an attempt to maintain a given quality of service. The pattern of \(M\) costs per mile, over time and over area, will indicate something of the intentions of the authorities with regard to road development.

1.5 THE POTENTIAL OF A CHANGED ROAD NETWORK

The early development of roads may be simply to allow movement and travel, i.e., basic access. Beyond the stage of first connections, the aim is generally to reduce the cost, time and difficulty of movement. The reduction of these elements can have very different effects, hence the use of road development in the planning for other objectives. It matters where, when and how the reduced costs are achieved, for change in one
part of the transport system entails a rearrangement of relative advantage and disadvantage elsewhere. All parts of the system (or of the economy) are competing for allocations; but also, some parts of the system are dependent on allocations to other parts of the system.

Each allocation contributes to the total structure and quality of the whole system, but varying amounts of improvement can result from similar dollar allocations, depending on where they occur in the network, on what facilities are provided, and the time span assessed for use of the facilities. There is a conscious choice to be made between, say, allocation to the extension of a low-grade peripheral link, and allocation to the widening and improvement of a busy link in a vital path. By relating the actual allocations to the amount of improvement "bought" for the whole system, a pattern of priority and preference may emerge, with indications of policy objectives being pursued from time to time.

The reduction of costs of movement creates a new field of economic potential in absolute and in relative terms. Existing activity in an area may be stimulated, sometimes to the disadvantage of similar activity in other areas; new activity of a different type may be attracted to the favoured area. Such adjustments and relocations will be partly reflected in the pattern, volume and composition of traffic flows - providing that the activities existing in, or attracted to, an area express a consistent demand for road transportation. Where the road investment provides a first link, or a link to enable competition with other modes of transport, or a link of
significantly improved quality, one would expect a significant response by the trucking industry to the new potential of lower running costs, shorter trip times, increased load dimensions, and re-routing of trips, provided that the nature and level of demand for transportation is sustained or increased. With the vast improvement of the B.C. road system from 1946 to 1971, and the dramatic removal of obstacles such as ferries and mountain passes, the response of the trucking industry ought to have been equally substantial and dramatic, even allowing for change within the trucking industry itself, due to technology, organization, regulation or other factor costs. There are important attenuating factors, such as rail competition, or the lack of generated growth in some areas. Areas favoured by investment, but lacking in response, are also informative about the nature of economic development. An important criterion of the success of investment is the degree to which the potential has been realized, and not just the potential improvement offered. Road investments, of course, are not made as an end in themselves, but should be related to the economic "mix" and "maturity" of an area, for these characteristics strongly influence the type and degree of response.

Observation of the trucking industry will certainly not tell the full story of the effects of road investment in B.C. A very important effect is in the volume and routing of tourist traffic, or in the good access to other activities such as dam-building, mines and sawmills. However, the trucking industry has been singled out because of its being highly sensitive to changes in the main network's structure and quality.
At this stage, the study can be considered partially closed and partially open. It is closed in the sense that the investment pattern has been described, the network changes measured, and the potential for response outlined. It is open in the sense that trucking is only a small part of the response to road investment, and that wider repercussions will occur as a result of reduced cost of access to different locations.

1.6 SUMMARY OF THE ARGUMENT

Investment in roads can be used as a means of achieving particular objectives, apart from the immediate relief of user demand or reduction of user cost. Over a long period, investment allocations will describe certain patterns, which are evidence of policies in force. A policy and a particular decision relating to it can be a powerful determinant of the shape, structure and quality of a network; yet, this may not be apparent from the usual method of relating certain economic indices to network measures.

Comparison of the road maps of 1945 and 1971 suggests that one of the main results of investment has been integration-by-road, of settlements within the province, and of the province, as a whole, with the rest of Canada and the U.S. northwest region. The trunk system is the instrument for those policy objectives attainable through investment in road transportation to the extent that activities depend on road transportation, and to the extent that affected activities are urban-oriented. Initial settlement and growth, particularly in B.C., are often
independent of the trunk system, but growth in the higher order activities is usually closely related. Improvements and additions to the trunk system rearrange the potential for social and economic interaction. Examination of the trunk system shows that the relationship between a change in investment and a change in that potential is highly variable.

Truck movements over the trunk system represent a particular type of interaction. Demand for it is expressed at a certain level of cost of movement. Reductions in the cost of movement, generally brought on by investment in road facilities, will allow that demand to increase if other conditions are permissive. If the trunk system is extended with new links, then the induced demand or the captured demand will show, to some extent, in truck movements. Response in the trucking industry is a valid measure of the effect of road investment, though the measurement is partial and entangled with many other effects and pressures.

The gain bought by an investment is not measurable in terms of facilities supplied; it depends very much on where and when the investment is made, in relation to total network structure, traffic generating areas, and paths through the system. Different evaluations give different perspectives on the "worth" of investments in road facilities.

1.7 ORGANIZATION OF THE STUDY

To place the study in its field, and to show the interests being exercised, a brief review of similar or related
studies is given in Chapter 2. Chapter 3 reduces a great deal of information on actual spending to a few summary patterns, the main effort being directed towards some general statements about the factors determining investment in particular districts, and an attempt to suggest arrangements of priorities. The attempt is carried over into Chapter 4, where the totals are broken down into classes of road and categories of spending. The classes and the categories are seen to be inter-dependent and substitutable to some extent. The dominance of the trunk system in the patterns and programmes of investment is then obvious, so that Chapter 5 separates the trunk system for closer examination. The huge total cost and cost per mile for a few vital links stand out in this description. Some suggestions are made about the possible reactions of users and activities to trunk investment. Some major structural changes are measured, and related to the cost of achieving them - but it is stressed that the structural measures alone are not a clear indicator of actual gain.

Chapter 6 looks at truck operations as one of the most important classes of road users. The available data are used to illustrate their importance in B.C. particularly. Trucks are used as the basis of measurement of link quality, and a simple simulation of operating costs is constructed, drawn from many experiments elsewhere and a compilation of a road inventory for B.C. Some indications of the reliability of the output of this are provided from other sources and from personal observations, made in July and September of 1972.
Simulated truck costs are then applied to the network in Chapter 7, not so much to describe what has happened, as to show how different perspectives and measurements can be applied to description. This method brings out the varying meaning of 'link importance'. Improvements are seen to occur on different scales, according to the perspective used.

Chapter 8 gives special treatment to an important consideration — how road improvements might work through to truck operator or user savings. Some estimates of gain for the B.C. situation are attempted. The attempt at least highlights the lack of usable data. The conclusion in Chapter 9 brings together the factual findings and some general thoughts arising from the study.
REFERENCES:


2 The provincial government provides an annual grant to the municipality of $25 per capita for "highways, pollution control, policing, and parks". It also pays 100 per cent for designated arterials; and for approved secondary roads, it pays 50 per cent of construction and 40 per cent of maintenance. The actual grant for highways alone was $4.5 million in 1959-60, now up to $64.5 million in 1971-2. Source: B.C. Financial and Economic Review, July 1972, pp. 33, 37, Department of Finance, Victoria, B.C.

3 R. Winfrey and C. Zellner describe three phases in the U.S. experience - the development period, the roadway surfacing period, and the high-capacity period. The B.C. experience can be described in similar fashion, though the actual phases occur at significantly later dates. NCHRP Report No. 122, Highway Research Board, (1971).


5 This opinion has been confirmed in discussions with officials of the Department of Highways. The less concrete but more powerful input to decisions has been policy determined outside the Department of Highways, especially concerning allocations to the inter-urban trunk system.

6 "Undifferentiated" in that the automatic recorders do not distinguish between directions of traffic; also, the total recorded is divided by 2, as if every vehicle had only 2 axles.

7 Conditions required for this uniform pattern of spending are elaborated in Chapter 3, Section 2.


CHAPTER 2

ANTECEDENTS OF THE STUDY

2.1 TRANSPORTATION STUDIES IN GEOGRAPHY

In translating economic and social behaviour into spatial terms, it is inevitable that transportation becomes a major concern to geographers. It is the means of least effort functions of human interaction; it is an important component in production functions and demand curves; it is a permissive factor in specialization of production, in changes in the range of markets, and in the tendency towards perfect knowledge amongst economic entities. For stimulation and development of the economic body, particularly in the economically backward countries, the circulatory system has been given very close inspection. Regional geography has gradually increased its recognition of transportation as a moulding force on regional character. The work of Ullman (1956), Isard (1956), and Garrison (1959-60) can be said to have established a foundation for transportation studies within geographic inquiry.

The function and form dichotomy of geography has had its expression, too, in transportation research. Questions of function came from the mainstream of economics into the
gravity model formulations and into the amplification of central place theory and later into diffusion studies. The most interesting treatment of form has been through network analysis. These models have provided geographers with a new perspective and a better framework on which to describe spatial interaction. Flows of goods and people, choice and location of routes, impacts of and adjustments to changes in accessibility, land use patterns, questions of central place functions and hierarchy have all been given a more realistic and complete treatment via network concepts and techniques.

This thesis draws together two streams of interest: (1) the role of transportation in economic development, and (2) the structure of networks. Especially over the last twenty years, in the programs of aid from abroad for underdeveloped countries, transport infrastructure has been of prime importance. Only recently has there been some drawing back from this position, as expectations of results have not always been fulfilled. A critical aspect of investment is the new potential created; even more critical, where capital is very scarce, is the degree to which that potential has been realized. In the following chapters, part of the new potential created by road investment in British Columbia will be measured, and an attempt will be made to indicate how that potential has been realized.
2.2 DESCRIPTION OF TRANSPORT NETWORKS

In the description of network structure, the abstraction of the transport system from its broader social and economic context seems to imply some deterministic dynamic of growth inherent in the network itself. Some studies have constructed networks from models of transport development, or from models of economic behavior, or from models guided by a particular constraint of length, cost, connectivity, etc. The assumption of consistent or coolly objective decision-making is vital to such models; but it can be argued that there is such variation within policy objectives and decision-making that this process, itself, becomes an important factor in the realized structure and quality of networks. Considerations of "social cohesion" or "political impact" or "minimum social disruption" really do inform many decisions on the provision of transport facilities, yet they cannot be fully built into the models constructed from empirical evidence elsewhere. This thesis will attempt to discover, from the patterns of investment, some of the policy objectives which might have influenced allocations of investment in B. C. The network will then be seen as a composite of various motives, which cannot be fully described by one summary measure. A measure of connectivity, or accessibility, may provide a neat summary of a physical condition of the network; but it tells little about the meaning of accessibility to the various users and non-users of the network.
2.3 INVESTMENT IN HIGHWAY FACILITIES

The description of road investment, following in this thesis, stays within the tradition of chorography. It is a first, useful step towards relating this one quantity to other data. There is a general pattern of development of roads in B.C. that partly corresponds with the ideal-typical sequence described by Taaffe et al. (1963). It is probably more accurate to describe their "phases" as processes which had already been in action well before this study opens, and which coincide, overlap, or compete with each other over time and over area. The processes seem to have been shaped more by deliberate policy, rather than by the "natural" or "spontaneous" adjustments implied in Taaffe's study. Another important difference is that their model was unaffected by external land connections, whereas external connection has been a very powerful influence in the development of roads in B.C. The problems and adjustments involved in considering external connection for a network, were treated by Kansky (1963, p. 64), and by Kissling (1968) for Nova Scotia and New Brunswick; however, the degree of weighting of nodes for the exogenous factor remains a contentious issue. Smith (1963) found distortion in the patterns of demand for freight movement to and from border-area towns.

Within the pattern of total spending, there are items of cost, the changing importance of which may indicate the objectives being pursued. For instance, there is some trade-off between maintenance costs and construction costs, and between user costs and operator costs. The highway
engineering literature abound with theoretical and empirical studies of such relationships, which can be roughly categorized as those dealing with facilities, and those dealing with traffic. The American Association of State Highway Officials, the Canadian Good Roads Association, the Highway Research Board and UK Road Research Laboratory publications have set up criteria for the design, structure and materials considered necessary for various levels of service in various physical and traffic conditions. The NCHRP Report No. 42 (1967) has described the relationship between construction and maintenance, a topic treated as well in the exhaustive textbooks of Oblesby and Hewes (1963) and Woods, Berry and Goetz (1960). These studies show that there are vital technical considerations affecting the eventual structure and quality of the network. The argument that engineering solutions are not necessarily optimal in a spatial sense may well be countered with the argument that many desirable spatial arrangements have no feasibility in engineering terms.

2.4 FLOWS, TRAFFIC BEHAVIOUR, AND SIMULATED TRAFFIC

The study of traffic and flows moves highway engineering one step nearer to that realm of geography known as spatial analysis. Beckman (1967), Quandt (1960), and Ford and Fulkerson (1962) have explored the theory of flows in networks, and George et al. (1961) and Gerlough and Capelle (1964) have theorized on traffic behaviour in a link. There has been much
empirical analysis of the behaviour of vehicles under different conditions. The AASHO Road Test has been the basis of highway economy studies since 1959. De Weille (1966) has compiled a similar series of tables, relating road design to vehicle running speeds, relating operating conditions to vehicle operating costs, and so on. The Highway Research Board, an agency of the U.S. National Research Council, has carried out many studies on specific relationships. These findings provide an understanding of the varying cost of interaction under varying conditions, an inconstant relationship that affects the workings of the gravity model. Geographic inquiry accepts and uses such findings, absorbing them into a general concept of accessibility. Gauthier (1968) and Kissling (1969) have converted technical data into generalized costs of movement. The apparently sensitive response of traffic flows, times and costs to different facilities, conditions and traffic composition, suggests that spatial analysis should pay closer attention to the "friction" of movement - this may have been somewhat neglected because of the concentration on nodes, urban centres, urban functions, etc. Kissling's work has somewhat balanced that record in studies relating economic indices to network measures.

Theoretical formulations, including the gravity model, describe traffic as homogeneous. Empirical studies have attempted to provide a breakdown of the composition of traffic. This is an important clue in the geographer's understanding of the nature and extent of interaction, and of the spatial arrangements it describes. The assumption of homogeneity of traffic is as
flawed as an assumption of undifferentiated productive activity at a point of traffic generation; but the regularities in observed flows are not yet sufficiently established to be usable from one case to another, a weakness with which most project evaluation or impact studies have to work.

While some studies have translated interaction into traffic flows, others have used commodity flows. In all cases, there is an attempt to relate concrete phenomena to abstract concepts. The same attempt is made in relating concepts to routes, networks, and rank order of towns - another level of abstraction where "spatial analysis" displaces the "geography of transportation."

A hierarchy of complexity can be discerned amongst the phenomena and concepts used in the analysis of spatial relationships. At the base are raw or simple aspects of movement - vehicle counts, pedestrian counts, commuters, freight rates, truck trips, capital movements, etc. At a second level, suggesting some simple patterns either in actuality or in one's way of observing the world, there occurs migration, commodity flows, bus timetables, land use distributions, newspaper circulation, origin-destination patterns. At a higher level, one refers to the abstract forms - hinterlands, service tributary areas, settlement patterns, urban place hierarchies, transport networks. The top level is made up of the concepts, such as demand, interaction, association, accessibility, dominance. In the following chapters, the concept of accessibility will be given identifiable form by the use of networks, and practical
measurement by the observation of truck performance. 18

2.5 INVESTMENT, ACCESSIBILITY, AND ECONOMIC RESPONSE

The relationship between investment in facilities and improved accessibility along a link is quite straightforward. The relationship between investment and change over the whole network is more involved. Burton (1962) provided a neat and simple treatment of the different gains resulting from the different placement of investment in a network. Kissling (1969) presented a method of measuring a "link's importance to an entire system". Werner (1968) suggested a more involved measurement of the relationship between hinterland changes and network or route changes.

The next step, relating investment and network changes to social and economic change, is a more tentative one. The response has to be simulated, or measured through a surrogate. Simulation by means of a gravity model has been questioned and refined by many writers, notably Carrothers (1956), Neidercom and Bechdolt (1969), Burch (1961) and Britton (1971). Because of changing parameters of interaction (such as terrain, or the seasonal demand for transportation), a gravity model has to be adjusted from case to case. In the B.C. economy, parameters of interaction vary from sub-region to sub-region, depending mainly on the degree of dependence on the metropolitan area, 19 the physical desirability of an area, and the degree of difficulty of travel. Gravity models are even more suspect where there is competition between modes of transport.
Wills (1971, p. 21) weighted distances between points by a scale relating travel speed to type of surface - a generalized scale, since data limitations were quite severe. Evidence from road user studies\textsuperscript{20} would suggest that the speed of 45 mph attributed to 2-lane paved roads is too high, especially since the simulated flows were to be related to actual traffic flows of the summer months when congestion is greatest. If this is so, then it might account for a portion of the unusually large exponent\textsuperscript{21} of 2.7 which gave the best prediction from the gravity model (Wills, 1971, p. 27). Further, his scale implied that gravel roads caused a 30 per cent greater restriction on movement than 2-lane paved roads: the restriction is probably stronger than 30 per cent, since other elements apart from travel speed, such as discomfort, hazard, and wear and tear, enter into the perception of distance.\textsuperscript{22} The measures of both restriction (denominator) and attraction (numerator) become even more controversial when dealing with seasonal traffic, and with flows biased by traffic of a particular type.

As for surrogates and indices of development, different measures are applicable in different circumstances, particularly depending on the maturity of the economy,\textsuperscript{23} and on the main function of the road improvement.\textsuperscript{24} If the investment provided initial access to a developed area, then traffic would be generated quite early,\textsuperscript{25} so than an index of activity related to road users or to higher-order functions would be appropriate. If the investment provided access for road-oriented initial development, then a suitable measure of response would be employment or production over a long term. If an investment
relieved congestion of existing facilities, then suitable indices of response could be retail sales, or trip times, or traffic flows. In urban or peri-urban areas particularly, land values are very sensitive to actual or expected changes in accessibility. On a very small scale, site attributes can be much affected by traffic patterns related to new investment. Investment to substantially improve existing facilities will probably cause a response in traffic flows and freight costs. In each case, there will probably be changes in hierarchical relationships between urban centres over the long term, as the revised transport system helps to rearrange attributes of relative location.

Improved road conditions and network structure will mean different things to different users - the practical implications of changed accessibility are highly variable. Walters (1961) explains some of the reactions in an urban situation, with implications about the measures appropriate for assessing the effectiveness of road investment. Wheat (1969) showed that manufacturing activity can be related to freeway development under certain circumstances. Gauthier (1968) sought a response to network change in the value of retail sales. Garrison (1965, p. 71-87) showed that integration between nodes, and the complexity of network flows, increase faster than general economic or general network development. Kansky (1963, p. 41-52) demonstrated that different indices of economic activity are associated best with different measures of transport infrastructure. O'Sullivan (1969) related different
levels of accessibility to various economic indicators and found widely different strengths in the associations. Kanaan (1965) found eight variables which needed to be taken together in assessing the effect of network change in Syria. All these studies emphasize that responses to levels and categories of transport investment are highly variable so that the indices of response, no matter how judiciously chosen, can only be partial.

2.6 SYNTHESIS OF THEMES AND INTERESTS IN THE LITERATURE

This study draws on the extensive treatment of transport investment in economic development. It uses network analysis as a way of looking at change in the highway system, but unlike other network studies in geography, attempts to highlight the importance of investment policies and decisions as a factor in the extent, quality and structure of the B.C. road network.

Investment has dramatically changed patterns of accessibility. Accessibility, a concept having widely different meanings and practical applications, will be described in terms of one class of road user. This description relies heavily on the work of Kissling (1969) and on the empirical data of the various Highway Research Board investigations. Indications of response to changed accessibility will be discussed in an attempt to discover how changes work their way through user behaviour, to have some measurable economic impact.
REFERENCES:

1 See the reviews of B. Berry (1959); J. Wheeler (1971).

2 For an account of the range and variety of network analysis, see P. Haggett and R. Chorley, (1969).


4 "The crux of a highway project is not its putative revenue, but its catalytic effect on economic development." Rimmer (1971), p. 15.

5 Taaffe, Morrill, and Gould (1963); Kansky (1963), Ch. 8; Garrison (1965), pp. 100-107.

6 R. Lachene (1965); P. Haggett (1965), p. 82; R. Merrill (1965).

7 See the summary of such attempts in C. Werner (1968); also, M. Beckman (1967); Quandt (1960) and Garrison and Marble (1958), Haikalis and Joseph (1961).

8 Meinig (1962); Wolpert (1964; 1970).

9 See also Winfrey and Zellner's description of road development, fn. 3, Chapter 1.

10 Canadian Good Roads Association (1963) and (1970); American Association of State Highway Officials (1960); Capelle et al. (1968); Quandt (1960); Haikalis and Joseph (1961); Woods et al. (1960); Oglesby and Altenhoffen (1969).

11 Beckman (1967); Ford and Fulkerson (1962); Gerlough and Capelle (1964); Plummer et al. (1961); Walters (1968); and George et al. (1961).

12 For example, Sawhill and Firey (1962); Stevens (1961); Saal (1950); Wagner and May (1960); Adkins et al. (1967); Claffey (1960); Winfrey (1963, 1969 and 1971).

13 See general comments in AASHO (1960); De Weille (1966); NCHRP Report No. 122 (1971).

14 NCHRP Reports 58, 70, 83, 89; Wagner and May (1960); Gwynn (1968); Plummer et al. (1961); Wolfe (1969).
15 J. Burch (1961); B. Harris (1964); D. Starkie (1969); M. Wills (1971).

16 W. Garrison and D. Marble (1965); J. Nystuen and M. Dacey (1961); R. Smith (1963); A. Scott (1967); L. Cummings (1967); J. Britton (1971).

17 Drawing on the work of A. Shimbel (1953); L. Katz (1953); W. Garrison (1960); I. Burton (1962); K. Kansky (1963); C. Kissling (1969).

18 Following the techniques used by Gauthier (1968); Kissling (1966 and 1969); Griffiths (1968).

19 This observation drawn from large-scale (census division) data, in K. Denike and R. Leigh, Regional Economic Development in B.C., unpub. mimeo, Department of Geography, UBC, (1971), p. 16; also, in Wills, (1971), p. 84.


21 Compared with, say, J. Burch (1961) who found an exponent of 2 suitable for simulating interaction along freeways; or Starkie (1969), who found a "best" exponent of 1.75; or Helvig (1964) who used 1.5 for calibrating a model of truck movements from Chicago. See also the comments of B. Harris (1964).

22 Hawkins (1960); NCHRP Report No. 122, p. 61-8. Gauthier's truck cost estimates support the 30 per cent figure (Gauthier 1968, p. 82) in Brazil. However, Heflebower's estimates for trucks in Venezuela suggests a restriction of about 100 per cent (in G. Fromm, 1965, p. 54). In B.C., average daily summer traffic between Kamloops and Princeton increased by about 90 per cent over 3 years, (1956-59), as the surface was upgraded and paved.

23 K. Denike (1971), pp. 20-1; W. Garrison (1965) and K. Kansky (1963) tested a number of indices to find those which best matched network measures at different stages of development.

24 W. Garrison et al. (1959), pp. 11-12.


26 Garrison et al. (1959); U.S. Bureau of Commerce (1964); Graybeal and Gifford (1968).


CHAPTER 3

TOTAL SPENDING ON HIGHWAYS IN B.C. 1946-71, BY DISTRICT

3.1 INTRODUCTION - AIMS AND SOURCES

This chapter surveys spending on highways as it was distributed amongst districts of the province and over time. It also offers some "ideal patterns" which might have occurred under certain conditions. The two perspectives are complementary. The dictates of sequence and interdependence apply to distributions both over time and over area. Just as the physical environment causes disparities in construction costs from area to area, so the economic environment, through inflation and variable factor composition, causes disparities in the real value of allocations from time to time. The figures are surveyed within electoral districts, and patterns are sought which might suggest policies in effect from time to time.

Description and interpretation of patterns of spending in B.C. require first of all a reduction in the complexity of the data as published in the Annual Reports of the Minister of Public Works (1946-55) and of Highways (since 1955). It might have been possible to extract summaries of major road developments only, from the annual "Financial and Economic Review" - but this is at fault, practically, for ignoring about half of
the total budget; and at fault, conceptually, for ignoring the fact of interdependence of all items of spending, particularly interdependence between "normal" spending and "expansionary" or improvement" spending.

The operation and administration of the Highways Department is organized into four regions and 34 local districts. The financial accounting for the Annual Reports is arranged according to electoral districts, which are essentially groupings of population having some homogeneity of interest and activities. The two types of division coincide in only a few cases. There is no consistent or necessary connection between the population grouping and the traffic generation within, or the flow across, the district. Since some electoral districts cut across traffic-generating sub-systems or embrace more than one sub-system, an accounting related to sub-systems of the transport network would have been more useful for tying together investment, traffic flow and economic response. The present accounting of the Department seems designed to deflect suggestions of unequal political influence in some electorates.

The number and shape of electoral districts have changed over the period (see Appendix I). Most of the changes took place in 1966. Thus, the accounting for some stretches of road is to be found in different districts over the period. Where possible, the accounting was traced back so that the aggregation used in this thesis is for the districts as if they had been exactly as in 1971 over the whole period. The most drastic re-arrangements, in terms of importance of roads
and amounts of investment, were between West Vancouver, Lillooet and Yale-Lillooet; between Similkameen and Yale-Lillooet; and between North Okanagan and Shuswap.

To simplify descriptions, all the Vancouver districts, the Burnaby districts and New Westminster, were grouped as one; Delta was "re-formed" to include the present ridings of Delta, Langley, Surrey and Richmond. Coquitlam was gathered back into Dewdney. The North Vancouver ridings and West Vancouver - Howe Sound were joined together. Oak Bay was included with the "Headquarters" account. Thus, the data are summarized and presented in the form of "Headquarters" plus 31 other districts.

The financial accounts detail the items of spending and their location on a particular road. Until 1956-57, maintenance and snow-clearing amounts were also described by location. Since then, they have been given in lump sums for each electoral district. To seek out patterns in the accounts, items were grouped into five categories and two classes. Categories were made up of: construction; surfacing and improvement; maintenance and minor improvements; snow-clearing; and surveys, rights-of-way, beautification and legal surveys. Classes were either trunk (main roads, arterials, inter-urban) or branch (feeders, local or farm roads), actual descriptions of which are set out in Appendix II.

Except for the maintenance and snow-clearing items, the accounts can not be faulted for detail. The most severe limitation, however, is in the shape and size of electoral districts. Generally, there is little correspondence apparent
between the nature of the road system and the nature of the area delimited by electoral divisions. This is largely inevitable, since roads within areas are also serving other roads and activities belonging to other areas.

The disparities in size, shape, road mileage and character of the reporting units have required a very restrained statistical treatment of the data. Because the units were not logically related to the quantities they enclose, there is no logical measure for making the quantities immediately comparable. The sequence of maps, following in this chapter, is an attempt to find a rationale for the variation in spending, and though the attempt does result in a better understanding, it does not provide a consistent explanation.

The possible factors influencing a district's share of the total are discernible at an intuitive level. However, too great a variability remains within the factors themselves to draw them together into a general mathematical expression - such as trunk mileage, improved mileage, terrain, climate, municipal spending, population, stage of development, and existence of trans-provincial paths. As well, there are two very influential variables - intended development and importance of external contacts - for which values are largely indeterminate. A simple "model" or argument about the basis of spending is therefore attempted in the next section. It provides a reference against which actual patterns of spending can be evaluated in the following section.
3.2 A CONCEPTUAL FRAMEWORK OF SPENDING

The primitive stage of road transport infrastructure generally consists of unconnected sub-systems. The earliest phase of regionally-planned development involves basic interconnections between resource areas and transport break-points, and between resource areas and populated centres. A second phase of development is characterized by integrative links between populated centres, and by demand-serving links of access for leisure and recreation purposes.

It is suggested that the two processes - basic connection and advancing integration - describe a very broad tendency of the growth of transport infrastructure for a developing economy. Lachene (1965) found a logical basis for the tendency while Taaffe et al. (1963) synthesized a similar model from experience in under-developed countries. Kansky (1963) simulated such a development from mathematical relationships between economic indices and network structure. The tendency will be obscured from time to time by the necessary responses to newly-generated traffic (in the form of enlargement of existing connections), and to user-cost or operator-cost differences between parts of the whole system. Since the authorities operate under a budget constraint, the facilities provided can only satisfy a certain level of demand over a limited period. In that interval, investment can be directed to other parts of the transport system, or to other social needs, until increasing costs and congestion demonstrate the need for adjustment of the original facilities. The length of that interval will depend
on the quality of the original facilities, and on the rate of generation of traffic. The quality of facilities can itself be a factor in the rate of traffic generation - along with other factors such as economic growth, supply of alternative modes of transport, the level of personal incomes, and the level of car ownership and usage.

In 1945, basic connections existed between the populated centres of B.C. (except into the Peace River district, and from Revelstoke to the east). Compared with the present system, the links, as indicated by the published tourist maps, were generally of low reliability, low quality, and high user cost. Investment in the first half of the period 1946-71 necessarily concentrated on them. In later years, the choices on where to invest and on what to provide, have been more numerous. Reading the Annual Reports and discussions with employees of the Department of Highways, confirm that strict economic surveys of the cost-benefit or before-and-after type have been rarely used. Decisions seem to have been based mainly on some general scheme of economic development, on undifferentiated traffic counts, and on informed guesses about the composition of traffic and the likely future demand for facilities.

An investment policy guided only by undifferentiated traffic counts over a long period, would respond to user demand, and would not make full use of the influence available to the transport component in achieving social and economic objectives. Such a policy would result in a particular pattern of highway
investment - concentrated around populated areas, extending along a narrow band between populated and/or producing areas, and extending to the points of export and external contact.

For traffic flows to be truly reflected in the pattern of road investment over a period, the following ideal conditions would be required:

a) All districts starting from the same stock of transport facilities, including vehicles.

b) A consistent relationship between road transport and other means of transport and communication.

c) A neutral policy towards economic and regional development.

d) Equal impediment to road construction, in all directions.

e) An assumption of no locational shifts of economic activities to areas not connected to the existing network.

f) A constant relationship between traffic volume and the cost of facilities needed to match that volume.

g) Road requirements of the province being uninfluenced by the paths of external connection.

h) A constant relationship between the cost of facilities and their contribution to network quality.

The exercise of setting up a logical model such as this to isolate one relationship is not rendered pointless by the first breeze of reality which will, obviously, deny the assumptions. The model shows the likely difficulties and likely factors in inferring an intention or a policy from an observed pattern. It also suggests the possible degree of variability in allocations to individual districts or stretches of road.
3.3 A FORMULA FOR AMOUNTS OF SPENDING?

Before plunging into the wealth of information provided by the published financial accounts, it is worth considering what really major forces lie behind a distribution of road investment. The first is population - roads are needed within and between most settled areas. The second is resources, which often require road connection for their development and full exploitation. Roads are required to ports and markets, and in the case of B.C., from the resource hinterland to the dominant metropolis. Thirdly, connections to other provinces make demands on the investment pattern.

Taking the actual amount spent in the electoral districts, an attempt was made to distribute it ($1347 million) according to the factors of population, external connection, and distance from Vancouver. For this exercise, distance was simply scaled from 30 (the Vancouver grouping) to 1 (such as Atlin, North Peace River and MacKenzie); a particular district was rated from Figure 2, Chapter 3, by the number of districts more remote from Vancouver which passed their traffic on to it. This is a recognition of the effect of through paths on traffic and road requirements for any "intervening" district. The suggested relationship of the three postulated factors is:

\[ I_x = \sum_{n}^{x} P_x \cdot D_x \cdot \sum_{n}^{x} (P \cdot D) + Ex \]

- \( I_x \) - expected spending in district \( x \)
- \( E \) - known actual cost of external connections
- \( P \) - population
- \( D \) - "distance" scale
- \( n \) - number of electoral districts
Because of the importance of the population factor, and because of the population distribution in the province, the distribution of investment from the above formula gave a tremendous exaggeration for the districts in the Lower Mainland and southern Vancouver Island. Vancouver actually received $42 million over the period; the "generated investment" was $500 million. For southern Vancouver Island, actual was $78 million, generated was $151 million. The disparities in populated areas are extreme, but two other factors operating together would have done something towards reconciling the actual and generated patterns - one, the formula assumed that all districts started in 1946 from an equal supply of facilities, but really, the populated districts were already well supplied before then; and two, the actual allocations of public money to the populated districts would have been much greater if the amounts of road grants through municipalities had been known and included.

The model gave a better simulation of the distribution of investment ($867 million) after excluding the populated areas of southern Vancouver Island and the Lower Mainland. The districts of pronounced overestimation - Okanagan, Kamloops, Rossland-Trail, Kootenay - were again those with concentrations of population. Prince Rupert and MacKenzie were overestimated, probably because of water transport serving their transport needs as much as road connections. Yale, Revelstoke, Atlin and Omineca districts were all noticeably underestimated. For the first two, the costs in the Fraser Canyon and Rogers Pass
boosted their actual allocations; Atlin district has received much attention for mining roads, and Omineca seems to have been "favoured" for having the Northern Transprovincial and the Stuart Lake road passing through it.

For the first distribution ($1347 million) the mean of \( \frac{\text{Actual-Theoretical}}{\text{Actual}} \% \) was about 70%. For the second distribution ($867), it was about 35%. Obviously the hypothetical distribution based on population, "distance" from Vancouver, and external connection, is only a weak indication of the actual investment pattern. The basic flaw is the unequal amounts of facilities in the districts before 1946. The value of the exercise was to point out the areas of marked deviations, in support of the suspected reasons for unequal amounts of spending, which were mainly the difficulty of construction in some areas; the complex relationship between size of population and road requirements; the deliberate policies of expansion; the importance of through traffic; and the existence of special projects, notably hydro-electric development.

Generally, "response to traffic flows", as measured by population and its position in through paths, does not seem to be a suitable standard by which to describe the distribution of road investment in B.C.

3.4 ACTUAL DISTRIBUTION OF INVESTMENT

Figure 2 provides a summary of total spending over the period. Superficial comparisons are to be discouraged,
Fig. 2. Total Spending by Electoral District 1946–71.

$ million
because of the varying size and content of the electoral districts. The meaning of the pattern of investment is obscured by this fact and by the varying mileage within the districts. Figure 3 shows the pattern of spending, still within the same irregular districts, but standardized according to the mileage "open" in March, 1962.² It provides a very different perspective.

The enormous costs per mile in the Lower Mainland reflect the impediment of reclaiming land from other uses (d, in previous section), the escalating facility costs in relation to increasing traffic (f, above), the effect of external connection, and the impediment of natural obstacles (Fraser River, and terrain from Burrard Inlet to Squamish). Obtaining rights-of-way in the North Vancouver, Vancouver, Burnaby and Delta districts, has averaged about 10-15% of the total spending. In the sparsely settled districts like Columbia and Omineca, it was less than 1%. Also, it is reasonable to assume that higher quality and higher capacity facilities are provided in areas having a relatively high and consistent traffic flow, as opposed to the many Interior areas where high levels of flow are experienced only on a few occasions in the summer.

Where difficult natural barriers had to be bridged or breached, costs per mile for the district were extraordinarily high. The allocation to Revelstoke-Slocan district showed the expense of replacing the Big Bend Highway; in Fort George district, it was the John Hart Highway and the Yellowhead
Fig 3. Total Spending per mile of Road Open 1946-71
$'000

Scale 1" = 100 mi.
Highway; in Prince Rupert, construction difficulties from the lower Skeena River to the city itself.

The allocations to the non-urban districts are somewhat depressed in Figure 3 by the inclusion in the divisor of all "open" roads - earth, gravel and tarmac. By excluding the "earth" roads, and adjusting the divisor to include all "improved" roads (i.e., gravelled, and surfaced roads), a different pattern emerges in Figure 4. One is justified in ignoring the earth roads, since such a relatively small cost per mile could be attributed to them. Thus removing the ranching roads of Yale-Lillooet and Cariboo districts, virtually doubles their cost per mile allocation. Similarly, there are notable changes in the districts of Peace River, Boundary-Similkameen, and Kootenay.

The allocations according to Figure 4 are not entirely satisfactory as indicators of underlying policy. The differences between neighbouring Kootenay and Nelson-Creston, or Omineca and Skeena, or North Okanagan and South Okanagan, are not to be explained by widely differing terrain or the number of urban settlements. Since over the whole period, costs per mile on the trunk inter-urban roads have averaged roughly five times those on the improved or local roads, an important variable behind the patterns of Figures 2, 3 and 4, is the proportion of the total mileage being constructed and maintained as part of the trunk system.

Table I helps to explain some of the anomalies existing in Figures 2, 3 and 4 - such as Rossland-Trail, Nelson-
Fig 4. Total Spending per mile Improved 1946-71

Scale 1” = 100 mi.

$’000
**TABLE I**

INFLUENCE ON COST-PER-MILE OF THE TRUNK MILEAGE

<table>
<thead>
<tr>
<th>Trunk as % of Improved Mileage</th>
<th>District</th>
</tr>
</thead>
<tbody>
<tr>
<td>over 50%</td>
<td>Shuswap, Columbia, Fort George</td>
</tr>
<tr>
<td>40 - 50</td>
<td>Rossland-Trail, Nelson-Creston</td>
</tr>
<tr>
<td>30 - 40</td>
<td>Kootenay, South Peace, Skeena, Dewdney, Chilliwack</td>
</tr>
<tr>
<td>20 - 30</td>
<td>Alberni, Yale-Lillooet, Boundary-Similkameen, Kamloops, Omineca, Prince Rupert</td>
</tr>
<tr>
<td>10 - 20</td>
<td>Comox, Cariboo</td>
</tr>
<tr>
<td>less than 10</td>
<td>North Okanagan, South Okanagan, Revelstoke-Slocan, Atlin, MacKenzie.</td>
</tr>
</tbody>
</table>

Table I helps to explain some of the anomalies existing in Figures 2, 3 and 4 - such as Rossland-Trail, Nelson-Creston, Columbia, and Fort George. According to Table I, Shuswap "ought" to have been much higher. However, in that district, trunk roads remained close to the valleys, so that construction has been relatively less expensive. Possible reasons for the differences between Comox and Alberni, between Omineca and Skeena, between Cariboo and Kamloops, between Kootenay and Columbia, are suggested by Table I.

The anomaly of Revelstoke-Slocan, and the difference between North Okanagan and South Okanagan, require further consideration. The extremely high cost per mile in Revelstoke-Slocan is due to the large amount of investment in access roads to the hydro-electric development schemes on the Columbia River - over $30 million since 1966. In the Okanagan, one
of the more costly items attributable to the South was the crossing of the Lake, earlier by ferries, later by bridge. Also, tarmac surfacing has been extended to a greater proportion of the mileage in the South than in the North.

3.5 POSSIBLE VALIDITY OF THE POSTULATED PATTERN

The pattern of spending suggested earlier in this chapter emerges, though very generally, from Figure 4 when viewed in conjunction with Table I. The southern quarter of Vancouver Island, and the Okanagan Valley, had benefited from road development before 1946 - hence their relatively low allocations in 1946-71. External connection accounts for a large part of the investment in Columbia, Revelstoke-Slocan, Fort George and Delta. Apart from these special cases, there remains a concentration of spending around the populated areas - Saanich, North Vancouver, Vancouver and Burnaby, Delta, Chilliwack, Dewdney, and Rossland-Trail. Also, there is a concentration of spending along the routes between populated areas, indicated by the greater allocations in districts having a large proportion of trunk mileage.

That the highway investment allocation has been used for purposes of leading or facilitating economic activity in certain areas, is suggested by the relatively high costs per mile in Alberni, Comox, Atlin and Peace River, when weighed against a general understanding of the type and degree of development in those areas.

From the diagrams, the processes behind the pattern
of investment over the whole period, can be generally described as:

a) filling in or upgrading the basic connections to population and resource centres,

b) adjusting the roads in areas of high population and traffic congestion,

c) providing good quality links as part of external connections, sometimes coincident with a),

d) assisting activity in remote areas ("remote" in relation to the main portion of the network).

3.6 BREAKDOWN OF THE WHOLE PERIOD - CONSTRUCTION PRICE CHANGES

Since the 1946-71 period is long enough to include different stages of road development, and different priorities amongst the policy objectives, and since the unequal districts are fitted over areas of different character and different economic activity, then a more precise description can be achieved only by breaking the period into shorter spans. This should show road development as a dynamic process, able to serve different objectives in different areas and at different times.

The peculiar physiography and population distribution of B.C. present special problems of investment allocation. The obstacles are so severe, the separate links so long, that a programme of improvement requires more of large, all-at-once inputs, rather than gradual extensions or upgrading. Only a very small proportion of the final benefits are obtainable from a partially improved link. The John Hart Highway, built in the
late 1940's, was of no benefit until all of it was completed through to Dawson Creek. The same is almost as true for the Yellowhead and North Thompson extensions to the Alberta border. Mountain passes and bridges can be regarded in the same way: Rogers Pass, Salmo-Creston, Richter Pass, and major bridges at Brilliant, Kelowna and Hudson's Hope, all required massive indivisible investment over a number of years. The effect is to make peaks and troughs in the allocations according to district.

It matters then, at what time a district received a large proportion of its total. If a pattern can be discerned from the timing of allocations, it will throw light on the motives behind road investment. It matters, too, because of the changing cost of construction.

A Highway Construction Price Index (HCPI) has been published by Statistics Canada, for each province, and for Canada as a whole, going back to 1956. The units of work have been held constant - such as an acre of clearing, a thousand cubic yards of levelling, a ton of surfacing and so on. The changing prices are drawn from the tender bid of the contractor who was awarded the job. All contracts awarded in a year are taken, then stratified according to the nature of the work and the area of the province, in an attempt to minimize the bias effect of difficulty of construction work. The HCPI does not relate to maintenance, minor improvements and survey work, which are all done by employees of the Department of Highways.

It is quite clear from Figure 5 and confirmed in
Fig 5. Highway Construction Price Index, 1961 = 100

n.b. constant inputs at changing prices
Source: Statistics Canada, Series 62520

* indicates provincial election year
conversation with officials of the Department of Highways, that the HCPI is closely related to the amount of work available. In other words, contractors bid up prices in the busy years, and later deflate their bids when competition is keener. The HCPI shows a general tendency of decline from 1956 to 1963, interrupted in 1959-60 by a sudden increase in the amount of work available. The general tendency reflects the introduction of very large, labour-displacing machinery, and the entry of a number of new firms into the industry. Since 1963, the HCPI has tended to rise back to the levels of the earlier, labour-intensive days.

The peaks in total spending correspond with (provincial) election years. Road improvement, particularly tarmac surfacing, is a highly visible and immediately effective demonstration of a government at work. Local activity helps relieve unemployment and increase retail sales at the local level. Since the Department of Highways has always operated on an annual budget (sometimes supplemented by Special Warrants issued through the Treasury Board), and hence has had a very restricted horizon of planning, its investment operations have been particularly susceptible to manipulation for short-term political impact. There is a good case for a three-year capital budget being allowed to the Department of Highways.

By smoothing out the election year peaks into three year averages, a calculated guess can be made as to the level of the HCPI without the inflationary pressure of election years. Without that pressure, total spending from 1956 to 1971 would have been about $35 million less than it actually was. In other
words, the province might have gained more or better facilities per dollar if the construction contracts had been let out evenly over the period.

Generally, work done in the 1961-64 period gave more "mileage" per dollar than in 1956-58 or in 1968-71. If a district had its total allocation concentrated in that middle period, then it probably gained relatively more, in terms of road facilities, than is apparent from the overall investment figure. It would be possible, though very cumbersome, to standardize the figure for each electoral district in each year since 1956-57, according to the HCPI. However, the total spending figure includes a significantly large (20-40%) amount of work not reflected in the HCPI - minor improvements, maintenance, snow removal, and surveys, performed by employees of the Department of Highways. It is more convenient to regard the figures of spending in their current dollar values, and to apply the HCPI only to those districts having a pronounced concentration in a period of noticeable inflation or deflation.

3.7 THE ALLOCATIONS OVER TIME

The whole period has been subdivided into eight sub-periods, using the peak in spending as a centre point for each subdivision.

Half of the total allocation was spent in the last 10 years. However, the increasing amounts of investment in construction and maintenance since 1959, have only served to keep pace with inflation of prices. If the inflation in other
prices is considered too - such as rights-of-way, day labour wages, materials - then the road facilities of the province have probably been expanding at a slower rate in each year since 1959-60. This confirms the division of increasing priority / decreasing priority suggested in the opening chapter.

TABLE II
BREAKDOWN OF SPENDING, BY PERIOD
(Incl. Federal spending on Trans-Canada Highway)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>% of Grand</td>
</tr>
<tr>
<td>1946-49</td>
<td>52.9</td>
<td>3.5</td>
</tr>
<tr>
<td>1949-52</td>
<td>85.3</td>
<td>5.6</td>
</tr>
<tr>
<td>1952-56*</td>
<td>142.4</td>
<td>9.3</td>
</tr>
<tr>
<td>1956-59</td>
<td>229.6</td>
<td>15.0</td>
</tr>
<tr>
<td>1959-62</td>
<td>244.9</td>
<td>16.0</td>
</tr>
<tr>
<td>1962-65</td>
<td>217.3</td>
<td>14.2</td>
</tr>
<tr>
<td>1965-68</td>
<td>265.0</td>
<td>17.4</td>
</tr>
<tr>
<td>1968-71</td>
<td>289.3</td>
<td>19.0</td>
</tr>
<tr>
<td>Grand Totals</td>
<td>1526.7</td>
<td>100.0</td>
</tr>
<tr>
<td>1969-72 (est.)</td>
<td>335.0</td>
<td>111.7</td>
</tr>
</tbody>
</table>

* Note that 1952-56 covers four years. Also, note that the adjustments for the first three periods are based on an estimated HCPI.

Source: Annual Reports, Minister of Highways 1955-6 to 1970-71
Annual Reports, Minister of Public Works, 1946-7 to 1954-5.

The fairly constant spending since 1960 also confirms the suspicion that the province is "coasting" on the benefits of an earlier period of intensive development. When adjusted for inflation, the rate of spending has added roughly constant amounts
of facilities throughout the 1960's whereas car ownership, private travel and truck operations have been growing at an accelerating rate. Since most of the vital connections have been put in, the next stage of spending may be for the "high-capacity period" described by Winfrey and Zellner.

TABLE III

INDICATORS OF ROAD USER ACTIVITY, B.C. 1950-72

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail Trade of Dealers, Garages, and Service Stns. $ millions</td>
<td>256</td>
<td>386</td>
<td>730</td>
<td>900**</td>
</tr>
<tr>
<td>Gas Tax* and Licence Revenue $ millions</td>
<td>20.0</td>
<td>51.7</td>
<td>101.5</td>
<td>150.0</td>
</tr>
<tr>
<td>Licensed Vehicles in B.C., private and commercial, thousands</td>
<td>288</td>
<td>584</td>
<td>988</td>
<td>1120**</td>
</tr>
<tr>
<td>Tourist Passenger Vehicles from U.S. into B.C. thousands</td>
<td>353</td>
<td>448</td>
<td>1000</td>
<td>1200**</td>
</tr>
</tbody>
</table>

* Some changes occurred over the period in the tax rate per gallon. If the earlier rate still applied, then the collections of 1968-69 would have been about $85 m, and in 1971-72, about $130 m.

** Estimates from 1971-72 provisional figures.


It is interesting to note from Table III that licensed vehicles and tax revenues "took off" in the first decade, but that retail trade and tourism "took off" in the second (see Fig.6,
following). The early "take-off" of ownership and fuel consumed suggest that there was pent-up internal demand which, when realized, attracted further activity in the form of more numerous or more expensive vehicles, equipment and services, and more tourists from the U.S.

Fig. 6 - Relation of Spending on Roads, to Indicators of User Activity

a) Current Dollars

\[
\begin{array}{ccc}
1950-1 & 1960-1 & 1970-1 \\
M & C & T \\
\end{array}
\]

M - Maintenance costs, in $00,000.
C - Total costs, in $000,000.
T - Taxes and licenses, in $000,000.
R - Retail Trade in $0,000,000.

b) Constant Dollars

\[
\begin{array}{ccc}
1950-1 & 1960-1 & 1970-1 \\
Ca & F & V \\
\end{array}
\]

Ca - Total cost, adjusted, in $ million.
F - Rural Traffic Flow Index 1954 = 100
L - Licensed vehicles in B.C. (x 10,000)
V - Tourist vehicles from U.S. (x 10,000)

Sources: As in Table III, also Annual Reports, Minister of Highways; Statistics Canada, 62,520, (see footnote 4, this chapter).

Figure 6 shows that total spending on roads, (excluding the Ferries Division) has declined as a percentage of revenue collected from road users - from about 200% in 1957,
to around 100% in recent years. What proportion of user taxes should be reinvested, is a very controversial issue, and it is not simply a question of one dollar amount related to another dollar amount.\(^7\) There are many other indirect or invisible investments made by sections of society on behalf of road users, such as provincial parks, police patrols, bus operation subsidies, commuter parking space. On the other hand, road users contribute more than just fuel taxes and licenses, through such things as sales tax on automobile accessories, income tax on commercial operators, fines, camping and parking fees. Without going into the area of social and economic priorities,\(^8\) it is enough to note that the early importance of road investment has been relatively diminished in recent years.

Figure 6a deals with amounts subject to varying degrees of inflation. Figure 6b relates quantities of constant value to the amounts of spending adjusted by the HCPI to constant (1961) dollars. The adjustment is approximate, since the maintenance and day labour operations have been treated by the HCPI, although they were not included in the calculations by Statistics Canada to produce that Index. It is probable, however, that inflation for those items has been greater than for construction alone, so that the adjustment is somewhat conservative. Still, Figure 6b does show how spending on roads went far ahead of users and visitors in the 1950's and early 1960's, but slipped back in recent years. It has been shown elsewhere\(^9\) that "miles travelled per year" increases as a person's disposable income increases, and further, it increases as the quality
of roads and tourist amenities are improved. That these things have been happening in B.C. is indicated in Figure 6b by the rural traffic flow index (average daily summer traffic for 30 points in the interior, plus Port Mann and Patullo bridges).\textsuperscript{10} This index clearly shows that the gap between facilities and use widened over the last 10 years, more than is apparent from the current dollar figures in Figure 6a.

The contention that pressure has been building up for a new period of more rapid expansion, is supported in both diagrams by the sharp upward turn in recent spending. Part of this is due to the extension-type routes (in the north of Comox district, in Atlin, in the Chilcotin, and to MacKenzie) and part of it is due to the final stages of the Yellowhead and North Thompson connections to Alberta. But the routes which have been recently receiving most attention are the Northern Transprovincial, especially along the lower Skeena River; the Trans-Canada on the east side of Kamloops; the Southern Transprovincial south of Nelson and west of Princeton; the Lougheed Highway from Agassiz to Haig; the Upper Levels Highway, the Knight Street bridge, and the Patricia Bay highway. The greatly increased attention to urban traffic needs is in accordance with the cyclic nature of road development.

3.8 DISTRICTS' ALLOCATIONS OVER TIME

Certain districts group together in certain time periods (Table IV), and suggest the main concerns of the
authorities at different times.

TABLE IV

GROUPING OF DISTRICTS ACCORDING TO THE SUB-PERIOD OF THEIR LARGEST SHARE OF TOTAL SPENDING

<table>
<thead>
<tr>
<th>Sub-Period</th>
<th>Districts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1946-49</td>
<td>Comox, Yale-Lillooet, Boundary-Similkameen, Nelson-Creston, South Peace.</td>
</tr>
<tr>
<td>1949-52</td>
<td>Cowichan, Dewdney, Kootenay, Cariboo.</td>
</tr>
<tr>
<td>1956-59</td>
<td>North Vancouver, Chilliwack, Columbia.</td>
</tr>
<tr>
<td>1962-65</td>
<td>Delta.</td>
</tr>
<tr>
<td>1965-68</td>
<td>Kamloops, Fort George.</td>
</tr>
<tr>
<td>1968-71</td>
<td>Saanich, Alberni, Dewdney (same as 1949-52), North Peace, Skeena, Prince Rupert.</td>
</tr>
</tbody>
</table>

NOTE: "Groupings" only are used, and not anything more definitive. This "soft" treatment is due to the nature of reporting units and their quantities.

The activity which gave likeness to the districts in the first 10 years was the development of trunk links for the "pulling together" of the province - for example, from Courtenay to Campbell River, from Hope through to Osoyoos, from Nelson across Kootenay Lake and south to Creston, the John Hart Highway, and from Cranbrook through to Alberta. In the following 10 years, the Trans-Canada dominated all activity. The difficult Sheep Lake section of the Southern Transprovincial affected the allocation to Rossland-Trail; and in Atlin, there was much concern with the Stewart-Cassiar road.

The 1965-68 period was dominated by the Yellowhead and North Thompson routes - the districts of Kamloops and Fort
George claimed an extraordinary 25% of the total spent in all districts. There already were railways serving the forest product industries along the Fraser and North Thompson Valleys, so that these routes were not of the pioneering type—probably they were intended to make easier inter-urban contact (Vancouver - Edmonton and Prince George - Edmonton - Calgary), and to complete new and interesting circuits for tourists, especially for those using the highly attractive Banff-Jasper route in Alberta. Further, the North Thompson route draws traffic off the Trans-Canada east of Kamloops, thus delaying the need for adjustment of that highway. The Yellowhead accentuates the position of Prince George as a hub city, and will certainly have encouraged more tertiary activity to complement the basic manufacturing which moved in during the 1960's, than would have occurred without the connection to Alberta.

There is a mixture of activities among the districts included in the most recent period (Table IV), and this mixture reflects the increasing range of finer choices open to the authorities. For Dewdney district, the investment has been to relieve congestion, by providing the north bank extension of the Lougheed Highway as an alternate to the Hope - Chilliwack section of the 401. Congestion has also forced the large investment in Saanich, for the widening and improving of the existing link between Victoria and Swartz Bay ferry terminal. In Alberni, there has been a recent effort to provide the basic links of good quality into Tofino and Gold River.
Major improvements to the existing North Transprovincial Highway show up in Skeena and Prince Rupert. In North Peace district, completion of the roads associated with the W.A.C. Bennett Dam was carried out in the last sub-period - probably a case of capital substitution, completing the link to a standard well above current needs, to avoid protracted maintenance costs and the start-up costs of contractors at a later date.

Again the high degree of difficulty in road construction in this province has an effect on the grouping in Table IV. A commitment of policy to improve access to certain districts equally, does not result in an equal allocation of investment, mainly because of the timing and difficulty of overcoming obstacles. There may be cases where in fact, similar priority was given to a number of districts, but resulted in vastly different allocations. Figure 7 illustrates the effect of commitments to construct or improve high-cost indivisible connections.

In North Vancouver, the peak represents spending on the Upper Levels Highway, and the Squamish Highway; in Delta, it was the 401 and the Deas Throughway occurring consecutively; in Yale-Lillooet, it was firstly the Hope-Princeton connection, and later the major improvements to the Fraser Canyon route. Kamloops was influenced more by the North Thompson route than by earlier work on the Trans-Canada. The Yellowhead Highway stands out dramatically for Fort George. The first peak in Revelstoke-Slocan indicates the work on the Rogers Pass route;
Fig 7. Share of Total Spending according to sub-periods, for selected districts.
(dotted line indicates % share over whole period).
and the second peak reflects the provision of access to hydro-electric development projects along the Columbia River.

3.9 EMPHASIS WITHIN SUB-PERIODS

In the previous section, changing allocations among the districts were scanned for indicators of underlying policy. The grouping of districts suggested some policies at work, inferences about which would be tempered by the varying degree of difficulty in construction being undertaken. Now if the total allocation to a district for the period 1946-71 is taken, and subdivided according to the share falling into each sub-period, a different pattern will emerge. This new perspective in effect "standardizes" the size, physiography and population variability between districts.

Because total spending has been increasing generally over the period, it might be expected at first that the most recent sub-period would have contributed most to the total for a district, and that any district which had its largest share in an earlier sub-period, particularly before 1956, must have been receiving an especially high priority.

The effect of generally increasing budgets (see Table V) is shown by the smaller grouping in the first decade, and the larger grouping in the last decade, when compared with Table IV.

If it is assumed that traffic flow has been increasing in all parts of the province, then it would seem that the first five districts listed in Table V would soon be receiving
greater priority for the relief of traffic pressure.

TABLE V
GROUPING OF DISTRICTS ACCORDING TO THE SUB-PERIOD OF THEIR MOST INTENSIVE ACTIVITY (CURRENT DOLLARS)

<table>
<thead>
<tr>
<th>Years</th>
<th>Districts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1946-49</td>
<td>None</td>
</tr>
<tr>
<td>1949-52</td>
<td>Cowichan</td>
</tr>
<tr>
<td>1952-56</td>
<td>Esquimalt, South Okanagan, North Okanagan, Mackenzie</td>
</tr>
<tr>
<td>1956-59</td>
<td>North Vancouver, Chilliwack, Yale-Lillooet, Kootenay, Columbia</td>
</tr>
<tr>
<td>1959-62</td>
<td>Vancouver-Burnaby, Delta, Rossland-Trail, Revelstoke-Slocan</td>
</tr>
<tr>
<td>1962-65</td>
<td>Boundary-Similkameen, Nelson-Creston</td>
</tr>
<tr>
<td>1965-68</td>
<td>Kamloops, Fort George, South Peace</td>
</tr>
<tr>
<td>1968-71</td>
<td>Alberni, Comox, North Peace, Atlin; and Saanich, Nanaimo, Dewdney, Shuswap, Cariboo, Omineca, Skeena, Prince Rupert.</td>
</tr>
</tbody>
</table>

In fact, the percentages for each of those districts have risen in the last few years, an indication of the cyclic need behind the provision of road facilities. For the last eight districts grouped in 1968-71, the greater part of investment was to relieve traffic congestion, or to upgrade the facilities to match the increased level of usage and desired standard of service. In the other four districts of the last sub-period, investment was mainly to provide basic linkages of the extension or pioneering type.

The very large, indivisible investments group the districts in the middle periods. Work on the Trans-Canada was the main priority of the 1956-62 period. For 1962-65, it was the Salmo-Creston link and the Richter Pass. In 1965-68, road
building for the Peace River Dam project boosted the allocation in South Peace district.

Much of the increasing budget has been consumed by inflation, and has not resulted in similarly increasing facilities. A truer picture of the priority given to particular districts can only be gained through an adjustment of spending, to take account of inflation. Changes to Table V as a result of this adjustment, are negligible - only four districts changed sub-periods. But because of the varying allocations to districts in different sub-periods, the effect of inflation was more severe in some than in others. Using the HCPI as an approximate regulator, the "cost" of inflation throughout the 1946-71 period has averaged just over 13%. Table VI shows the incidence of that inflation over the districts.

**TABLE VI**

PERCENT REDUCTION FROM 1946-71 TOTAL, AFTER ADJUSTMENT FOR INFLATION

<table>
<thead>
<tr>
<th>%</th>
<th>Districts</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Delta, Boundary-Similkameen</td>
</tr>
<tr>
<td>9</td>
<td>None</td>
</tr>
<tr>
<td>10</td>
<td>Yale-Lillooet</td>
</tr>
<tr>
<td>11</td>
<td>Cowichan, Vancouver-Burnaby, Nelson-Creston</td>
</tr>
<tr>
<td>12</td>
<td>South Okanagan, Rossland-Trail, Kootenay, South Peace</td>
</tr>
<tr>
<td>13</td>
<td>Esquimalt, Comox, Chilliwack, North Okanagan, Columbia</td>
</tr>
<tr>
<td>Average</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Nanaimo, Dewdney, Shuswap, Cariboo, Omineca, Atlin, MacKenzie</td>
</tr>
<tr>
<td>15</td>
<td>North Vancouver, Revelstoke-Slocan</td>
</tr>
<tr>
<td>16</td>
<td>Kamloops, Skeena</td>
</tr>
<tr>
<td>17</td>
<td>Fort George, North Peace</td>
</tr>
<tr>
<td>18</td>
<td>Saanich, Alberni</td>
</tr>
<tr>
<td>21</td>
<td>Prince Rupert</td>
</tr>
</tbody>
</table>
Saanich district has probably been affected more than any other by inflation of construction and other prices. A large portion of recent spending there was for buying rights-of-way, costs of which have certainly risen faster since the 1961 base year than the price of units of road construction. Table VI emphasizes that in the comparison of districts' allocations, distribution over time-periods is an important factor.

The different shaped profiles in Figure 8 reflect different stages of development and the different demands on the road system. In Comox, the basic connections are still being put in; in Revelstoke-Slocan and Fort George, the major obstacles have been overcome. The main roads through Omineca and Cariboo are being upgraded. The recent large shares in Yale-Lillooet, North Okanagan, Saanich and North Vancouver, reflect measures being taken to relieve congestion on main throughways. The inflation-gap has increased in the latest period. The cycle of provision of road facilities has come round to relief of urban and semi-urban congestion, in areas of very high non-building costs such as land reclamation, legal surveys, traffic disruption, and coordination with other utilities. These two things combined mean that the real gain in actual facilities is now much less than it was a decade ago, and that current spending should be measured against current needs, not against previous levels of spending.

The profiles in Figure 8 show a concentration of spending in just one or two sub-periods. This again emphasizes
Fig 8. Distribution of District Totals, according to sub-period 1946-71 (plotted for 3-year averages).

---

is adjusted for inflation

---

%  20  15  10  5

COMOX  NORTH VANCOUVER  YALE - LILLOOET

%  20  15  10  5

NORTH OKANAGAN  CARIBOO  OMINeca

%  45  40  35  30  25  20  15  10  5

REVELSTOKF- SLOCAN  FORT GEORGE  SAANICH
the occurrence of large indivisible investments, a problem in looking at the allocations over time. The early commitments to vital links stand out - from Hope through to Osoyoos, from Prince George to Peace River, and so on. The dominant influence of the Trans-Canada project is very pronounced (especially since construction prices were declining in the middle period). The attention to districts off the Trans-Canada route is indicated in the last two sub-periods (Table V), as facilities elsewhere were upgraded to a similarly high standard, (Omineca, Skeena, Prince Rupert, South Peace, Cariboo), and as new facilities were extended (Comox, Alberni, Dewdney, Atlin, and Cariboo).

3.10 THE TOTAL ALLOCATION REVIEWED

The dominant processes revealed in the inspection of allocations over time and area are mainly four, and fall in some temporal order: basic connections - firstly to Peace River and Hope-Princeton, more recently to Kelsey Bay, Port Hardy, Tofino, Chilcotin; external connections - notably the Trans-Canada, Deas Throughway, Yellowhead and North Thompson links; local intensification - especially farm and tourist roads, in Okanagan and Cariboo particularly; improvement, relief, replacement - these are usually around urban areas, and at rapidly escalating costs.

A variation of the process of basic connection has been extension or pioneering, as in Atlin, or to Stuart Lake in Omineca.
The pattern of investment has frequently revealed the difficulty of road-building in the province, the consequent "lumpiness" of investment, and the highly variable per mile cost of links.

The pattern showed the limited choice amongst urgent needs in the early years, compared with the wider range of alternative choices existing today. In order to decide amongst these finer choices, there is a greater need for a definition of policy objectives, a longer planning horizon, and more measureable input to the investment decision.

Although it is somewhat obscured by the peculiar arrangement of accounting districts, there has been a pattern of spending around and between areas of concentrated population, not completely disturbed by disparities of construction costs or development policies.

It was possible to discover some of the major factors underlying the general pattern - population, distance, existence of through paths, and external connection were dominant. Proportion of trunk mileage, proportion of improved mileage, terrain and climate make up a second group of important factors.

There were suggestive deviations from the general pattern - such as the roads for hydro-electric development, or for pioneering, or for tourist circuits. Such roads, in support of special objectives, have taken a significant proportion of the spending in Atlin, Prince Rupert, Comox, Peace River, Fort George, Kamloops, Revelstoke-Slocan, Omineca, and Cariboo.
The distribution of a district's share over different time periods indicated the changing priorities in provision of facilities. There is some evidence of sequence and inter-dependence, but the non-homogenous reporting units disturbed such patterns.

There has been a peaking of activity around election years, which has brought on some extra costs in the form of inflated contract prices. Extra spending in election years was generally given over to some large contracts of reconstruction and paving, and to increased local activity of maintenance and improvement. The first type is very "visible" to the public generally; the second type increases local employment and local incomes directly.

Construction prices have risen over the last ten years, which reflects increasing wages and perhaps the bias of more difficult work in remoter areas (Skeena, Port MacNeil, Chilcotin, Lougheed).

Interpretation of the pattern of spending was tempered by the concentrations in times of high or low construction costs. The effect of inflation over the period has been unevenly spread amongst the districts.

The approach to interpretation of the data on spending - through hypothesising some ideal pattern out of experience elsewhere and logical deductions - provided a useful perspective on likenesses and deviations to the pattern. It helped to show up the stronger group of factors, existing amongst many others, which influence a pattern of investment, but which may not become obvious if one works outward from the data to the elements.
REFERENCES:

1 Support for the "soft" treatment comes from comments in Robinson (1956); Thomas and Anderson (1965); Robinson and Caroe (1967).

2 "Open", in the definition of the Department of Highways, includes all roads improved beyond the "clearing only" stage. 1962 was chosen since it marks a plateau of both spending and road extension, for the whole period.

3 A large proportion of these costs has been repaid by the B.C. Hydro Corporation to the Department of Highways. In the treatment of total spending on roads, these repayments have been included, since they represent a real cost to the Province, and a real addition to the total stock of road facilities.


5 1957-8 and 1963-4 were years of approximately equal spending. 58 contractors were present in the first year, absent in the second; 76 were absent in the first, present in later year. Only 40 were present in both lists of tenders.

6 The deflationary effect on the HCPI of more intense competition in the slack years has been taken into the "guess". This increased competition would result from the attraction of new firms during the busy period.

7 Commission of Inquiry into Road User Charges, 1959, Victoria, B. C.

8 A.A. Walters, The Economics of Road User Charges, (1968) also, Walters (1961).


CHAPTER 4

SPENDING ON B.C. HIGHWAYS, 1946-71, ACCORDING TO CATEGORIES

4.1 PURPOSE OF THE CHAPTER

The previous chapter described the pattern of total spending over time and over area. Within the total, there were identified five categories and two classes of items of spending. It is suggested that all these items are really interdependent, and that inspection of their shares over time and area will offer some insights on the intentions of the authorities. A hypothetical sequence of spending, based on a process of integration of an already settled area, is offered as a way of approaching description of the B.C. experience of road development. Development of a branch system might entail development of the trunk system, or might be a substitute for it. Provision of high standard trunks might excite a local demand for development of apparently inferior branch roads. Trunk roads might be adjusted to discourage or avoid local branch traffic. As for the categories, maintenance and capital costs may be mutually substitutable to some degree. Survey work indicates the opening up of new routes or the realignment of existing ones. Right-of-way costs, which are generally lumped into construction costs, will tell of the
specific difficulties of road provision in some areas. Gravelling, surfacing, or re-surfacing costs may indicate where the authorities perceive a build-up in traffic flow, or the need for preventive maintenance. Disaggregation of the gross figures in this manner should provide a better understanding of the pattern and purposes of investment.

4.2 RELATIONSHIP BETWEEN TRUNK DEVELOPMENT AND BRANCH DEVELOPMENT

By definition, trunks serve points in the real world - they are usually "downtown" to "downtown". Only a very small proportion of total traffic has immediate access to them (i.e., to origins and destinations located on trunks). Branches, again by definition, draw or distribute traffic from or to these places. Increasing economic activity generally requires more traffic and more space, the former demanding increased capacity or quality of facilities, the latter demanding extension of facilities. Over a long period of development of a road system, with traffic flows generally increasing, one might expect a tendency to spend an increasing proportion on the branch or feeder or "back-route" roads (B). Given a demand-led investment programme, then logically, this general tendency would be interrupted from time to time by spending on the trunk system (T), to relieve congestion and maintenance costs occurring with increased traffic volume. At high levels of urban development, trunk spending will again be dominant, to cater for inter-urban complementarity, as
happened with the U.S. interstate freeway system. A graph of the T/B ratio will describe a series of waves over time and, perhaps, also over area. The areal differences in height and frequency of waves would be due to the relative position of a district in the total pattern of traffic flows. Those areas near the centre of a network, in terms of traffic flows, would experience the earlier waves of T development. Such simple profiles would depend on the authorities following a neutral, demand-led programme of investment.

Fig. 9 - Hypothetical Presentation of Trunk/Branch Ratio of Spending

a) "Central" area  
b) "Peripheral" area

Figure 9 is an idealized representation of the pattern one might expect in a central and in a peripheral area of the road system. The frequency of the T crests would depend on the quality and capacity of the existing facilities, together with the rate of generation of traffic. If the authorities worked with a long planning horizon, and if the budget allocations were only loosely constrained, then the
frequency of T costs would be reduced.

These two considerations would affect the height of the wave variations. For original or pioneer connections, the crest is likely to be very pronounced - that is, a very large proportion of the district's allocation going into that one job. Crests representing improvements or adjustments of a facility would be rather smaller, given the same size allocation to the district. However, if a link had to be rebuilt or replaced, then the crest would again be very pronounced. The trough following such a crest would be very steep and deep, since the new facilities would reduce operating and maintenance costs for at least a few years.

The T/B ratio provides a conceptual device with which to approach the masses of figures to be derived from the financial accounts. It is a way of illuminating trends within districts and sharp deviations which suggest build-up of traffic or costs, or which suggest the pursuit of some other particular objective. Comparison of districts would indicate the relative importance of the two road classes from time to time with implications as to the nature of traffic flows and economic activity in certain areas.

One cannot assume that a linear relationship exists between the change in traffic volume (F) and the change in cost of road facilities (R). The following diagrams indicate the large step additions to accumulating costs for various facilities at different levels of flow.
Fig. 10 - Generalized Diagrams of the Relation of Increasing Flow to the Accumulating Capital and Maintenance Cost of Facilities

a) Change from ferry to bridge

b) Addition of truck lane on hills, 2-lane highway

c) Elimination of intersection by an overhead crossing

d) Replacement of 2-lane highway by limited access freeway

R = accumulating cost of facilities
F = traffic flow

Source: Synthesized from statements in Winfrey and Zellner, NCHRP Report No. 122, p. 60-5; 80-5; and in Tallamy Associates, NCHRP Report No. 42, p. 9, pp. 41-55.

In each case, there is a period of sharply rising costs just before the adjustment, and a period of minimal cost after the adjustment. In (c) above, operating and maintenance costs for the intersection are dispensed with. In (a) and (d), there is a relatively long period before costs start to increase
again; whereas in (b), the respite in operating and maintenance costs is relatively brief. A curve representing user cost would show a sharp fall after each adjustment: in the case of (a) and (c), it would decline to almost zero.

The case of (a) and (b) above can quite possibly occur in branch development (B) as well, and may help to explain the depths of some of the troughs occurring in Figure 9. The troughs can be regarded as an absence of T, and/or as an indication of a particularly large investment in B. The B development, whether new construction or improvement, can be generally described in three processes:

i) **interconnection** or **integration:** the "back-route" connections between the trunks, which also serve minor intermediate communities and activities. In British Columbia, such routes are Kelowna-Rock Creek, or Clinton-Lillooet-Lytton, or Little Fort-100 Mile House.

ii) **intensification:** increasing the sub-regional network impinging on a node. This has occurred around Dawson Creek and around Williams Lake and Quesnel.

iii) **pioneering:** extending peripheral branches and basic connections - such as to Tofino, to Bella Coola, to Mackenzie, or to Port Hardy from Sayward.

At the earliest stage of road development, the T/B ratio of simple mileage would be biased towards B - that is, numerous local roads for exploration, farming, forestry, gathered in sub-systems and drawn together by superior rail or water transport. Such was the case with the Fraser Valley,
Okanagan, West Kootenay and East Kootenay sub-systems before 1946 - they were drawn together by the railway and not by the poorly established trunk roads.

4.3 SPENDING IN B.C. 1946-71, BY ROAD SYSTEM

Table VII shows a distortion to the ideal pattern postulated in the preceding section. The proportion of B to T dipped in the middle years before resuming a rapid trend towards B. The decline in the middle years highlights an element of external policy strongly influencing the allocations within the province. The years 1956 to 1962, saw the busiest activity in building the Trans-Canada Highway. Federal money spent in the National Parks is included in the T amounts; so is a large share (roughly 50% of the total for the Trans-Canada) of federal money provided for all other sections of the highway. The province had to allocate money to that route - perhaps more than was warranted from a purely local point of view - in order to get the benefits of the cost-sharing scheme. The highway, from Victoria through to Field, has taken about $330 million over the whole period, of which about $180 million has come from the Federal Government. In one sense, the external connection has distorted the "natural" or purely local allocation which would have occurred; in another sense, the cost-sharing scheme has released certain provincial funds to be used elsewhere in the provincial road system.
TABLE VII
TOTAL SPENDING IN THE DISTRICTS, ACCORDING TO ITEM AND TO ROAD SYSTEM, 1946-71

<table>
<thead>
<tr>
<th>Period</th>
<th>Construction and Improvement ($m. current)</th>
<th>Construction &amp; Improvement ($m. 1961)</th>
<th>All Items*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>T</td>
<td>B/T %</td>
</tr>
<tr>
<td>1946-49</td>
<td>3.8</td>
<td>33.4</td>
<td>18</td>
</tr>
<tr>
<td>1949-52</td>
<td>7.0</td>
<td>41.9</td>
<td>13</td>
</tr>
<tr>
<td>1952-56</td>
<td>18.7</td>
<td>76.7</td>
<td>13</td>
</tr>
<tr>
<td>1956-59</td>
<td>25.5</td>
<td>162.0</td>
<td>13</td>
</tr>
<tr>
<td>1959-62</td>
<td>20.2</td>
<td>190.9</td>
<td>13</td>
</tr>
<tr>
<td>1962-65</td>
<td>34.5</td>
<td>141.8</td>
<td>60</td>
</tr>
<tr>
<td>1965-68</td>
<td>82.8</td>
<td>128.4</td>
<td>60</td>
</tr>
<tr>
<td>1968-71</td>
<td>105.9</td>
<td>114.5</td>
<td>60</td>
</tr>
<tr>
<td>Total 1946-71</td>
<td>298.5</td>
<td>899.6</td>
<td>33</td>
</tr>
</tbody>
</table>

* Note the breakdown of maintenance and snow-cleaning items between T and B is not perfectly correct. Only until 1956-7 were details provided in the accounts of where in the district the cost was incurred. For all later years, an estimate of the breakdown has been made, based on relative T/B mileage, and adding a percentage factor for the extra costs likely on T roads. Error is likely to result in a slight exaggeration of the B share. Since the amounts involved are about 15 per cent of total, and since the bias is consistent over the period, then any error should not upset the validity of the general trend shown by the percentages.

Despite that dip of B in the middle period, the general trend is clear. Since the greater proportion of T spending occurred earlier than that of B, it is necessary to adjust the total for each into constant (1961) dollars by means of HCPI (Table VII). The differences are not significant except in recent years.

Amongst the districts, the T/B ratio can serve as
a rough guide to the demands on local road development.

TABLE VIII
PERCENTAGE OF TOTAL SPENT ON BRANCH SYSTEM 1946-71

<table>
<thead>
<tr>
<th>Percentage Range</th>
<th>Districts</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9</td>
<td>Columbia</td>
</tr>
<tr>
<td>10-19</td>
<td>Chilliwack, Yale-Lillooet, Fort George, Delta, Rossland-Trail, Kootenay, Skeena, Nelson-Creston, Kamloops.</td>
</tr>
<tr>
<td>20-29</td>
<td>Saanich, North Vancouver, Dewdney, Boundary-Similkameen, Shuswap.</td>
</tr>
<tr>
<td>30-39</td>
<td>Vancouver, South Peace, North Peace, Cariboo.</td>
</tr>
<tr>
<td>40-49</td>
<td>Omineca, North Okanagan, South Okanagan, Prince Rupert.</td>
</tr>
<tr>
<td>50-59</td>
<td>Cowichan, Revelstoke-Slocan.</td>
</tr>
<tr>
<td>60+</td>
<td>Esquimalt, Nanaimo, Comox, Alberni, Atlin, Mackenzie.</td>
</tr>
</tbody>
</table>

Vancouver Island, Revelstoke-Slocan, Omineca, Peace River, Cariboo, Okanagan and Prince Rupert have averaged a relatively high proportion of B (over 30 per cent). In these districts, traffic for off-highway areas has received greater attention: farm and ranch roads; mining roads; basic connections in the north of Vancouver Island; roads for hydro-electric developments in Revelstoke and Peace River. Special projects in Prince Rupert district included the road to Port Edward, and from Masset to Skidegate on the Queen Charlotte Islands. Trunk development has been much more dominant in Skeena, Fort George, Columbia, Nelson-Creston, Rossland-Trail and Kootenay. All but the last have experienced expensive and difficult construction projects; but also, areas of settlement in these districts have been rather confined, as is
apparent from the tourist road map published by the provincial government. The T/B ratio, in such cases, seems to describe the nature of economic activity in a district, as to whether it is concentrated or dispersed - a consistently high elevation of the profile suggests either an early stage of road connection, or a confined pattern of activity; a low elevation suggests a district "growing" locally with well-developed trunk routes, or with none at all, and having a dispersed pattern of activity.

Such an interpretation could be used only as a first approach to the breakdown of spending. As with all rough guides, there are some large anomalies. Delta, Chilliwack, Yale-Lillooet, Kamloops and Shuswap have quite a high degree of development, as indicated by any map of roads or of population distribution. However, their B proportion over the whole period has been depressed by the relative dominance of spending on the Trans-Canada trunk. Kamloops was also affected by the large allocation to the North Thompson trunk.

In developed areas, after trunks of good quality have been put in, a higher B ratio can be expected, but with very pronounced waves of T, mainly because adjustments to facilities are extremely expensive in built up areas with large traffic flows. In less developed areas, the T waves would probably be less pronounced, as minor adjustments can be made to meet the demands of increasing, but still much lower, levels of traffic flow. However, this second generalization has not held true for B.C. in the 1946-71 period.
The T connections have been in large, indivisible lumps, involving long distances and difficult obstacles. The generalization may hold true in rural districts for the present and immediate future, since the basic links of good quality have been put in, and relatively minor improvements can be made - such as truck lanes, controlled access, and improved vision.

A serious difficulty in interpreting the T/B ratio for a particular district is that large additions to T may be forced in a district because of pressure coming from elsewhere in the system, and not at all associated with the state of B in the district. The Trans-Canada and North Thompson Highways have been cited as examples. The same is true of the Northern Trans-provincial through Skeena district, or the Salmo-Creston link. A further difficulty is presented by the electoral divisions cutting across sub-systems of roads - a district may include more than one direction of T and, therefore, waves will appear more frequently than if there is a single trunk with minor branches (see Figure 11). In such cases, the relative importance of each road category in terms of spending can be assessed by comparing the T/B ratio of mileage with the T/B ratio of spending from time to time.

Fig. 11 - Diagrams of Trunk Mileage within Electoral Districts
a) Cariboo  b) Kamloops
4.4 CHANGES IN THE T/B RATIO OVER TIME

A number of districts have been selected for observation of the pattern described by the T/B ratio. The average height of the T percentage line will vary from district to district, depending mainly on the percentage or capacity of trunk mileage within the total mileage included in an electoral district. Costs of T per mile have averaged about four or five times those of B. For example, the T percentage for Chilliwack, Fort George and Columbia has remained higher than average, while that of Comox, Alberni, and North Okanagan has remained below average (see Figure 12). The declining proportions of T mileage in Cariboo, Kootenay and North Okanagan suggest some further opening up of these districts has been taking place.

Comox district bears out the sequence, postulated earlier, of an area at the periphery of a road network - a higher proportion of T, gradually decreasing for a while, a significant new addition to T, then a reversion to the trend. The trunk route here is from Courtenay to Kelsey Bay; the branch routes, which are of the extension and pioneering type, are into the Gold River and Port MacNeil areas.

Saanich typifies the profile to be expected more commonly in urbanized districts. The profile shows peaks representing the large effort required to provide thoroughfares in built-up areas. The first peak was for spending on the Trans-Canada Highway emerging from Victoria (1953-55); the second peak represents spending on the highway from
Fig 12. Spending on Trunk System as % of Total Spending, for selected districts (plotted for 3-year averages)

Victoria to Swartz Bay. After a brief respite, another peak appears at the end of the period, as another large investment is required to relieve the traffic pressure which has built up along this route (Patricia Bay Highway). Much of the branch system in this and other urbanized districts will not be allocated spending through the Department of Highways - rather, through the local municipalities.

Cariboo shows the general trend of the T/B ratio undisturbed by pressures external to the district, such as extra-provincial connections. Kootenay has a similar profile, though its period of prime attention to T was more protracted, because of inclusion in the district of trunk routes covering five directions.

Delta also includes trunk routes covering many different directions - Deas Throughway, 401 Highway, 99 Highway. The T wave was very pronounced and spread over quite a long period. The deep trough in Delta's profile indicates a change of emphasis, investment now catering for relief branch roads for local traffic - particularly the Knight Street Bridge. External influence shows up in Delta's accounts in the provision of over-passes for the railway to Roberts Bank and of an access road to the port.

North Okanagan exemplifies the expected profile of investment in a well-developed rural area. There was an early, moderately high concentration on the T routes, declining sharply after the basic connections of good quality were completed. Since pressure of local and through traffic built
up considerably, more investment had to be put back into T - in this case, widening and improving the arterials about Vernon.

The use of three-year averages in plotting the T/B ratio gives a better indication of the purposes of investment than the profiles provided by annual allocations. These can be distorted from a general trend by a number of factors, such as unfavourable weather and run-off conditions in a particular area, or the satisfaction of short-term political aims, or the absence of a suitable contractor, or the need to coordinate with the projects of other authorities. Also, the direction of spending for political gain may vary from year to year and from district to district: in one case, it might be for improving local farm roads; in another case, it might be for removing an obstacle on the main trunk system. Further, because of the lump-sum nature of many projects in road facilities in B.C., the investment "pie" cannot be cut in any ideal pattern from year to year. Projects started or re-started in an election year have often required another two or three years for the contract to be completed. As an indication of the variation in the T/B ratio from year to year, the six districts selected above are represented in Figure 13. The high degree of variation in Saanich is due to the accounting of progress on the Patricia Bay Highway. Note that Cariboo and Kootenay profiles show an upturn in the latest year, contrary to the general trend - this reflects new investment in upgrading the trunk routes to the increased level of usage.
Fig 13. Trunk-Branch Spending, for Selected Districts (plotted annually).
4.5 MEANING OF THE TRUNK/BRANCH DIVISION OF SPENDING

The T/B ratio is a useful device for setting about describing what has happened in road development: but it is not very useful for planning purposes, and it is a poor basis for prediction. There is obviously some interdependence of branch development, traffic flow, and trunk development, but consistency is lacking. Up to a certain stage, branch roads that open up a district will generate traffic from the branches and into the trunks. They will also attract traffic along the trunks and into the branches - notably, tourist traffic. In such circumstances, spending on one system will eventually require spending on the other, given that economic activity in a district is sustained or increased. Trunk development might not require local branch development, however, if the trunk is for traffic passing through an unattractive area; but if urban centres on a through path are able to trap some of the passing traffic, then over a long period, economic activities there might require more space and perhaps, therefore, some expansion of branches.

Beyond the stage of interdependence of systems, when traffic corridors become constricted, spending on B might be, to some extent, substitute for spending on T. Consider the case where a high proportion of traffic on a trunk is really local traffic - that is, on a trip less than a complete urban-to-urban movement. An alternative route might be provided to serve the local traffic, thereby reducing the need for further investment in the trunk route (see Figure 14). Substitution
of B for T probably occurs only at "very high" levels of traffic flow. The alternate might not show up in the accounts of one particular district.

Fig. 14 - Diagrams of Relationship of B and T Systems
(WIDTH OF LINE PROPORTIONAL TO FLOW AND FACILITY COSTS)

a) Interdependence of B and T

This sequence is typified by the Fraser Canyon route (on a very broad scale), and by the Okanagan Highway (on a sub-regional scale).

b) Substitution of B for T

This sequence is typified by the building of Knight St. Bridge; or, on a much larger scale, the Little Fort-100 Mile House connection, or the Kelowna-Rock Creek "back-route". In these latter cases, the relief of pressure is, more specifically, providing more alternatives for tourist traffic.

Even if the determining relationship of trunk to branch can be discerned, there is still an important difficulty in relating the T/B trend to, say, traffic counts, and projecting it into the future. This difficulty lies in the varying relationships of levels of flow to costs of facilities, which were set out in Figure 10, with very generalized dimensions. The exact dimensions of the relationship vary from case to
case, and their causes may well be political and social, rather than economic and engineering. Which class of costs to minimize is essentially a political and social question - user cost? or immediate capital cost? or long-term total cost? Quality of service provided by the facility involves travel cost, running speed, total travel time, reliability, safety and ease, and so on. Standards guiding the planners are politically or socially determined. Therefore, the T/B ratio would become a useful predictor only if the standards were strictly determined and strictly adhered to, and if the planning horizon were constant for all projects. These are unrealistic conditions. The ratio remains, then, a descriptive device for ordering hindsight and for illuminating a process within road development.

As a descriptive device, the T/B ratio has pointed out a significant trend in the allocation of total spending in B.C., and in the allocations for various districts. It has shown the effects on spending patterns of the processes of basic connection, local intensification and route substitution. Its elevation on the graphs has indicated the relative importance of the respective road systems from district to district. It has emphasized the importance of external connections in the road-building history of B.C.

The T/B ratio has provided a very general commentary on the policies behind allocations of spending on areas of the province. Earlier, the obvious intentions were to develop basic trunk connections of high cost and good quality; and later, there was more emphasis on local branches and alternate
routes. The concern for good external connections became clear - Trans-Canada, Yellowhead, North Thompson, Deas Thoroughway. Relief of traffic pressure has appeared as a significant objective in recent years - in Saanich, North Vancouver, Delta, Dewdney, Yale-Lillooet, and North Okanagan. Evidence of the policy of extension or pioneering was provided by the ratio in Atlin, Comox, Alberni, Prince Rupert, Cariboo and Omineca. In general, the ratio helps one recognize the trends in road development, which a static representation (as in Chapter 3) does not clearly illustrate.

4.6 THE RELATIONSHIP BETWEEN MAINTENANCE AND CONSTRUCTION COSTS

As roads are upgraded, maintenance costs (M) generally decrease for the same traffic volume (F). If a gravel road is redesigned and rebuilt with a tarmac surface, then the operations of grading, brushing, patching and shouldering will be virtually eliminated. A high capital cost offsets long-term M. If F rises greatly on the new facility, then it is possible that other operating costs will increase, such as ice and snow clearing and road patrols.

So after the basic connections are put into a district, generally M will become a greater proportion of the district budget, while declining in actual amount. The situation will hold until increasing F forces up M (and eventually forces new additions and improvements), or until quality and extent of service are increased. At first, F will be able to
increase much faster than $M$, until the operating capacity of the facility is approached. With increasingly higher levels of $F$, particularly on a deteriorating surface, $M$ and user costs will increase faster than $F$.

Maintenance costs per mile, in a purely technical sense, are the outcome of climatic conditions, quality and capacity of design, roadbed and surface, and the level and composition of $F$. Grade and curvature characteristics are sometimes important factors also: but $M$ is in no way "tied" to $F$, for there is a vital intervening decision about what quality of service to provide. The criteria influencing such decisions will be evolved at two levels - guidelines from the central administration, and assessment of actual needs at the district level. Where a facility is due for replacement in the near future, or where the authorities are intending to slow the generation of traffic on a particular link, then quality of service ($Q$) might be allowed to decline. Generally, however, as $F$ rises, $M$ will also rise, to maintain $Q$. If $M$ is increasing faster than $F$, then $Q$ will be improving over a constant road system (assuming no inflation).

The B.C. Department of Highways seems to have pursued such a policy of improving $Q$ - additions to $M$, particularly on vital routes, appear to be greater than increases in $F$. Apart from maintenance of surfaces and shoulders, markings and signposts, the expensive items attendant to high $F$ are the patrols against hazards and delays.

In the deliberate development of a road system, large
capital investments will often be made for construction of basic connections, as a way of keeping down long-term maintenance and user costs. The extent to which such substitution can be carried out depends on the perceived demands of the total transport system, the priority accorded to various objectives of road construction, and the limitations of the department's budget. When concentrating on just a few expensive, indivisible projects, M, and therefore Q, in other parts of the road system will be decreased; but after the main connections of good quality are put in, M per mile will decline in the short run. This situation allows the authorities to extend basic maintenance services, and to increase Q over a greater mileage. A costly trunk facility will eventually benefit the off-highway back-road users (such as farmers) by releasing more of a district's M budget for use in the branch system.

Districts having a low proportion of M to C would logically be in a "development phase" or "relief phase" of road-building. Relief can take the form of upgrading, widening, restricting access, or replacing a route. Districts with a high proportion of M to C are being overlooked in the development phase, or are enjoying the benefits of recently built facilities, or are building up to a congested high-cost situation on ageing facilities.

In B.C. over the whole period 1946-71, M increased at a faster rate than C. Figure 15 shows that the trend was interrupted about 1960-63, when M actually declined, following a period of very heavy spending on C. Since then, M has risen
at an average 6.5% per year, C at about 2%. From 1946 to 1956, M averaged about 25% of all spending. This proportion declined in the middle years of intensive construction activity to about 14%; but since then, has edged back to around 20%.

Fig. 15 - Relationship of Construction, Maintenance and Traffic Flows, B.C. 1946-71

(Plotted for 8 sub-periods).

\[ F - \text{Rural Traffic Flow Index} \div 20 \text{ (see fn. 3.10)} \]
\[ C - \text{Total Construction Costs} \div 10, \text{ \$million} \]
\[ M - \text{Total Maintenance Cost,} \text{ \$million} \]

Interpretation of the increases in M, particularly since 1963, is essentially speculative. Certainly, some of the increases are due to higher wages for day-labour, as these would fall disproportionately on M rather than C. Maintenance operations are generally more piecemeal, with delays and broken shifts, and more labour-intensive, than full-scale construction contracts. This is especially true of patching or small improvement jobs, where traffic interference is an important factor. Some part of the increases is due to
the greater extent of the road system, which has increased at an average of just under 1 per cent per year. Yet another identifiable part of the increases is due to the rising cost of ferry operations, mainly in Comox, MacKenzie, Omineca, Nelson-Creston and Revelstoke-Slocan - costs have risen to improve the quality and extent of service, and to keep ahead of increasing F. However, costs for all ferry operations, excluding the B.C. Ferries Division, have remained at a fairly constant 15 to 17 per cent of total M, over the last ten years.

Therefore, it seems that increasing M is due largely to operations intended to maintain Q as F has risen, and operations intended to improve Q over a larger part of the road system. There are no indications in the accounts as to which intention was the stronger, though it might be discoverable from the accounts of operations at the district level, before aggregation into electoral districts. A general indication is obtained by imposing the total M line onto Figure 6a of the previous chapter. Despite all the improvements of structures and surfaces, M rose more sharply than gas tax and licence collections, suggesting that Q was being more than maintained in the face of increasing F. Further, in the Annual Report of 1964-65 (p. 72) the Senior Maintenance Engineer referred to "the improving standard of highway maintenance"; and again, in the Annual Report of 1966-67 (p. 73), to "the growing demand for improvements and paving carried out under our day-labour programme". The conclusion, that Q is
being increased and extended, is supported also by the financing formula for district M costs. This allows a 7 per cent increase from year to year, on top of any new construction work which would actually reduce the current need for M.

The pronounced take-off in M costs occurred in 1966-67 (up 16 per cent over previous year), with another boost in 1969-70 (up 14 per cent). The 1966-67 financial year followed a winter of heavy snowfalls, so perhaps some part of the increase is due to repair of damage caused by pavement deterioration and spring run-off. This explanation does not account for the high levels of M being sustained in subsequent years. Those two outstanding years correspond with election-year activity, which would help explain the increasing Q and the increasing extent of maintenance services. There appears to be no communality in the character of districts being favoured with increases (generally more than 20 per cent over the previous year). Now, given the different needs of the various districts, and the apparently indiscriminate allocation of increased M, the conclusion must be that M was not being used as a factor in a specific policy, but as a means of satisfying user demand in a general way.

4.7 MAINTENANCE COSTS OVER AREA

The M allocations in 1970-71 ranged from about $500 per mile-improved in the Similkameen-Okanagan areas, up to about $2,900 in the Lower Mainland. Precise figures are unobtainable from the accounts since dollar amounts are given
by electoral districts while mileages are listed by highways administrative districts. Also, it has not been possible to calculate for all the electoral districts since some are split between, or spread across, more than one highway district.

Still, the grouping of districts by M costs per mile is indicative of the purpose behind their allocations. The Lower Mainland ($2,900) is about double that of the next ranked area. Rossland-Trail, Nelson-Creston and Revelstoke-Slocan are grouped about $1,200 to $1,500; Fort George and Comox around $1,000; Prince Rupert, Kootenay and Yale-Lillooet $800; Kamloops, Shuswap, Omineca and Skeena between $600 and $700, and Peace River, Cariboo, Okanagan, and Boundary-Similkameen all between $500 and $600.

Referring back to the factors offered as determinants of M cost (para. 3, Section 4:6), one has to discount the quality of facilities as a generally pervasive factor in current allocations. It was suggested that high quality facilities would reduce M costs per mile; but in the distribution in the preceding paragraph, high M costs are associated with areas of higher quality facilities (as measured by the very broad standard of miles paved); and vice-versa, except in the Boundary-Okanagan areas. Nor do climate and terrain provide a general explanation of the M allocations, though they have contributed to the grouping about $500 to $600.

The most important determining factor is almost certainly the level of flow. The pressure on facilities in
the Lower Mainland is indicated by the tremendously high allocation of $2,900 per mile (which is about 10 per cent of the capital cost per mile of the 401 freeway west of Port Mann bridge). The need for a new period of C spending, related to the relief of congestion, is again shown. In more remote areas, with much lower levels of F, the M allocation is much reduced, despite the more severe physical conditions - Skeena, Columbia, Comox, Prince Rupert. The allocations of M are almost certainly led by user demand, and not guided by a policy of differential improvement of one district over another.

4.8 THE MEANING OF M COST PATTERNS

As stated earlier, M costs relative to other spending were high in the decade from 1946, declined in the next period through to 1965, then rose again. The peak of $11.7 million in 1956-57 was not exceeded until 1964-65, and since then, the total has grown every year. High costs in the early years heralded a period of intensive construction. The improved quality and capacity of facilities, and the replacement of some ferries, allowed the reduction of M spending for about five years. It is likely that the rapidly rising costs in recent years herald yet another period of intensive construction.

It is noticeable that the areas of highest M costs per mile are also the areas having generally the lowest proportions of M costs to total C costs for the whole period. The
pressure for new facilities is in the areas of costliest provision of facilities. There is, then, some urgency in finding alternative means of relieving or diffusing that pressure in order to break out of the provision - generation - congestion spiral. Whether the new facilities will be provided soon is a question of policy, and this matter is not confined simply to the Department of Highways. In any case, allocations of M have been shown as only a weak guide to policy at work, being more closely tied to levels of user-demand than to wider objectives. The evidence for the intentional pursuit of specific objectives is in the capital allocations, and for the period as a whole, in the allocations to the trunk system.
REFERENCES:

1 See NCHRP Report No. 42, 1967, Ch. 4. The study tries to find uniform M per mile, to be applied by all authorities concerned with the U.S. Interstate Highways.


3 Includes only paved and gravel roads. It is assumed that M costs on earth roads are kept to a bare minimum.

4 Obstacles and damaged pavements are probably more tolerable if met only once (e.g., on tourist vacation), than those met regularly (e.g., on commuter or shopping trips in urban areas).
CHAPTER 5

INVESTMENT IN THE TRUNK NETWORK

5.1 INTRODUCTION

Since 1946, the trunk roads have taken about 67% of total spending. Population distribution and natural barriers constrain the shape and number of inter-urban routes; also, new pioneer or extension routes and relief of urban congestion have come to receive higher priority. Consequently, this proportion has declined to around 50% in recent years.

The actual size of the amount spent on trunk roads would alone justify a special treatment of these roads. But a stronger justification is in the role played by the trunk system in the development and integration of B.C., especially since 1946. Describing the timing, distribution and cost of trunk development is the necessary first step towards understanding a large part of the transport-economy relationship. The data will be reduced here to total cost and per mile cost of each link, and outstanding disparities and correspondences will be explained. The important question of how closely investment on a link might be related to response at the connected node, will then be considered in some detail. To
get an idea of the general response, changes in traffic flow will be related to investment in links. Some measures of structural change will be made, to show the varying contributions of particular links to the total system. Structural measures by themselves will be seen as not particularly helpful towards an understanding of economic effects of link additions.

5.2 IMPORTANCE OF THE TRUNK SYSTEM

A generalized response to road investment is more readily observable on the trunk system, although the branch roads offer many cases of small-scale, isolated responses. The most important influence of the trunk system is that it confers relative locational advantages amongst the set of nodes in the Province, either by providing access, or by reducing the cost of movement of people and goods. Not only do relationships between nodes change, but probably also the relationships of intervening settlements to end-point nodes. Small local stores and domestic or farm services, which survive in a market constrained by a high friction of distance, will be exposed to competition from the higher order nodes. These intervening activities tend to disappear, unless they can adapt to serve the market of passing traffic. Thus, the development of a trunk system, in the interests of efficiency of distribution, can cause social disruption which has to be "paid for" in other ways - relocation and retraining of individuals, shift in land values, taxes, and so on. Hodge (1965, and 1969) showed how
some trade centres die or change under the pressure of competition and the quest for efficiency, a tendency strongly accentuated by transport development. He showed that not all factors of production or elements of society are equally fluid and responsive, a fact often overlooked or assumed away in assessing costs and benefits. Trunk development is not seen as wholly beneficial all of the time.

Hutchinson (1972, p. 499) contends that where the economy and the highway system are both well developed, as in Southern Ontario, then changes in transport costs through highway investment are so small that they appear to have little impact on the location or prosperity of economic activities, so that the "use of user benefits only is justified" in assessing the repercussions of investment. There is some truth in that statement: but one suspects that the economic activities referred to are confined to the manufacturing sector, which have generally lower mobility than other urban activities. For certainly there are significant responses to changed accessibility patterns caused by freeway or subway transit developments, in retailing, office functions, residential buildings, warehousing and distribution, and not limited to intra-urban markets only. The problem of evaluating repercussions of investment in developed areas is really one of identifying the affected activities and the affected components within them.

A second major influence of the trunk system is on the potential for social and economic integration. Isolation is often a contributory factor in social or political dissension;
remote communities often feel neglected, "missing out" on opportunities available to the rest of the population, while their visible, physical connections are actually or relatively inadequate. This phenomenon is not quantifiable, yet it may influence road-building priorities, as suggested by the protests of Gold River and Port Hardy residents during election time in 1972, or by the occasional agitation of Merritt citizens for building of the Coquihalla route as an alternative to the Fraser Canyon route. A trunk road system usually provides a greater potential for regional interaction than the railway or river systems (which serve more specific locations, resources and transport functions).

Investment in the trunk system will tend to reduce the total freight bill for the Province. Increasing specialization, a feature of most advanced economies, places increasing emphasis on the distribution function. This emphasis is particularly pronounced in B.C., where the demand for imports is high, where the avenues of imports are few, where the resource-development nodes are dependent on external supplies of almost everything, and where the metropolitan area has such a dominance over its hinterland. Since the per capita cost of internal distribution in B.C. is so very high, investment in the trunk system can eventually have a strong income effect, to be expressed initially in the intensity of activity at favoured nodes.

Freight costs may be reduced either directly or indirectly. The truck operator, experiencing lower driver costs and vehicle costs, may offer lower rates in order to attract
more shipments. If he maintains the earlier charges after significant road improvements, thereby increasing his profits, then other operators might be attracted into the route, to force down freight charges. (In B.C., the possibilities of entry are constrained by regulations administered by the Public Utilities Commission). If the road improvements enable competition with rail, water, or air services which previously enjoyed a monopoly situation, then freight rates will tend to decrease, depending on the nature of goods being transported.

One looks at the trunk system for its total effect on population and economic activity at or about a node. Connection or improvement will affect almost all activities at a place, some substantially, some to a negligible degree. This is in contrast to improvement in a branch road, which usually affects only a segment of the road-user population about a node, so that the income effect of reduced transportation costs is reflected in only some of the activities in or about a node.

Finally, tourist traffic, which greatly influences some activities and some decisions to invest in various sub-regions, is perhaps more strongly affected by trunk than by branch development in B.C., (assuming equal attractiveness of sub-regions), because of the large distances to be travelled to parks and areas of interest and retreat. Tourists probably prefer well-developed trunks to reach the favoured areas, and then relatively undeveloped branches to maintain the desired sense of escape, originality, wilderness, or seclusion.

So for their greater influence on provincial and regional development, for their greater effect on locational
advantage, social integration, overall freight costs, tourists and the majority of road users, the trunk roads are separated for more detailed description.

5.3 BUILD-UP OF THE TRUNK NETWORK

In the following chapters, the provincial road system is reduced to the trunk routes of the Interior (north and east of Hope), plus the Trans-Canada Highway from Vancouver to Hope. This is done for simplicity and convenience - the Vancouver 'node' sprawls far about the link assigned to it; the ferry services and the possible inter-urban routes or sub-urban roads supplied by the municipalities, confuse the relationship between investment and traffic flow. Also, the distinction between local traffic and inter-urban traffic is relatively vague in the Lower Mainland and southern Vancouver Island. This exclusion does not greatly affect the main issue of the following chapters, which is the relation between investment and inter-urban traffic, particularly trucks. The intention is to set a stage for comparison of road improvement and truck-related economic activities.

Between 1946 and 1971, the total amount spent on the limited trunk on surveys, right-of-way, construction, surfacing and improvements (excluding maintenance, snow-clearing and patrols) was approximately $770 million. Figure 16 shows the investment according to the period in which each link had its "major" allocation - "major" being loosely defined as more than one-third of the total occurring in one period. Most links
Fig 16. Development of the Trunk Network, by Period.
(link indicates a period of "major" investment)
*costs here not exactly true, because of simplification of network structure; Vernon-Kamloops link is really Vernon-Monte Cr.; and Merritt-Lytton is really Merritt-Spences Bridge.

Fig 17. Total Cost of Links in the Trunk System 1946-71

$ million (surveys, right-of-way, construction, paving, improving).
Fig 18. Cost per mile, for Trunk Links 1946-71 $'000
appear more than once, as the intensive activity extends over from one time period to another, or is repeated in another form in a later period.

The picture is complicated by the facilities existing before 1946, and does not imply that all links were of equal capacity and condition at that date. There is an obvious emphasis on the Southern Transprovincial in the first period (there was no Trans-Canada at that time), displaced in the second period by development in the southern Interior. The third period shows a diversity of activity, dominated by the Trans-Canada. The final period shows a shift to the North Central and Northern Interior.

Figure 17 shows the development of the trunk system according to the cost of links, and reflects the enormous obstacles in connecting certain nodes. More was spent between Hazelton and Terrace than in all the Okanagan trunk mileage. The Yellowhead and North Thompson routes stand out as tremendous commitments, of the order of the Rogers Pass or Fraser Canyon links, but with apparently less justification or urgency. Connections to and between towns in the West Kootenay district have been noticeably expensive, mainly because of the cost of bridges and of gaining enough width along the confined river valleys.

Figure 18 shows the per mile cost of links in the trunk system. The distribution emphasizes the importance of the Trans-Canada Highway, and generally shows up the effects of difficult terrain and river barriers - Salmo-Creston, Nelson-Kinnaird, Hazelton to Prince Rupert and Kitimat, Hope to Cache
Creek. Two-thirds of the links have cost less than $200,000 per mile, and most of the others are to do with the Trans-Canada, which was built to a higher standard of design. This per mile cost is an average figure for a link; there are parts of links having costs far above or far below the average, and a finer picture of the incidence of costs could have been presented from the financial accounts of the Annual Reports. The figures are put together in this form (Figures 16, 17, 18) because of the concern of this study with investment and traffic between pairs of nodes and along major routes.

One is tempted to ascribe all the disparities in per mile costs to the occurrence of bridges, hilly terrain, the severity of winter and drainage requirements, or to the existence of facilities before 1946. It is virtually impossible to apply a factor representing the degree of difficulty afforded by terrain or climate. Rise and fall, or percentage gradients, do not tell the full story, for there is a different solution of curves, grades, rock removal, culvert filling, clearing, shouldering, gravel supply and gravel crushing for each situation. Survey and design costs vary from place to place, particularly if bridges are involved. Right-of-way costs become significant in urban road developments. Inflation of contract prices has hit harder on some links than on others. Standards of construction are themselves a variable factor, depending mainly on expected traffic, projected life of facilities, desirable level of service, and funds available.

There are, however, cases where the greater per mile
investment has been in response to current or expected traffic volumes. The 401 route from Vancouver to Rosedale is the most obvious; expensive additions of passing lanes from Hope to Cache Creek, Salmon Arm to Sicamous, Prince George to Tete Jaune Cache, and from Hope to Princeton are also detailed in the accounts. Widening of the highway from Kelowna to north of Vernon, the alternate entry from the south into Prince George, the interchanges at Castlegar, the overhead bridges at Valleyview, and the replacement of ferries, are all examples of costly additions to highway capacity. Breaching of the passes can be regarded as integration or as additions to capacity of the system - Creston-Salmo, the No. 3B to No. 3 connection north from Rossland, the Richter Pass, and the Cranbrook-Wasa alternate.

There are cases where the high expenditures are due to specific projects or to longer-term policy objectives. Hydroelectric development has required much road investment on the Vernon-South Slocan link, and on the Chetwynd-Hudson's Hope-Fort St. John link. The Terrace-Kitimat link was constructed in support of the smelting activity, while the extensions to the border from Yahk and Elko presumably are designed to help attract more tourists. This is part of the motivation behind the expenditure on the Yellowhead and North Thompson highways, which are perhaps also intended to increase interaction with settlements in the Prairie Provinces, and to increase the market range of producers at Vancouver, Prince George and Prince Rupert particularly.
In the build-up of the trunk network, there have been different priorities at work, some of these becoming visible in the size of allocations per link. But the presentation of figures in abstract graph form conceals some real world facts that strongly influence the allocations. Firstly, the nodes are of vastly differing size and traffic-generating capability, so that one might expect more costly facilities to be provided between larger centres, all other conditions being equal. Secondly, existence of a link in a major path tends to be a greater factor in the size of its allocation than the character of the nodes which it connects. Compare, for example, the allocations to radials from Merritt, with those from Creston, or Radium, or Salmon Arm. Lower standards of construction, especially in curves, width and alignment have been possible about Merritt; around the other nodes, particularly Salmon Arm, higher standards have been "forced" by the traffic and importance of the through routes.

5.4 LINK INVESTMENT AND NODE ACTIVITY

An important question thus arises, particularly from Figure 18 - given the variability of allocations, and given the strong influence of through-path development, can any connection be made between the relative dollar allocations to links and the relative importance or intensity of activity at the nodes? In other words, is the cost of overcoming difficulty and distance in travel related consistently to the resulting degree of activity at nodes?
In an isolated situation, with equal difficulty of road construction, a much larger investment in one direction will provide better facilities for one link than for another in a different direction. This will lessen, relatively the costs of travel on one side. Assuming that the surrounding nodes are of equal size, complexity and attractiveness, then more traffic will flow to the favoured direction. The resulting changes in economic activity and node importance are then relatable, in a general way, to the relative dollar allocations. However, if the existing attraction of nodes is unequal, then a better connection from a minor to a major node may adversely affect activity at the minor node, by increasing the market range of the larger's activities. Another minor node, whose link has only a small allocation, may survive because of the protection of distance and travel costs. In such a case, there is no clear connection between relative dollar allocations to links and relative importance of node activity.

Further, a significant part of the allocation might benefit users in a general way not relatable to any particular node. The comfort and amenity aspects, such as wide shoulders, landscaping, clear and frequent signs, and roadside stopping places, will probably have very little influence on users' behaviour between any two nodes. For long-distance recreational travel, the investment might have some directional effects, in making one area more attractive to tourists than another.

Reduction of hazard and accidents, also, seems to be a virtue belonging to the whole system, or to a major path.
Certainly the greater incidence of the reduction will be felt initially by users from nodes at the end of an adjusted link, because they are more likely than tourists, more likely than business travellers from elsewhere, to make more trips along the link. However, this assumes that there is equal probability of accident or damage for each vehicle on the link at any time, which is unrealistic in the case of habitual users. It would be interesting to know of the pattern of accidents on a trunk link, whether there is a higher ratio of trips to involvement for local residents than for tourists and travellers, given the same traffic conditions.

This concern for the incidence of accident costs might seem like quibbling; but, in fact, accidents are extremely costly. In the U.S., their "cost approaches ... the amount spent yearly on highway construction and maintenance. Traffic accidents may control the ultimate answer of the economic value ... of a proposal".\(^2\)

Apart from the disposition of the allocated funds, there is also the problem of the nature of nodes being connected. Some nodes will respond to link improvement immediately—especially those with products dependent on truck transport, those with activities now able to reach a certain threshold, and those sufficiently distant from larger competing centres. For other nodes, the response may be gradual and protracted. In some cases, a supporting change or investment may be required to enable a node to respond at all to the new potential. Greenwood, in B.C., has not been able to trap any of the potential
for development provided by the improved highway; Armstrong and Oliver have perhaps lost something because of improvements on links to Vernon and Osoyoos.

Another stumbling block to the correspondence of the size of allocations with activity at nodes, is the position of a link added to the network (Burton, 1962). This difficulty has been mentioned earlier, concerning the effect of major paths. It needs to be emphasized that allocations to link up sub-systems of the network may achieve a large degree of improvement for the whole system (if only in abstract terms of connectivity rather than in terms of traffic flow). That improvement may not rebound to the benefit of the end-point nodes, since traffic may simply pass through to larger nodes that were formerly attainable by a more circuitous route. The link from South Slocan to Vernon has a great effect on the totality of the network; the Chetwynd - Fort St. John link has a very small effect. Provision of a link from Revelstoke or Golden through to Tete Jaune, would have an intermediate effect on connectivity and traffic flow. A greater effect on traffic flow, but not on connectivity, would result from the provision of a Vancouver - Squamish - Clinton trunk link. These examples are suggested in order to illustrate the very different possible outcomes of link addition, regardless of dollar amounts, because of the sub-systems and pairs of nodes being connected.

Finally, it is possible to have increased flows on an unchanged road system, simply because of node activity having been stimulated by development related to other modes of
transport. Prince George, and the Peace River oil and gas development, are examples of such a change.

The conclusion must be that to relate expected change in activity to the funds available for adding, or improving, a link, is a poor basis for planning and decision-making. Yet when budget allocations are discussed, and records of progress advertised, the dollar amounts are emphasized - a way of implying that $10 million spent here and $10 million spent there are just the same in utility or welfare for the Province. The distribution factor and the time factor are often ignored, as they were in many project developments in the Third World (Wilson et. al., 1966). The greater intensity of activity and traffic flow in developed economies probably conceals misallocation or under-utilisation (if they do occur) by more rapid adjustment, relocation, and re-routing.

To gain a general impression of the relationship discussed above, total dollars spent on links from 1946 to 1971 were related to percentage change in traffic flow from 1954 to 1971 in a simple regression test. Comparable statistics are not available before 1953-54. The inclusion of spending before that date is to bring into the relationship some vital investments which probably had an effect on traffic flow in the mid 1950's, but which were begun in the late 1940's - particularly on the Southern Transprovincial and John Hart Highways. Twenty-seven links were chosen, to try to represent traffic patterns, without being too repetitive - six out of the nine on the Trans-Canada route; seven of the sixteen of the Southern Transprovincial; three out of nine serving the Okanagan area;
two on the Cariboo Highway, two on the North Thompson, two in the Peace River area, two between Prince Rupert and Prince George, plus Merritt-Kamloops and Vernon-South Slocan. No attempt was made to indicate the nature of the relationship - the investment could be a response to local demand for movement, or could initiate or stimulate it.

**TABLE IX**

RELATIONSHIP OF DOLLAR ALLOCATIONS AND FLOWS, ON SELECTED LINKS

<table>
<thead>
<tr>
<th>Traffic Flow related to:</th>
<th>Total Spending ($m) on 27 links 1946-71</th>
<th>Spending per mile ($000) on 27 links 1946-71</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>+.37</td>
<td>+.36</td>
</tr>
<tr>
<td>exponent</td>
<td>9.75</td>
<td>.90</td>
</tr>
<tr>
<td>constant</td>
<td>431.2</td>
<td>389.4</td>
</tr>
</tbody>
</table>

From the previous discussion, the direction and weakness of the correlation in Table IX are to be expected. Stronger correlation was found on the Trans-Canada and Okanagan links taken together, than on those in northern districts taken together; which suggest, perhaps, that the correlation was influenced by existence of important through paths, a higher concentration of urban settlement, and by facilities having been provided before 1946.

5.5 NETWORK IMPROVEMENT FROM THE ALLOCATIONS

The B.C. road system does not lend itself well to the purely structural measures of networks, as used by Garrison et al. (1965), Garrison (1960), and Burton (1962). Because of
the wide variation in length of links as presented in this study, accessibility indices derived from the counting and scaling of links give some nonsense answers. For example, the 170-mile link from Prince George to Tete Jaune Cache is counted the same as the 9 miles from Kaleden to Penticton; the devious South Slocan-Vernon link is counted the same as the direct Vernon-Kelowna link. According to this set of links and nodes, the minimum path from Calgary to Kamloops would take a route through Tete Jaune. The addition of a new link (say, Cascade to Kinnaird and Rossland, or Cranbrook to Fort Steele to Wasa) can add to minimum paths by requiring the inclusion of intersection nodes. On the other hand, addition of a link can reduce minimum paths by allowing routes to by-pass some nodes, as has happened with the Richter Pass, the Salmo-Creston Highway, and the Nelson-Vernon highway. This particular problem of measurement and interpretation was mentioned by Kansky (1963, p. 128), who changed from topological to metrical values when describing the general characteristics of dispersion, accessibility and circuity.

Nor are the topological indices which Kansky offered (1963, p. 10-28) particularly meaningful in describing change in the B.C. network since 1952. The measures of connectivity, density, edge length and node weights, are more useful for comparing change in one network with change in another network. It means little to measure the degree of connectivity for the B.C. trunk network as having changed from 8.5% to 9.5% over the period. His Eta, Pi, and Theta indices, which generally
decrease as networks and economies develop, may in fact have increased in the case of B.C., because of the addition of just three particular links. The Iota index will tell something of the intensity of use of the network (miles divided by nodes times a traffic flow or population factor), but this is not necessarily related to dollar allocations, as was discussed in the previous section. For intensification is not really the story of development in the B.C. road system - the set of nodes has been held almost constant, and only 9 links have been added. Admittedly, three of these have caused significant structural changes (Yellowhead, North Thompson, Slocan links); still, the larger result of investment has been an improvement of the links of a quite stable system, rather than a profound structural change.

More meaningful figures of accessibility according to structure are found if the paths are forced to follow realistic routes - that is, some sense of value informs the selection of paths. As an indication only, of the structural effect of adding new links, the paths from four peripheral and two central nodes to all other nodes have been counted, the routes of which were selected on the basis of what seemed likely with the previous, and current, road conditions, (Table X). The Slocan link brings the greatest amount of structural change because it crosses between sub-systems, from the Central Interior-North Okanagan, to the Kootenay district. Both these districts have a relatively high density of nodes. If all node scores were calculated in this fashion, the apparent importance of the Slocan link would grow increasingly larger, as the clusters of
## TABLE X

**EXAMPLE OF STRUCTURAL CHANGE RESULTING FROM LINK ADDITION**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vancouver</td>
<td>519</td>
<td>510</td>
<td>519</td>
<td>519</td>
<td>510</td>
<td>504</td>
<td>2.9</td>
</tr>
<tr>
<td>Kamloops</td>
<td>399</td>
<td>392</td>
<td>293</td>
<td>399</td>
<td>286</td>
<td>283</td>
<td>29.1</td>
</tr>
<tr>
<td>Ft.MacLeod</td>
<td>699</td>
<td>699</td>
<td>625</td>
<td>533</td>
<td>459</td>
<td>443</td>
<td>36.6</td>
</tr>
<tr>
<td>Ros.-Trail</td>
<td>526</td>
<td>524</td>
<td>402</td>
<td>526</td>
<td>400</td>
<td>384</td>
<td>27.0</td>
</tr>
<tr>
<td>Edmonton</td>
<td>417</td>
<td>364</td>
<td>417</td>
<td>405</td>
<td>352</td>
<td>339</td>
<td>18.7</td>
</tr>
<tr>
<td>Pr.Rupert</td>
<td>815</td>
<td>813</td>
<td>753</td>
<td>775</td>
<td>711</td>
<td>681</td>
<td>16.4</td>
</tr>
</tbody>
</table>

| Total     | 3375                    | 3302                        | 3009                   | 3157                      | 2718                 | 2634                     | 22.0                |

| % Reduction 1952-71 | 2.2 | 10.8 | 6.5 | 19.5 | 22.0 |


nodes repeat the advantageous change in routing. This scale of importance bears no relation to the scale of allocations over the period - for example, $14 million was spent on the Slocan link, $51 million on the Yellowhead, and $40 million on the North Thompson.

Nor does the link importance measure (Kissling, 1969, p. 117) provide any better account of the relationship between investment allocations and contributions to network structure. The measure counts each time a link occurs in the minimum structural paths between all pairs of nodes. In the 1952 network, the most important links were Cache Creek-Clinton, Cache Creek-Kamloops, and Osoyoos-Kaleden. In the 1971 network, the first two maintain their predominance, but the Richter Pass and Slocan links have taken the "pressure" off the Okanagan route, while the Rogers Pass addition gives a boost to the "use" of the Sicamous-Revelstoke link. "Pressure" and "use" refer to structural measures only; but they also show a very weak correspondence with the size of investments as presented in Fig. 17 and Fig. 18. The link being affected structurally might not be the one receiving the allocation.

5.6 MEASUREMENT OF NETWORK CHANGE

The point has been clearly made, that structural change and dollar allocations do not have a consistent nor meaningful relationship. Structural measures are a somewhat deceptive description of network development. Kansky "tied" structure to economic development, and Burton used structural
change as a preliminary method for highway planning - the implication of both being that economic development and investment in transportation ought to bring structural changes of a certain type and order in the network and its parts. The generalizations seem to ignore the fact that a resource-exploiting economy might require a hub-and-spoke structure, not greatly interconnected, while a uniform farming or specialized manufacturing economy might require a pyramid-lattice structure having greater connectivity. The examples from the B.C. experience show that without weighting the nodes, without valuing the links, and without assessing the real-world gain provided by an allocation, the measures of structure are virtually useless for planning and often confusing for description.

The dollar allocations have to be passed through a medium of "improvement bought" before they can be related to response at the nodes. Allocations to the various links are intentionally and inevitably unequal - an allocation related only to existing traffic demand and to miles of distance, would reinforce existing patterns of movement and activity, and would ignore the real-world costs of construction. The degree of improvement can be measured in a number of ways, relating to specific links and nodes or to the total network, and these will be applied in the following chapters.
REFERENCES:


2 Winfrey and Zellner quote the U.S. experience (NCHRP Report No. 122, p. 59) - $11 billion for accidents, $13 billion for highways per year. Many of the highways are designed with accident reduction as a major objective. From an Illinois study of 1958, rural accidents accounted for 25% and commercial vehicles' accidents 10% of the total (p. 60). In B.C., in 1970, 28% of the 70,000 accidents were in rural areas, 10% of all vehicles involved were commercial. (Statistics Canada, 53001, Motor Vehicle Traffic Accidents, 1970).

3 Scores taken from calculations prepared mainly for Chapter 7 of this thesis.
6.1 INTRODUCTION

Accessibility is a potential relationship between at least two locations. It is realized only by users making, or intending to make, trips or contacts between places. It implies an element of cost, and not just a physical connection. Kissling (1966), O'Sullivan (1969) and Wheat (1969) have shown that realization of the potential relationship is quite sensitive to the costs of movement and to the structure and content of activities at the various locations. This chapter argues that part of the effect of highway investment on accessibility throughout the Province can be seen in a particular class of road user - large trucks - which relates quite closely to the more basic economic activities. The improvement bought by investment has to pass through the medium of road users before its effects can be expressed in other activities. The measurement of improvement provides a basis for examining responses in road-oriented activities at various locations.

The following sections attempt to justify, first logically, then from empirical evidence, the choice of a large truck for measuring improvements in roads. The great importance
of trucking activity, especially in B.C., will be demonstrated. The content, methods and empirically-tested relationships involved in the simulation of truck costs in B.C., are presented in the fourth section of this chapter, and in Appendix III. The final section presents some of the output of the simulation, and offers some evidence on its reliability. In chapter 7, the simulated costs will be used in a network context, to show the variable degrees of improvement bought by individual link investments. The correspondence of truck costs and investment, and of truck costs and traffic flows will be considered.

Estimates of actual savings to large trucks through road improvements are attempted in chapter 7 and 8, the reasoning being that the 'surplus' has to be accumulated at the service function (i.e. freight operations) before savings will be passed on to, and cause adjustments in, other activities.

6.2 THE CHOICE OF A LARGE TRUCK FOR EVALUATING LINK CHANGES

Current users are the first beneficiaries of road improvements: a new potential in production and consumption is provided by the change in running cost, travel time, comfort, safety and increased capacity. Studies from the U.S. show that commercial vehicles usually gain more than private vehicles.¹ This results from the higher time cost of commercial vehicles and drivers' wages,² and the greater significance of these items in total cost. At 1970 prices, the total cost for heavy truck travel over 50,000 miles is about $22,000, of which fuel is $4,000, repairs and tyres $7,000, and drivers' wages and
depreciation of equipment about $11,000.\textsuperscript{3} It is unlikely that truck cost reductions would ever determine by themselves the allocation of investment, since commercial vehicles make up only 20-25% of registrations in Canada and U.S., many of them involved in urban activity where they are greatly outnumbered by private and commuter vehicles, or involved in regionally-dispersed but locally-oriented farm activity.\textsuperscript{4} But trucking activity is a good indicator of response to road improvement, as it is an expression of transport as a derived demand.

The truck is more tied to basic economic activity than the car. The truck can be regarded as part of the highway facilities. Truck transport is part of the total production costs for a place. The private car can be regarded as consumer of the highway facilities; it is part of the final demand attributable to a place. Observation of the private car raises the question of personal travel and recreation, a higher order and more variable activity,\textsuperscript{5} not so closely tied to general economic activity at a point. This is particularly true of B.C., where the amount of personal travel varies greatly from season to season, and probably also in orientation (e.g. metropolitan residents touring the central and northern interior, and residents of resource-exploiting towns travelling to warmer and/or urban areas after a confined winter).

Most of the initial development of primary resources in B.C. has been related to rail or water transport. However, further growth of these urban places has been inhibited by inaccessibility of various kinds, a small local market, and
concentration on a few very specialized functions. "Inaccessibility" can include factors of high cost, seasonal disruption, discomfort, unreliability, circuitous routes and remoteness from major paths in the system. Highway development has enabled greater contact with other towns and sub-regions, an increase in visitor or passing traffic (which constitutes an enlarged market), opportunity for tertiary activity, and competition with rail and water transport. Competition has not been confined simply to inter-urban freight charges - delivery time, point-to-point service, and flexibility of schedules and routing have been important factors.6

Where the road provides initial access to an area, new economic development may follow, depending on resources, relative attractiveness, supporting activities, remoteness from existing supply or production centres, and the dynamism in the economy generally. Such development would certainly be reflected in trucking activity. But the investment in B.C. roads since 1946 has been largely for a vast improvement of existing links, and for connections to already-developing areas. So the reflection of investment in trucking activity is not so obvious as with initial access: it now depends on the degree of improvement bought, together with the transport needs of activities at a place, and with the ability of those activities to respond to the new 'field of potential'.7

This field of potential results from the present location of users, their remoteness, and the shape and capacity of the network. Partly because of the importance of paths through the system, and partly because of the varying market size and
range of activities, it is not simply a point-to-point phenomenon, i.e. the potential spreads over continuous space around favoured locations, the concentric ranges of advantage being bent towards the through paths to exploit passing flow or make use of the lower costs of movement on the generally superior facilities. The ability of a node or sub-region to respond depends, in general terms, on its maturity or level of development. More specifically, it depends on the mix of activities, some of which will be able to trap more of the market, either from the flow on a path or from areas previously served from other locations. Thus, distance from competing centres is a determining factor in the response. Some places may benefit from improved accessibility, but because of their differing demands for transportation, not all activities at a place will respond in similar fashion. The favoured activities might enlarge or improve their facilities, the investment being released by reductions in supply or distribution costs (increased profits), or being made in anticipation of reduced trip cost of shoppers (increased sales). Focussing on truck costs disposes one to find the first type of adjustment, where some of the new potential has been trapped. The plotting of truck cost savings later in this and the next chapter, will show which places and which routes have been more favoured than others, suggesting places worth examining for their economic response.

But caution is needed in affirming the strength of the relationship. Wheat (1969) postulated a close relationship between 'interstate freeway access' and 'increased manufacturing activity' in the U.S., but found that it had to be supported as
well with such factors as initial size of cities and the existence of air services. Werner (1968) suggested that more attention should be paid to the efficiency of networks, and not just their structural attributes, in assessing economic response. In the same publication, Gauthier took a second look at the road system of Sao Paulo State in Brazil, to add a capacity constraint to the inter-urban links, to better reflect the reality of potential use. In his 1970 article, Gauthier relaxed even further the relationship between transport investment and economic development. Empirical studies, especially those of the Brookings Institute series, support this tendency. In 1959, Zettel was warning that although highway investment sets up a gravitational pull for some places, and starts a chain reaction, the timing and direction of that reaction cannot be closely mapped. The difficulty is in the use and incidence of benefit. Some part of highway benefit goes into lowering distribution and production costs, which might be passed on as lower final prices. Assuming an elastic demand for goods and services, total demand will then increase, thus generating more activity. But a large part of the highway benefit does not release income nor provide for added production - it is contained in personal time, convenience and comfort, which can be attributed almost totally to private cars. The underlying implication is that highway investment and change in transportation costs will induce some growth. Wills (1971) showed that in B.C., economic growth measured by liquor sales at nodes was generally well in advance of changes in accessibility - a reflection of the resource-based activities
relying on rail and water transport. The higher order activities will be more closely related to road development, for they require more frequent and more flexible movement of people and goods than is offered by other modes. Increasing integration of the provincial economy will entail more use of variable routing, i.e. trucks, than the more confined and centralized rail routes. Expansion of market range of some centres of the Interior will be permitted or constrained by road conditions and running costs rather than by rail service.

Lower freight charges will affect only some activities. Reductions in factor costs of resource-processing industries will generally be of minor importance, although some benefit will accrue to quarrying and logging operations that can use highways rather than trails; and some production centres, such as Cassiar, would probably respond to better road connections. Primary producers will probably benefit, either by increasing sales over a wider market, or by lower distribution costs which will allow them increased economies of scale, higher profits, or to compete in price with producers from other areas - for example, Cariboo beef with Alberta beef, or Okanagan fruit with imported fruit. But which urban functions are affected? Retailers will generally be able to reduce their prices or increase their variety of stock, thereby attracting a wider market if there is sufficient elasticity of demand for their goods. Thus they might capture part of the market of other centres. Wholesalers might be able to reduce their stock, because of increased reliability and speed of service; some might even be forced out by wholesalers at
larger centres. This has occurred with rationalization of gasoline and milk distribution. Commercial activity serving people and businesses will show little response to freight cost reductions, for it is essentially market-oriented, being affected more by the prevailing cost and frequency of private trips and by the availability of alternative communication.

So the relation between truck cost reductions and economic activity must be limited in general to a set of activities, occurring in places having a certain remoteness from competing places. Tracing out the truck cost savings shows up part of the new potential due to investment in roads; the structure of activity at favoured nodes would need to be known in order to suggest with some certainty the response; and the size and type of subsequent investment would need to be known in order to identify the degree and nature of response to the new potential.

6.3 TRUCKS IN THE TOTAL TRAFFIC

If a connection is implied between truck cost savings and response of user activities, the question arises as to how much costs have to change before the savings become usable, both to truck operators and to shippers. Many studies of user benefit (cited in following pages) have wrestled with this problem. Realization of time savings depends on the degree of improvement relative to total travel time; on the relative importance of time in the total trip cost; on the purpose of the trip; on the income level of users; on the importance of other travel
features such as comfort, convenience, reliability, directness, safety, and congestion; and on the relative attributes of competing modes of transport. Such features are largely subjective; more objective evaluation occurs where time savings are realizable in out-of-pocket or capital costs, or are vital to the marketing of goods and services.

Generally, commuter traffic has a low evaluation of the money cost of time, weighing against convenience, privacy and congestion. Tourist and recreational traffic has a relatively low evaluation of time savings, being more concerned with safety, amenity, reliability and comfort. Personal and business travel probably weights time and comfort together, especially over longer distances where train or air travel becomes possible. It would seem then, that the technique of converting time savings to money values stands on weak logical grounds.

Yet these generalized assertions above, do not match one's personal experience - people do show a great sensitivity to delays. The apparent contradiction between response to time cost and response to money cost has stimulated much research. Winfrey and Zellner (1971, p. 61) sum up the problem:

"Travel time has psychological attributes that give it, perhaps, an importance beyond its real monetary value. People do not like to be delayed ...are more satisfied if they keep moving while in their vehicles ...even preferring that to a trip that requires less time but involves more stops."

The need to put a value on the cost of time has been imposed by the accepted technique of highway economy studies. Time savings are often the main justification for projects,
hence the need to convince the financing authorities that time means money. In a review of cost-benefit studies, Fleischer (1962, p. 12-3) found that time benefits ranged from 43% to 134% of all other benefits. Commercial vehicle time was 37% to 73% of all benefits attributable to all users' time, and was 17% to 88% of all benefits in another set of studies. But for most personal travel, including commuting, time savings do not release any income for other purposes (unless one is going to assert that 'income' is a function of all time and money together).

Truck operators probably perceive place to place time savings as vital, especially if the conversion from time to money savings is realizable. Employed drivers, who in B.C. can choose to be paid an hourly or a per mile rate,13 would regard time savings as a bonus in leisure; if time saved can be turned into more trips and more miles covered in a month, then they gain in money terms as well, and the truck owners gain greater revenue-miles from existing capacity.

For each type of travel, there is a minimum at which time savings become meaningful. Thomas (1967) suggested that commuters do not value time savings of less than 5 minutes per trip. Small savings for one vehicle, multiplied by the daily traffic, and then valued at an average hourly cost, do not give a realistic measure of benefit. Over-the-road savings of up to 30 minutes mean little to most travellers and truck drivers, the savings being used by the latter for longer stops or more relaxed paperwork and checking of equipment.14 Unless or until the truck driver or operator sees the advantage of rearranging his schedule for the whole round trip, properly co-ordinated
with terminal facilities, then small savings from link to link will not be 'added up' and used.

Fleischer (1962, p. 5,17,289) refuted the assumptions underlying time-savings analysis in highway economy. Time saved does not have immediate economic value. Not all increments of saving can be added, he said, hence the fallacy of valuing total hours of time saved at the average straight-line time for drivers and vehicles. Minimum hours and subsistence arrangements for drivers often negate the potential savings to the owners of over-the-road and terminal changes. 'Large' time savings might make a difference in operations over a certain range, provided that cargo supply is continuous, and drivers' hours flexible - in which case operators could hope to achieve a greater revenue-mileage over a year.

Certainly out-of-pocket costs will be reduced as roads are improved - for tyres, brakes, suspension, accidents - but, as has been emphasized they are small in relation to time costs. The conclusion of Fleischer, after studying a fleet operation on the U.S. West Coast, was that the company was unable to take advantage of gains due to road improvements until 'substantial' gains accrued over an eight-year period, allowing reorganization of operations, schedules and warehousing (p. 286-9).

His study deals with only one company. It is likely that competitors, while inhibiting the readjustment of the observed company, entered the industry to provide better service, perhaps deflating freight charges relative to other prices, and thus delivering to the economy generally some of the savings to be expected from improved roads. It is largely the structure
of the industry and competing modes, (including the ramifications of regulation), and the transport needs of activity in a region, that determine the effect of improved operations on producers and consumers. There is a lag time, and possibly an indeterminate relationship, between road improvements and truck operations, and between truck operators' and users' adjustments. These weaknesses are kept in mind in the simulation of cost savings in the following pages - the savings are indicative only, and their effects need to be studied nearer to the level explored by Fleischer.

Restricting the cost estimates to large trucks only, excludes a large proportion of highway users. In 1950, there were 288,000 vehicles registered in B.C., of which 74,000 were commercial. The latter were growing at about 9% per year. In 1961, the total was 584,000, of which 117,000 were commercial; and in 1971, the figures were 1,084,000 and 228,000 respectively. Commercial vehicles include a wide range of vans and light trucks, often associated with local delivery, small services and farming. 'Inter-city for-hire' registrations were 7% of all commercial vehicles in 1964, but accounted for about 80% of ton-miles covered by commercial vehicles. On the interstate freeway in Oregon, Fleischer (1962, p. 36) found trucks to be 19% of all vehicles, the heavy trucks alone being 6%. Commercial vehicles in observed rural traffic vary with the time of day - at 4 a.m., about 65% of total traffic; at 6 a.m., 35%; at 8 a.m., 18%; at noon, 14%; and at 6 p.m., 11%.

Observations during daytime travel in July and September, 1972, on the main highways of B.C., showed trucks to be
about 10% of traffic passing in the opposite direction, heavy trucks being 7%. Sawhill et al. (1970, p. 36) found that large trucks were about 6% of total traffic on metropolitan freeways about Seattle, declining to 1% in peak periods. Saal (1950) found that all commercial trucks made up 18% of traffic on 4-lane highways, and 25% on freeways. This proportion would probably have changed since then, as the rate of increase of private vehicles has exceeded that of commercial vehicles.¹⁹

Traffic counts in B.C. do not differentiate between types of vehicle. However, a survey carried out in the summer of 1972 by the Department of Highways attempted to give a breakdown of composition.²⁰ At 46 stations, observations were made for parts of one or two days during July or August, to count the number of cars, visiting cars, campers, pick-ups, light and heavy trucks and buses. Since most observations began at 9 a.m. or 10 a.m., and ended at 4 p.m. or 5 p.m., the proportion of trucks in the total daily traffic is underestimated. Many trucks, particularly in the summer, will move at night time to avoid other traffic and to meet schedules. Also, the car traffic has greater seasonal variation than the truck traffic. The overall results of the survey showed heavy trucks as 5% of weekday traffic, 2% of weekend traffic, and 3.7% overall. If light trucks are included, the percentages are 11, 5, and 8 respectively.

The Department of Commercial Transport keeps aggregate annual figures for vehicles calling at weigh stations. The count is done manually, and there is some doubt about its
reliability. The stations do not operate around the clock, so that many truck movements are unrecorded. The total checked has remained remarkably constant - 1.31 million in 1966-7, 1.34 million in 1969-70. In 1970-1, there was a general slump to 1.27 million, but this recovered to 1.39 million in 1971-2. Considering that there are about 18,000 'inter-city for-hire' registrations, and allowing for out-of-province operators, then the check-ins per heavy truck are only about 70 per year. This seems rather low for the likely annual mileage of 50,000, suggesting that the weight-checking stations have a poor time- and area-coverage. Comparison with general counts at the permanent traffic stations supports that contention. Thirteen locations were comparable in 1971 - commercial vehicles averaged only about 1.4% of annual traffic. Excluding those stations obviously counting much commuter traffic (such as east of Patullo Bridge) the proportion was 4.2%, still very low in relation to registrations.

The Annual Report of the Department of Highways records traffic on ferries. Taking a random sample of years and places in the last decade, 'trucks' have averaged 21% of total vehicles carried. It should be noted that most of the ferries now occur on the branch routes only: that is, not serving inter-urban traffic as defined in this study. Nevertheless, the complete coverage by ferry operators results in a figure nearer to the registrations. Statistics Canada (see ref. 6:17) provided an outline of truck operations in the province in 1964. The average yearly mileage for heavy trucks was 30,000; the average revenue per truck was about $13,000.
and the average ton-mile revenue about 4.5 cents. It is interesting to note that 33% of the total mileage was covered while the truck was empty, and that 63% of total ton-mile capacity was used, indicating the frequent absence of back-haul loads. Live animals gave the highest ton-mile revenue at 14 cents, general freight gave 5 cents, crude materials 5, and fresh food 3.6.

The 'For-hire Trucking Survey of B.C. 1970; Statistics Canada, series 53-224) updates the previous information. It provides some interesting commentary on the imbalance of flows and revenues to and from Vancouver (see chapter 8 of this thesis). There is a greater disparity in revenues than in tonnages, because the shipments 'valuable' to truck operators, such as general freight and end products, are those which originate mostly in or from Vancouver. The estimated total revenues of for-hire inter-city carriers was $195 million in 1970 - about the same as total farm cash receipts.

U.S. studies in 1957 showed that trucks took 61% of frozen fruit and vegetable shipments, 90% of poultry, 50% of canned goods, and were generally increasing their share. In B.C., the proportions are probably higher, because of the less competitive rail service and the gathering of populated areas within the competitive range of trucks. Parcel mail out of the Lower Mainland has been distributed by truck rather than train since 1962.

Some trans-continental hauliers offer faster-than-rail service. All of the fresh fruit moves by truck. Some imported cars are taken by truck from Vancouver to Edmonton.
More fresh fish is being trucked out of Prince Rupert to the Prairie and U.S. Interior markets. All these are only suggestions of the importance of truck operations. Obviously, the data from which to assess the importance of trucking in the total transport function of B.C. is very patchy and in some cases, unreliable. A separate study is required to analyze the importance and structure of the trucking industry in B.C., to detail the changes due to road investment, technology, competition, and users' preference, and to support an understanding of spatial changes in the economy.

6.4 METHOD OF SIMULATION OF TRUCK OPERATING COSTS

The accuracy of a simulation depends on the quality of data available, on the strength and stability of logically- or empirically-supported relationships, and on the successful arrangement in steps of natural or induced processes that are generally fluid and continuous. Quantities and relationships have to vary by measurable degrees, or be ignored by the simulation. The fineness of measurement depends mainly on the purposes of the simulation. If one is seeking the 'truth' in travel costs between places, then the simulation includes such detail as oil consumption, gear changes, rise and fall in feet, drivers' response to congestion, drivers' fringe benefits, and so on. Less detail would be required to provide a fleet operator with an estimate of his running costs. For most studies of spatial relationships in Geography, even more generalized measurements have been made, using only time or total distance
data. It was suggested in an earlier chapter that the deterrent component in the gravity model ought to be more thoroughly described and quantified - but not to the extent of having a fine measure in the denominator as against a gross measure in the numerator. Since the relationships between travel cost, frequency of travel, prices of goods and general economic activity are not clearly defined nor necessarily determinate, it would be inconsistent to apply a strict estimate of costs to a rather vague assessment of response. Indicative quantities only are required for this study, to pick out the varying degree of change for links in the network.

The most detailed simulations of truck costs have come from the civil engineers, some working on engine and vehicle design, others on the design of facilities.\textsuperscript{23} Increasing refinement of the parameters usually entails a multiplication of the data requirements, hence the restriction of empirical tests to very small sections of highways.\textsuperscript{24} Highway economy studies generalize from the basic research.\textsuperscript{25} Guidelines for use on evaluation of projects generalize further, adjusting to the data available and to the purposes of the evaluation.\textsuperscript{26}

Roberts (1966) used a substantial amount of detail in preparing a simulation for truck costs in developing countries. The 8 variables for the link and 12 for the truck require some data not generally available in that situation. The fineness of the simulation and the effort required, seem out of balance with the type and degree of response which one might expect in those circumstances. A similar criticism might be applied to
the simulation used by Griffiths (1968), which included very fine margins of fuel, oil, and tyre costs in a model for assessing road development projects in Dahomey. Gauthier described the difficulty of obtaining information on transportation costs in Brazil, mainly because the industry "is characterized by a large number of very small firms" (1968, p. 108). Using locally generated estimates, Gauthier included overhead charges, initial equipment costs and administrative expenses to derive a set of values relating transport costs to length of haul over different types of surface. The relationship between travel cost and administrative and overhead costs was discussed by Stevens (1961) and Adkins et al. (1967); generally, the relationship is too weak or indeterminate to fix a measure of gain due to road improvement.27 Kissling (1966) relied mainly on the guidelines of Stevens (1961) and AASHO (1960) in obtaining running speeds and operating costs for Nova Scotia, from a highway inventory taking in 10 variables. For lack of time and information, the present study takes in only 7 variables describing the link, to derive running speeds, link time and cost for a 70,000 lb. gross tandem semi-trailer.28 Elaboration of the content and mechanics of the simulation is provided in Appendix III.

The description of links in the B.C. road system has been compiled from topographic maps, tourist maps, and by tracing the development history of each link through the accounts in the Annual Reports. The years 1952, 1962 and 1971 have been chosen to mark stages in highway development. Route data before 1952 are scarce; investment data are available only until March 1971,
at the time of writing. Distances and ferry delays have been taken from published tourist maps. Zones of legal speed restrictions have been estimated from topographic maps and, in the latest year, from personal observations. The type and condition of surfaces has been taken from tourist maps, topographic maps, references in the accounts, and personal observation. Lane and roadway widths - for which the data are least reliable - have been estimated from topographic maps, references in the accounts and personal observation. Grades have been estimated rather crudely from topographic maps, calculating the total rise and fall over a link, and modifying the gradient factor where references in the accounts suggested cut-and-fill or redesign operations had taken place. Curves could not be estimated from the available information. Volume of traffic was measured from the Department of Highways summer traffic counts of 1953, 1954, 1962, and 1971.

Average running speeds on straight, level, unimpeded surfaces were set at 50mph. for paved and 38mph. for gravel. Speeds within legal zones were set at 20mph. - legal zones indicate a higher frequency of intersections, crosswalks, traffic lights, stop signs, on-street parking etc., which reduce speeds within urban areas. Personal observation on a Thursday in September, 1972, of trucks passing through Kamloops and Vernon, supported the 20mph. estimate.

Lane and roadway widths reduce desired or free speed. From the sources referred to, a range of factors was derived for Table XI. Indications from comparison of calculated and observed speeds suggest that greater restrictive influence
should apply on narrow and restricted roads in the earlier years.

**TABLE XI**

PERCENTAGE OF FREE SPEED, UNDER WIDTH RESTRICTIONS

<table>
<thead>
<tr>
<th>Description</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open: 12' lanes, good shoulders,</td>
<td>.......</td>
</tr>
<tr>
<td>good vision</td>
<td>96 - 100</td>
</tr>
<tr>
<td>Narrow: 10'-12' lanes, poor shoulders,</td>
<td>.......</td>
</tr>
<tr>
<td>adequate vision</td>
<td>88 - 95</td>
</tr>
<tr>
<td>Restricted: less than 10' lanes, poor shoulders, poor vision</td>
<td>.......</td>
</tr>
</tbody>
</table>

The danger is that the width factor is applied with the grade and volume factor in hilly winding sections, giving an unrealistic cumulative restraint; whereas the presence of a grade factor more or less cancels out the effect of a width factor, as the vehicle is slowed by gravity rather than by driver's caution.

A measurement of the total rise and fall was taken from maps, i.e., each time the road crossed a 100' contour line. The average rise and fall, a slightly better indicator of severity, was found by dividing the total by the link distance. This measure is not as precise as Kissling's 'critical gradient' (1969, p. 114) in measuring the effects on truck speed. A range of factors was derived from experiments elsewhere. Grades also increase the rate of fuel consumption by a greater margin than that caused by a decrease in speed, due to gear reduction. So a factor for extra fuel consumption on grades was added, (see Table XII).
TABLE XII
INDICES OF FREE SPEED AND NORMAL CONSUMPTION, DUE TO INCREASING RISE AND FALL

<table>
<thead>
<tr>
<th>Rise and Fall*</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>(total R. and F. miles)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modern paved</td>
<td>95</td>
<td>85</td>
<td>74</td>
<td>62</td>
<td>53</td>
<td>46</td>
</tr>
<tr>
<td>Old paved</td>
<td>93</td>
<td>82</td>
<td>71</td>
<td>57</td>
<td>47</td>
<td>40</td>
</tr>
<tr>
<td>Gravel</td>
<td>98</td>
<td>92</td>
<td>81</td>
<td>72</td>
<td>66</td>
<td>60</td>
</tr>
<tr>
<td>Consumption</td>
<td>110</td>
<td>120</td>
<td>145</td>
<td>170</td>
<td>200</td>
<td>230</td>
</tr>
</tbody>
</table>

* Total Rise and Fall is found by counting the number of times the road crosses 100' contour lines, then multiplying by \( \frac{1000}{5280} \), to supply the scale with an integer.

Note: reductions of speed on gravel are less severe because of the lower base speeds attributable to gravel roads. The reductions on modern pavements are relatively less severe because of the realigning of curves, grades and cuttings during reconstruction.

Incorporation of a factor to reflect volume of traffic was most difficult. The traffic counts are patchy and do not tell of the frequency of trucks in the total stream. The summer counts overstate the average annual daily flow. Without knowing the hourly distributions of traffic, it is impossible to deduce the length of periods when flow is approaching capacity. Also, one can only generalize very broadly in saying that truck drivers and owners will avoid congested periods by rescheduling. Such rescheduling carries an extra penalty to the operator in overtime or night shift rates, so the application of a factor for daytime congestion is not entirely indiscriminate (Table XIII).

Fuel consumption varies according to running speed, gross weight, engine power, gradients and so on.\(^{34}\)
TABLE XIII

PERCENTAGE OF FREE SPEED, UNDER AVERAGE DAILY FLOWS

<table>
<thead>
<tr>
<th>Volume</th>
<th>Paved</th>
<th>Gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3500 per day, 2 lane</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>3500 - 5500</td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td>&gt;5500</td>
<td>92</td>
<td>90</td>
</tr>
</tbody>
</table>

Note: the factors are somewhat inflated for this simulation, since they are applied after width and grade factors. The greater hazard of vision and increased spacing reduces the speed on gravel surfaces by a slightly wider margin.


For simplicity, this simulation ties consumption to speeds and gradients only. Consumption decreases for speeds from 20 to 35mph., then starts to increase (see Table XIV). Fuel is one cost whose total might rise because of improvements to road facilities. Cost per gallon is set at 40 cents.

TABLE XIV

INDICATIVE FUEL CONSUMPTION AT AVERAGE RUNNING SPEEDS
(vehicle 3-S-2, diesel, 70,000lb. gross)

<table>
<thead>
<tr>
<th>Speed</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallons per mile</td>
<td>.26</td>
<td>.23</td>
<td>.20</td>
<td>.20</td>
<td>.22</td>
<td>.26</td>
<td>.28</td>
</tr>
</tbody>
</table>

The calculation of hourly cost of vehicles and drivers has provided widely differing values. Kissling (1966) used $3.00 per hour; Fleischer (1962) used $3.90; Adkins et al. (1967) used $4 to $8; Winfrey and Zellner used $3.75; and Koppelman used $6.00. Based on the existing Teamsters' Union contract, drivers' wages in B.C. are set at $5.00 per hour, and
an average of $0.60 is allowed for subsistence (meals and overnight stops). Following the example of Adkins et al. (1967, p. 36), $2 has been added for drivers' welfare (holidays, workers' compensation, etc.) and vehicle depreciation. The justification for these inclusions is that on an improved link, less time is spent, and therefore less of the direct operating cost is attributable to that section. The total time cost applied in this simulation is $7.50 per hour.

Vehicle maintenance and repair cost is a complex function of average speed, weight, loads, surfaces, stops, speed changes, curves and grades. Using evidence gathered in test sections elsewhere, the cost of repairs, maintenance and tyres was set at 18 cents per mile for old gravel, 17 cents for normal gravel, 13 cents for old pavement, and 12 cents for pavement under 8 years old (where this information was available from maps and the financial accounts).

6.5 OUTPUT FROM THE SIMULATION

From the data and relationships outlined in the previous section and in Appendix III, truck costs on each link were calculated for 1952, 1962, and 1971. An example of the information obtained is give in Table XV.

Note that the dollar figures are in 1971 values - this is the cost of running a 1971 truck at 1971 factor prices over a link whose condition has been described at three stages. The figures are not comparable with Gauthier's - he included administrative and overhead costs, the figures being in Brazilian
TABLE XV

TRUCK OPERATING COSTS ON SELECTED LINKS

<table>
<thead>
<tr>
<th>Year</th>
<th>Link</th>
<th>Miles</th>
<th>Av. speed</th>
<th>Time hours</th>
<th>Time Cost $</th>
<th>Fuel Cost $</th>
<th>Repairs tyres $</th>
<th>Total Cost $</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952</td>
<td>Hope-Princeton</td>
<td>83</td>
<td>31</td>
<td>2.7</td>
<td>20.04</td>
<td>10.74</td>
<td>10.79</td>
<td>41.55</td>
</tr>
<tr>
<td>1962</td>
<td>Penticton-Kelowna</td>
<td>48</td>
<td>35</td>
<td>1.37</td>
<td>10.29</td>
<td>4.61</td>
<td>5.76</td>
<td>20.66</td>
</tr>
<tr>
<td>1971</td>
<td>Revelstoke-Golden</td>
<td>92</td>
<td>28</td>
<td>3.27</td>
<td>24.50</td>
<td>18.55</td>
<td>11.96</td>
<td>55.01</td>
</tr>
</tbody>
</table>

cruzeiros deflated to 1940 values. However, the figures are somewhat comparable with Kissling's, though he used a 30,000 lb. truck and a lower hourly cost. (see Table XVI)

TABLE XVI

RELIABILITY OF CALCULATED COSTS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10-20</td>
<td>$4-11</td>
<td>$5-9</td>
</tr>
<tr>
<td>20-30</td>
<td>$9-16</td>
<td>$9-14</td>
</tr>
<tr>
<td>30-40</td>
<td>$15-27</td>
<td>$14-18</td>
</tr>
<tr>
<td>40-50</td>
<td>$16-29</td>
<td>$18-24</td>
</tr>
<tr>
<td>50-60</td>
<td>$22-30</td>
<td>$25-28</td>
</tr>
<tr>
<td>60-80</td>
<td>$25-40</td>
<td>$29-40</td>
</tr>
</tbody>
</table>

The times per link from the simulation are comparable with actual observations taken in 1972, using a small car. Tests of the reliability of the small car speeds, taken on six different links, showed that they overestimated the truck speed by 4-8% on flat or rolling terrain, and by 8-12% on hilly terrain.
These have been adjusted for inclusion in Table XVII. For further comparison, average running speeds for Greyhound buses were taken from the Spring, 1972 schedule. Fleischer (1962, p. 74) noted that the average speed for the bus was usually about 5-10% faster than the truck's. For Table XVII, the listed bus speeds have been reduced by 10%, the higher figure being used because of the frequency of hilly country, in which buses usually perform better than trucks.

**TABLE XVII**

<table>
<thead>
<tr>
<th>Link</th>
<th>Calculated Av. speed</th>
<th>Greyhound speed (adj)</th>
<th>Private car speed (adj)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tete Jaune - Little Fort</td>
<td>36.4</td>
<td>37.8</td>
<td>39</td>
</tr>
<tr>
<td>Prince George - Tete Jaune</td>
<td>42.6</td>
<td>38.7</td>
<td>42</td>
</tr>
<tr>
<td>Cranbrook - Yahk</td>
<td>41.6</td>
<td>41.4</td>
<td>43</td>
</tr>
<tr>
<td>Hope - Lytton</td>
<td>36.5</td>
<td>36.0</td>
<td>39</td>
</tr>
<tr>
<td>Greenwood - Osoyoos</td>
<td>28.6</td>
<td>34.2</td>
<td>35</td>
</tr>
<tr>
<td>Hope - Princeton</td>
<td>33.0</td>
<td>34.2</td>
<td>35</td>
</tr>
</tbody>
</table>

The conclusion from Table XVI and Table XVII is that the estimates given by the simulation for 1971 surfaces are reasonably useful and reliable for the purposes of this study. The margin of error is probably greater on those links which have not been personally tested - Prince Rupert to Prince George and to Fort St. John, and Vernon to Slocan, Nelson, Kootenay Lake and Creston. Some discrepancies appearing in the output
are probably due to error of interpretation or inadequacy of data. The range of per mile costs is 40-50 cents for most links, which compares well with Stevens' 1961 estimates of 38-40 cents.

It is interesting to note the wider range in cost estimates as compared with those of Nova Scotia. Kissling (1969, p. 124-5) explained that

"average speeds on the links may seem low ... it must be remembered that small settlements are numerous in Nova Scotia ... as well, there are poor overtaking conditions, narrow winding and undulating roads ... narrow bridges."

With more open country between links, average speeds in B.C. have been much higher for equivalent distances. Where average speeds were similar, as in the Okanagan and Annapolis valleys, then the higher vehicle and driver cost applied in B.C. forced the total link cost relatively higher. On the longer links, faster average speeds in B.C. have kept total costs within the same range as in Nova Scotia.

It is also interesting to note the high degree of correlation with the link values used by Wills (1971). He allowed 45mph. for a private car travelling over a paved road, and 30mph. over a gravel road. Comparing his car times and the simulation's truck costs for a random 40 links of 1952 and 1971, the result was \( r = .98 \). This shows the close linearity of time and costs, especially for commercial vehicles, and suggests that in some cases, accessibility can be fairly evaluated in terms of link distance, surface and time only. This is particularly true where driving conditions are 'smoothed out' and
costs averaged to a per mile or per hour basis. However, the simulation appears sufficiently discriminating, since the correlation on only those links deemed to be 'hilly' or 'restrictive' falls to \( r = .74 \). (see also Figure 24 in the next chapter).
REFERENCES:

1 Fleischer (1962) p. 12; Hall et al. (1970) p. 35. The latter found that trucks were 5.6% of traffic, but gained 12% of annual time savings on metropolitan freeways.

2 This point demonstrated by Adkins et al. (1967); and in U.S. Bureau of Public Roads, Dept. of Commerce (1961).

3 The truck referred to is a diesel tandem-tractor (5 axles in 3-S-2), gross weight of 70,000lbs., which is quite typical of the long-distance hauliers in B.C. Estimates from gross figures of Statistics Canada, series 53-222, suggest $8,000 for repairs and tyres, and $3,000 for fuel, lower for the latter because of the inclusion in their sample of smaller-engine trucks.

4 From the literature, it seems that the truck operators' lobby exerts some pressure for the general disposal of funds to highway development, but that its main effort is in the fields of taxation and regulation.

5 The proponents of recent work attempting to predict recreational and personal travel would probably dispute this statement - NCHRP Reports no. 82, 89, 44; Plummer et al. (1961) p. 74-85; Thomas and Thompson (1970) p. 1-19; Wolfe (1969) p. 105-21. Very simply put, the recreational travel into or out of a place will depend mainly on its relative amenity and attractiveness. Two places of equal size and personal income, but of unequal attractiveness, will probably have similar levels of truck activity, but different levels of recreational travel.


7 This term suggested and enlarged upon by Lachene (1964) p. 184-6.


9 Hodge (1965); O'Sullivan (1969); Kissling (1967); Cummings (1967).

10 This factor was built into the models of Kissling (1966) p. 145; Wills (1971); and Haynes and Ip (1971) p. 359.

11 Fromm (1965); Wilson et al. (1966); Brown (1966).

12 Adkins et al. (1967); Winch (1963); Claffey (1960, 1961); Curry (1963); Thomas and Thompson (1970); Thomas (1967); Haney (1967); and Lisco (1967), these last three reported by Winfrey and Zellner.
13 Set out in the articles of Master Freight and Cartage Agreement, General Teamsters' Union, Local 181, Vancouver, B.C. in January, 1972. The hourly rate is $5.00, the mileage rate is $0.15. If the average speed for the whole trip exceeds 33mph., then the mileage rate is more rewarding for the hired driver.


19 Trend for B.C. and Ontario is assumed to be similar in U.S. Commission of Inquiry into Road-user Charges. Victoria, 1959. p. 15.

20 Output of the survey was kindly made available by Mr. Harding, Traffic Branch, Dept. of Highways, Victoria.

21 Estimate derived from statistics cited in ref. 16 and 17, above.


23 Firey and Petersen (1962); Clark (1968).

24 Saal (1950); Claffey (1961 and 1971); Sawhill et al. (1970).

25 Stevens (1961); Lang and Robbins (1962); Winfrey (1963); Roberts and Soberman (1967); Adkins et al. (1967); Soberman and Clark (1970).

26 AASHO (1960); Ritter (1960); Hawkins (1960); de Weille (1966); Griffiths (1968); Koppelman (1970).

27 This assertion supported by inferences from Statistics Canada, series 53-005; and from Fleischer's 1962 account of a firm's adjustment.

28 The Dept. of Highways now keeps a detailed inventory of the roads; so, more accurate simulations should be possible in future.


35 This amount is justified as follows: if the vehicle is reasonably used for 50 hours per week for 50 weeks, the yearly total of 2500 hours gives an allowed cost of $5000. Since vehicles last about 8 years, with a replacement cost of about $30000, then the allowed amount will cover replacement and drivers' welfare.


37 Repairs: paved, 8 cents; gravel, 11 cents.
Tyres: paved, 5 cents; gravel, 6 cents.
CHAPTER 7

CHANGE IN THE NETWORK INDICATED BY TRUCK COSTS

7.1 INTRODUCTION

The preceding chapter has supplied a reasonable measure of improvement on each link. The sum of the links at different times gives a general idea of change in the network since 1952. That sum, however, is not a true reflection of the use of the network, for certain links are more vital than others in terms of structure and of use. Link importance can be measured in three ways - by counting the number of times a link occurs in minimum paths between pairs of nodes; by weighting the links by recorded or estimated traffic flow; or by observing the change in node accessibility scores with successive removal of vital links from a network. In this chapter, link improvements will first be considered for themselves, then related to investments per link (out of ch. 5), and then given measurement in a network context. The intention of this last measurement is to show that the 'return' on an investment depends very much on where it is placed in the network.

7.2 INVESTMENT ALLOCATIONS AND TRUCK COST SAVINGS

Some relatively small allocations have achieved
remarkably large savings (compare Fig. 17 and 18 with Fig. 19 and 21). These were cases of upgrading from gravel to tarmac with relatively little reconstruction - on the radials from Merritt, from Sicamous to Enderby Jn., from Greenwood to Grand Forks, and Dawson Creek to Fort St. John. Such changes reflect the large penalties applied to speeds and repair costs on gravel surfaces, in this simulation.

For purposes of comparison of investment and truck cost savings, the ratio of dollars per mile to each 1% saving in truck costs, is set out in Fig. 23. The lower quantities indicate a lower expenditure per unit of savings. Breaching of the passes between Revelstoke and Golden, Salmo and Creston, Cascade and Kinnaird, Osoyoos and Keremeos, Hope and Princeton, appear to have been fully justified by this measure. Investments in the bridges at Kelowna, Castlegar and Hudson's Hope, are also shown up favourably. Savings on the Northern Trans-provincial appear to have come rather 'cheaply'. The huge costs of bringing improvements to built-up areas and confined routes, are shown up by the Vancouver-Hope-Lytton-Cache Creek links. On the other hand, these costs would be justified by those links having the heaviest traffic flows of the whole network.

The devious connection between investment allocations and truck cost savings has been implied in the discussion of link investment and node activity in section 4 of chapter 5. A weak correlation was found between the size of investment and change in traffic flow on a link. A stronger correlation is to be expected in relating truck cost savings to traffic flows,
Fig 19. Simulated Heavy-Truck Costs, 1952 Links (\$, rounded)
Fig 21. Simulated Heavy-Truck Costs, 1971 Links, (rounded)
Fig 22. 1971 Costs Related to 1952 Costs (1971 ÷ 1952%).

*comparison based on current route as against previous alternate route.
Fig 23. Spending per Mile Related to Unit Savings in Truck Costs
($'000 per mile, per 1% saving 1971 over 1952).

∅ possible savings negated by traffic build-up,
(a) no comparison possible,
* % gains measured against shortest alternative existing in 1952.
partly because improved roads generally divert and often generate traffic, partly because traffic has been generally increasing over all of the Province, and partly because of the inclusion of some vital paths in this particular correlation. The effect of such an inclusion is that traffic on the link is more related to the function of the path, rather than to the cost-saving attributes of a particular link (see Table XVIII).

TABLE XVIII

RELATIONSHIP OF INVESTMENT, TRAFFIC FLOWS AND TRUCK COSTS

<table>
<thead>
<tr>
<th></th>
<th>Investment per link (27)</th>
<th>Investment per mile (27) (all)</th>
<th>Change in Traffic Flow (27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>.36</td>
<td>.25</td>
<td>.33</td>
</tr>
<tr>
<td>exponent</td>
<td>.176</td>
<td>.119</td>
<td>.180</td>
</tr>
<tr>
<td>constant</td>
<td>87.6</td>
<td>87.2</td>
<td>89.7</td>
</tr>
</tbody>
</table>

That truck cost savings correlate very weakly with the size of investment is not surprising. It is perhaps a fault of the set of observations that gives a higher correlation of savings with total link cost than with per mile link cost—four links with relatively huge total cost cause a strong bias, which is somewhat weakened after the division into per mile cost. For both correlations, build-up of traffic congestion on some important and costly links has negated some of the effects of the investment; a more precise timing of the relationship might well find strong correlation at an earlier time, gradually decreasing as traffic increases. This is indicated
by the slightly higher correlation for all links, a grouping which includes a larger proportion of the more remote, uncongested links. The correlations are weakened perhaps because some costly construction items, such as bridges, do not show up as truck cost savings, due to the generality of description used in the simulation. Nor would their important effects of permitting heavier loads, and of reducing accidents and maintenance costs be shown in truck operating costs. As for the correlation generally, it might be that costs in the earlier years were underestimated for lack of precise information on road surfaces and design, thereby underestimating as well the degree of improvement for the later year.

The method of simulation causes underestimation of another kind. Factors indicating restriction caused by traffic congestion applied only in the last year, since none of the traffic counts in the earlier year reached the critical level. It might well be that a lower level applied, in fact, in earlier years, because of narrower roads. The generality of map descriptions prevented such a factor being applied fairly; in any case, the restricting width factor had already been applied more to the 1952 surfaces than to those of 1971. The underestimation still occurs, however, because the simulation does not tell what would have been the cost of running a truck with present levels of traffic, over the old surfaces. This difference brings up the argument, well presented by Griffiths (1968, ch. 3) that "with and without" tests are often more meaningful than "before and after" tests, especially where traffic generation or shifts in activity occur.
The weakness of the correlations shown in Tables IX and XVIII has important implications for development planners. The connections between investment, facilities bought, transport savings and economic response, cannot be assumed to be of a particular quantity or particular constancy. Ridley (1969, p. 4) recognized the fickleness of the relationships. For his model of time savings in an improved network, he stipulated that unit travel times on each link vary in a specified manner with the amount of investment in the link. Then, most important, he noted that $"investment per link and savings per link, vary from link to link". But as well as these disparities, there are often very different increases in public welfare from similar allocations to roads, communications, power development, recreation areas, and so on. It cannot be expected that sub-regions will attract investment from elsewhere (given suitable economic conditions) in some constant relation to the public investment in transport infrastructure.¹ Investment, production, pricing and marketing decisions will be influenced by accessibility of different kinds, and this varies greatly for any given allocation of investment. Further, the effectiveness of an allocation to one sub-region might depend on investments and adjustments in other sub-regions. A very simple example of this is the dependence of private investment in Sukunka River coal mining on public investment in port facilities in other sub-regions. In the Denike model (see ref. 7:1), the public investment ought to be credited to the sub-region containing the dependent activity.
7.3 LINK CHARACTERISTICS OF TRUCK COST SAVINGS

The total cost for a 1971 truck moving over all the links of 1952 was $2032; in 1962, it was $1854 (91% of the 1952 sum); and in 1971, it was $1693 (83%). Replacing the Big Bend and Cascade-Rossland routes by the new links, gives a 1971 sum of $1629 (80%).

Some routes have benefitted more than others (see Table XIX).

TABLE XIX

IMPROVEMENTS IN TRUCK OPERATING COSTS
(1971 costs as % of 1952 costs, using new links)

<table>
<thead>
<tr>
<th>Complete Route</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vancouver to Field</td>
<td>70</td>
</tr>
<tr>
<td>Vancouver to Crows Nest</td>
<td>84</td>
</tr>
<tr>
<td>Cache Creek to Prince George</td>
<td>86</td>
</tr>
<tr>
<td>Prince George to Dawson Crk.</td>
<td>78</td>
</tr>
<tr>
<td>Prince George to Pr. Rupert</td>
<td>78</td>
</tr>
<tr>
<td>Keremeos to Sicamous</td>
<td>83</td>
</tr>
<tr>
<td>Cranbrook to Golden</td>
<td>86</td>
</tr>
</tbody>
</table>

Certainly the 401 and Rogers Pass additions to the Trans-Canada Highway have shown up significantly; but the other improvements to this route are not so pronounced, because of the increasing density of traffic absorbing some of the gains. With constant levels of traffic flow over the period, savings on this route would have appeared about 5% greater. Similarly, the Okanagan route would have been about 80% instead of 83%. It is obvious from the table that the routes which have had major reconstruction
(Nthn. Trans-provincial, John Hart), have shown much greater savings than those undergoing partial improvement, (Sthn. Trans-provincial).

Figures 19, 20, 21, 22 and 23 set out the quantities provided by the simulation of truck costs. Generally the weighting factors used were satisfactory, as they gave results from the current, verifiable data which are not contradicted by observations in the field. The generally lower-than-observed speeds (see Table XVII) are perhaps due to the simplified mechanics of the simulation, which applies the restraining factors consecutively to the base speeds (see Appendix III). More realistically, there should have been a cut-off level, where the width factor was not applied when certain gradient factors occurred, or where volume factors should not have applied when other factors occurred, and so on. For 1952 costs, the general impression is that they are too low, probably due to the inadequate data and uncertain map interpretation for that period. Probably road widths were really more restrictive in 1952 than suggested in this simulation. Parts of the old road, which are still to be seen between Cache Creek and Kamloops, in the Fraser Canyon, and along the North Thompson, suggest that speeds and costs would have been much more seriously affected than was indicated by the map descriptions. (As an example, a doubling of the penalty for width restrictions would have increased the total costs by about 2%). Also, had curves been included, and critical gradients more accurately measured, then the costs against the 1952 network would have been relatively greater. In favour of the simulation, it can be said that the
costs as indicators are satisfactory, that the same data and factors have been used consistently, and that the results do discriminate between links of different size, type and terrain. They are perhaps more reliable for comparisons of links within years, rather than across time periods, because of the differing quality of the data input.

For a general indication of the relative cost on various links, the 1971 costs have been divided by distance to give a truck cost per mile average figure, (see Fig. 24). The links having ferries or mountain passes show up clearly as very costly per mile. On mountainous stretches, there is the combined effect of increasing lapsed time and fuel consumption. The averaging of link costs obscures the fact that only some sections are severe; a finer breakdown of links would help to identify these sections. That so many average costs fall about 40 cents is not surprising - this cost is the outcome of a running speed around 40mph., which is quite consistent with observed speeds in these conditions. As the average speed increases, the driver cost per mile decreases, but fuel and repair costs increase. For example, savings in time on the 401 and Cariboo Highways offset the extra running costs at higher speeds. So if the driver's cost continues to increase faster than other factor costs, the importance of a high average running speed and the avoidance of congestion will be enhanced. There may be now a need for by-passes, particularly around Penticton, and widening between Cranbrook and Kimberley, to reduce costs due to congestion. Whether reduction of running costs in these areas is the most beneficial objective, is a
Fig 24. Average Truck Cost per mile, 1971 links, cents.
Because drivers can switch to a mileage rate as they prefer, there is an extra complication in the interpretation of over-the-road costs. In the following diagram (Fig. 25), it is assumed that drivers will take the higher rate where applicable; also, repairs are set at 12¢ per mile up to 35mph, then become 13¢. There is no penalty for extra consumption on grades, (though in reality, a truck averaging 20-25mph. is almost certainly consuming more than proportional amounts of fuel).

Fig. 25 - Running Costs for Large Truck, at Increasing Speed

![Graph showing Running Costs](image)

**Source:** Synthesized from Highway Research Board literature cited in ch. 6.

Fig. 25 shows that increasing speed beyond 40-45mph. provides no immediate savings, except to the driver in the form of increased leisure at the same wages. Perhaps also the shippers and receivers benefit from the shorter transit time of goods.
But the real gain is in the increased utilization of vehicle and driver, which depends mainly on the supply of cargo and the co-ordination of end-point facilities. How adjustments might be made will be discussed in the next chapter.

The implications for private car users are not easily discernible. The simulation is not directly relevant to private cars, since other factors and a different evaluation of time would be required of it. The influence of grades will be less for cars than for trucks, as will the deviation from free speeds at intersections and curves. As free speed is approached, the 'felt' cost of other traffic and congestion becomes much more acute. Because fuel is a larger component of total running costs for private cars, increasing speeds and consumption may appear more significant. But running cost for private cars is not a greatly important item when weighted against such things as motel and campground charges, meals and initial cost of vehicle. Saving in accident cost is something due to the society as a whole rather than being felt by any particular user. Generally, for private cars, the response to road improvement will come more from the sense of comfort, speed, safety, reliability and convenience, rather than from money savings.3

The figures presented so far in this chapter give a very simple, even unrealistic, view of the network. The total value of all links in 1971 ($1693) is for the use of each link once by one truck, whereas certain links are in fact used much more frequently than others. So a smaller degree of improvement on a vital link, say, Kamloops to Cache Creek, multiplied many times by the degree of use, can supply a larger total
benefit than a greatly improved peripheral link which is used relatively infrequently, say, Terrace to Hazelton. Such relationships are considered in the following section.

7.4 LINK CHANGES IN A NETWORK CONTEXT

Descriptions so far refer to the characteristics of links. It was shown earlier that major paths of the network affect these characteristics, and that network change can differ greatly from link change due to the same investment. There are two aspects of network behaviour which influence the evaluation of a link. One is its frequency of use in real terms, its traffic flow relative to others'. Savings multiplied by flow gives a fair indication of a link's contribution to current network quality. The second aspect is its frequency of occurrence in minimum paths between all pairs of nodes in the network. This measure shows how potentially important or vital the link is to the whole system. For example, the Merritt to Princeton link is busier than the Prince George to Chetwynd link, according to traffic counts; yet the latter is more vital in that it joins up two sub-systems.

It was noted earlier in the chapter that the average saving for one truck was about 18%. More accurate figures on truck movements would allow the calculation of gross savings over the whole network. From the patchy statistics available, an arbitrary proportion of 5% has been applied to the summer traffic counts, to derive an estimate of heavy truck traffic on the 27 links which were selected in Table IX and XVIII as
representative of the whole network. One truck over the 27 links showed a saving of 22%; weighting the links by the estimated truck traffic gave a saving of 63% overall. The average daily summer saving on the 27 links was about $47000—that is, a saving in 1971 compared with running the same number of trucks, with the same factor costs, over 1952 surfaces. The average daily summer saving on the whole network (70 links) was about $72000. The Golden-Revelstoke link alone contributed about $23000, and the 401 freeway and Kelowna Bridge about $4000 each. A conservative estimate of the annual savings to heavy trucks on the interior trunk network is $12-$15 million.4

Some examples of change in valued accessibility have been taken from the network to show the importance of major paths. The network was enlarged to make it more complete, to reflect more closely the likely use of various routes. The nodes of Edmonton, Jasper, Banff, Calgary, Fort Macleod and Rest-of-Canada were added to the east; the nodes of Rest-of-U.S. and Rest-of-America were added to the southern interior. The effect, structurally, was to increase the importance of interior nodes relative to the Vancouver node, and to offset the effect of the many nodes from Prince Rupert to Prince George. Finer adjustments could be made with population or traffic weightings. Costs on the external links have been estimated, not simulated; their degree of improvement has been deliberately exaggerated.

Using the expanded network, valued accessibility of the same nodes as appeared in Table X has been calculated—
that is, the cost of reaching all other network nodes directly from each of the named nodes. Table XX emphasizes the remoteness of Prince Rupert, and the proximity of Kamloops and Rossland-Trail, to the network as a whole.

**TABLE XX**

'SHIMBEL ACCESSIBILITY'** IN 1971 TRUCK COSTS

<table>
<thead>
<tr>
<th>Node</th>
<th>1952 surfaces</th>
<th>1971 surfaces</th>
<th>1971 as % of 1952</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vancouver</td>
<td>14882</td>
<td>11908</td>
<td>80**</td>
</tr>
<tr>
<td>Kamloops</td>
<td>10024</td>
<td>7981</td>
<td>80**</td>
</tr>
<tr>
<td>Prince Rupert</td>
<td>28263</td>
<td>21140</td>
<td>75</td>
</tr>
<tr>
<td>Edmonton</td>
<td>20550</td>
<td>13287</td>
<td>65</td>
</tr>
<tr>
<td>Rossland-Trail</td>
<td>12327</td>
<td>9679</td>
<td>78</td>
</tr>
<tr>
<td>Fort Macleod</td>
<td>17447</td>
<td>12074</td>
<td>69</td>
</tr>
<tr>
<td><strong>Total (6)</strong></td>
<td><strong>103493</strong></td>
<td><strong>76069</strong></td>
<td><strong>73.6</strong></td>
</tr>
</tbody>
</table>

* Shimbel accessibility scores are found by adding up the cost of moving from the named node, to all other nodes in the network, using minimum paths. The number of trips is equal to (n-1) nodes.

** Note: costs for Vancouver and Kamloops would have been about 2% lower had congestion factors which applied in the later year, been ignored.

These costs are indicative only - there is a danger of giving too much authority to the truck cost estimates by applying them too specifically in tables and matrices.

In chapter 5.5, the importance of the Slocan, Yellowhead and North Thompson links was pointed out; and Fig. 22 showed the great effect on costs of the improved Trans-Canada links east of Almon Arm. Because of their respective positions relative to these routes, Kamloops and Edmonton have benefited
more than Vancouver and Rossland-Trail. That Rossland-Trail and Prince Rupert showed a greater degree of savings overall, than Kamloops and Vancouver, is due to the differing degree of improvement on links adjacent to them. All of the paths from Vancouver began with the sequence 88 - 90 - 91 or 88 - 91 - 99; from Kamloops, they were mostly 90 -, or 92 - (see Fig. 22). But from Rossland-Trail, the paths began with 82 - 44, or with 88 - . All paths from Prince Rupert began with the sequence 71 - 75 - 82 - 83 - 83 - 78. Improvements in Alberta were exaggerated, so that paths from Edmonton began with 55-, 70-, or 75-; and from Fort Macleod, they were 67-, or 80-. Hence there appeared to be a great improvement in the 'centrality' of those two nodes. The point is, that the degree of improvement to the total network supplied by a link, can depend greatly on the link's position relative to paths in the system, and on the 'size' of the node it connects.

7.5 MINIMUM PATHS IN THE NETWORK

In order to examine the statement that the gain achieved by an investment depends on where it is placed in the network, it is necessary to use the simulated truck costs in designating minimum paths. Realistic estimates are now inserted for the Alberta links. There is no insistence that the calculated paths are going to be followed by each truck, even if the simulated costs are true. There may be good reasons for taking more 'devious' paths, such as avoiding difficulty in winter conditions, longer routes but faster average speed to
avoid congestion, part-load delivery or pick-up, and preferred meal or overnight stops. It is one of the precarious assumptions in network measures, that users' paths will be identical with calculated paths.

The calculation of minimum paths, accessibility indices and link importance scores, was done by means of a computer programme derived from Kissling's work at McGill University (1966), and developed by R. Whitaker and K. Denike of the Geography Department at U.B.C. Only a small part of the output will be considered in this thesis.

For simpler description of change, 15 nodes out of the 59 used in the network have been selected to represent the main traffic-generating areas. Table XXI sets out the Shimbel indices for each of the selected nodes - that is, the cost of reaching all other 58 nodes by the shortest path. The quantities differ slightly from those in Table XX because of the adjustments to the links in Alberta. Again the centrality of some nodes (Kamloops, Kelowna, Revelstoke), and the remoteness of others (Prince Rupert, Dawson Creek), are emphasized. These are potential figures only, and do not reflect actual movements between nodes. But even so, this representation of the network as a build-up of paths rather than of links, gives a truer picture of improvement - the average saving is now 26%, as compared with 18% shown by the simple sum of the links. The repeated counting of some vastly improved links accounts for the larger overall gain - such as the Rogers Pass, Kelowna-Penticton, Salmo-Creston, Vernon-South Slocan, and the Yellowhead Highway. Improvement has been spread unequally,
TABLE XXI
SHIMBEL INDEX SCORES FOR SELECTED NODES

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vancouver</td>
<td>15358</td>
<td>12274</td>
<td>80</td>
</tr>
<tr>
<td>Kamloops</td>
<td>11068</td>
<td>8000</td>
<td>72</td>
</tr>
<tr>
<td>Kelowna</td>
<td>11056</td>
<td>8386</td>
<td>76</td>
</tr>
<tr>
<td>Osoyoos</td>
<td>11419</td>
<td>8908</td>
<td>78</td>
</tr>
<tr>
<td>Rossland-Trail</td>
<td>12402</td>
<td>9799</td>
<td>79</td>
</tr>
<tr>
<td>Nelson</td>
<td>12496</td>
<td>9739</td>
<td>75</td>
</tr>
<tr>
<td>Creston</td>
<td>13883</td>
<td>10390</td>
<td>75</td>
</tr>
<tr>
<td>Cranbrook</td>
<td>14382</td>
<td>10260</td>
<td>71</td>
</tr>
<tr>
<td>Fort Macleod</td>
<td>17218</td>
<td>12047</td>
<td>70</td>
</tr>
<tr>
<td>Calgary</td>
<td>16709</td>
<td>11219</td>
<td>67</td>
</tr>
<tr>
<td>Revelstoke</td>
<td>11966</td>
<td>8856</td>
<td>74</td>
</tr>
<tr>
<td>Edmonton</td>
<td>19487</td>
<td>13943</td>
<td>72</td>
</tr>
<tr>
<td>Dawson Creek</td>
<td>19413</td>
<td>15481</td>
<td>80</td>
</tr>
<tr>
<td>Prince George</td>
<td>15394</td>
<td>10717</td>
<td>70</td>
</tr>
<tr>
<td>Prince Rupert</td>
<td>28231</td>
<td>20652</td>
<td>73</td>
</tr>
<tr>
<td>Total</td>
<td>230932</td>
<td>170671</td>
<td>73.9</td>
</tr>
<tr>
<td>Total, without Yellowhead link:</td>
<td>175814</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>Total, without N. Thompson &quot; :</td>
<td>171675</td>
<td>74.3</td>
<td></td>
</tr>
<tr>
<td>Total, without both these links:</td>
<td>177470</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>Total, without Slocan Link :</td>
<td>172696</td>
<td>75</td>
<td></td>
</tr>
</tbody>
</table>

mainly because of the proximity of the chosen nodes to some of these links, particularly Calgary and Prince George. This same phenomenon was noted in connection with Table XX, in the previous section.

It can be noted from Table XXI that the Yellowhead link has been more 'important' structurally than the North Thompson. This is due to the number of nodes west of Prince George
which would use paths along this link into Alberta, Rest-of-Canada, and even into the East Kootenays. The North Thompson is one of three or four alternatives for traffic from B.C. nodes to Edmonton and Jasper. The strong effect of the provision of the Vernon to South Slocan link is also shown up in the table.

The importance of links can be indicated by their frequency of occurrence in these potential minimum paths; frequency is here a measure of structure, not of actual usage, and is very much dependent on the distribution of nodes about the network. For example, the Cascade-Grand Forks link scores high because it joins one cluster of nodes (Okanagan) with another cluster (West Kootenays). The changes in link importance scores are set out in Table XXII. In both years, the two links north and east of Cache Creek were the most important structurally.

### TABLE XXII

**LINK OCCURRENCE IN ALL PATHS**  
(Number of times a link appears in all the minimum paths between all pairs of nodes)

<table>
<thead>
<tr>
<th>Link</th>
<th>1952</th>
<th>1971</th>
<th>1971, without...</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>NT.</td>
</tr>
<tr>
<td>Cache Cr.-Clinton</td>
<td>559</td>
<td>434</td>
<td>462</td>
</tr>
<tr>
<td>Cache Cr.-Kamloops</td>
<td>535</td>
<td>418</td>
<td>427</td>
</tr>
<tr>
<td>Kamloops-Salmon Arm</td>
<td>247</td>
<td>193</td>
<td>175</td>
</tr>
<tr>
<td>Revelstoke-Golden</td>
<td>253</td>
<td>198</td>
<td>228</td>
</tr>
<tr>
<td>Penticton-Kelowna</td>
<td>427</td>
<td>222</td>
<td>217</td>
</tr>
<tr>
<td>Osoyoos-Kaleden</td>
<td>512</td>
<td>179</td>
<td>173</td>
</tr>
<tr>
<td>Keremeos-Kaleden</td>
<td>149</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>Cascade-Grand Forks</td>
<td>423</td>
<td>187</td>
<td>190</td>
</tr>
<tr>
<td>Nelson-Lake-Creston</td>
<td>305</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kimberley-Wasa Jn.</td>
<td>157</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Wasa Jn.-Radium Jn.</td>
<td>159</td>
<td>263</td>
<td>274</td>
</tr>
<tr>
<td>Tete Jaune-Jasper</td>
<td>58</td>
<td>199</td>
<td>184</td>
</tr>
<tr>
<td>Richter Pass</td>
<td>0</td>
<td>102</td>
<td>102</td>
</tr>
<tr>
<td>Yellowhead (Y)</td>
<td>0</td>
<td>176</td>
<td>184</td>
</tr>
<tr>
<td>Slocan (S)</td>
<td>0</td>
<td>150</td>
<td>145</td>
</tr>
<tr>
<td>Creston-Salmo</td>
<td>0</td>
<td>212</td>
<td>223</td>
</tr>
<tr>
<td>North Thompson (NT)</td>
<td>0</td>
<td>73</td>
<td>0</td>
</tr>
<tr>
<td>Hudson's Hope</td>
<td>0</td>
<td>82</td>
<td>82</td>
</tr>
</tbody>
</table>
The re-routing of potential traffic is now shown to have a significant effect on nodes and links far removed from the link actually determining the adjustments. The interdependence of investment allocations becomes obvious; or, as Wills (1971) put it, they are "shocks to the whole system". According to the 1952 network, 'traffic' from Prince George to the East Kootenays came down through the Okanagan and then along the Southern Trans-provincial Highway. By 1971, this was directed down the Yellowhead, through Alberta, and south through Radium. This adjustment, plus the Slocan link, have greatly reduced pressure on the Okanagan and No. 3 highways. The North Thompson has diverted some 'traffic' which would have used the Trans-Canada Highway. The Yellowhead is again shown as having had a greater structural effect than the North Thompson. It would serve paths between those nodes west of Prince George, and those south of Banff and as far west as Golden and Creston; whereas the North Thompson has only three nodes to the east, some of which are reached through Banff and Calgary. For the same reason, the North Thompson link occurs in fewer paths than the Hudson's Hope link, which supports all the 'traffic' which would move between Fort Nelson - Fort St. John and all the nodes west of Creston.

The great effect of the Slocan link on potential traffic is due to the fact that it links up large sub-systems of the network. The investment in this link, originally to help in hydro-electric development, may well pay off in the long run by diverting traffic from other links where reconstruction and expansion would prove rather costly. Similarly,
the Salmo-Creston link has become a very important part of the whole system, and has taken the pressure off Kootenay Lake ferries (see Table XXIII).

TABLE XXIII

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Vehicles on ferry</th>
<th>$ Maintenance, all ferries in Nelson-Creston district</th>
</tr>
</thead>
<tbody>
<tr>
<td>1962-3</td>
<td>186000</td>
<td>369000</td>
</tr>
<tr>
<td>1963-4</td>
<td>141000</td>
<td>341000</td>
</tr>
<tr>
<td>1964-5</td>
<td>89000</td>
<td>289000</td>
</tr>
</tbody>
</table>

Source: Annual Reports, Minister of Highways, Victoria, B.C.

The description of structural change has referred to potential traffic only. It is obvious that there has been a large degree of integration of the network, from the reductions in the number of links required to get from node to node. But to put these changes in a truer light, the 14 most important 'links' of the network in 1971 have been rated according to their 1971 summer traffic flow, (see Table XXIV).

Table XXIV shows that only in the Okanagan and along the Trans-Canada east of Cache Creek do structural paths and link importance measures correspond to any marked degree with the real use as measured by summer traffic flows. As was mentioned in chapter 5, in considering Burton's use (1962) of structural measures to identify important links in the highway system of Northern Ontario, the link frequency measure can be a deceptive indicator, at the mercy of a particular distribution and selection of nodes and links. However, it gives a
TABLE XXIV

RELATIONSHIP BETWEEN LINK OCCURRENCE AND ACTUAL TRAFFIC

<table>
<thead>
<tr>
<th>Link</th>
<th>Occurrence Rank</th>
<th>Occurrence Range</th>
<th>Traffic as % of busiest link, 1971</th>
<th>Traffic, 1971 Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>CacheC.-Pr.Geo.</td>
<td>1</td>
<td>434-358</td>
<td>31-20</td>
<td>1 Van.-Hope</td>
</tr>
<tr>
<td>CacheC.-Kaml.</td>
<td>2</td>
<td>418</td>
<td>47</td>
<td>2 Pent.-Kelowna</td>
</tr>
<tr>
<td>Pr.G.-Hzelt.</td>
<td>3</td>
<td>364-220</td>
<td>17-8</td>
<td>3 Lytt.-Cache C.</td>
</tr>
<tr>
<td>Kaml.-Vernon</td>
<td>4</td>
<td>297</td>
<td>19</td>
<td>4 Kaled.-Pentic.</td>
</tr>
<tr>
<td>Radium-Wasa.</td>
<td>5</td>
<td>263</td>
<td>20</td>
<td>5 Hope-Lytt.</td>
</tr>
<tr>
<td>Kaled.-Vernon</td>
<td>6</td>
<td>246-216</td>
<td>67-40</td>
<td>6 Sica.-Revel.</td>
</tr>
<tr>
<td>Yahk-Cranbrook</td>
<td>7</td>
<td>230</td>
<td>18</td>
<td>6 Cache-Kaml.</td>
</tr>
<tr>
<td>Sicam.-Revelst.</td>
<td>8</td>
<td>224</td>
<td>51</td>
<td>8 Kaml.-S. Arm</td>
</tr>
<tr>
<td>Cranb.-Wasa(95)</td>
<td>9</td>
<td>221</td>
<td>17</td>
<td>8 Revel.-Golden</td>
</tr>
<tr>
<td>Osoy.-Cascade</td>
<td>10</td>
<td>215-187</td>
<td>15</td>
<td>10 Kelowna-Vernon</td>
</tr>
<tr>
<td>Salmo-Crest.</td>
<td>11</td>
<td>212</td>
<td>10</td>
<td>11 Princet.-Kerem.</td>
</tr>
<tr>
<td>Yahk-Crest.</td>
<td>12</td>
<td>211</td>
<td>20</td>
<td>12 Gold.-Banff</td>
</tr>
<tr>
<td>Kaml.-S.Arm</td>
<td>14</td>
<td>193</td>
<td>40</td>
<td>14 Cache-Clint.</td>
</tr>
</tbody>
</table>

useful description of potential interaction about the network, which provides a different perspective than that offered by current traffic counts. For example, traffic counts at present would appear not to 'justify' the huge investment that went into the Yellowhead link; but the link importance measures show its vital role in terms of structure and potential traffic.

7.6 THE CHAPTER REVIEWED

This chapter has condensed a lot of generated data to a series of maps and tables. Description of the actual data has
been deliberately kept to a minimum, for two reasons. The output of the simulation should not be used as if it is definitive, since there is some doubt about the route descriptions, particularly of the base year (1952). But also, the main intention of the chapter was to use those indicative costs to explore some measures and perspectives provided by the network context.

Link investments can not be rated simply by their total cost, or cost per mile. There is great variability in the relationship between dollars spent, facilities bought, and immediate gain achieved. Fig. 23 gave an interesting view of cost per unit of gain on each link; but the 'costs' would be very much altered if the degree of use were added into the calculations.

Nor should the link characteristics be considered for themselves alone. Some extra user costs or savings on a particular link might be due to changes occurring elsewhere. There is an interdependence of investments in terms of paths and of adjustments over time. There is an interdependence of traffic routing, as was shown by the output of the minimum path calculations.

A point-to-point evaluation of a link misunderstands its real contribution to a network. The sum of link savings showed an improvement of only 22%; when adjusted to take account of traffic flow, the same links showed a saving of 63%. The network is really a build-up of paths rather than a build-up of links.

Links valued by their current use gave a good indica-
tion of real improvement in the network. Yet the counting of links' occurrence in possible paths of the network provided an indication of potential gain. It showed how vital a link is to the whole system. This measure has to be taken together with a flow measure, for the two will rarely correspond. The former is subject to the selection and spatial distribution of nodes and links; the latter is subject to the current arrangement and 'size' of traffic-generating areas. They would correspond only if all nodes were of equal traffic-generating capacity, and if all minimum paths were the same as the actual paths of users.

The reduction in the overall total of links in all potential paths showed that the network has become more integrated over the period. Structurally, the Yellowhead and Slocan links have contributed most towards this.

The unequal gains in accessibility for some nodes show that the ability of traffic to take advantage of some vastly improved routes varies from place to place. In other words, the contribution made by an improved link to the total network quality depends every much on its position relative to through paths and relative to traffic-generating areas. Some well-used through routes were seen to have had larger gains than others, because of the favourable sequence of improved links.

Removal of some links from the actual network has shown their relative contributions to network structure and quality, and the 'shocks' which they have passed on to other links.
A reasonable estimate of the overall gain in heavy truck running costs was provided from the simulation and summer traffic counts. Some suggestions of the reactions of users to changed running costs were offered. These will be examined more closely in the next chapter, and a corroborating estimate of improvement will be approached from another angle.
REFERENCES:

1 This was done in a model-building study of investment allocation, applied to B.C., in K. Denike, The Role of Transportation Investment in Economic Development. (1972).


4 Two gross assumptions are made here: firstly, that there were no competing modes in 1952. For example, the use of trains to by-pass the costly Big Bend route is deliberately ignored in forming this estimate. Also, it is assumed that weight and size restrictions were the same then as now.
It is a belief central to investment in road facilities that users' savings in time, accident costs, running costs, equipment, and so on, will generally bring greater efficiency in the distribution function, and relatively lower costs for producers, shippers and consumers. In chapter 5, this connection was asserted in a too general way. The manner in which cost savings work through truck operations to the economy is very indeterminate. One needs to regard the equipment, degree of utilization, fixed overhead costs, variable overhead costs, running costs, driver cost, depreciation, competition, fleet operation, cargo supply and so on, as working parts of a mechanism that determines revenues, total costs, profitability and tariffs. An exhaustive treatment of trucking operations takes one into the field of business management, an indication that the major problems are in the 'overheads' rather than in 'over-the-road' costs. Alternatively, one needs to take Fleischer's method (1962), of pulling apart the operations of just one firm. The highway research literature has confined itself to over-the-road costs, to identify which costs are affected by road conditions and to what degree.1
Taking the simplest case of an owner-operator, a breakdown of costs can be made, as was done in p. 13-14 of the journal, "Truck Canada", May, 1972. Using a $30000 truck and trailer, the fixed costs (registration, insurance, interest, depreciation and bookkeeping) are about $10000 per year. A reasonable salary, 'paid' to himself, is $12000; and $1500 (5%) is a reasonable return on his investment. These target figures affect the desired revenue mileage to be covered in a year, on top of which is mileage covered while empty. In the 1964 survey by Statistics Canada, the empty proportion was about 35%. To cover 50000 revenue miles per year - which is reasonable in the light of the 1964 survey findings and the expected life of vehicles - the total mileage will be about 77000, with total costs (including fuel, repairs and tyres) about $38900. So the contracts which he enters into must pay about $0.78 per mile. Assuming an average payload of 20 tons, the desired ton-mile revenue is 3.9 cents, which lies within the range discovered by the survey.

The example above pretends that no terminal, pick-up or delivery costs are borne by the owner-operator. The effect of repaving surfaces, as used in the simulation in Chapter 6, was a reduction in repairs from 13¢ to 12¢. By itself, this means only a 0.2 cent reduction in the desired contract price of this operator. Increased speed over better surfaces would reduce per mile cost of all items. Neither of these changes for paved roads was well brought out by the simulation, because of the generality of description of road surfaces.
The $0.78 per mile revenue is an average figure. Really, the operator requires a much higher reward on 'head-haul' contracts because of the necessity of under-cutting tariffs to get any 'back-haul' contracts. The pattern of freight movements in B.C. makes for very keen back-haul competition. Figure 26 shows the disparity in flows.

Fig. 26 - Freight Movements in B.C. 1970


Revenues from outward traffic from Vancouver are $2\frac{1}{2}$ times those from inward traffic, whereas tons of freight are only $1\frac{1}{2}$ times greater. The lesser revenue per ton for the inward freight (average $7.55$ as against $12.68$) is due to the nature of commodities, and to under-cutting of tariff charges. The freight outward from Vancouver contains a larger proportion of end
products ($25 per ton revenue) and general merchandise ($38 per ton); whereas the inward freight has a large proportion of food products ($10 per ton), crude materials ($4) and fabricated materials at $11 per ton.

In general, most truck shipments originate in the Lower Mainland; much of the produce of the Interior, particularly forest and mineral products, is served by railways. Specialized operations - such as refrigerated trailers out of the Lower Mainland or Prince Rupert, or new car distribution, or householders' removal - are severely affected by the lack of back-haul freight. So if the owner-operator referred to earlier can capture more freight, and reduce the empty proportion to, say, 20%, then the required average contract price is reduced to $0.63 per mile.

Such an improvement due to rationalization is perhaps the major intention of fleet- and warehouse operations. Not only are pick-up and delivery costs for the operator reduced for them, but also the organization of full loads and the optimization of space-weight relationships become possible. Reductions in waiting time and over-the-road time, together, can allow the fleet operator to achieve greater revenue mileage from less equipment, thereby reducing his overhead fixed costs. He might further avoid some of these costs if he uses leased equipment to cover periods of increased activity or to handle loads with particular handling or trailing requirements.

Where does the effect of improved roads come in? If the road improvement allows the owner-operator to increase his speed from 31 to 35mph, he will be able to cover 86000 miles
per year, working the same hours as before, and getting freight as and when he is available. At 35% empty, his revenue mileage becomes 56000; and after adding the extra fuel and repair costs, his desired contract price becomes $0.74 per mile.

The fleet operator using employed drivers, may not be able to take full advantage of the time savings, since his drivers will switch to the mileage rate of pay above 32mph. The operators' gain will then be in the utilization of equipment. If he has 10 vehicles and is able to adjust his services to the improved running speeds, then he will be able to cover the same mileage with 9 vehicles only. So he avoids the extra depreciation, interest, registration, insurance and driver cost of the 10th truck. With the same degree of utilization (65%), his contract price could become $0.70. He is then able to invest the capital formerly due to the tenth truck in warehouse, advertising or local delivery operations, which will increase and stabilize his freight supply.

For a larger fleet operator, the picture becomes more complex - there are scale economies available to certain aspects of the operation, but increasing overheads may occur as well. Economies will probably appear in the purchasing of fuel and equipment, financing, repair and maintenance facilities, warehousing, scheduling, co-ordination of types of equipment and flexibility of service. Increasing costs will probably appear in advertising, billing, intra-urban collection and delivery, and total space requirements. This second group of costs might eventually result in a higher degree of use of road and terminal equipment and staff, by capturing a greater volume and more
regular supply of freight for both directions of each trip.

If an increase in speed from 31 to 35 mph allows a reduction in the contract price from $0.78 to $0.70, then it is possible to make a very general estimate of what this means to the economy as a whole. The Statistics Canada survey of 1970 provided information on tons carried and ton-miles covered by 'for hire' trucks only. Table XXV summarizes the information relevant to B.C.

**TABLE XXV**

FOR-HIRE TRUCKS, FREIGHT MOVEMENTS - B.C. 1970

<table>
<thead>
<tr>
<th>Direction</th>
<th>Tons (m)*</th>
<th>Miles each ton carried</th>
<th>Cost per ton per trip **</th>
<th>Cost per ton per trip ***</th>
<th>Per ton savings</th>
<th>Annual savings $ mil.</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.C. to everywhere and from everywhere</td>
<td>18.5</td>
<td>264</td>
<td>10.30</td>
<td>9.24</td>
<td>1.06</td>
<td>19.6</td>
</tr>
<tr>
<td>Vancouver, to everywhere and from everywhere</td>
<td>11.0</td>
<td>320</td>
<td>12.48</td>
<td>11.20</td>
<td>1.28</td>
<td>14.1</td>
</tr>
<tr>
<td>Vancouver, to rest of B.C. and from rest of B.C.</td>
<td>9.3</td>
<td>127</td>
<td>4.95</td>
<td>4.45</td>
<td>0.50</td>
<td>4.7</td>
</tr>
<tr>
<td>same, with 15 ton average payload</td>
<td></td>
<td></td>
<td>6.60</td>
<td>5.93</td>
<td>0.67</td>
<td>6.2</td>
</tr>
</tbody>
</table>

* m = millions  
** at 31 mph., 78¢ per mile, and 20 ton payload  
*** at 35 mph., 70¢ per mile, and 20 ton payload


The high average distances for the first two directions in Table XXV reflect the long hauls to and from the Prairie
provinces and Ontario particularly. Consequently, the possible savings due to faster speeds appear much greater than those for the freight moving within B.C. only. Also, the cost per ton per trip of freight within B.C. is relatively low, most likely because of the nature of the goods. Perhaps also the average payload of 20 tons is too high for trips within B.C.; the apparent savings become larger if each trip is said to carry only 15 tons.

The estimates in the final column of Table XXV complement and support those made in section 4 of chapter 7. The present estimates are for a given change of speed only, by for-hire trucks only. Many links have provided increases of at least 4 or 5 mph. in the last decade; almost all of them have provided such increases since 1952. As well, there have been significant reductions in repair and tyre costs, and in the utilization of equipment. It is quite likely then that the estimate of annual savings of $15 million is reasonable, even conservative - that is, the difference of operating these particular 1971 vehicles at 1971 costs and with the 1971 industry-structure, over 1952 surfaces.

REFERENCES:

1 Most of the analysis of trucking operations depends on the study of Fleischer (1962), and on Adkins et al. (1967).

2 Cost figures are taken from the "Truck Canada" article cited, and from the Statistics Canada survey, (1970).
CHAPTER 9

CONCLUSIONS

9.1 THE APPROACH

The desire to examine the pattern of investment arose from a dissatisfaction with the 'classic' network analyses, which characteristically related change in some measure of transport or of spatial arrangements to change in some economic indices. Whatever measures were used, only in a few cases was there an attempt to describe the direction of the relationship. In the real world, adjustments in the relationship pass through a determining medium, here generalized as the 'investment decision'. The 'decision' includes aspects of social objectives, official policy, local concerns, financing, co-operating authorities, and the timing and order of projects. Over a long period, a pattern and deviations within it were discernible as outcomes of the investment decision.

Concentrating on the investment decision and its outcome inevitably disposes one to find cases of four kinds - those which lead activity into new areas; those which lag in that they connect up already developed areas; those which are required to assist in other development projects; and those which relieve congestion around developed areas. This last
kind might be considered as leading or lagging economic activity, depending on the timing of measurement of changes: congestion might 'force' the provision of better facilities, which might in turn assist further economic growth. The issue of timing has not been adequately considered in the 'classic' analyses, but it is one of the virtues of the investment decision approach that it brings this issue into the open.

Such an approach shows investment in transportation as a positive instrument in planning. Sometimes its role has been over-rated, but its limited effectiveness has been more clearly recognized in the last decade. Investment in facilities can confer relative advantage on some areas or some activities, as indicated by the differential savings in truck operating costs over the links of the B.C. network. The absence or delay of apparently necessary investment might be sometimes regarded positively as well, if the objective is reduction of urban growth or equalization of opportunity.

Some later studies in network analysis, notably those of Kissling and O'Sullivan, have related types of economic activity to different aspects of accessibility, in recognition of the fact that different transport facilities can serve different purposes at different times. Observation of the pattern and type of investment throws light on these changing purposes—such as pioneer, relief, feeder, tourist or through-route. Such inferences can be made with only a superficial analysis of economic activities in affected areas. This approach brings less defined measurement of the transport/economy relationship, but a broader understanding.
An important consideration for planning purposes, which comes out of the observation of investment, is the relationship of gains in accessibility to the costs of achieving them. There is extreme variation within this relationship. It is an important factor in understanding the apparent transport/economy interaction; but also, for questions of social justice, since the investment is usually 'public', the users 'private', and the activities being measured by the economic indices usually also 'private'. The response to investment and changed accessibility has been quite thoroughly researched: the incidence and disposal of benefit could well do with more attention.

Cost-benefit analysis has been much criticized for its partiality, or the inability to incorporate all the real-world changes into its neat equations. This thesis does not attempt to deflect any of those criticisms. It was acknowledged in the first chapter that the changes observed here were to be only a small part of the real changes. The 'costs' were only those reported by the Department of Highways, and excluded such things as spending by municipalities, the opportunity or interest costs of investment, or related costs borne by other public or private authorities. The 'transport system' ignored other competing or complementary modes. The measure of benefit was deliberately kept narrow and simple, to show the degree of immediate improvement offered by changed facilities.

The use of such improvement is the crucial issue in development planning. It is extremely difficult to trace the gains through the users and dependent-users to their emergence
as a tangible economic effect, as opposed to describing what happened here and what followed there. It is inevitable that there are very disparate economic responses to apparently similar changes in facilities: the intervening factors, such as the range of markets and the transport needs of activities, were set out in the first chapter. The thesis goes through the necessary first step, of showing how the changes in facilities were achieved, and has shown a small part of the potential for response, in the form of truck operating costs.

The final defence of this particular approach, of focussing on how and where investment was made, is that it provides a better understanding of the formation, functions and purposes of links and networks, as opposed to the static summary of the transport/economy relationship. The former helps interpretation and historical treatment; the latter helps precise measurement and prediction of the relationship.

9.2 THE PATTERN OBSERVED

The pattern of investment in B.C. roads is inevitably guided strongly by user-demand. Current users experience the difficulties of bad surfaces, delays, hazards and so on, and usually express their feelings with a large degree of unanimity. The authorities are not passive, however: their speed and degree of response to that demand can sometimes be a regulating factor in economic activity, as in the case of the third crossing of Burrard Inlet. That traffic flows often increase sharply after new facilities are supplied, can obscure whether the government role is a positive or permissive one.
Policy decisions, taken in a national, provincial or regional context, have also influenced the pattern of investment. It has been said that in B.C. the government has given an exceptionally positive role to the transport factor in economic development. Whether this has been stronger than in other societies developing their transport infrastructure, would have to be tested by some sort of comparative ratio of 'leading investment' to 'total investment', the difficulty being in quantitatively defining and identifying the former.

'Leading' investments may be taken as those which provide exceptionally high quality facilities to a particular area or route, relative to the rest of the system; which provide capacity 'well in excess' of current levels of use or of expected traffic generated from favoured nodes; which re-direct traffic from existing routes; which immediately and substantially reduce costs of movement to or within certain areas; which open up new areas; or which cater for some less measureable objectives such as national defence, regional integration or support of other projects.

Within those broad terms, there were many large investments in B.C. that could be considered 'leading'—the North Thompson and Yellowhead Highways, improvements and user-cost reductions on the Northern Trans-provincial from Prince Rupert, parts of the Trans-Canada Highway when first built, the Vernon-South Slocan link, the Chilcotin Highway west from Williams Lake, the 3B route north-west from Rossland, roads to various mines and mills (such as at Cassiar, Highland Valley, Prince George or Mackenzie), the roads for hydro-electric development
north and south of Revelstoke and around Hudson's Hope, and the roads to Barkerville, Garibaldi, and Buttle Lake. This is not an exhaustive list: the problem with offering these suggestions is that the purpose of routes may have changed over the period. For example, the original Hope-Princeton route could be regarded as an investment for integration, the kind of investment whose real worth cannot be fully measured in economic terms; current adjustments to that route can be regarded as forced by user demand, i.e. 'lagging'.

Apart from being characterized as leading or lagging some measure of demand, investments can be described in terms of especially serving a process of development. In the B.C. case, such processes were basic connection, external connection, pioneering, intensification, integration, relief of traffic pressure, and improvement of driving conditions. Such processes are not exclusive, but there is some logical basis, and some evidence from B.C., that they exist in sequence. Roads considered to be serving particular processes were identified in earlier chapters. The general trend from basic connection to intensification, relief and improvement was shown up by the relative amounts spent in the trunk and branch systems. Some interdependence of the amounts was described in ch. 4. However, there is only a very weak necessity and even less constancy in the relationship, and it was made less visible by the shape, size and content of the reporting units.

The relationship between maintenance costs and construction costs was examined in the light of two hypotheses that spending on maintenance can be an instrument of policies
other than satisfying users' standards or expectations; and that the respective levels of spending are interdependent and substitutable to some degree. The pattern of spending showed many cases to support the latter statement. But it dismissed the former statement, since the distribution of maintenance spending appears to be tied to levels of use and to increasing levels of service. The highest per mile costs of maintenance occurred in busy, vital sections of road, partly due to patrols, and partly due to more expensive patching and resurfacing. The emphasis on safety, speed and reliability forces up maintenance costs, usually in the more built-up areas experiencing the most expensive provision of facilities.

A recurring element in the pattern of investment was the large, indivisible investment needed to bridge a river or breach a pass. Such a situation in road-building prevents the authorities from gradual expansion of improvement (as would seem to be possible in the prairie and plains regions) whereby spending and benefit can be seen to progress close together. Another recurring sight was the peaking of spending around election years. This brought a cost to the province in the form of inflated contract prices. Another form of social or political maneuvering that brings a cost to the province, is the greater use of day-labour crews where contract work might in fact be less costly per mile. For example, day-labour crews employed by the Department of Highways did all but the surfacing of the Kelowna-Rock Creek road through South Okanagan and Boundary-Similkameen districts, whereas the total size of the project (about $4m.) might have justified a contract job. The
use of road spending in the pursuit of other welfare objectives is, of course, a legitimate one, but it is often ignored in the narrow treatment of cost-benefit analyses.

There were many indications of the cyclical nature of spending, the momentum being regulated mainly by levels of traffic. In the last few years, the cycle has come around again to an emphasis on the relief of traffic congestion, particularly in the Lower Mainland. Generally, the inter-urban links elsewhere have been able to cope so far with the increased annual traffic flows. For most of them, capacity is approached only on a few occasions in the summer months, presenting a difficult reconciliation of large fixed investments and protracted underutilization of capacity.

Traffic flow does not give the full measure of the dependence of areas on particular links. Much depends on the availability of other modes and on the extent and nature of activities' demand for transportation. Traffic flow may be a fair indicator of the importance of the Agassiz-Haig section of the Lougheed Highway, but could not convey the importance of the Stewart-Cassiar link, the Alberni-Tofino link, or the Yellowhead Highway. Roads which 'make things possible' require a different treatment to that provided by the traditional cost-benefit analysis. 'With and without' measurement is certainly preferable to 'before and after' measurement in such cases, but would still not take in the full effects of initial road access. Further research into these effects may be useful, if only to supply a more definite but qualitative scale of response to initial access.
The attempt at characterizing the pattern of spending by a mathematical description was suggestive but not successful. It seems that population, external connection and amount of through path mileage account for much of the variation in districts' totals, but are not reliable indicators. Where larger populations 'would have' forced up the totals, a significant part of road provision was hidden in spending by and through the municipalities. The seasonal differences in road use suggest that the population factor overestimates the spending required in the Interior districts, for two reasons: many activities in the Interior do not rely greatly on road access; and many of the roads are relatively un-used, in terms of actual traffic numbers, for 7 or 8 months of the year. The seasonal range of traffic flows will continue to present difficult choices for the authorities, concerning the quality of facilities and the standards of maintenance.

9.3 THE MEASUREMENT OF IMPROVEMENT

One of the most important findings of the analysis was the varying 'importance' of links depending on the perspective used. In budget terms, those which require the biggest total investment will be held up as most important - such as the Yellowhead, Rogers Pass, or Port Mann Bridge. A different scale will emerge if costs per mile are used, and again a very different scale if truck cost savings per unit of spending are used. Varying significance is attached to a link, depending on the perspective taken - the link per se, the link in terms
of current flow, or the link in terms of minimum paths and potential flows. The implications for planners are serious - similar amounts of spending buy very different amounts of improvement; and the contribution of a particular link improvement to the total network quality is highly variable. Therefore, the timing of improvement and benefit becomes critical. Traffic might build up quite suddenly, and consume all of the 'benefit' in a short time. Relatively large savings for low levels of traffic might appear extravagant, yet they might help re-locate activities, rather than simply intensify use of current activities, and in the long run reduce the total social cost of movement.

The truck costs were used in a number of ways to demonstrate the variable meaning of improvement. For one vehicle using each of the links, the savings over 1952 were 22%; for a selection of nodes evaluated in terms of Shimbel accessibility scores, the average savings was 26%; and for a representative sample of links weighted by their actual flow, it was 63%. The Shimbel indices showed how different gains occurred for different places, according to the degree of change on adjacent links. The link importance measure showed the interdependence of routes, and the consequent interdependence of investments. Pressure might build up elsewhere because of investment in a particular area. The link experiencing most congestion or highest operating costs, need not be the one where remedial investment is applied. Both the structural and the valued-link measures supported the contention that the B.C. road network has become much more integrated, especially since 1962.
No matter how the improvement is measured, there remains a very difficult problem in tracing its utilization. Interpretation of private users' response to the improved roads has been almost completely avoided in this thesis. It is obvious though, that the B.C. situation needs to be examined in the light of commuters' and tourists' response to better roads, since much of the investment is now directed towards those two groups. Even limiting one's field to trucks allows only a 'guess' at the degree of response. There are two levels of response - the trucking industry as a whole, and individual firms or operators. Gray (1969) looked at the first level, concentrating mainly on regulation and competition; Fleischer (1962) looked at the second level. A useful study would combine the two perspectives, relating the response to road investment.

Most of the network studies in Geography have looked at the response amongst activities, relatively few have observed the road users, where the initial response and short-term adjustments occur. Two estimates of savings were made in this thesis, the one working up from traffic counts, and the other working back from a survey of freight movements. A number of hypothetical situations involving a truck operator were presented, to show the initial and possible adjustment to road improvements. Given the data, it is possible to trace through the adjustments, which leads to the difficult stage of whether or how savings will be made available to shippers, producers and consumers, and whether or how they will make adjustments.
Geographers have tended to assume away the mechanisms by which improved surfaces and networks affect accessibility, and by which this in turn affects the adjustment of activities. One obvious example has been the rather deferential treatment of the deterrent or friction component of the gravity model. Planners, particularly in foreign-aid type projects, have often failed to take into account the mix and maturity of activities, and their real transport needs. Tracing over-the-road savings through truck operators and private users to shippers and producers might well provide an understanding of the diversity of transport needs. So no apology is made for taking this study through the researches of the highway engineering and highway economy fields, in order to understand better how spatial rearrangements may occur.

From such research as to the use of potential gains, it might be possible to arrive at some measure of transportation needs for a district, as attempted rather sketchily in ch.3, taking into account the devious relationships of investment, improvement and use. The essential decisions on 'needs' will remain political and social ones. That provision of facilities promotes use and, eventually, 'needs', has been shown in many situations. As the cycle in B.C. has moved round in recent years to the costly relief of congestion in urban or near-urban areas, one wonders how far the demand for mobility and access will be met, before the deliberate reactions of increased central densities, dispersed office and retail and manufacturing functions or use of alternative transport systems will occur to reduce or diffuse demand. Integration of the network increases faster.
than general economic development, but costs in urban areas have been increasing at an even faster rate, and this may inhibit the authorities' attempts to give a positive direction to economic and social development through the investment in roads.
BIBLIOGRAPHY AND APPENDICES
BIBLIOGRAPHY

SOURCES:


British Columbia, Department of Finance. Financial and Economic Review. (annual)

British Columbia, Department of Trade and Industrial Development. B.C. Facts and Statistics. (annual)


General Teamsters' Union. Local 181. Master Freight and Cartage Agreement. 1972-73 Vancouver, B.C.


Statistics Canada. Motor Carriers Freight Quarterly. Series 53-005


"Truck Transportation Canada". Toronto. May 1972.

ON HIGHWAY ENGINEERING:


ON TRANSPORTATION'S EFFECTS ON THE ECONOMY:


Harris B. A Note on the Probability of Interaction at a Distance. Jnl. of Reg. Sci. v. 5. no. 2. 1964. p. 31-35.


O'Sullivan P. Transport Networks and the Irish Economy. London School of Economics, Papers in Geography no. 4. 1969.


Walters A. The Economics of Road User Charges., for World Bank Staff Occasional Papers, no. 5. Johns Hopkins Press. 1968.


ON THEORY AND MEASUREMENT OF NETWORKS:


Pitts F. A Graph Theoretic Approach to Historical Geography. Prof. Geog. v. 17, no. 5. 1965. p. 15-19.


ON VEHICLE BEHAVIOUR AND PERFORMANCE


APPENDIX I

CHANGES IN ELECTORAL DISTRICTS SINCE 1946

Vancouver-Point Grey was subdivided in 1966 into six districts: Point Grey, South, Centre, Little Mountain, East, Burrard.

Burnaby was subdivided in 1966 into three districts: Edmonds, Willingdon, North.

Delta was subdivided in 1966 into four districts: Delta, Richmond, Surrey, Langley.

Dewdney lost its western sector to Coquitlam in 1966.

North Vancouver was subdivided in 1966: Capilano, Seymour, and West Vancouver - Howe Sound which included the southern section of the former Lillooet district.

Nanaimo lost some of the islands to an extended Saanich and The Islands. The adjustment to Nanaimo also entailed some adjustment to Cowichan - Newcastle, whose name was then changed to Cowichan - Malahat.

Lillooet lost its southern sector to West Vancouver - Howe Sound in 1966, and its remainder was merged in with Yale - which was extended to the east, - to become Yale-Lillooet.

Similkameen lost some of its western territory to Yale-Lillooet in 1966, and was then joined with Grand Forks - Greenwood to become Boundary - Similkameen.

Fernie and Cranbrook were combined in 1966 to become Kootenay.

Kaslo-Slocan was joined with the former Revelstoke to become Revelstoke-Slocan. Revelstoke lost some territory to the former Salmon Arm, which then became Shuswap. The adjustment to form Shuswap also involved some alteration to North Okanagan's northern boundary.

Peace River was split after 1956 into North and South divisions.
APPENDIX II

THE TRUNK ROADS AS USED IN THIS THESIS

Vancouver Island: Victoria to Swartz Bay; from Victoria, the No. 1 Highway north to Nanaimo; the road from Parksville to Alberni; the Island Highway from Nanaimo to Kelsey Bay.

Lower Mainland: Squamish to Horseshoe Bay; the Trans-Canada from Horseshoe Bay east to Hope, and north and east to the Alberta border; Marine Drive from Horseshoe Bay to the City, until replaced by the Upper Levels Highway; No. 1 from Vancouver, along Kingsway, across Patullo Bridge and eastwards, until replaced by No. 401; Hastings-Barnet thoroughfare and Lougheed Highway east to Haig; No. 499 from Vancouver south to U.S. border; Ladner Ferry until replaced by Deas Tunnel; No. 17 to Tswawassen Terminal; Ladner Trunk Road east to Langley; No. 99 from Surrey to U.S. border; No. 13 from Aldergrove towards Bellingham; Abbotsford - Mission No. 11; and Agassiz to Rosedale.

Southern Interior: Southern Trans-provincial No. 3, including all sections of 3A and 3B; Rossland - Paterson, the original Rossland to Cascade until replaced; Trail to Waneta; Remac to Nelway; Yahk to Kingsgate; Creston to Porthill; Elko to Roosville; Princeton - Merritt - Kamloops and - Spences Bridge; the Okanagan Highway from Keremeos and Osoyoos north to Sicamous, Salmon Arm and Monte Cree; Cranbrook - Kimberley and north, and Cranbrook - Fort Steele and north; the South Slocan to Vernon link (though included as part of branch development in terms of the spending on hydro-electric projects).

Northern Interior: Kamloops - Tete Jaune Cache - Prince George. Hope - Lytton - Cache Creek - Prince George; Prince George to Chetwynd and Dawson Creek and via Hudson's Hope to Fort St. John; from Tupper to Dawson Creek and north to Fort Nelson; from Prince George west to Prince Rupert and Kitimat.
APPENDIX III

CONTENT AND METHODS OF THE SIMULATION OF TRUCK COSTS*

Identify link.
Identify miles (D) of surfaces, P paved and G gravel.
Identify miles of legally restricted speeds (L).
Identify widths for various sections, convert to factors (W) as in Table XI.
Count up total rise and fall in feet from 100" contour maps, divide by link distance, to get average rise and fall; convert to factors for speed (H) and for fuel consumption (N) according to Table XII.
Take traffic flow from published counts, convert to factors (V) according to Table XIII.
Add in any ferry delays (Y).
Set base speeds at 50mph. for P, and 38mph. for G.

STEPS:
1. Total D - legal D = (Dp + Dg)
2. Legal D ÷ 20mph. = time over legal D.
3. 50 x Wp = speed over paved sections, allowing for W.
4. 38 x Wg = speed over gravel sections, allowing for W.
5. step 3 x H = speed over paved, allowing for W and H.
6. step 4 x H = speed over gravel, allowing for W and H.
7. step 5 x V = speed over paved, allowing for W, H and V.
8. step 6 x V = speed over gravel, allowing for W, H and V.
9. step 7 x Dp = time over paved sections.
10. step 8 x Dg = time over gravel sections.
11. sum steps 2, 9, and 10 = link time.
12. link time ÷ D = average running speed.
13. Find consumption at this speed, see Table XIV.
14. Add extra grade factor to consumption (Table XIV) to get average consumption.
15. total D x average consumption = fuel consumed.
16. fuel consumed x $0.40 = fuel cost on link.
17. step 11 + Y = total link time.
18. link time x $7.50 per hour = driver and truck cost on link.
19. (Dp + legal D) x paved repair costs = repair cost on paved.
20. Dg x gravel repair cost = repair cost on gravel sections.
21. sum steps 16, 18, 19, 20 = total link cost.

* Computer Programme put together by Larry Meyer, Dept. of Geography, U.B.C.